Hancock County Flood Risk Reduction Program

DRAFT - Proof of Concept Update

July 9, 2018

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Sign-off Sheet

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Executive Summary

Hancock County and the City of Findlay, Ohio areas experience frequent and significant overbank flooding from the Blanchard River and its major tributaries, Eagle Creek and Lye Creek. Stantec Consulting Services Inc. (Stantec) recommended the Hancock County Flood Risk Reduction Program (HCFRR Program) in the April 2017 Proof of Concept Report as an alternate to the 9.2-mile Western Diversion of Eagle Creek proposed by the U.S. Army Corps of Engineers, Buffalo District. The recommended HCFRR Program comprised of several independent projects including Hydraulic Improvements along the Blanchard River in Findlay and dry storage basins on Eagle Creek, the Blanchard River, and Potato Run. The HCFRR Program is described in full in the Stantec April 2017 report titled, "*Hancock County Flood Risk Reduction Program Final Report: Data Review, Gap Analysis, USACE Plan and Alternatives Review, and Program Recommendation*" (Proof of Concept Report). The MWCD Board and the Conservancy Court approved the Hydraulic Improvements component of the HCFRR Program advancing forward after the Proof of Concept Report was submitted. Phase 1 of the Hydraulic Improvements project is in the final design stage.

Subsequent to issuing the Proof of Concept Report, Stantec participated in a number of additional coordination and outreach initiatives, including a series of local public meetings. Several questions and concerns were raised by project stakeholders and landowners regarding the proposed flood mitigation measures, particularly the dry-detention storage basins. In addition, a significant flood event occurred along the Blanchard River in July 2017, putting flooding back into the forefront of conversation.

The Maumee Watershed Conservancy District (MWCD) requested Stantec perform additional analyses and provide additional data to support ongoing planning efforts related to the HCFRR Program. Additional data to refine the HCFRR Program included the processing of Light Detection and Ranging (LiDAR) aerial survey data previously collected, subsurface exploration data, processed meteorological data, feedback from the public meetings, and results from the Stantec Hydrology Report (November 2017).

The MWCD requested Stantec use the additional data collected and perform analyses to refine the hydrologic and hydraulic analyses related to the proposed flood mitigation measures. Stantec was asked to refine the HCFRR Program recommendation to address some key concerns with the stated goals in mind:

- reduce the footprint of the proposed storage facilities;
- reduce the number of parcels potentially impacted by construction;
- reduce the number of structures potentially impacted by construction;
- increase the acreage of agricultural land protected;
- reduce the risk of flooding to structures and roadway crossings upstream and downstream of the basins; and
- reduce the opinion of probable cost.

Stantec reviewed feedback from the community, processed additional survey data, and finalized the hydrologic analysis to help refine the study. The additional data collected verified the residual risk of the Program components and allowed the team to update the benefits and impacts of the considered alternatives. Stantec addressed the concerns of the community by reducing the footprints of the proposed storage facilities to reduce the impacts of construction. With the reduction in impacts also came the reduction in anticipated benefits from the proposed storage basins, particularly at the Blanchard River storage site.

Stantec once again recommends that MWCD advance with a flood risk reduction program comprised of the following independent projects:

1. Hydraulic improvements to the Blanchard River within the City of Findlay to be completed in two phases. Phase 1 includes the removal of four (4) low head dams or riffle structures and the widening of the floodplain bench between the Norfolk Southern railroad and Broad Avenue. Phase 2 involves modifying the railroad bridge for addition conveyance capacity. These improvements can be made independently of other alternatives.

2. A dry storage basin on Eagle Creek adjacent to US 68 in lieu of the diversion channel. This project has similar benefit as the diversion at a reduced cost.

3. Dry storage basins on the Blanchard River and Potato Run, upstream of Mt. Blanchard. Providing storage at these locations reduces the secondary peak of the flood wave that occurs in Findlay due to singular storms and helps in reducing the risk for out-of-bank flooding along the reach of the Blanchard River between Mt. Blanchard and Findlay. Reducing the risk of flooding along that reach has the ancillary benefits of reducing flood frequency to agricultural areas and reducing flood potential along Lye Creek due to potential overflow between the Blanchard River and Lye Creek during large flood events.

Stantec revised the hydrologic and hydraulic models to incorporate the HCFRR Program, generated revised water surface profiles, and provided a refined opinion of probable cost for each Program component to Jack Faucett Associates (JFA) to complete an updated Benefit-to-Cost Analysis (BCA). The refined preliminary opinion of probable cost for the HCFRR Program is approximately $153.8 Million with contingency. The base benefit-to-cost ratio (BCR) calculated by JFA for flood control alone is 2.21. The BCA of the HCFRR Program demonstrates that the recommended flood risk reduction measures are cost effective. The Net Present Value substantially exceeds the cost, indicating that it is an efficient infrastructure investment. In addition, the BCR of 2.21 reveals a substantial benefit margin over costs. This indicates that for each dollar of investment in the HCFRR Program, the community will receive $2.21 in estimated benefits. JFA also estimates that implementation of the proposed Program would produce certain environmental benefits. These environmental benefits are expected to increase the BCR to 2.94.

Abbreviations

ACE	Annual Chance Exceedance
AWA	Applied Weather Associates
BCA	Benefit Cost Analysis
BCR	Benefit-to-Cost Ratio
BFE	Base Flood Elevation
CFS	Cubic Feet per Second
CY	Cubic Yards
HEC-FDA	Hydrologic Engineering Center's Flood Damage Assessment
HEC-HMS	Hydrologic Engineering Center – Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center – River Analysis System
HTRW	Hazardous, Toxic and Radioactive Waste
JFA	Jack Faucett Associates
LiDAR	Light Detection and Ranging
MSG	The Mannik & Smith Group, Inc.
MWCD	Maumee Watershed Conservancy District
NED	National Economic Development

NEPA	National Environmental Policy Act
NRCS	Natural Resources Conservation Service
ODNR	Ohio Department of Natural Resources
ODOT	Ohio Department of Transportation
OEPA	Ohio Environmental Protection Agency
OGRIP	Ohio Geographically Referenced Information Program
OHPO	Ohio Historic Preservation Office
PMF	Probable Maximum Flood
RED	Regional Economic Development
SOW	Scope of Work
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
WSE	Water Surface Elevation

1.0 INTRODUCTION

Hancock County and the City of Findlay, Ohio areas experience frequent and significant overbank flooding from the Blanchard River and its major tributaries, Eagle Creek and Lye Creek. The U.S. Army Corps of Engineers, Buffalo District (USACE) and Hancock County Commissioners executed a Feasibility Cost Sharing Agreement in September of 2008 to conduct a feasibility study which addressed Flood Risk Management in the Blanchard River Watershed. The feasibility study ultimately resulted in the USACE proposing a 9.2-mile flood diversion channel outside Findlay to the south and west of the City. The diversion channel was proposed to convey flow from Eagle Creek and discharge into the Blanchard River west of Township Road 130. The project advanced through the planning stages resulting in a Draft Environmental Impact Statement (Reference 1 - USACE "Draft EIS" – April 2015) and an unpublished Draft "Final EIS" (Reference 2 – Draft "Final EIS" – March 2016) for the proposed project.

Stantec Consulting Services Inc. (Stantec) was contracted by the Hancock County Commissioners in July 2016 to complete design and permitting for the Western Diversion of Eagle Creek (USACE Plan); the project recommended by the USACE. Stantec was hired to provide professional services related to the continuation of this flood risk reduction project in planning phases. The first planning phase included Stantec's review of existing data associated with the analysis completed by the USACE in search of potential data and analysis gaps. A plan was developed by Stantec to address perceived gaps and collect additional information prior to proceeding with planning Phase II; the refinement of the proposed project.

The Hancock County Commissioners transferred control of the project to the Maumee Watershed Conservancy District (MWCD) at the beginning of the second planning phase. This phase included a Work Plan containing methods and schedules to fill in the gaps identified during Phase I, evaluation of the USACE Plan (Alternative 13) presented in the Draft Final EIS, and confirmation of the USACE Plan's effectiveness (Proof of Concept). Phase II was completed in distinct parts. Part A included additional data collection and analysis and Part B included review and refinement of the initial proposed design concept. Stantec was also requested to study potential project modifications and other implementable solutions during Part B. Phase I and Phase II were completed and are documented within the Stantec report titled, "*Hancock County Flood Risk Reduction Program Final Report: Data Review, Gap Analysis, USACE Plan and Alternatives Review, and Program Recommendation*" (Reference 3 – "Proof of Concept Report" – April 2017).

Stantec ultimately recommended in the Proof of Concept Report that MWCD implement an alternate to the USACE diversion channel; the Hancock County Flood Risk Reduction (HCFRR) Program. The recommended HCFRR Program comprised of several independent projects including Hydraulic Improvements along the Blanchard River in Findlay and dry storage basins on Eagle Creek, the Blanchard River, and Potato Run. After the Proof of Concept Report was submitted, the MWCD Board and the Conservancy Court approved the Hydraulic Improvements component of the HCFRR Program advancing forward. As of the writing of this document, Phase 1 of the Hydraulic Improvements project is in the final design stage.

Additional data were collected, and project refinements were made since the Proof of Concept Report was submitted in response to feedback received from the community and project stakeholders. This Proof of Concept Update Report summarizes the additional data collected, and describes the other analyses performed by the Stantec team used to refine the HCFRR Program.

2.0 BACKGROUND

The study area is the Blanchard River Watershed, a sub-basin of the Western Lake Erie Basin in northwestern Ohio. The Blanchard River Watershed boundary is within Allen, Hancock, Hardin, Putnam, Seneca, and Wyandot Counties. The Blanchard River Watershed drains to the Auglaize River, which then flows into the Maumee River before entering Lake Erie. Figure 1 shows an overview of the Maumee River Watershed. The Blanchard River Watershed consists of alluvial flatlands prone to flooding, resulting in repeated flood damages, including the population centers of Findlay and Ottawa.

This report focuses on the Upper Blanchard River watershed near the City of Findlay and the surrounding areas within Hancock County. Figure 2 shows an overview of the Upper Blanchard River watershed. The Findlay area experiences damages from overbank flooding because the Blanchard River and its major tributaries, Eagle, and Lye Creeks, do not have sufficient capacity to convey the flow during significant storm events. The Blanchard River and its tributaries can convey small, frequent storms. However, during large rainfall events, flow exceeds channel capacity and overbank flooding occurs through the City and in nearby agricultural areas. Historical evidence shows substantial damage during large events, such as the 4% annual chance exceedance (ACE) (25-year) or greater floods, and during more frequent storms with higher intensities.

Per the National Weather Service's Advanced Hydrologic Prediction Service, "Major Flood Stage" on the Blanchard River near Findlay occurs when United States Geological Survey (USGS) gage 04189000 at County Road 140 depth readings are at 13.5 feet or greater. Figure 3 shows the historic annual peak flood crests at USGS gage 04189000 downstream of Findlay. The gage data at this site indicates the Blanchard River has reached or exceeded major flood stage in seventeen of the years since 1913, including most recently in July of 2017. Of these seventeen events, seven have occurred since 2007. Six events between 2007 and 2017 are among the top eleven stages on record; four events peaked at more than 3 feet over major flood stage; and the August 2007 event reached a peak stage near the maximum recorded depth of 18.5 feet in 1913.

Flooding has caused extensive damage to downtown businesses and nearby agricultural and residential areas. Water levels can remain above flood stage for several days, often inundating bridges and approach roads requiring closure. Rescue operations are often required during the floods, and significant cleanup and restoration expenses are incurred by the local, state, and federal government.

The repetitive flooding prompted the Western Lake Erie Study authorization under the Water Resources Development Act of 1999 (WRDA 99). The Hancock County Commissioners requested assistance from the USACE to study and recommend ways to reduce significant flood damages adjacent to the Blanchard River and its tributaries.

Figure 1 – Maumee River Watershed Map

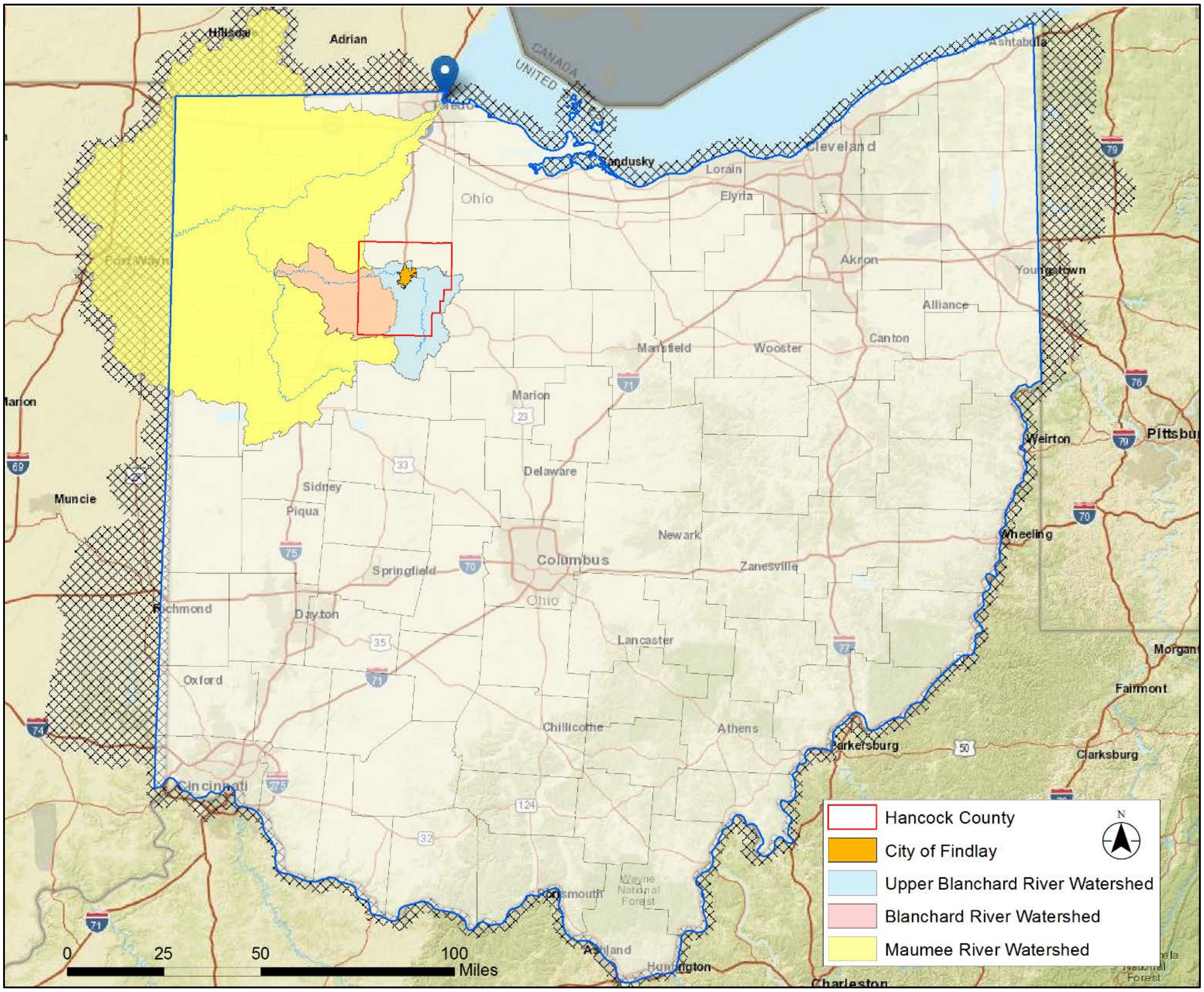


Figure 2 – Upper Blanchard River Watershed Overview Map

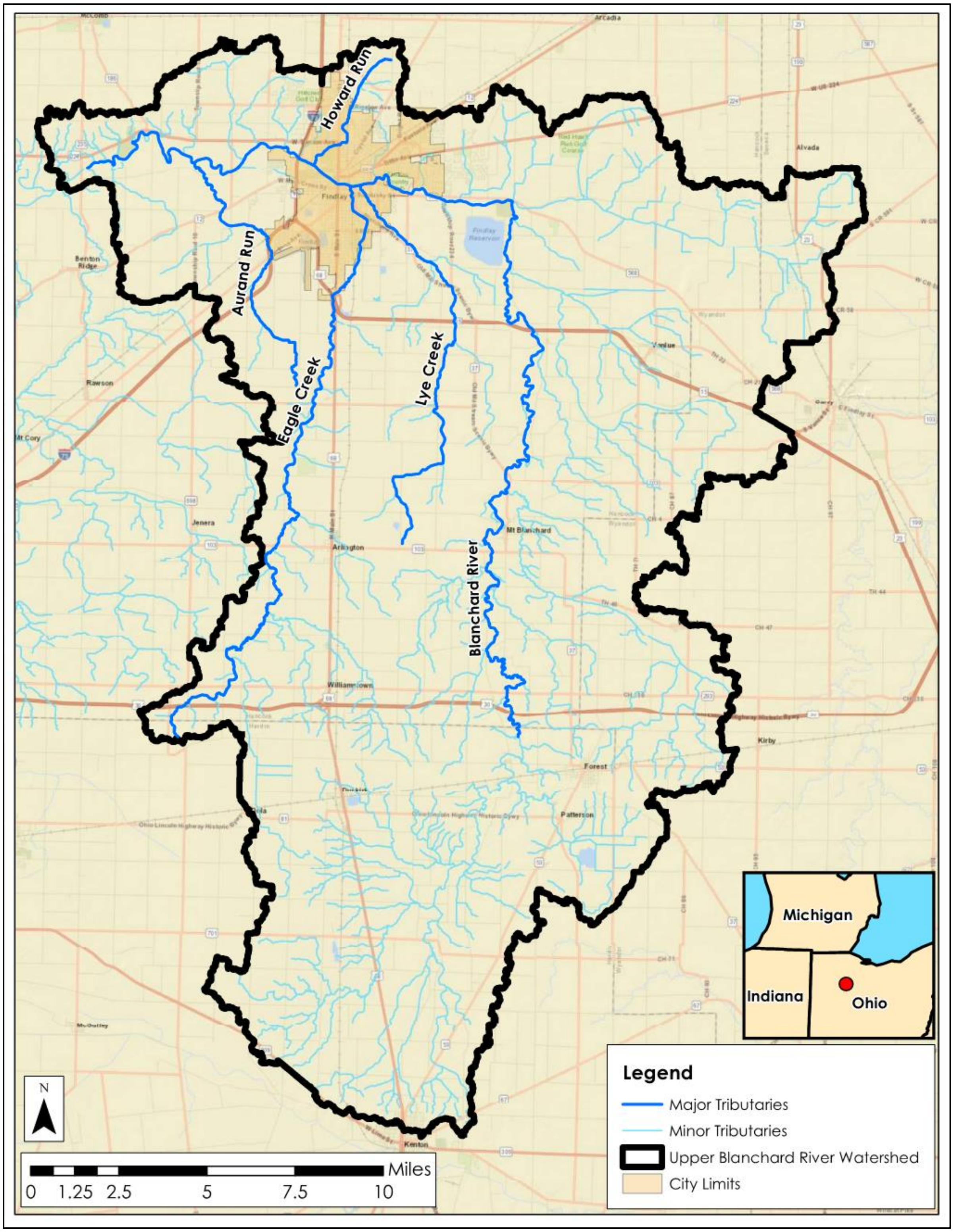
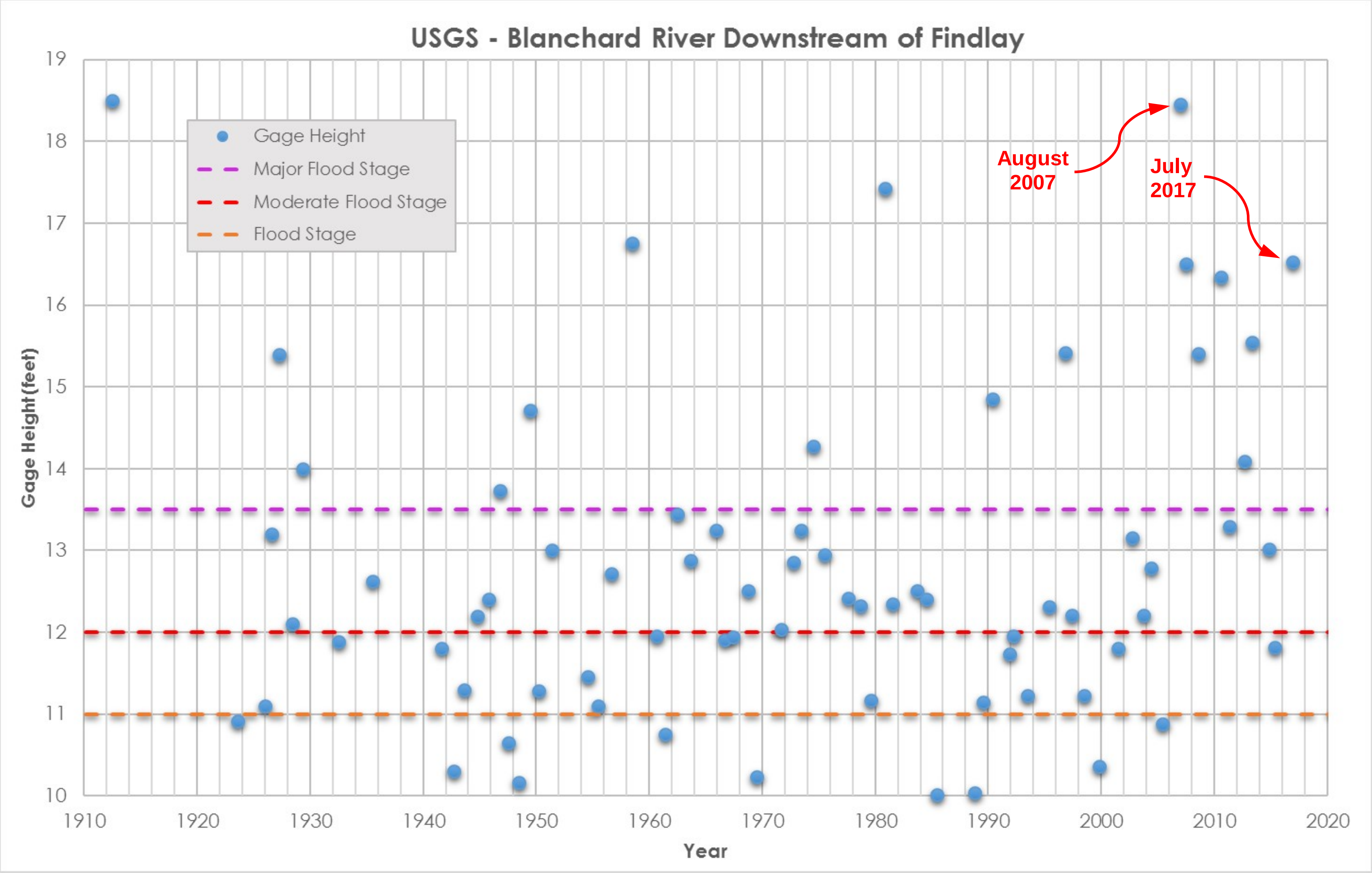


Figure 3 – Historic Flood Crests at USGS Gage 041879000 at County Road 140



2.1 USACE STUDY

The purpose of the USACE study was to evaluate measures for flood risk management in the Blanchard River Watershed, focusing on areas within the City of Findlay. The findings presented within the USACE Feasibility Report were used to determine if there existed a federal interest in providing flood risk management improvements in the Blanchard River Watershed near Findlay. The overall objective of the study was to reduce flood risk and improve the overall quality of life for the residents of the Findlay area. The USACE developed plans to address these objectives including a “No Action” plan and various combinations of structural and nonstructural measures. The USACE evaluated the economic and environmental impacts of each and then reported a recommended plan. The Feasibility Report and Draft EIS presented the results and the public, agency, and peer review comments. Alternative 13, the Western Diversion of Eagle Creek, was the plan that had the highest Benefit-to-Cost Ratio (BCR) and maximized annual net benefits. From this screening, the USACE recommended Alternative 13 as the plan that best met the National Economic Development objectives because it provided the highest net benefits.

2.1.1 USACE Plan – Western Diversion of Eagle Creek

The Western Diversion of Eagle Creek was proposed to divert flood flows from Eagle Creek to the Blanchard River at a location approximately five miles downstream of the City of Findlay. The diversion channel was proposed to extend approximately 9.2 miles and consist of a trapezoidal channel. The plan included the construction of an in-line diversion structure in Eagle Creek to control the amount of flow diverted to the diversion channel from Eagle Creek. The diversion channel associated with Alternative 13 was expected to completely remove over 200 acres of land from agricultural use.

The gated flow control structure would restrict flow in Eagle Creek to 100 cfs when the Blanchard River was forecasted to be above the 20% Annual Chance Exceedance (ACE) flow (5-Year) event. Flows greater than 100 cfs would be directed into the diversion channel. The diversion channel was designed to convey the 4% ACE (25-Year) event, about 3,000 cfs. Flows greater than 3,000 cfs would continue downstream in Eagle Creek. Figure 4 provides an overview of the USACE Plan.

The USACE prepared a total project cost (TPC) estimate for the final plan using detailed cost estimating tools. The preliminary estimate for initial project costs with contingency applied was $80,902,000. The Draft Final EIS reports the BCR for Alternative 13 as 1.03. This preliminary estimate was then escalated for inflation through project completion. After applying interest during construction, the project was estimated to cost $86,574,000 and the final BCR fell to 0.93. The USACE Plan was in jeopardy of not being eligible for federal funding since the project’s BCR was less than one.

Figure 4 – USACE Plan (Alternative 13)

*Source: USACE Buffalo District Website: http://www.lrb.usace.army.mil/Portals/45/docs/Blanchard/August2015/August-2015-Recommended-Plan.pdf

2.2 PROJECT DESIGN TRANSITION

The Hancock County Board of Commissioners indicated it was going to examine the feasibility of implementing the project without USACE assistance and requested that any background study information be provided to the engineering consultant hired for the implementation of the project. The project changed from one led by the USACE to a locally-led, community driven project led by MWCD in cooperation with the Hancock County Commissioners and City of Findlay. When the City and County elected to move away from USACE as the lead agency and begin working through MWCD on a local level, the client confirmed that this is now a community driven project.

Stantec was contracted to complete the design and environmental permitting for the USACE recommended project. The project advanced, despite having a preliminary BCR less than 1.0, because the team, including MWCD, the County, the City, and Stantec, believed that with greater flexibility in project options that more benefits would be realized, resulting in a more favorable BCR. Studying the benefits of flood mitigation through a regional perspective allows the impacts experienced by the community due to repeated flooding to be placed into a greater context.

In July of 2016, Stantec began working on the continuation of this flood risk reduction program in phases. This work is referred to as the “Proof of Concept”.

2.3 PROOF OF CONCEPT

The “Proof of Concept” was broken into two distinct phases. The first phase included Stantec’s review of existing data associated with the analysis completed by the USACE. The second phase included refinement of the proposed USACE Plan, including the study of potential project modifications and other implementable solutions across the watershed. These two phases of work are documented within the Stantec “Proof of Concept Report” (Reference 3 – April 2017). The report summarizes the project background and the tasks performed by the Stantec team during Phase I and Phase II and includes a recommendation by Stantec for a flood risk reduction program.

2.3.1 Stantec Recommendation

The Western Diversion of Eagle Creek will reduce flood levels in Findlay and is still a viable alternative. However, Stantec determined it was not the most cost-effective solution. Stantec ultimately recommended in the Proof of Concept Report (April 2017) that MWCD implement an alternate to the USACE diversion channel; the Hancock County Flood Risk Reduction (HCFRR) Program. The goal of the proposed HCFRR Program was to cost-effectively reduce the impacts caused by the 1% ACE event by:

- Decreasing the water surface elevation (WSE) at Main Street in Findlay and other major egress routes to permit passage of emergency response vehicles;
- Reducing the number of residential properties required to obtain flood insurance;
- Reducing prolonged inundation and increasing retention of productive farmlands;
- Protecting public parks and facilities from flooding; and
- Preserving opportunities for job creation and retention in and around the City of Findlay and Hancock County.

The recommended HCFRR Program comprised of a suite of independent projects including:

1. Hydraulic improvements to the Blanchard River within the City of Findlay to be completed in two phases. Phase 1 includes the removal of four (4) low head dams or riffle structures and the widening of the floodplain bench between the Norfolk Southern railroad and Broad Avenue. Phase 2 involves modifying the railroad bridge for addition conveyance capacity. These improvements can be made independently of other alternatives.

2. A dry storage basin on Eagle Creek adjacent to US 68 in lieu of the diversion channel. This project has similar benefit as the diversion at a reduced cost.

3. Dry storage basins on the Blanchard River and Potato Run, upstream of Mt. Blanchard. Providing storage at these locations reduces the secondary peak of the flood wave that occurs in Findlay due to singular storms and helps in reducing the risk for out-of-bank flooding along the reach of the Blanchard River between Mt. Blanchard and Findlay. Reducing the risk of flooding along that reach has the ancillary benefits of reducing flood frequency to agricultural areas and reducing flood potential along Lye Creek due to potential overflow between the Blanchard River and Lye Creek during large flood events.

The Blanchard River WSE reduction during a 1% ACE (100-Year) event was simulated as 3.6 feet (reducing the flooding duration from 50 hours to 15 hours) with the proposed HCFRR Program in place. Approximately 2,850 parcels were expected to be removed from the floodplain. The preliminary opinion of probable cost developed for the HCFRR Program was approximately $160 million. That preliminary opinion of probable cost included a 30% contingency. Based on the Benefit-to-Cost Analysis (BCA), the resulting BCR for the Program was 1.60. The BCR demonstrated that the Program benefits outweighed the costs and that the Program would be highly beneficial to the Hancock County community and its residents.

2.3.2 Proof of Concept Report – Subsequent Events

2.3.2.1 Hydraulic Improvements – Phase 1

After the Proof of Concept Report was submitted, the MWCD Board of Directors and the Conservancy Court approved of the Hydraulic Improvements component of the HCFRR Program advancing forward to design in May of 2017. Phase 1 of the Hydraulic Improvements project has since progressed through agency coordination, engineering, and design over the last year. Stantec presented the final (95%) design for Phase 1 of the Hydraulic Improvements during the MWCD Annual Meeting in May of 2018. Figure 5 shows a rendering of the proposed floodplain bench on the right descending bank at Swale Park, looking to the north.

Pending approval, construction is anticipated to begin at the end of summer in 2018. The proposed Hydraulic Improvements will increase the flow capacity and hydraulic efficiency of the Blanchard River through the City and lower the WSE during a range of flooding events. The lowered WSE will result in a reduced risk of transportation and structure impacts due to flooding. The WSE is expected to be reduced by about 0.8 feet during a 1% ACE event once Phase 1 of the Hydraulic Improvements are implemented at an estimated cost of about $11.8 Million (including a 10% contingency). The proposed project and natural channel design elements are anticipated to have several benefits including increased wetland function, improved water quality, improved fish passage and aquatic habitat, and enhanced recreational opportunities.

Figure 5 – Rendering of the Hydraulic Improvements, Phase 1 – Floodplain Bench

2.3.2.2 Public Outreach, Local Meetings

Subsequent to issuing a draft and final version of the Proof of Concept Report, Stantec participated in a number of additional coordination and outreach initiatives, including a series of local public meetings (2/22/2017, 4/25/2017, 4/26/2017, 5/24/2017, and 1/24/2018). Several questions and concerns were raised by project stakeholders and landowners regarding the proposed flood mitigation measures, particularly the dry-detention basins. Public comments and a response to each of the comments have been posted to the Program webpage: HancockCountyFlooding.com. These comments have informed the decision-making processes and have helped shape the direction of the flood mitigation program.

2.3.2.3 July 2017 Flood Event

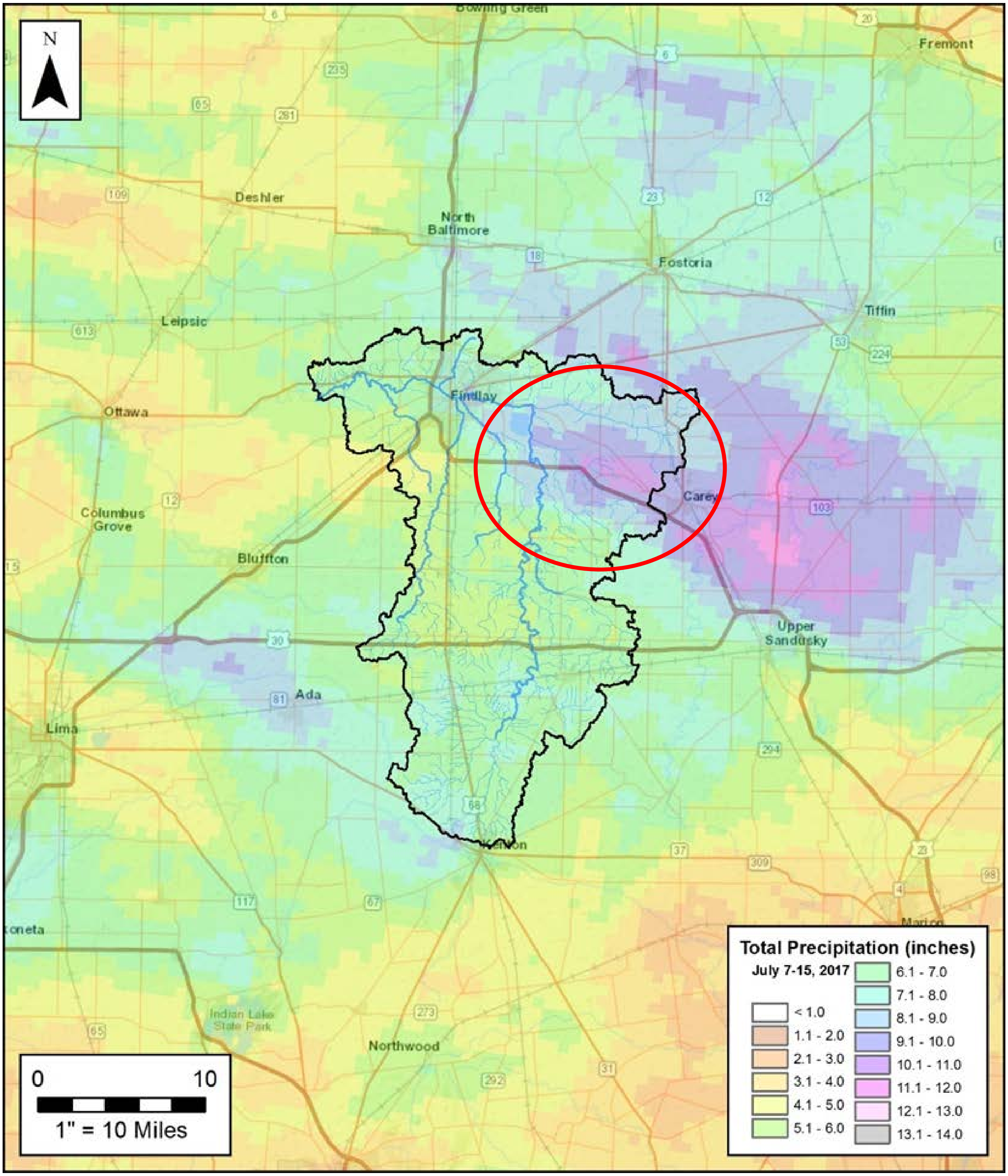
A significant flood event occurred along the Blanchard River on July 14, 2017; putting flooding back into the forefront of conversation. Figure 6 through Figure 8 show images of flooding during the July 2017 event. The flood event produced the 5th largest crest on record according to the USGS gage on the Blanchard River downstream of Findlay (Historic USGS Gage Records (048189000)). The July 2017 event occurred with a storm center downstream of the proposed dry storage basins. Figure 9 shows how the total rainfall for the July 2017 event was spread spatially across the watershed. Concerned residents in the community questioned the anticipated effectiveness of the proposed HCFRR Program if a storm in the future were positioned in a “worst case” position within the watershed, like that of the July 2017 event.

Figure 6 – Blanchard River at Main Street During the July 2017 Flood Event

Figure 7 – Intersection of E. Main Cross Street and Martin Luther King Jr. Parkway During the July 2017 Flood Event

Figure 8 – Main Street (Looking North) During the July 2017 Flood Event

Figure 9 – July 2017 Flood Event – Precipitation



2.3.2.4 Stantec Hydrology Report

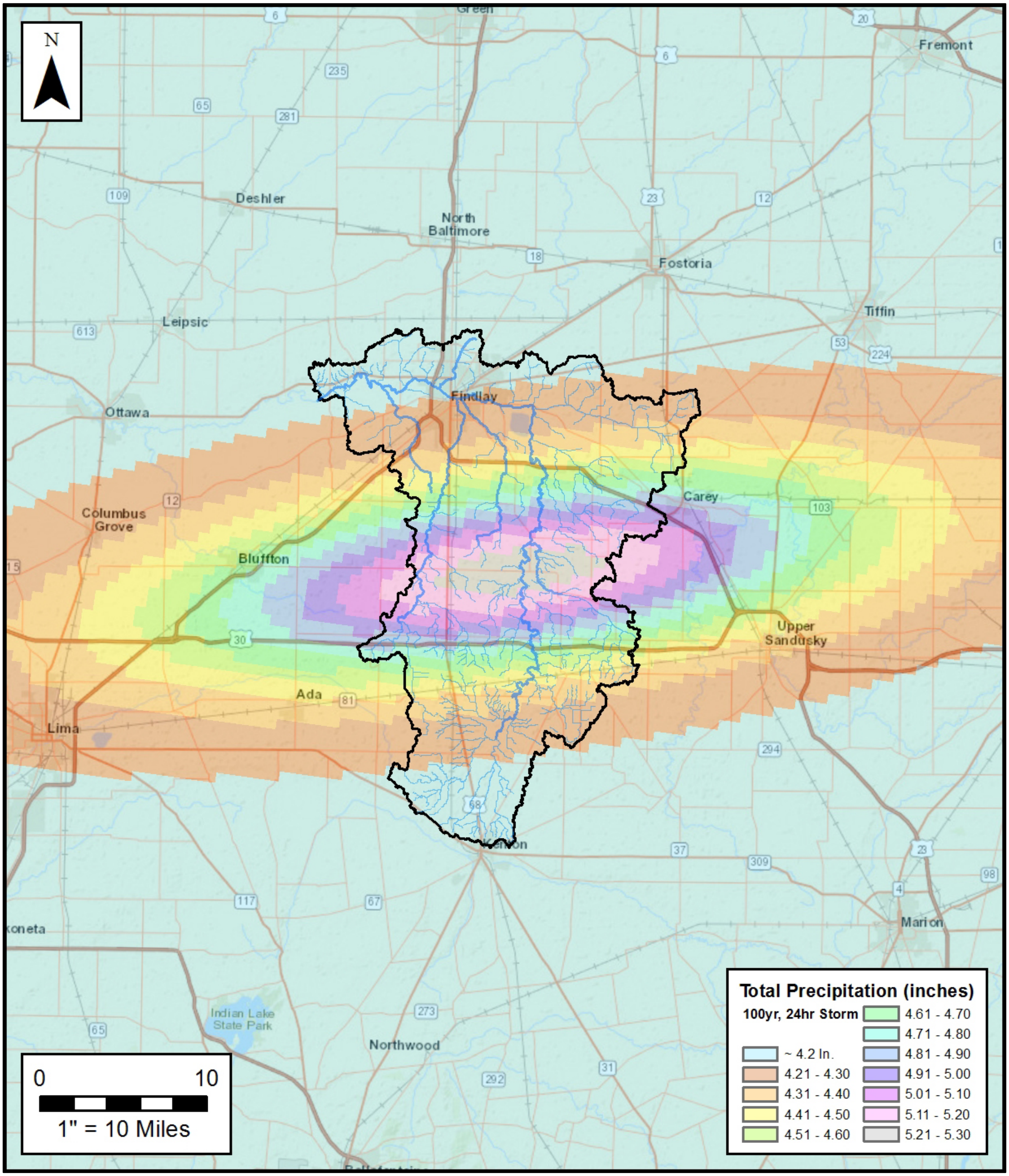
The April 2017 Proof of Concept Report used a version of the USACE Buffalo District Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) (Reference 4) model of the Blanchard River watershed with minor modifications for hydrologic modeling. Stantec made modifications within the HEC-HMS model (October 2011 geometry) to provide a comparison to available river gage information, update subcatchment areas, and represent the proposed flood mitigation measures for the Proof of Concept Report.

An SCS Type II design storm was applied uniformly to the watershed for hypothetical events for the April 2017 Proof of Concept Report. The updated Proof of Concept hydrologic model was consistent with the USACE approach and produced acceptable, albeit, conservative results. Peak discharges from the hydrographs produced from the HEC-HMS model were used as inputs to an unsteady-state Hydrologic Engineering Center River Analysis System (HEC-RAS) (Reference 5) hydraulic model refined by Stantec. The slightly modified HEC-HMS model was used with the updated HEC-RAS model to evaluate various flood mitigation options.

Through a parallel effort, Stantec was authorized to update the hydrologic modeling to better reflect storm events that could be expected to occur in Hancock County. Stantec worked with Applied Weather Associates (AWA) to study meteorological conditions in the region and develop better model input data. The 1% ACE event can relate to many different hydrographs and flow rates. The WSEs observed through Findlay vary depending on the intensity, location, and durations of the storm events. AWA determined a custom temporal and spatial pattern for the hypothetical "Typical Storm" for the watershed using historical data. Model simulations now include a more accurate representation of the spatial and temporal patterns for hypothetical storm events. Figure 10 shows the "Typical Storm" pattern developed as part of the hydrology refinement.

The HEC-HMS model was re-calibrated with processed radar data from two additional calibration storms (September 2011 and June 2015), in addition to a revised simulation of the August 2007 storm which produced an event similar to the "flood of record". Stantec reviewed the HEC-HMS model data and determined the September 2011 calibrated geometry would most appropriately represent the hydrologic response of the Blanchard River Watershed during a typical large storm event. The adjusted calibration favorably compares to and is supported by gage-based frequency analyses on the Blanchard River at the USGS Gage 04189000 downstream of Findlay. Stantec determined the overall watershed centroid would be the critical placement of the storm center and the 24-hour duration was most appropriate based on historical and observed data.

Figure 10 – "Typical Storm" Pattern Developed for the Hydrologic Update



The result of the hydrology refinement and model calibration is the ability to develop a more accurate prediction of discharges in the watershed for a given storm event. A separate Stantec report, "*Hydrologic Evaluation of the Blanchard River*", (Reference 6 – Hydrology Report – November 2017) was issued final in November of 2017. The report describes the updated hydrologic modeling and resulting model discharges. A complete copy of the Hydrology Report is included as Appendix A. The Hydrology Report was already in DRAFT form when the July 2017 event occurred so precipitation and flood data from the event were not included in the discussion.

The HEC-HMS model associated with the Hydrology Report submittal replaces the USACE HEC-HMS model and the model used for the Proof of Concept. Stantec concluded that the revised HEC-HMS model and subsequent discharges developed as a part of the Hydrology Report are based on more refined and complete analyses than previous hydrologic studies of the area. The magnitude and trends predicted by the results are consistent with prior efforts and therefore, do not invalidate the previous hydrologic modeling. Stantec does not recommend updating results within the April 2017 Proof of Concept Report, which was a planning level document, but recommended that the revised HEC-HMS model be used for future flood mitigation planning, benefit-to-cost analyses, and design efforts in the watershed area to the extent applicable.

2.3.3 Proof of Concept – Next Steps

The MWCD requested Stantec obtain additional data and complete analyses to support ongoing planning efforts for the HCFRR Program that consider feedback received during public meetings from the community and other project stakeholders, analysis of the July 2017 flooding event, and the Hydrology Report issued by Stantec in November of 2017 (Appendix A).

Additional data to refine the HCFRR Program included the processing of Light Detection and Ranging (LiDAR) survey data previously collected by Kucera International (Kucera), subsurface exploration data, processed meteorological data, feedback from the public meetings, and results from the Hydrology Report.

The MWCD requested Stantec use the additional data collected and perform analyses to refine the hydrologic and hydraulic analyses related to the proposed flood mitigation measures. Stantec was asked to refine the HCFRR Program recommendation to address some key concerns with the stated goals in mind:

- reduce the footprint of the proposed storage facilities;
- reduce the number of parcels potentially impacted by construction;
- reduce the number of structures potentially impacted by construction;
- increase the acreage of agricultural land protected;
- reduce the risk of flooding to structures and roadway crossings upstream and downstream of the basins; and
- reduce the opinion of probable cost.

In an ideal scenario, reviewing these measures would result in reduced impacts and a reduced opinion of probable cost without significantly reducing the benefits of the proposed HCFRR Program. Stantec coordinated closely with stakeholders during the refinement process since some of stated project goals have competing objectives. MWCD requested Stantec update the opinion of probable cost and complete a new BCA once the recommended HCFRR Program was refined.

Since the July 2017 storm center occurred downstream of the proposed dry storage basins, MWCD also requested that Stantec study the July 2017 event in detail, provide analysis on how the proposed HCFRR Program would have fared if the projects were in place during the event, and perform a flood risk gap review.

3.0 PROOF OF CONCEPT – ADDITIONAL DATA COLLECTION

Additional data and information were either processed or collected after the Proof of Concept Report was submitted in April of 2017. This data is described in the following sections.

3.1 AERIAL SURVEY

Kucera flew an aerial survey in late November and early December 2016 during leaf-off and crop-harvested conditions. The survey covered approximately 280 square miles around Findlay and the nearby vicinity within the Blanchard River watershed. Figure 11 shows the extents of the aerial survey. Kucera performed the 4 ppsm (about 2-feet point spacing) aerial LiDAR survey and 0.2-feet resolution digital stereo aerial photo capture covering the project area. Kucera provided a project-wide 0.2-feet resolution digital orthoimage coverage. The aerial data was georeferenced to aerial sensor measured airborne GPS/IMU control and ground based surveyed control. The digital aerial photography and aerial LiDAR survey supports 1-inch = 20-feet scale, 0.5-foot contour aerial mapping and georeferenced raw LiDAR point cloud data.

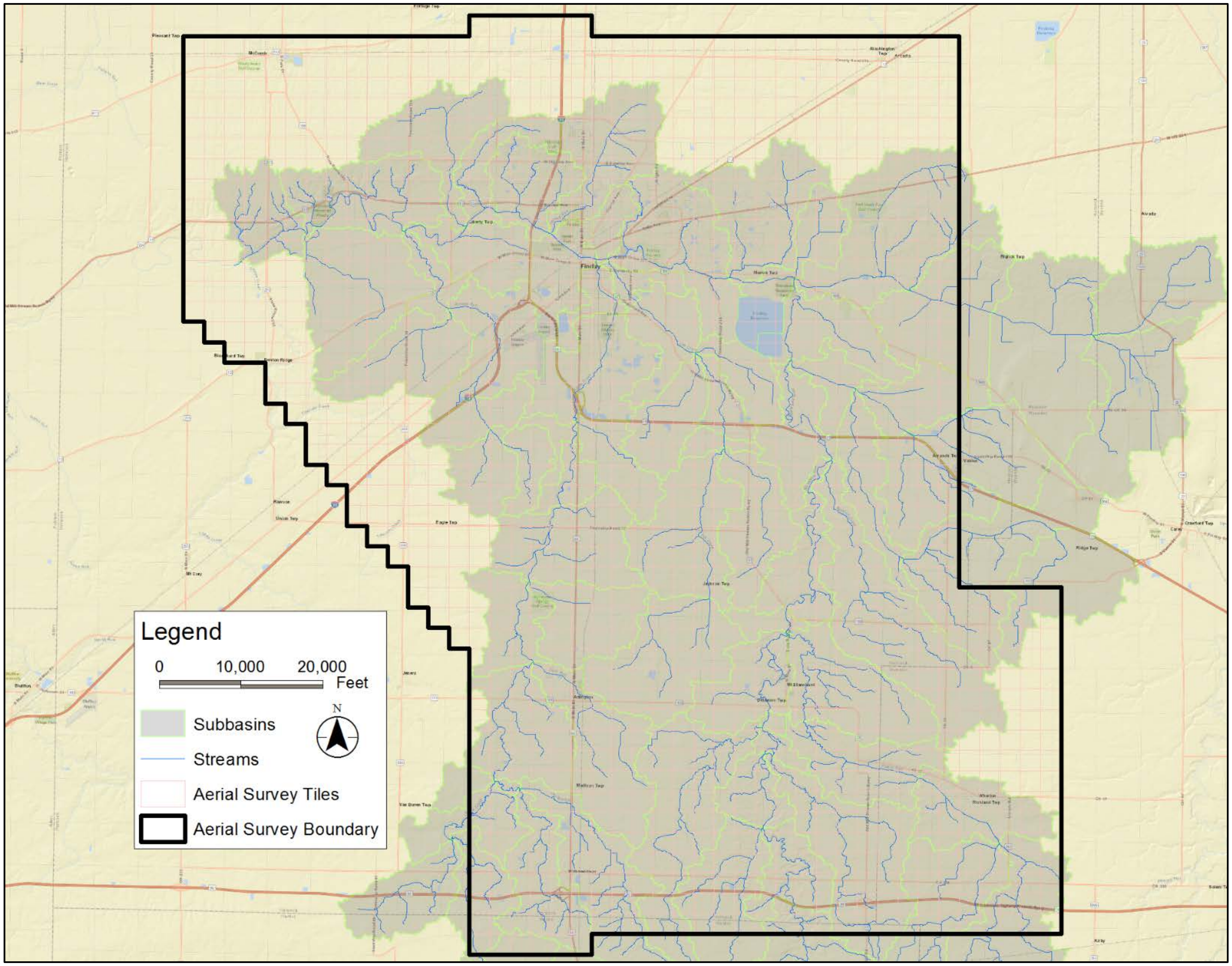
3.1.1 Additional Processing of Prior-Acquired LiDAR Survey

For the Proof of Concept refinement, Kucera provided digital terrain model (DTM) mapping for the project wide area consisting of hydrographic feature breaklines (e.g. lakes, ponds, rivers, and streams) stereo-compiled from the georeferenced aerial photo imagery and a “bare earth” Digital Elevation Model (DEM) extracted from the georeferenced LiDAR return in a thinned “model key point” format. The hydro-DTM mapping represents ground topography conditions as of the time of source aerial acquisition. The data is accurate to within approximately 0.2-feet vertically and horizontally in relation to the project ground control. The project datums are NAD 1983/2011 Ohio State Plane North Zone Horizontal and NAVD88/12A Vertical. The data was processed without the necessity for additional flights or field data collection since the survey was flown in 2016.

The processed aerial survey data was used to support final design of the Hydraulic Improvements and conceptual design refinement for the other Program components. The topographic data supports the concept refinement process by providing more accurate estimates of the available storage capacity and the volume of earthwork that would be required to construct the dam embankments.

This processed LiDAR data also supports a more accurate assessment of potential flood impacts as it can be used to develop better inundation mapping and better estimates of the elevations at which structures are impacted by a flood. The LiDAR survey was used to update the first-floor elevations within the project’s structure inventory. The structure inventory is an important part of the BCA performed for the Program.

Figure 11 – Kucera Aerial Survey Extents



3.2 GEOTECHNICAL DATA

Several assumptions were made relative to the suitability of existing soils within the proposed project areas for construction of the recommended dam embankments in the April 2017 Proof of Concept Report. As a result, conservative assumptions were made with respect to the development of the opinion of probable costs for the proposed dry storage basins. For example, a top width of 20 feet and 4H-to-1V side slopes were originally assumed for the proposed embankment at Eagle Creek. Additional geotechnical sampling in the vicinity of the proposed dams and subsequent testing were necessary to enable confirmation that the materials on-site are suitable for use as embankments and to refine the opinion of probable cost at each dam location.

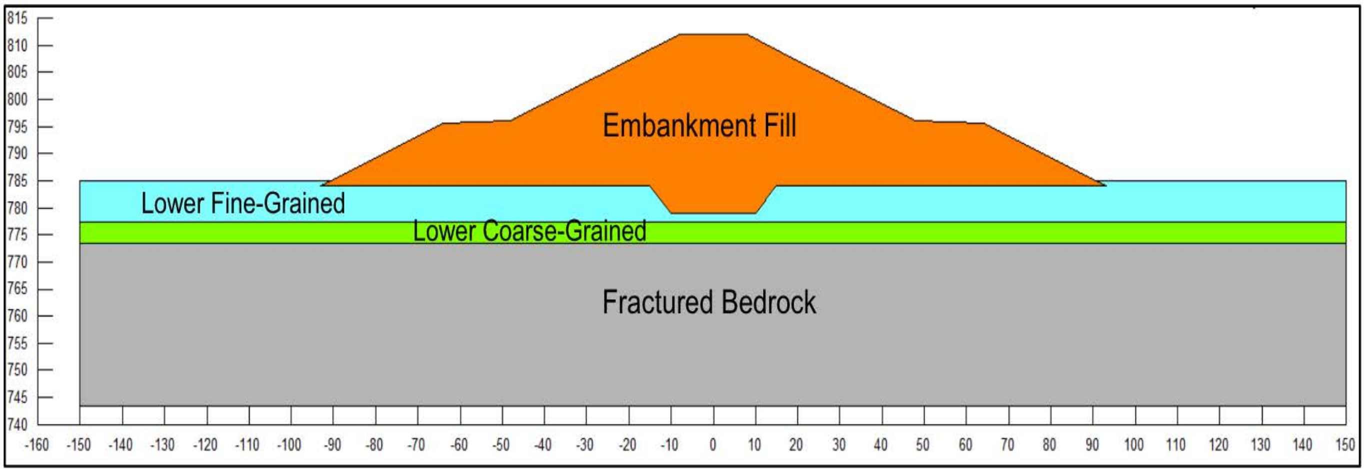
3.2.1 Supplemental Geotechnical Exploration and Analyses

Stantec completed additional geotechnical exploration and analysis to support the refinement of the HCFRR Program. A "*Report of Geotechnical Exploration*" was prepared by Stantec to describe the analyses and is included as Appendix B (Reference 7 – Geotechnical Report – April 2018).

The Geotechnical Report describes how four borings were advanced within the public right-of-way to obtain preliminary geotechnical data for the proposed dams. Two borings were obtained at the Eagle Creek site. Two more borings were advanced near the proposed Blanchard River dam to provide subsurface information. Conditions for the Potato Run dam were assumed to be similar to conditions at the Blanchard River dam alignment since property access was not available for explorations. While the dam alignments have shifted slightly as the Proof of Concept Update advanced, the boring locations are expected to be close enough for planning level design.

Seepage and slope stability analyses were performed for the Eagle Creek Dam and Blanchard River Dam sites. Two cross sections were considered for each of the two evaluated sites. One cross section considered the maximum height of the proposed structures, requiring mid-slope benches in the dam embankment. Figure 12 shows the Eagle Creek dam section at maximum height. The second cross section considered reaches of the dams where the height would be a maximum of 16 feet before requiring a mid-slope bench. Material parameters for analysis models were estimated from laboratory testing or typical published values.

Figure 12 – Eagle Creek Dam Section – Maximum Height



The stability analyses results met the minimum factor of safety requirements according to USACE for the scenarios studied except for one load case for the proposed Eagle Creek Dam. The case that did not meet the minimum factor of safety requirement considered steady-state seepage at the elevated flood pool. It is unlikely that steady-state seepage would develop at the flood level because the dam is proposed to be used for detention only.

Additional exploration, including drilling, sampling, instrumentation, in-situ testing, and laboratory testing should be performed to further define the borrow sources and foundation soil and rock near the proposed dam locations. Future phases of work should separately explore and characterize the conditions for the Eagle Creek, Blanchard River, and Potato Run dam locations.

The preliminary findings indicate that approximately 10 to 15 feet of suitable borrow soil would be available below the topsoil layer in the locations of the borings. A borrow source study should be performed to determine the available quantity of site specific fill materials. The study should include laboratory testing to determine design parameters of potential borrow soil, including optimal compaction, shear strength, potential dispersivity, and saturated and unsaturated permeability.

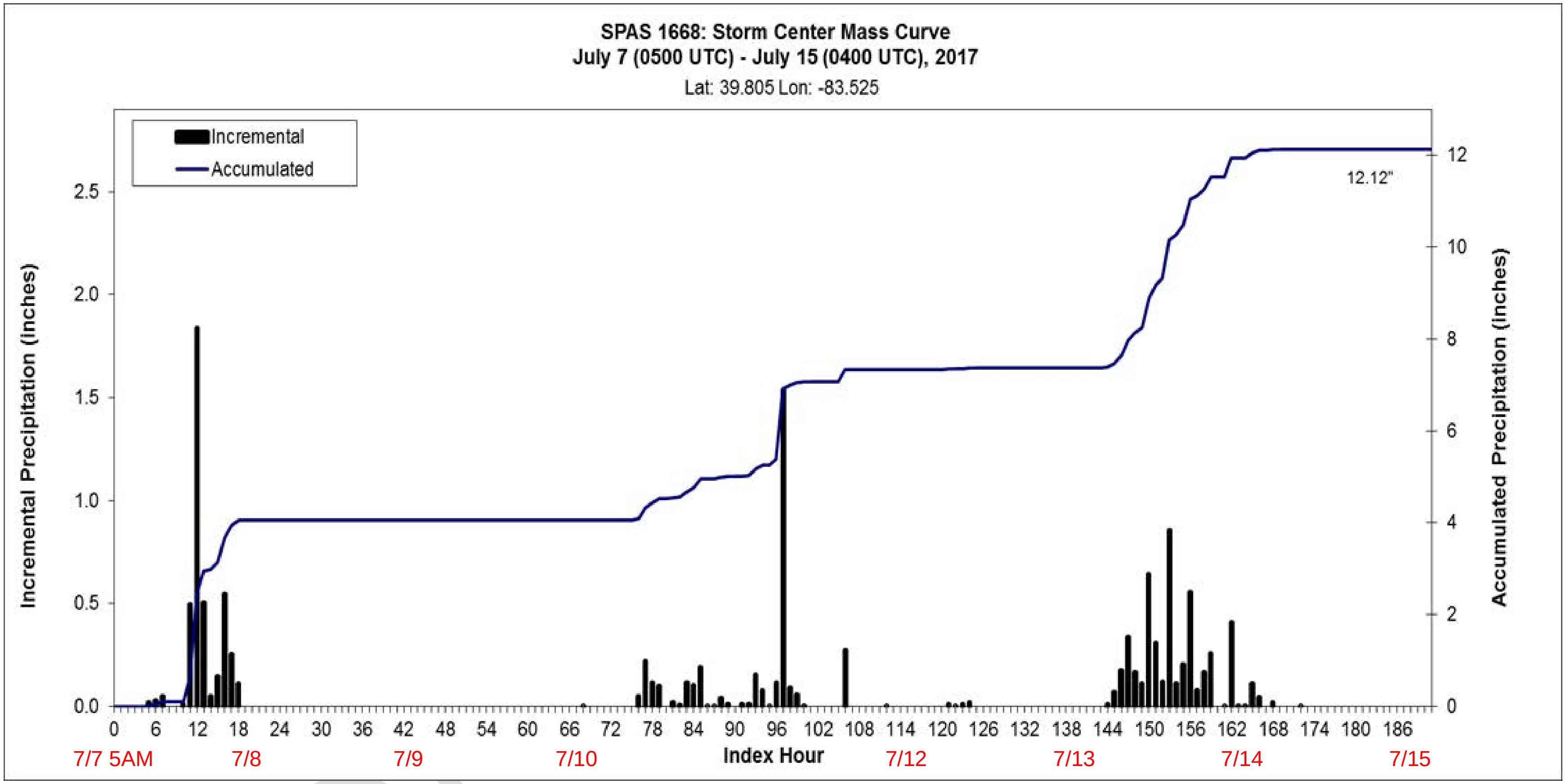
Stantec recommends conducting additional geotechnical borings, test pits, and/or other exploration methods at regularly spaced intervals to adequately characterize subsurface conditions. Explorations should include locations along the dam alignments and at select cross sections and should obtain information to support the design of foundation treatment and/or necessary seepage control measures for the sites.

3.3 JULY 2017 – METEOROLOGICAL DATA

Stantec coordinated with AWA to obtain corrected radar data for the July 2017 flood event. AWA considered a period between 5AM on July 7, 2017 and 5AM on July 15, 2017 (192 hours) and observed that more than 12-inches of rainfall occurred over portions of the watershed during that timeframe. Figure 13 shows the total rainfall event consisted of three separate events. About 4-inches of rainfall occurred over a period of about 12 hours on July 7, another 3.5-inches occurred over a period of about 30 hours on July 10 and 11, and about 5-inches occurred over about 24 hours on July 13 and 14.

Based on NOAA Atlas 14 depth-duration-frequency curve data, the first storm (4-inches over 12 hours) was nearly a 2% Annual Chance Exceedance (ACE) (50-Year recurrence interval) storm event. The second storm (3.5-inches over 30 hours) was about a 20% ACE (5-Year) event. The third storm (5-inches over 24 hours) was larger than a 2% ACE (50-Year) storm event. In total, more than 12-inches of rainfall over the 8-day period categorizes the July 2017 combination of storms at over a 0.1% ACE (1000-Year) recurrence interval.

Figure 13 – July 2017 Storm Center Mass Curve



**Source: Applied Weather Associates*

Figure 9 (Page 2.15) shows how the total rainfall for the period was spread across the watershed. As discussed in the Hydrology Report (Reference 6, Appendix A), rainfall patterns and precipitation depths can be highly variable over a relatively small spatial area. Figure 9 (Page 2.15) illustrates this discussion as it shows the entire watershed did not receive the same rainfall depths. The northeast region of the watershed received about 12-inches of rain while the overall watershed received about 7-inches over the 8-day period, which is still a 2% ACE (50-Year) recurrence interval.

Figure 14 presents USGS gage data illustrating how the rainfall that occurred across the watershed translated to runoff in the Blanchard River. Figure 14 shows the Blanchard River gage downstream of Findlay (#04189000) experienced a minor flood peak of about 900 cfs on July 9 after the first 4-inch storm. It then hit a larger peak of about 3,000 cfs on July 12 after the second 3.5-inch storm. Finally, on July 14 at about 10AM, the Blanchard River peaked at 10,100 cfs after the last 5-inch storm. Figure 15 shows the HEC-RAS estimate of the hydraulic rating curve at Main Street in Findlay. The rating curves shown in Figure 15 reference flow and depths estimated at Main Street along the Blanchard River. These depths are not the same as the gage heights reported at the USGS gage on the Blanchard River at CR 140. Main Street is used as a reference point for planning purposes as this location represents a centralized location to where flooding typically occurs within the community near the confluence of the Blanchard River with Eagle and Lye Creeks. The 10,100 cfs flow rate during the July 2017 event would have peaked at a depth of about 17.4 feet (at Main Street) based on the rating curve. The orange line on Figure 15 shows that if Phase 1 of the Hydraulic Improvements were constructed, the WSE at Main Street would have been reduced by about 1.1 feet based on the improved hydraulic efficiency of the Blanchard River.

Figure 14 – USGS Gage 04189000 – July 7-22, 2017

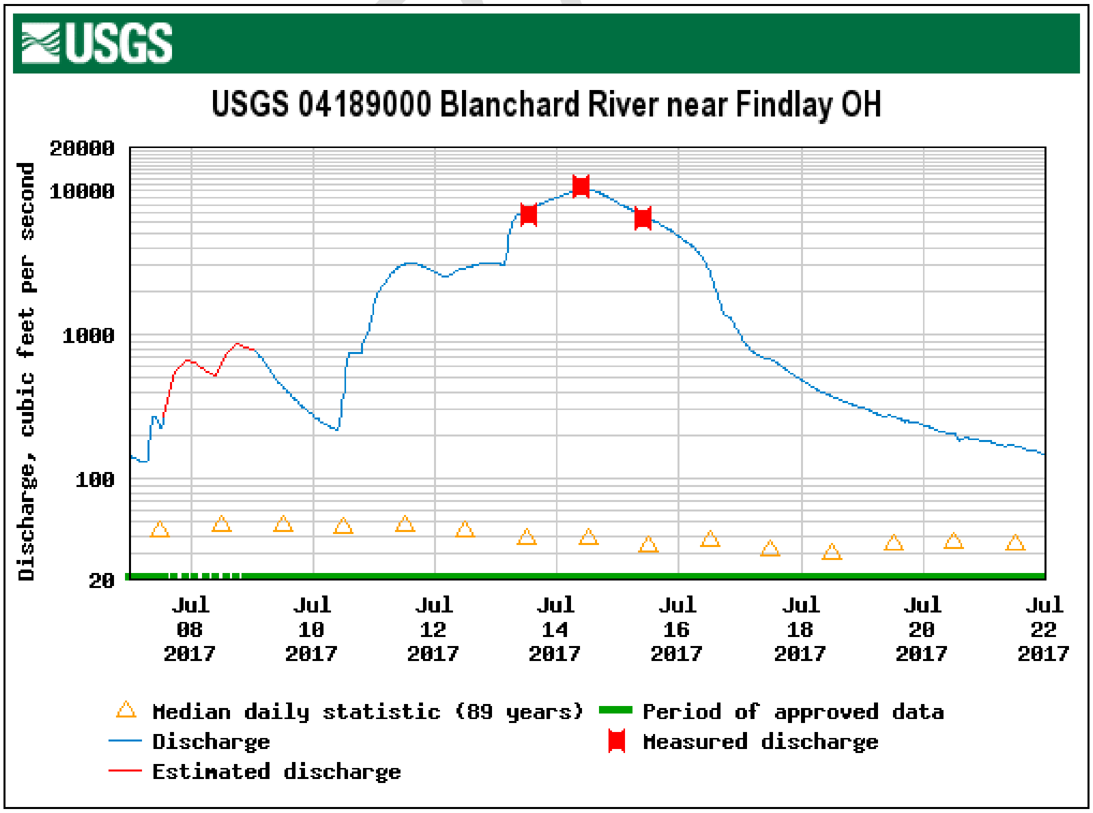
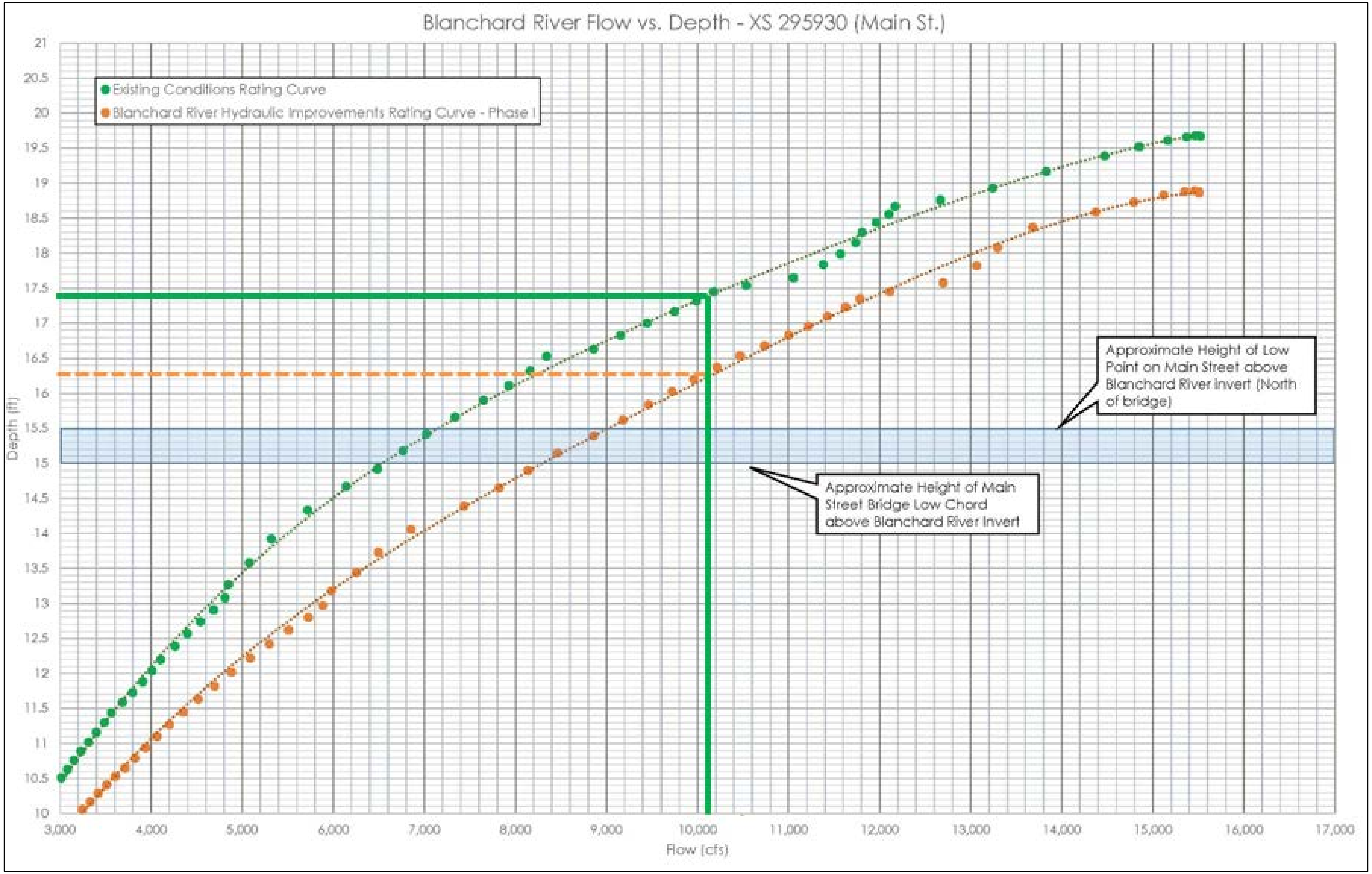


Figure 15 – Hydraulic Rating Curve at Main Street (HEC-RAS XS 295930)



4.0 PROOF OF CONCEPT – REFINEMENTS

Stantec reviewed the following information to refine the HCFRR Program and update the Proof of Concept:

- feedback from the public meetings and project stakeholders;
- results from the revised hydrology model and Hydrology Report;
- processed LiDAR survey data;
- results of the geotechnical exploration; and
- processed July 2017 storm event data.

Much of the feedback received during the public meetings indicated that the community desired projects that had fewer direct impacts on land at a lower cost. Stantec took this information into consideration when attempting to refine the proposed mitigation alternatives by reducing the footprints of the proposed storage facilities and seeking to increase the efficiency of the natural topography to maintain similar flood risk reduction benefits.

4.1 FACILITIES REVIEW – STORAGE VOLUME

Multiple locations were considered for regional dry storage facilities during the initial Proof of Concept phase to determine if suitable sites exist; if the storage areas were effective at reducing flood levels in the watershed and if the storage could be cost-effective. The Ohio Geographically Referenced Information Program (OGRIP) DEM was used to develop stage-storage curves for that preliminary review, analysis, and selection of the sites. Stantec utilized the processed LiDAR data from Kucera containing higher resolution and accuracy to verify the stage-storage curves developed as part of the original Proof of Concept Report.

One of the facilities reviewed during the 2017 Proof of Concept phase was a location on the Blanchard River upstream of State Route 15 (Figure 16). This site was considered as a potential option for storage due to its proximity to Findlay (capturing a large percentage of drainage area). The roadway elevation along State Route 15 near the Blanchard River is approximately 805 feet. Assuming 2 feet of freeboard, the existing ground stage storage curve was analyzed up to 803 feet (about 1,600 acre-feet) to predict potential benefit in reducing the peak flow rates. Due to the substantial volume of water and peak flow values observed on the Blanchard River, 1,600 acre-feet did not provide a significant benefit in reducing the peak flow rate. This site was not selected for further review during the Proof of Concept stage because the available storage volume and resulting benefit was minimal compared to the expected impact and cost of the facility.

The facility at State Route 15 was once again reviewed during the Proof of Concept Update to confirm if there was a significant difference in available storage volume based on a comparison of the data between the OGRIP DEM used for the Proof of Concept and the Kucera LiDAR data processed for the Proof of Concept Update. Figure 17 shows a comparison of the stage-storage curves developed at the site of the proposed storage facility upstream of State Route 15. The newly processed LiDAR data confirms the volumes calculated previously during the Proof of Concept phase. The change in stage-storage volume at this site was negligible for modeling of flood events. A similar analysis was done at the Eagle Creek storage facility proposed during the Proof of Concept (Figure 18) as well as the other basins considered. The updated survey data helped Stantec to confirm the three sites that were originally selected for analysis as valid and provided the information necessary to once again rule out the other sites previously considered as viable options, but were not selected for advancement.

Figure 16 – Storage Location Considered on the Blanchard River at State Route 15

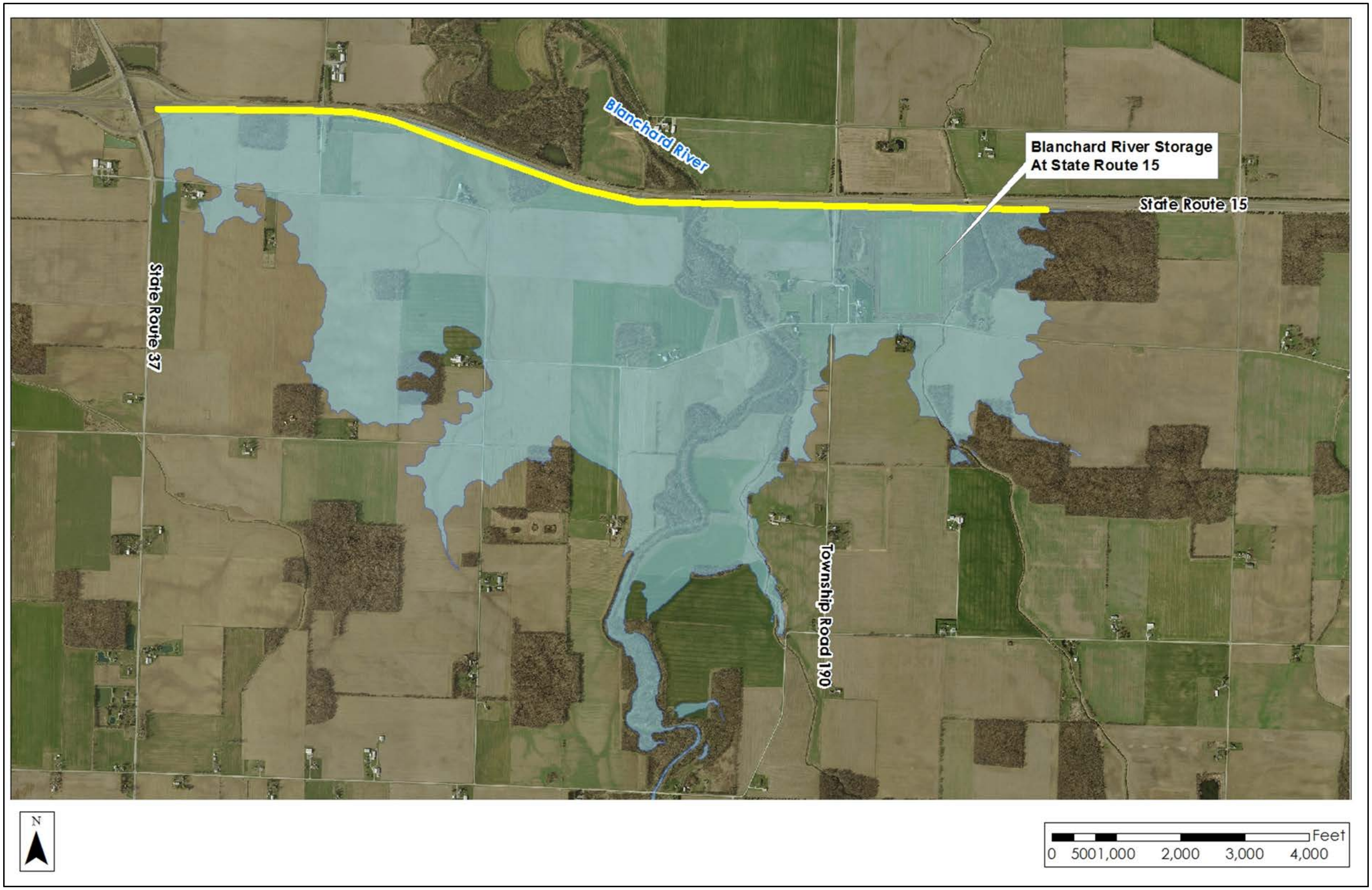


Figure 17 – Stage-Storage Review (Upstream of State Route 15)

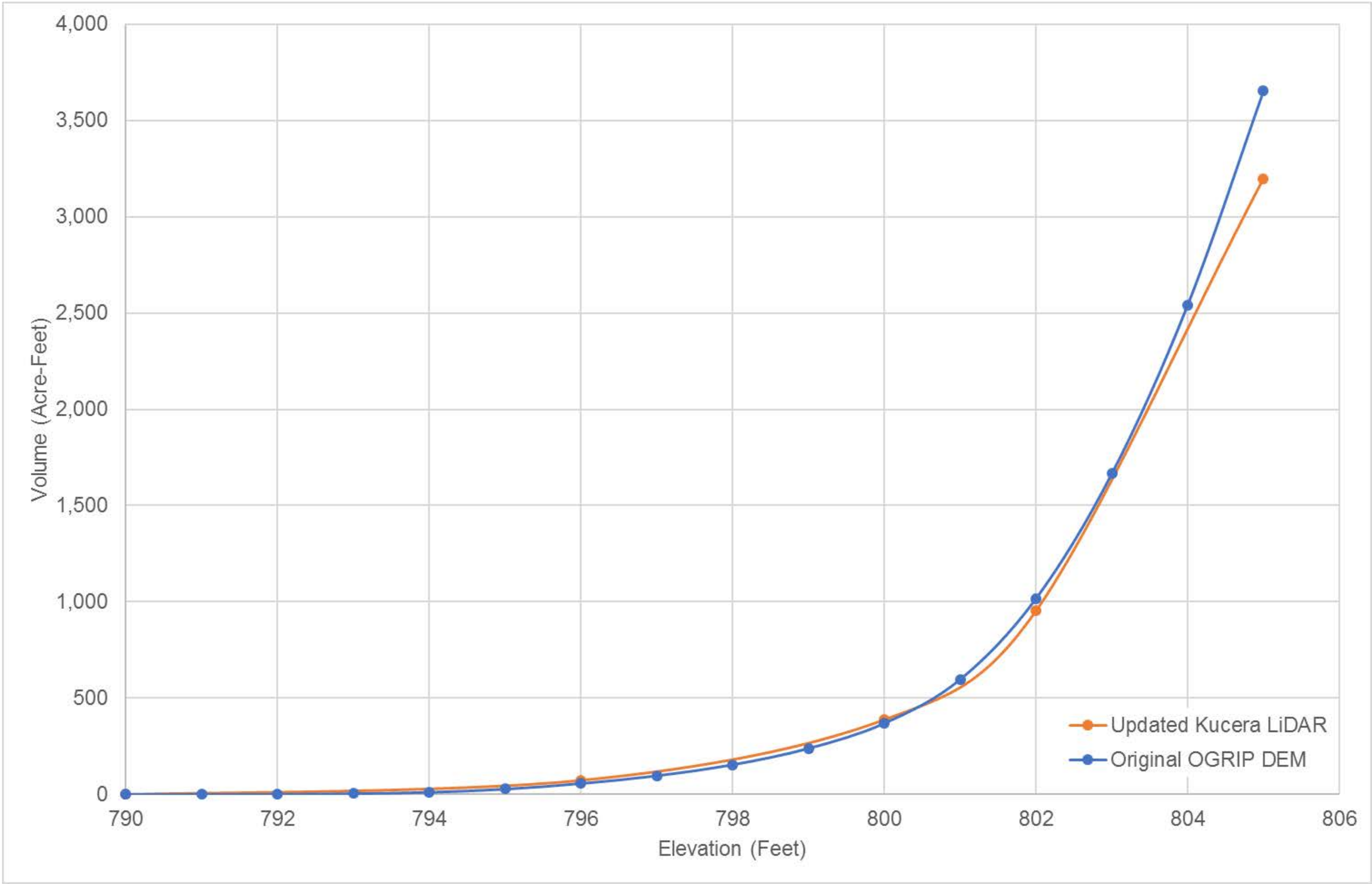
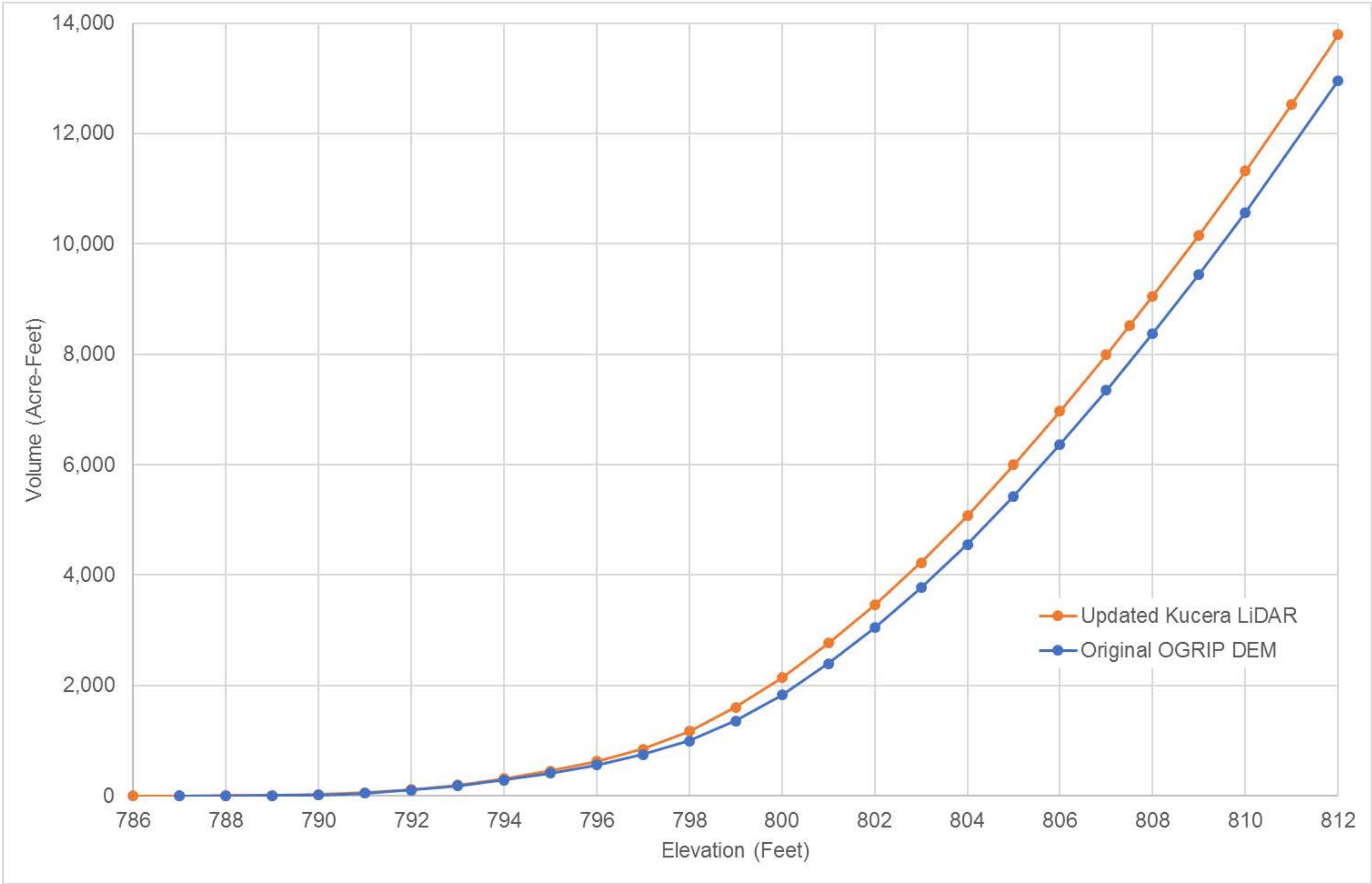


Figure 18 – Stage-Storage Review (Eagle Creek Dry Storage Basin – Proof of Concept)



4.2 DRY STORAGE BASIN REFINEMENT

Stantec evaluated at least three (3) configurations for each of the dry storage basins recommended in the April 2017 Proof of Concept Report by utilizing the revised hydrology model, geotechnical data, and additional LiDAR data. The Stantec Team attempted to balance the impacts, cost, and benefits of the proposed facilities by refining the footprint and geometric design. Stantec first reviewed the original Proof of Concept layout with the updated topography and revised hydrology model. A second configuration was considered with the smallest footprint Stantec determined to effectively reduce at least a moderate risk of flooding downstream. The first two configurations served as working products to bracket the updated recommended solution.

The goal of the revised recommended option was to not only reduce the risk of flooding in Findlay, but also to provide flood protection of agricultural areas along the reaches downstream of the basins and to reduce potential impacts to land, structures, and roadways due to project construction. The over-arching goal of the refinement process was to determine the recommended conceptual configuration (size, location, and general geometry) of the proposed dry-storage basins that will cost-effectively provide flood risk-reduction downstream while reducing the impacts from construction.

4.2.1 Eagle Creek Dry Storage Basin

The cross-sectional geometry used at the Eagle Creek Basin for the April 2017 Proof of Concept was conservative in nature because the necessary subsurface data was not available at that time. A 20-feet top width and 4H-to-1V side slopes were used in that dam embankment cross-section. Stantec used the additional geotechnical exploration data (Appendix B) to refine the geometric design of the Eagle Creek dam and develop typical cross-sectional geometry (Figure 12). The following geometry was assumed to reduce the footprint of the dam while providing the necessary flood protection:

- Crest elevation = 812 feet
- Embankment side slopes = 2.5H-to-1V
- Bench elevation = 796 feet
- Crest and bench width = 16 feet to allow for vehicle access for maintenance and monitoring
- Bench sloping = 2 percent to provide surface drainage
- Excavation of 1 foot to remove vegetation and topsoil under the dam footprint
- Cutoff trench = 5 feet deep x 20 feet bottom width with 1H-to-1V side slopes
    - USBR suggests the use of a cutoff trench. The depth and bottom width were assumed to provide sufficient equipment access during construction.

The April 2017 Proof of Concept Report shows the storage facility proposed at Eagle Creek (Figure 19) as impacting about 1,140 acres of land. Out of the 1,140 acres impacted, 880 acres were designated as “agricultural”. Agricultural area includes “Cultivated Crop” and “Hay/Pasture” categories within the National Land Cover Dataset (NLCD). Stantec reviewed multiple layouts of the proposed Eagle Creek storage facility to refine the concept’s layout and cost. Figure 20 shows the multiple layouts considered at the Eagle Creek Dry Storage Basin site.

Figure 19 – Eagle Creek Dry Storage Basin (April 2017 Proof of Concept)

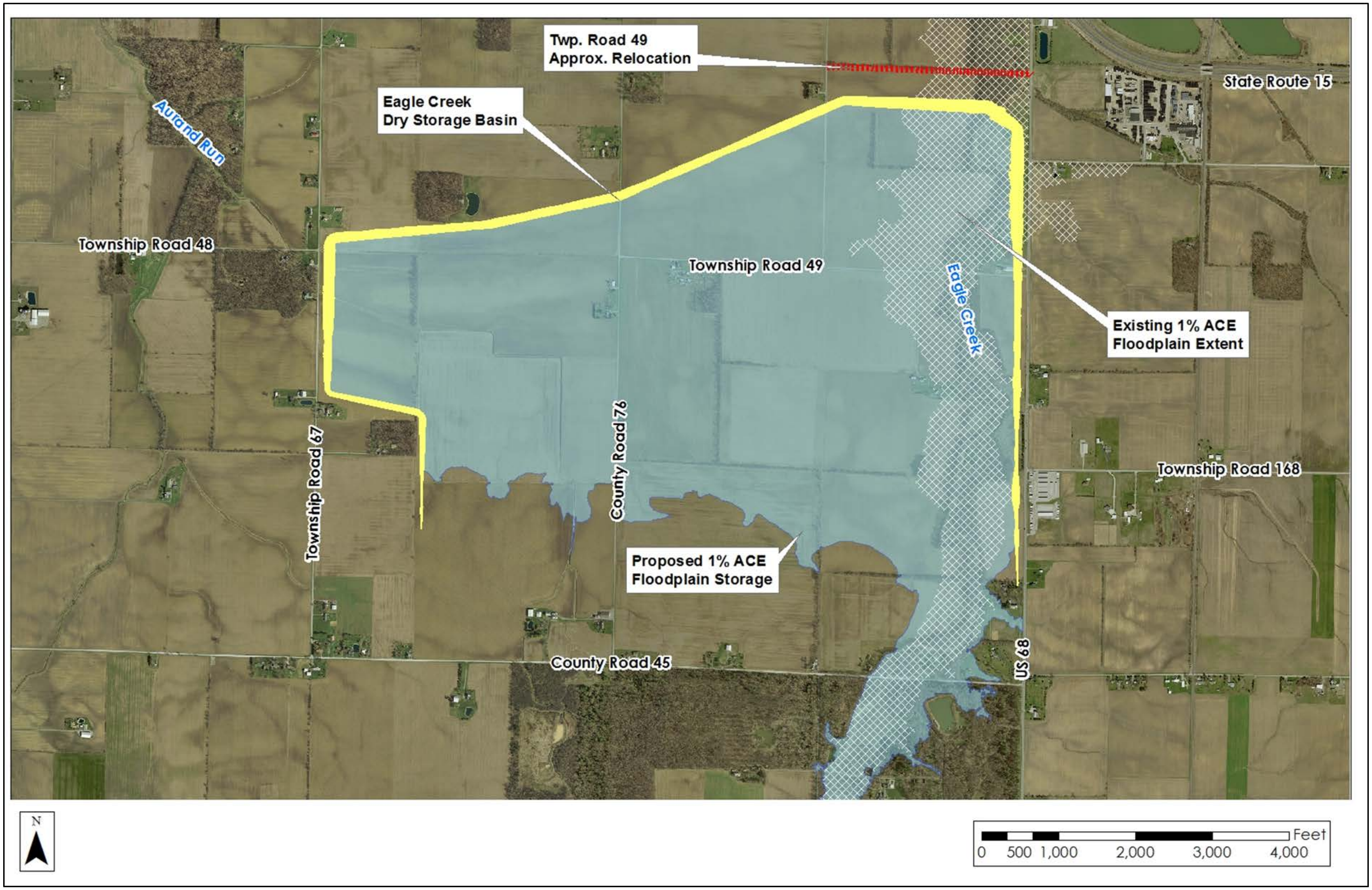
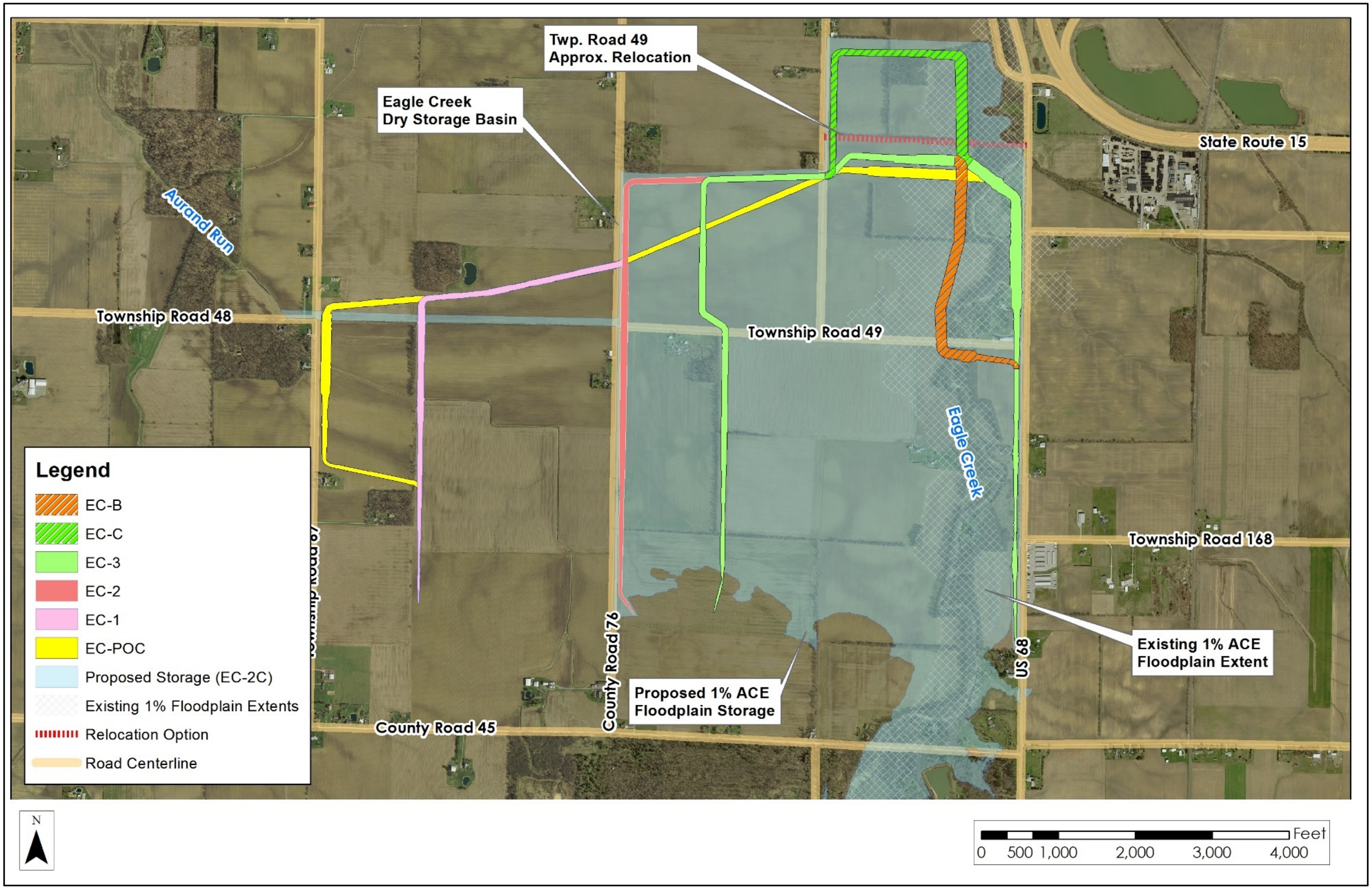


Figure 20 – Alternative Footprints Considered for Eagle Creek Dry Storage Basin



Stantec took advantage of the proposed Eagle Creek basin and its proximity to Aurand Run by using the waterway as an auxiliary spillway discharge point. The proposed storage facility would release a nominal, controlled amount of flow (200 cfs to 500 cfs) out of the west side of the basin through a proposed ditch (near an existing drainage feature). Channel modifications downstream along Aurand Run would potentially be needed for this configuration.

Stantec also used the hydrologic model to consider various flow rates passing through the Eagle Creek principal spillway to iteratively evaluate and find a range of potential storage volumes required for the proposed basin. A static culvert was used in the analysis to discharge a range of flows downstream through Eagle Creek. Stantec's analysis revealed that at least 500 cfs should pass through the Eagle Creek spillway to maintain a reasonably cost-effective footprint. The maximum flowrate from the dry storage basin should be no more than about 1,100 cfs. The model shows that flow begins to overtop the channel's banks and affect existing structures when the discharge through Eagle Creek is greater than 1,100 cfs.

Table 1 shows the costs for alternative footprints at the Eagle Creek site based on the amount of discharge to Eagle Creek. The model assumes about 500 cfs is outlet to Aurand Run in these scenarios. The size of the storage footprint relates to how much excavation is needed to obtain a large enough storage capacity. Costly excavation is required for the smaller footprint alternatives (EC-3B for example) to achieve the storage volume needed to reduce the risk of flooding.

In general, there is a greater reduction in flood risk for the community when discharging 500 cfs out of the Eagle Creek spillway compared to 1,100 cfs. However, discharging only 500 cfs through the principal spillway requires the footprint of the storage facility to increase and/or the cost to increase due to land impacts and the size of the auxiliary spillway required. The optimal discharge rate to balance flood risk reduction, cost, and impacts is likely between 500 cfs and 1,100 cfs. Further analysis of the outlet flow rate would occur if detailed design is advanced. Figure 21 through Figure 24 show graphical representations of the cost curves for the Eagle Creek alternatives with additional data that was used to help inform a refined layout recommendation.

Table 1 – Alternative Footprints and Discharge Considered at Eagle Creek

Alternative Footprint	Acres Impacted by Construction	500 cfs Discharge	1,100 cfs Discharge
		Total Cost	
Proof of Concept (EC-POC)	1,140	$62.2 MM	$55.7 MM
EC-1C	1,153	$65.3 MM	$58.5 MM
EC-1	1,087	$60.7 MM	$56.0 MM
EC-1B	1,046	$65.9 MM	$56.9 MM
EC-2C	936	$65.4 MM	$56.2 MM
EC-2	871	$81.0 MM	$59.7 MM
EC-2B	830	$85.1 MM	$58.8 MM
EC-3C	796	$93.1 MM	$60.1 MM
EC-3	730	$99.6 MM	$63.5 MM
EC-3B	689	$113.8 MM	$86.6 MM

Figure 21 – Eagle Creek Alternatives Cost Curve with Structure Impacts (500 cfs)

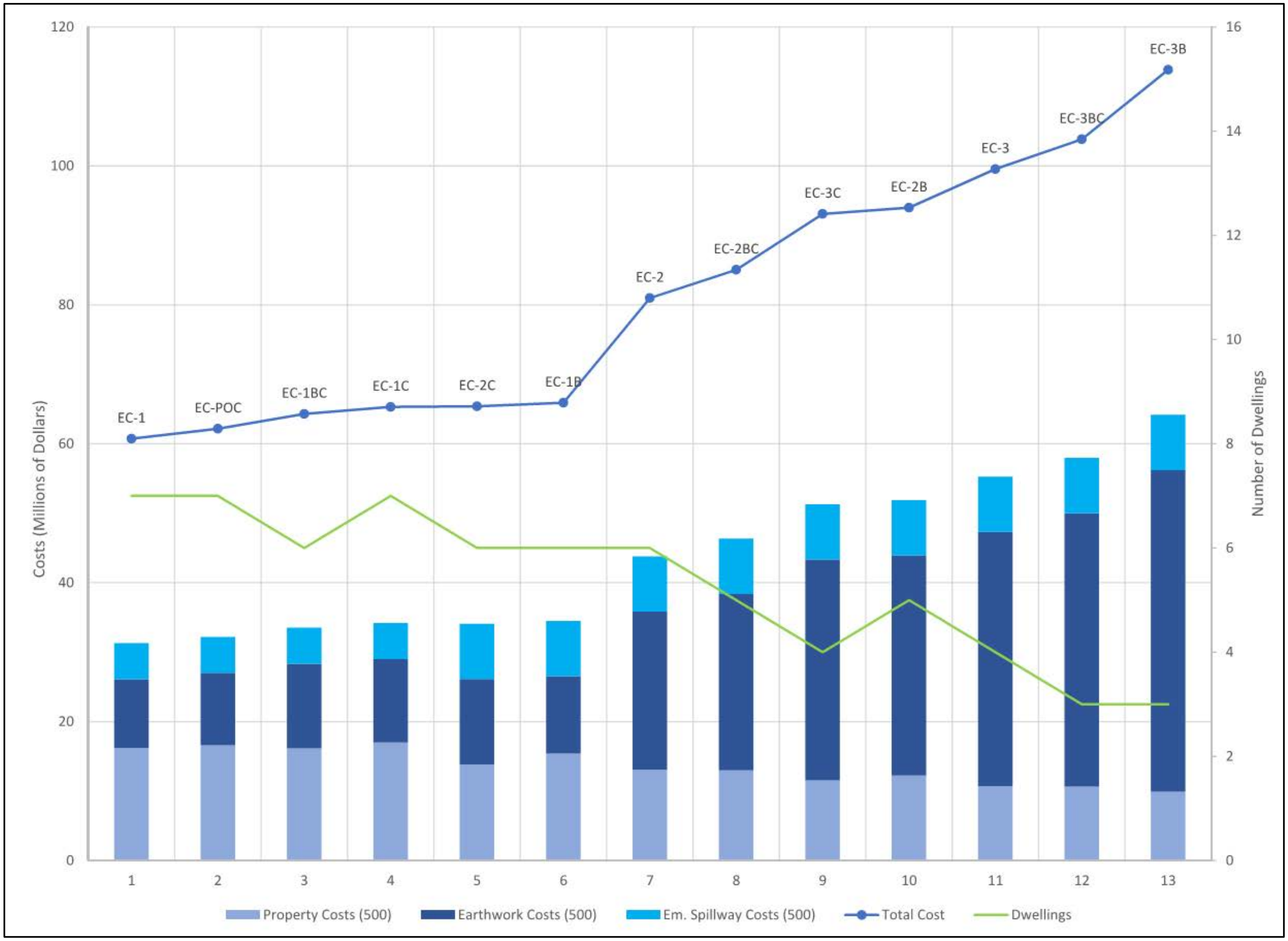


Figure 22 – Eagle Creek Alternatives Cost Curve with Land Impacts on the X-Axis (500 cfs)

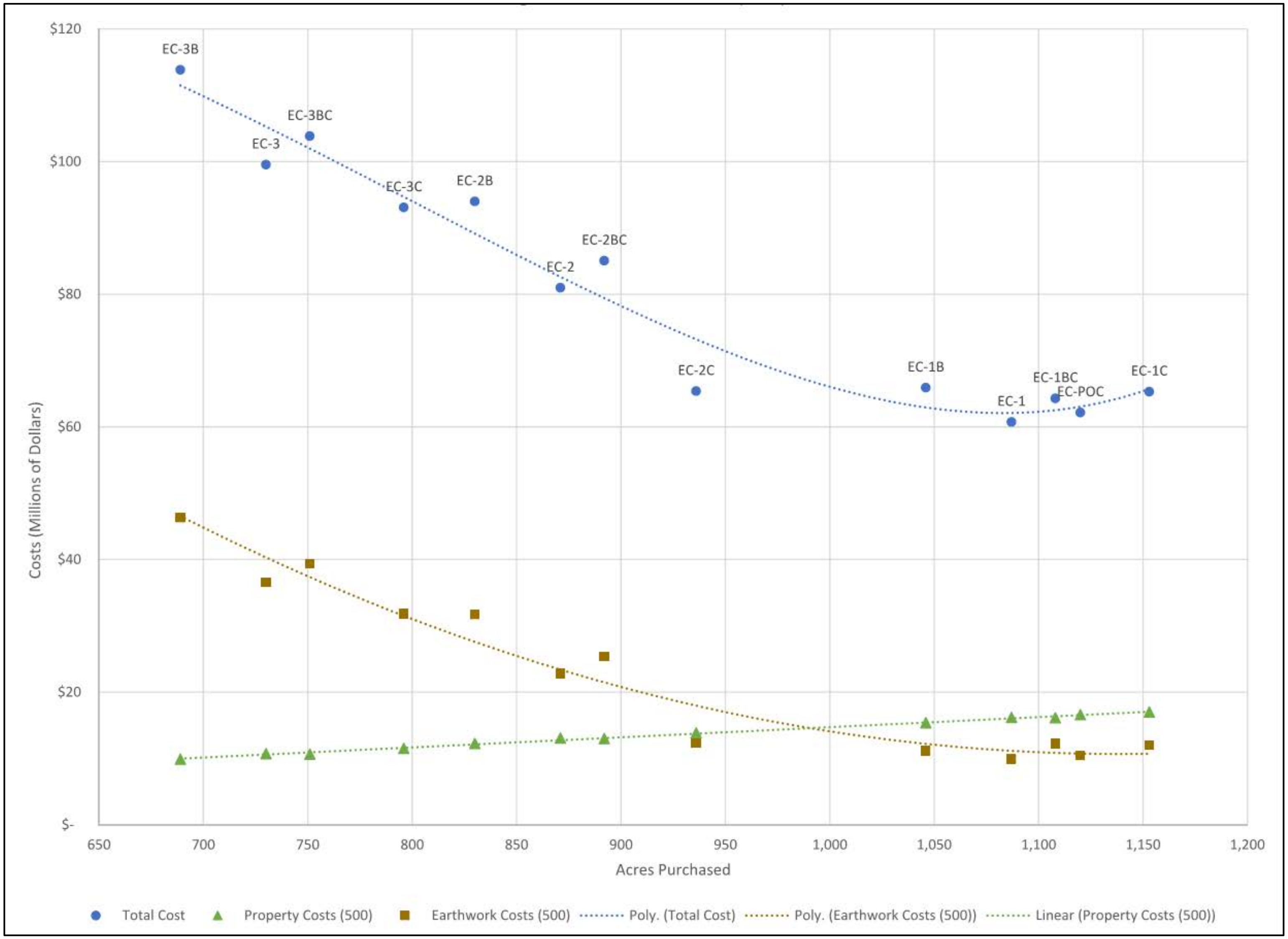


Figure 23 – Eagle Creek Alternatives Cost Curve with Structure Impacts (1,100 cfs)

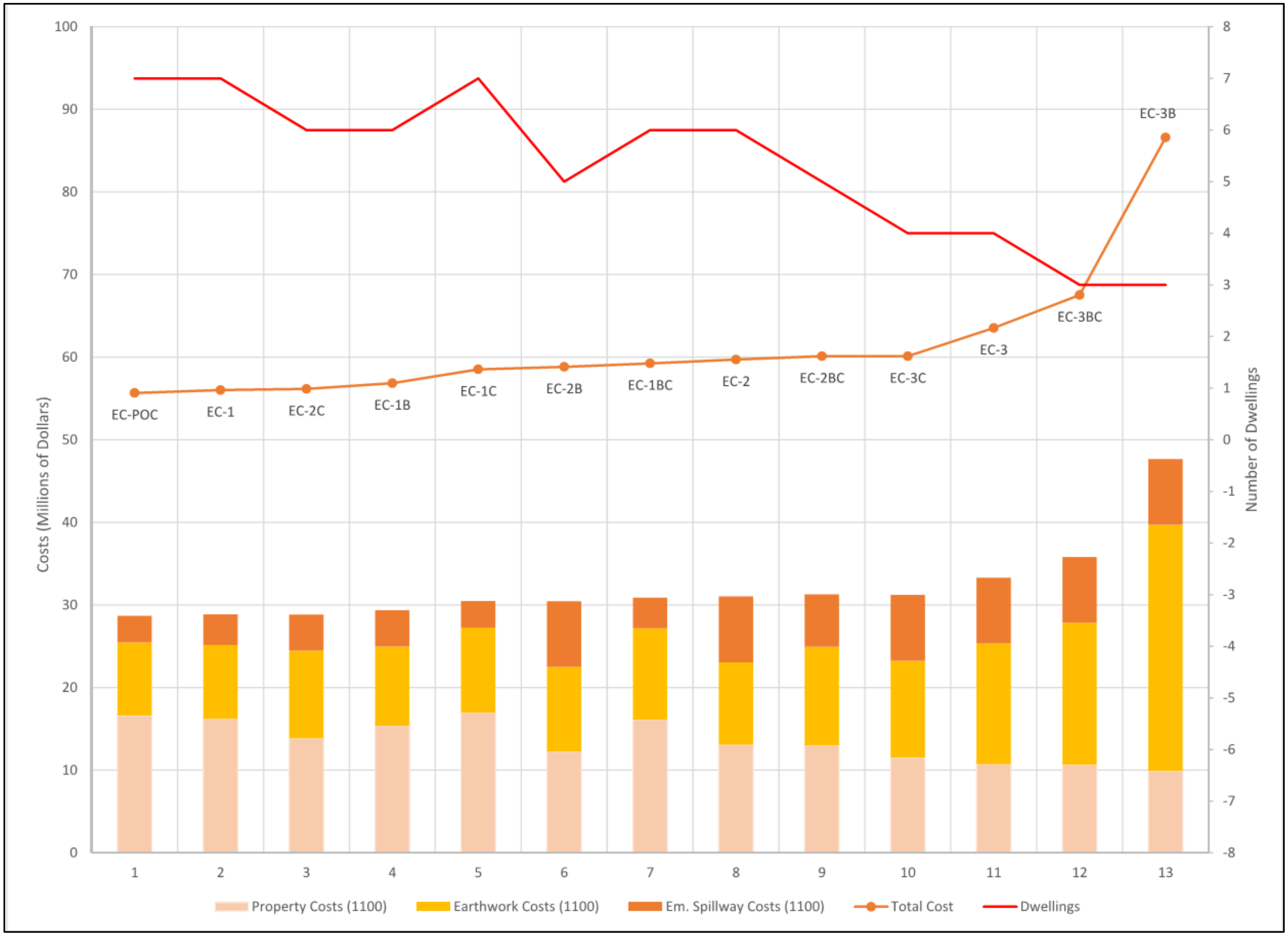
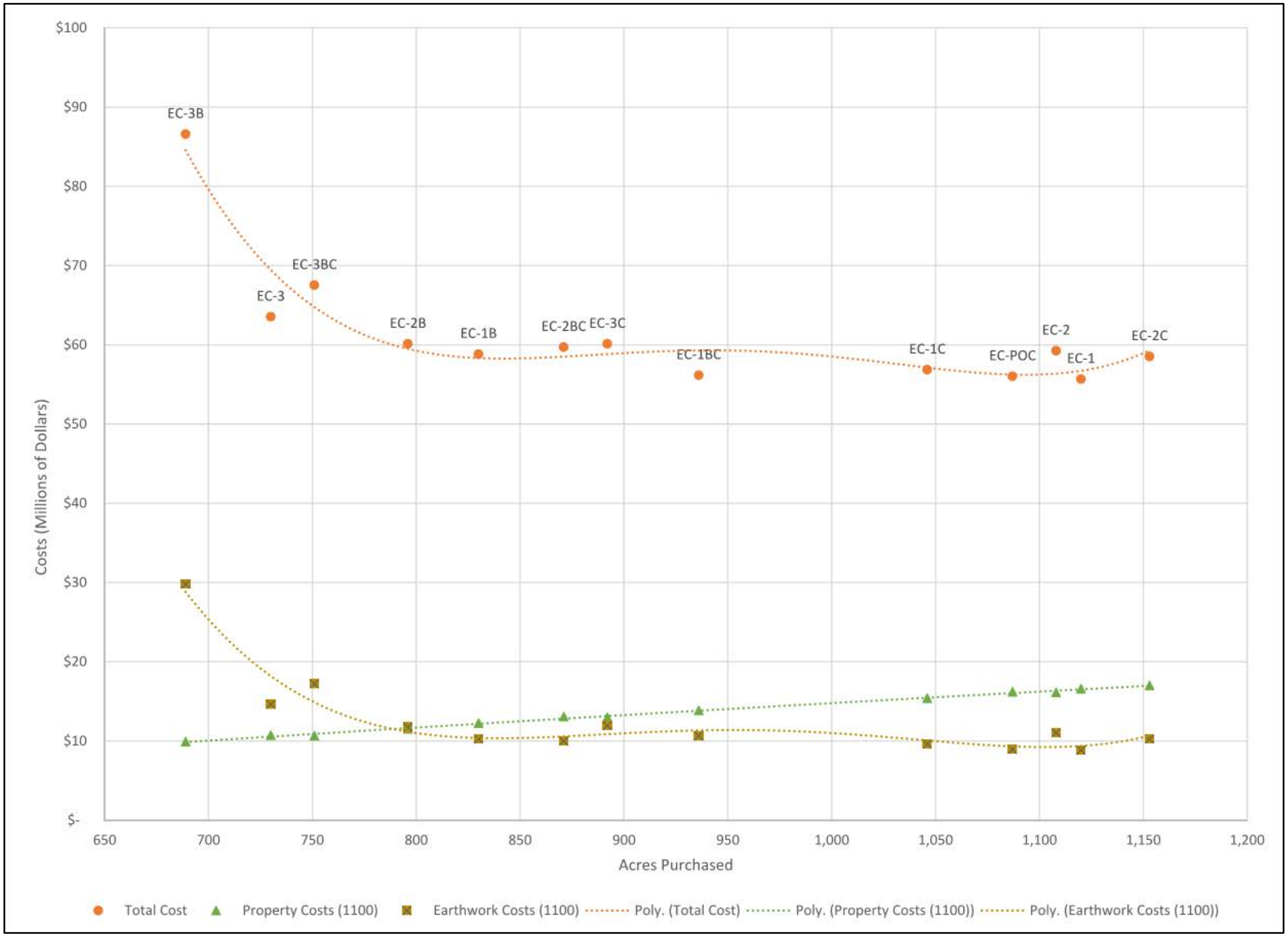


Figure 24 – Eagle Creek Alternatives Cost Curve with Land Impacts on the X-Axis (1,100 cfs)



4.2.1.1 Eagle Creek Auxiliary Spillway

The Ohio Department of Natural Resources (ODNR) would likely require a facility like the one proposed on Eagle Creek to safely pass 100% of the Probable Maximum Flood (PMF) (about 22 inches of rain over a 24-hour period). The cost to construct a spillway that is sized to pass the resulting PMF flow is a major driver in the opinion of probable cost. For this analysis, a roller-compacted concrete spillway was assumed. Stantec attempted to balance the spillway length and freeboard to reduce the anticipated cost during the refinement process. Further analysis of the spillway would occur if detailed design is advanced.

4.2.1.2 Eagle Creek Recommended Refinement

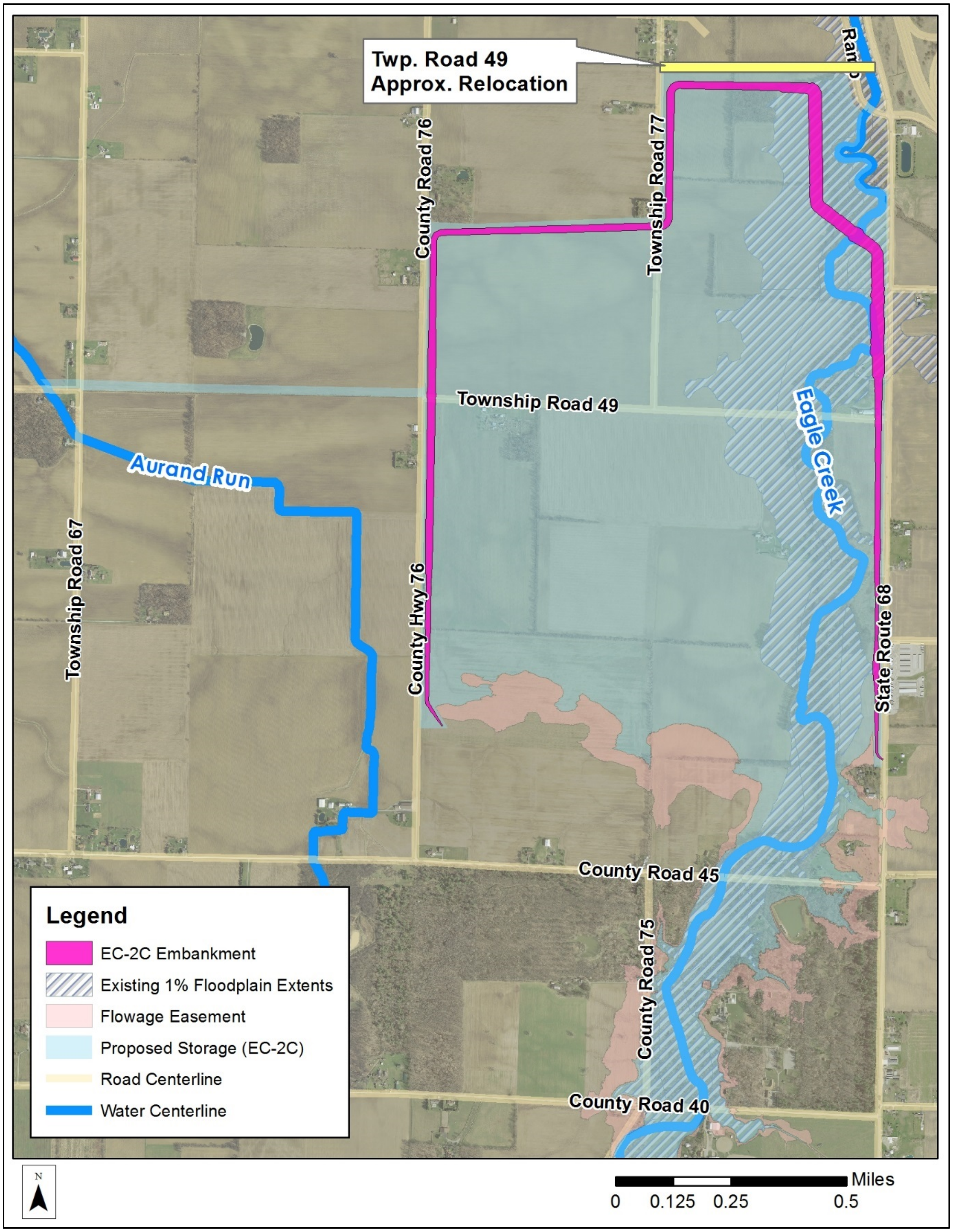
Stantec recommends Eagle Creek alternative layout EC-2C as the refined concept. The east side of the perimeter embankment in the recommended configuration runs parallel to US 68 beginning near the intersection with County Road 45. The northern side of the embankment is aligned generally north of Township Road 49 near the State Route 15 exit ramp (to southbound US-68). The western limits were revised to be east of Township Road 76. Figure 25 shows the refined footprint for the proposed basin. The proposed Eagle Creek storage area would intercept about 51 square miles of Eagle Creek's headwaters. In addition to the proposed 1% ACE footprint of the Eagle Creek facility, Figure 25 shows the anticipated flowage easements to account for reservoir operations between the 1% ACE event and the PMF. Flowage easements occur on privately owned land where an entity may have certain perpetual rights, namely the right to flood in connection with the operation of the reservoir and other related activities.

The proposed footprint reduces the area impacted by construction (from the April 2017 layout) by about 204 acres. The smaller footprint is still sized for the 1% ACE event but has fewer impacts (eight less structures impacted) than the layout that was considered in the April 2017 Proof of Concept Report and is expected to be about $4 Million less based on the preliminary opinion of probable cost. Table 2 provides a comparison of the impacts associated with the Eagle Creek dry storage basins from the April 2017 Proof of Concept Report and the refined layout recommended in the Proof of Concept update (EC-2C). Construction of a dry storage basin at this location would significantly reduce the peak flows in Eagle Creek and would decrease the risk of flooding along Eagle Creek and the Blanchard River.

Table 2 – Comparison of the Eagle Creek Recommended Dry Storage Basins

Description	April 2017 Proof of Concept	June 2018 Proof of Concept Update (EC-2C)
Acres Impacted by Construction	1,140	936
Acres Impacted Outside of Existing Floodplain	860	596
Agricultural Acres Impacted by Construction	880	675
Parcels Impacted by Construction	50	43
Structure Buyouts	14	6
TOTAL COST	**$69.5 MM**	**$65.4 MM**

Figure 25 – Eagle Creek Dry Storage Basin – Refined Footprint (EC-2C)



4.2.1.3 Township Road 49 Relocation

Conceptual alternatives for relocation of Township Road 49 were considered since construction of a proposed dry storage basin at Eagle Creek would alter existing local transportation routes and affect access to US-68. Stantec provided three conceptual planning level transportation alignments that could potentially mitigate the impact to Township Road 49.

Conceptual Alternative 1

Figure 26 shows Township Road 49 relocation Conceptual Alternative 1. This scenario would construct a new US-68 southbound exit ramp from eastbound State Route 15. A deceleration lane would begin just south of the overpass bridge. The terminal intersection with US-68 would be improved. The existing exit ramp would be removed north of Township Road 80. The remaining portion of the exit ramp could be restriped and converted to a two-way township road for local traffic, tying back in to the existing Township Road 80. Advantages for this concept is that one bridge structure (the ramp over Eagle Creek) would be removed from the state system and it creates logical termini for the interchange ramps. A disadvantage is that it is the highest cost alternative estimated between $1.5 MM and $2.0 MM.

Conceptual Alternative 2

Figure 27 shows Township Road 49 relocation Conceptual Alternative 2. This concept terminates the existing US-68 southbound exit ramp onto a relocated Township Road 80. The remaining portion of the existing US-68 southbound exit ramp south of Township Road 80 would be widened and converted to a two-way road for the remaining length. This option maximizes existing infrastructure and is the least expensive alternative, expected between $0.5 MM and $1.0 MM. The disadvantage is that the new location of the exit ramp is not a logical location for a ramp terminus.

Conceptual Alternative 3

Figure 28Figure 27 shows Township Road 49 relocation Conceptual Alternative 3. This concept terminates the existing US-68 southbound exit ramp onto a new east/west Township Road. The remaining portion of the existing US-68 southbound exit ramp south of the proposed Township Road would be widened, restriped, and converted to a two-way road for the remaining length. This option is expected to cost between $0.7 MM and $1.3 MM. The disadvantages are that the new location of the exit ramp is not a logical location for a ramp terminus and traffic could enter the US-68 southbound exit ramp in the wrong direction.

Figure 26 – Township Road 49 Relocation – Conceptual Alternative 1

Figure 27 – Township Road 49 Relocation – Conceptual Alternative 2

Figure 28 – Township Road 49 Relocation – Conceptual Alternative 3

4.2.2 Blanchard River Dry Storage Basin

The upper Blanchard River watershed has about 350 square miles of drainage area contributing flow through the City of Findlay. Much of this drainage area is routed directly into the Blanchard River. The Blanchard River is approximately 50 miles in length from the top of the watershed through downtown Findlay. The Blanchard River near Mt. Blanchard flows parallel to, and is west of, County Road 17. Potato Run, a tributary to the Blanchard River about 4,000 feet to the east, flows on the east side of County Road 17. Storage options were considered at both locations due to the undulating terrain near the river corridor that could lead to cost-effective solutions with minimal impacts to the surrounding area.

There are two distinct flood peaks that occur during large flood events in the Blanchard River Watershed. The second flow peak is almost entirely the result of flow contributions from the Upper Blanchard sub-watershed as discussed extensively in the April 2017 Proof of Concept report. A reduction in peak flow rate from the Upper Blanchard watershed would contribute to the reduction of flood risk not only in Findlay, but also in Mt. Blanchard and along a long stretch of the Blanchard River corridor where flow routinely leaves the banks during larger storm events (including the Blanchard to Lye crossover). The peak flow rate through Mt. Blanchard could be reduced by as much as 4,000 cfs, depending on the combination of different sized embankments on the Blanchard River and Potato Run.

A preliminary cross-section was created for the Blanchard River storage facility for the April 2017 Proof of Concept. Stantec used the additional geotechnical exploration data (Appendix B) to refine the geometric design of the Blanchard River and Potato Run dams and develop typical cross-sectional geometry. The following typical cross-sectional geometry was assumed for analysis to reduce the footprint of the dams while providing the necessary flood protection:

- Crest elevation = 858 feet
- Embankment side slopes = 2.5H-to-1V
- Bench elevation = 842 feet
- Crest and bench width = 16 feet to allow for vehicle access for maintenance and monitoring
- Bench sloping = 2 percent to provide surface drainage
- Excavation of 1 foot to remove vegetation and topsoil under the dam footprint
- Cutoff trench = 5 feet deep x 20 feet bottom width with 1H-to-1V side slopes
  - USBR suggests the use of a cutoff trench. The depth and bottom width were assumed to provide sufficient equipment access during construction.

The storage facility on the Blanchard River upstream of Mt. Blanchard (April 2017 Proof of Concept) impacted about 8 structures, 2 roads, and 770 acres of land. Figure 29 shows the dry storage basins on the Blanchard River and Potato Run as shown the in April 2017 Proof of Concept Report. Out of the 770 acres impacted, 585 acres were designated as “agricultural” based on NLCD information. Analysis during the Proof of Concept phase showed that up to 12,000 acre-feet of storage could be available on the Blanchard River to reduce the peak flow rates downstream, however, the available storage volume resulted in several structures being impacted.

Stantec reviewed several storage options and dam heights on the Blanchard River to refine the concept’s layout and cost, but mainly to reduce the expected social and environmental impacts. Figure 30 shows the multiple layouts considered at the Blanchard River Dry Storage Basin site. Stantec refined the available storage capacity by shifting the location of the alternative dam embankments downstream to utilize the natural efficiency of the topography and to reduce the elevation of the embankment.

Figure 29 – Dry Storage Basins on the Blanchard River and Potato Run (April 2017 Proof of Concept)

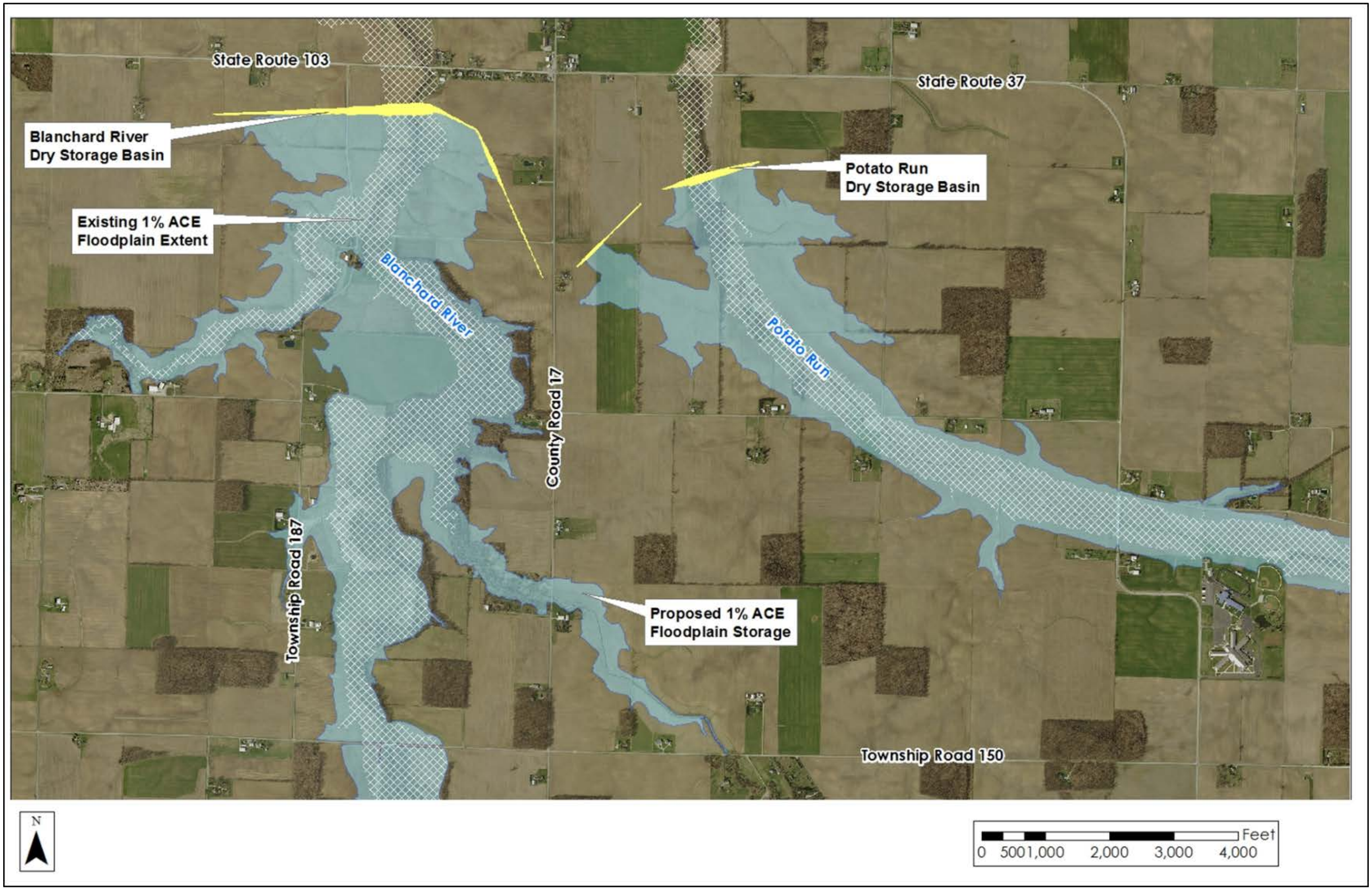


Figure 30 – Alternative Footprints Considered for Blanchard River Dry Storage Basin

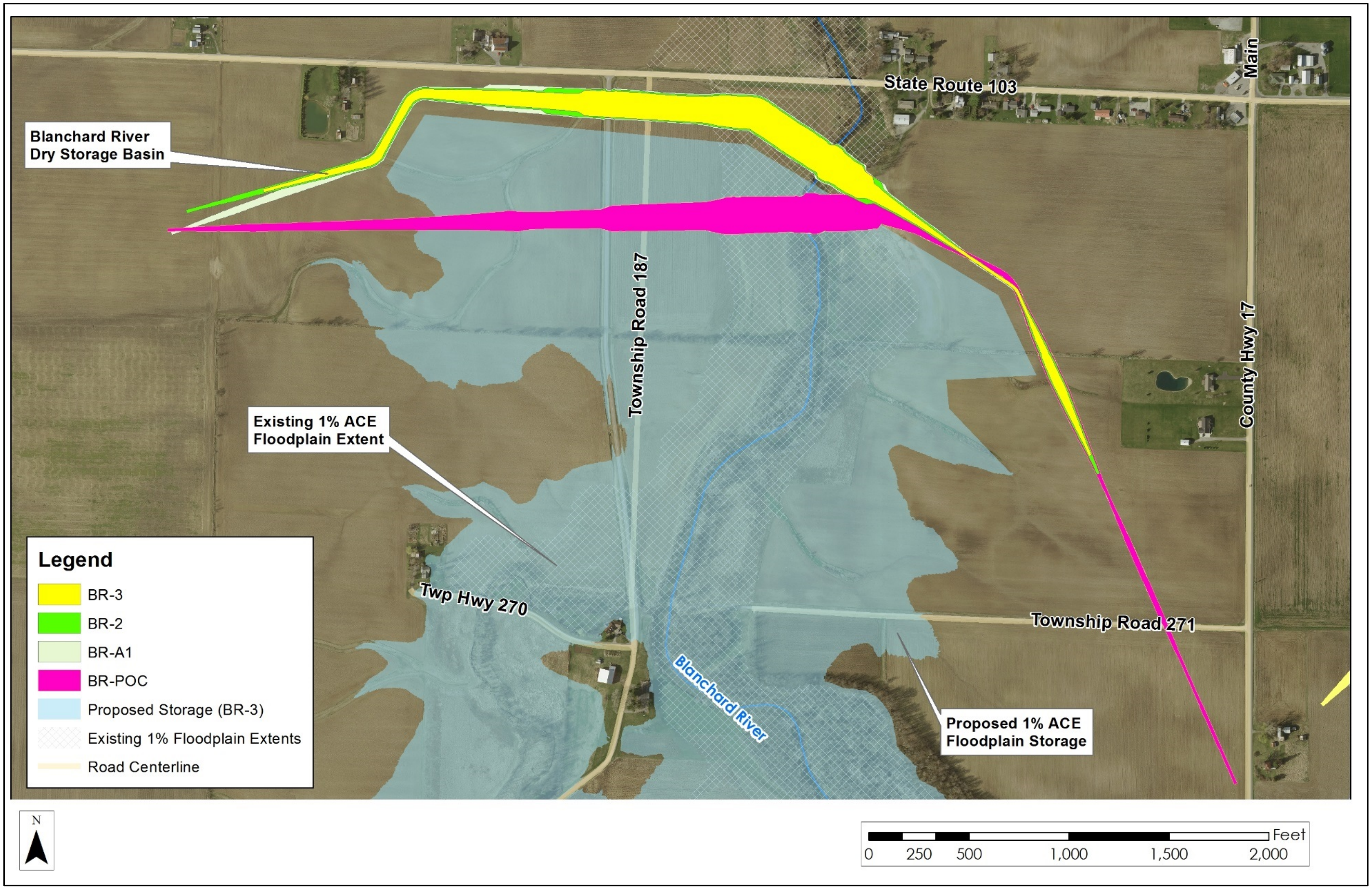
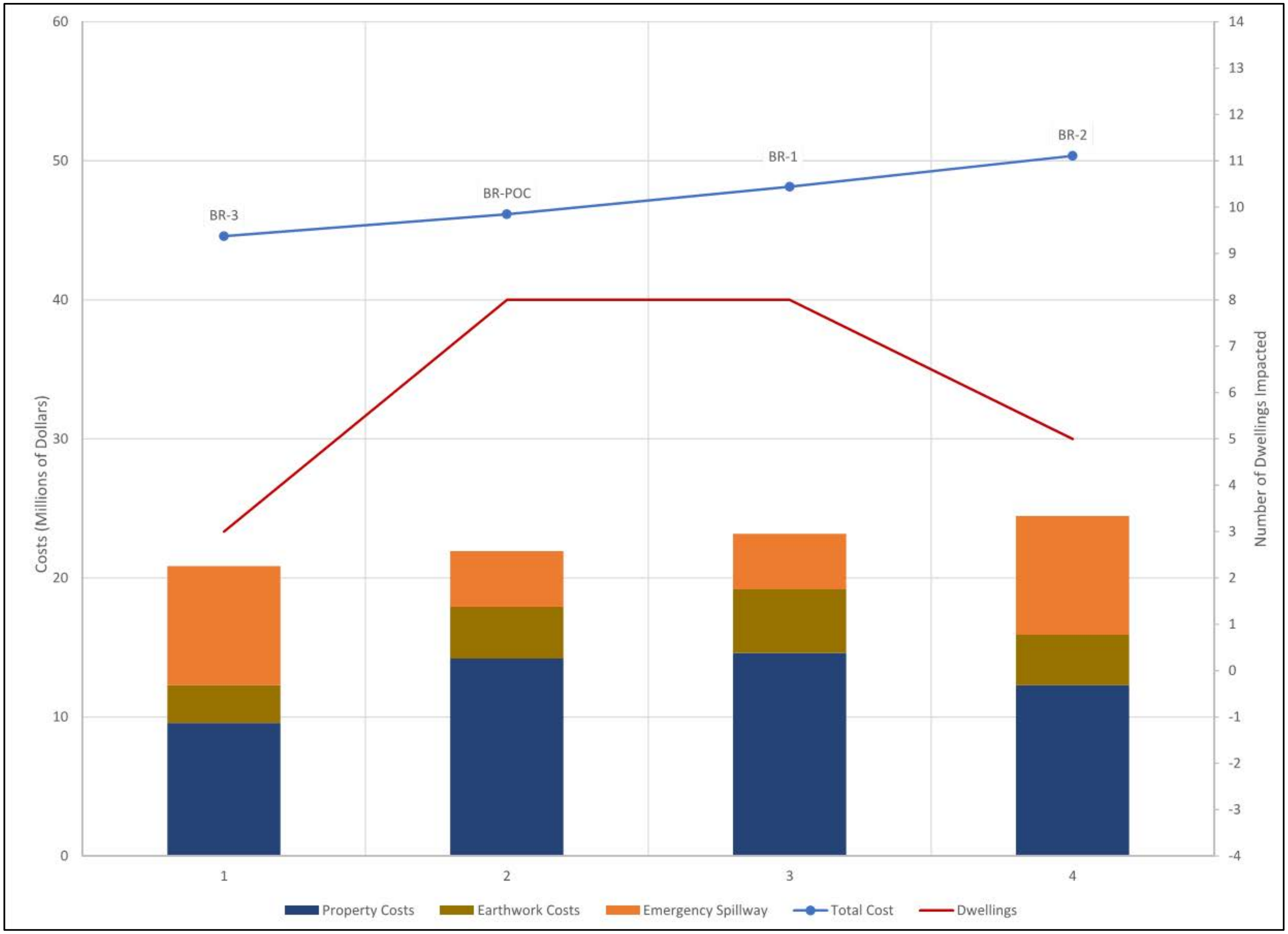


Table 3 shows the costs for alternative footprints and dam heights at the Blanchard River site. The shorter dams provide less storage capacity and therefore less flood risk reduction benefit. The cost increases for the shorter dams are due to the size of the auxiliary spillway required. The cost to construct a spillway that is sized to pass the PMF flow was a major driver in the opinion of probable cost calculations. Stantec attempted to balance the spillway length and freeboard to reduce the anticipated cost during the refinement process. Figure 31 shows a graphical representation of the cost curves for the Blanchard River alternatives with additional data that was used to help inform a refined layout recommendation.

Table 3 – Alternative Footprints and Configurations Considered at Blanchard River

Alternative Footprint	Acres Impacted by Construction	Dam Crest Elevation (feet)	Probable Maximum Flood Elevation (feet)	1% ACE Water Surface Elevation (feet)	Total Cost
Revised Proof of Concept (BR-POC)	774	858	856	851	$46.8 MM
BR-1	809	858	856	851	$48.1 MM
BR-2	797	856	854	851	$50.4 MM
BR-3	614	853	851	848	$44.8 MM

Figure 31 – Blanchard River Alternatives Cost Curve with Structure Impacts



4.2.2.1 Blanchard River Recommended Refinement

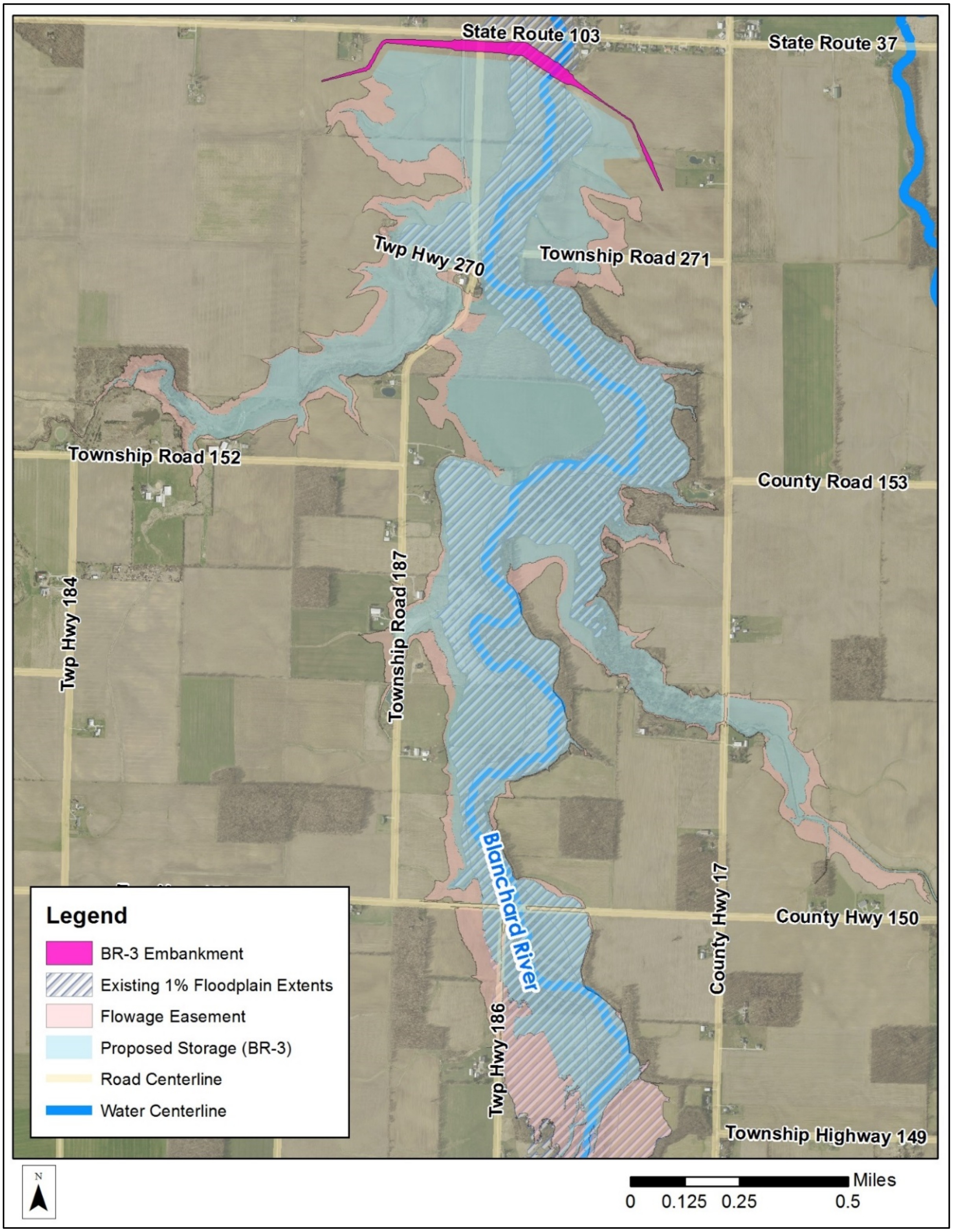
The larger Blanchard River storage basin (BR-2) provides more flood risk reduction benefit than the smaller basin (BR-3), and the April 2017 Proof of Concept basin at Blanchard River provides even more benefit. However, the best way to reduce impacts to structures at the Blanchard River site is to select option BR-3 since the spillway elevation is designed for the 1% ACE event at 848 feet and the maximum PMF elevation is set at 851 feet. These elevations reduce the number of structures expected to be impacted. Further analysis and survey of structure elevations in the vicinity of the dry storage basins could inform the analysis if detailed design is advanced.

If impacts to structures are the biggest driver for the site at the Blanchard River, then Stantec recommends alternative layout BR-3 as the refined concept. This option provides the smallest footprint considered and the least number of impacts while still reducing at least some risk of flooding downstream during events with low recurrence intervals. Figure 32 shows the refined footprint for the proposed basin. The smaller footprint is still sized for the 1% ACE event but has fewer impacts and fewer benefits (more flow passes through the principal spillway) than the layout that was considered in the April 2017 Proof of Concept Report. The dam's spillway was sized to have the capability to pass 100% of the PMF. Table 4 provides a comparison of the impacts associated with the Blanchard River Dry Storage Basins from the April 2017 Proof of Concept Report and the refined layout recommended in the Proof of Concept update (BR-3). The revised layout for the storage basin on the Blanchard provides far less impacts compared to the April 2017 recommendation at a similar cost. The benefits are also reduced due to a decreased storage capacity for layout BR-3. The reduction in storage capacity will yield increased peak flows and longer flooding durations along the Blanchard River compared to April 2017 recommended layout.

Table 4 – Comparison of the Blanchard River Recommended Dry Storage Basins

Description	April 2017 Proof of Concept	June 2018 Proof of Concept Update (BR-3)
Acres Impacted by Construction	774	614
Acres Impacted Outside of Existing Floodplain	348	255
Agricultural Acres Impacted by Construction	585	410
Parcels Impacted by Construction	49	49
Structure Buyouts	8	3
TOTAL COST	**$44.7 MM**	**$44.6 MM**

Figure 32 – Blanchard River Dry Storage Basin – Refined Footprint (BR-3)



4.2.3 Potato Run Dry Storage Basin

The refined typical cross-sectional geometry developed for the Blanchard River was also used for the Potato Run Dry Storage Basin. The storage facility on Potato Run upstream of Mt. Blanchard (April 2017 Proof of Concept) impacted zero structures and 568 acres of land. Figure 29 shows the dry storage basins on the Blanchard River and Potato Run as shown the in Proof of Concept Report. Out of the 568 acres impacted, 484 acres were designated as “agricultural” based on NLCD information. Analysis during the Proof of Concept phase showed that storage volumes were available on Potato Run to reduce the peak flow rates downstream with minimal impacts to structures and roadways.

Stantec reviewed several storage options and dam heights on Potato Run to refine the concept’s layout and cost and flow discharge. Figure 33 shows the multiple layouts considered at the Potato Run Dry Storage Basin site. Stantec refined the available storage capacity by shifting the location of the alternative dam embankments downstream to utilize the natural efficiency of the topography.

Figure 33 – Alternative Footprints Considered for Potato Run Dry Storage Basin

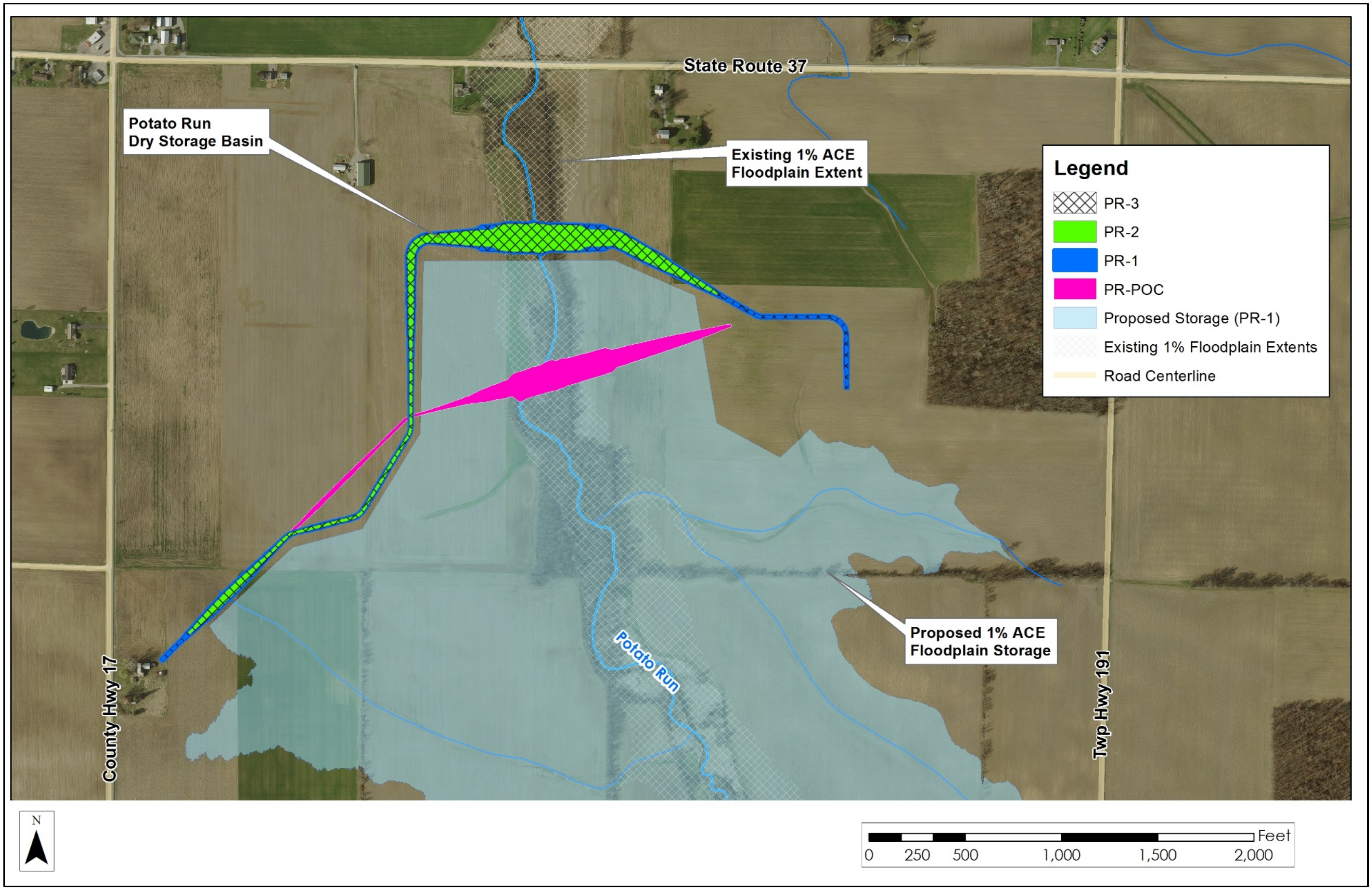
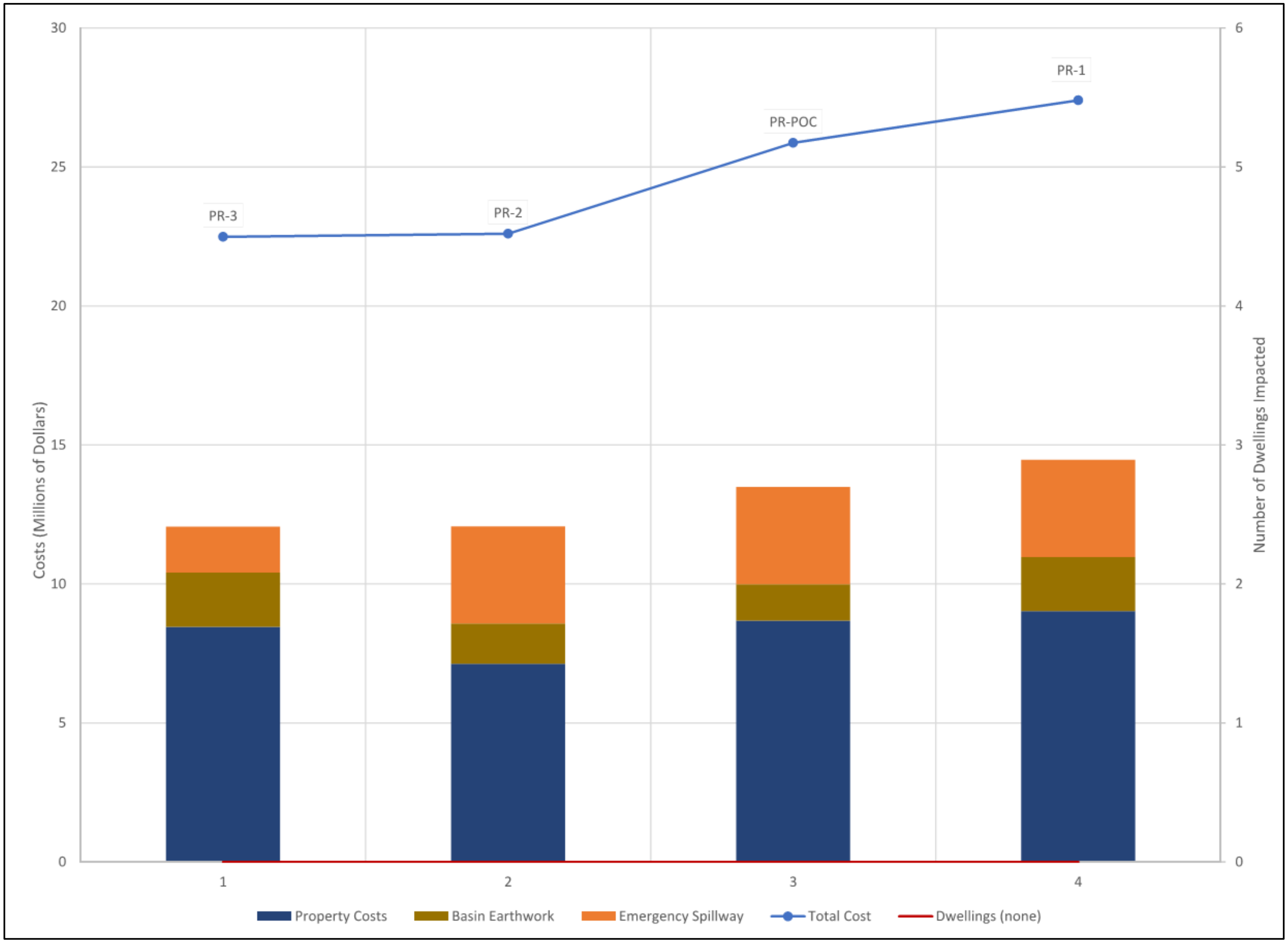


Table 5 shows the costs for alternative footprints and dam heights at the Potato Run site. The shorter dams provide less storage capacity and therefore less flood risk reduction benefit. The cost increases for the shorter dams due to the size of the auxiliary spillway required. The cost to construct a spillway that is sized to pass the PMF flow was a major driver in the opinion of probable cost calculations. Stantec attempted to balance the spillway length and freeboard to reduce the anticipated cost during the refinement process. Figure 34 shows a graphical representation of the cost curves for the Potato Run alternatives with additional data that was used to help inform a refined layout recommendation.

Table 5 – Alternative Footprints and Configurations Considered at Potato Run

Alternative Footprint	Acres Impacted by Construction	Dam Crest Elevation (feet)	Probable Maximum Flood Elevation (feet)	1% ACE Water Surface Elevation (feet)	Total Cost
Revised Proof of Concept (PR-POC)	568	859	857	854	$25.9 MM
PR-1	597	859	857	854	$27.4 MM
PR-2	456	857	855	852	$22.6 MM
PR-3	456	859	857	842	$22.5 MM

Figure 34 – Potato Run Alternatives Cost Curve



4.2.3.1 Potato Run Recommended Refinement

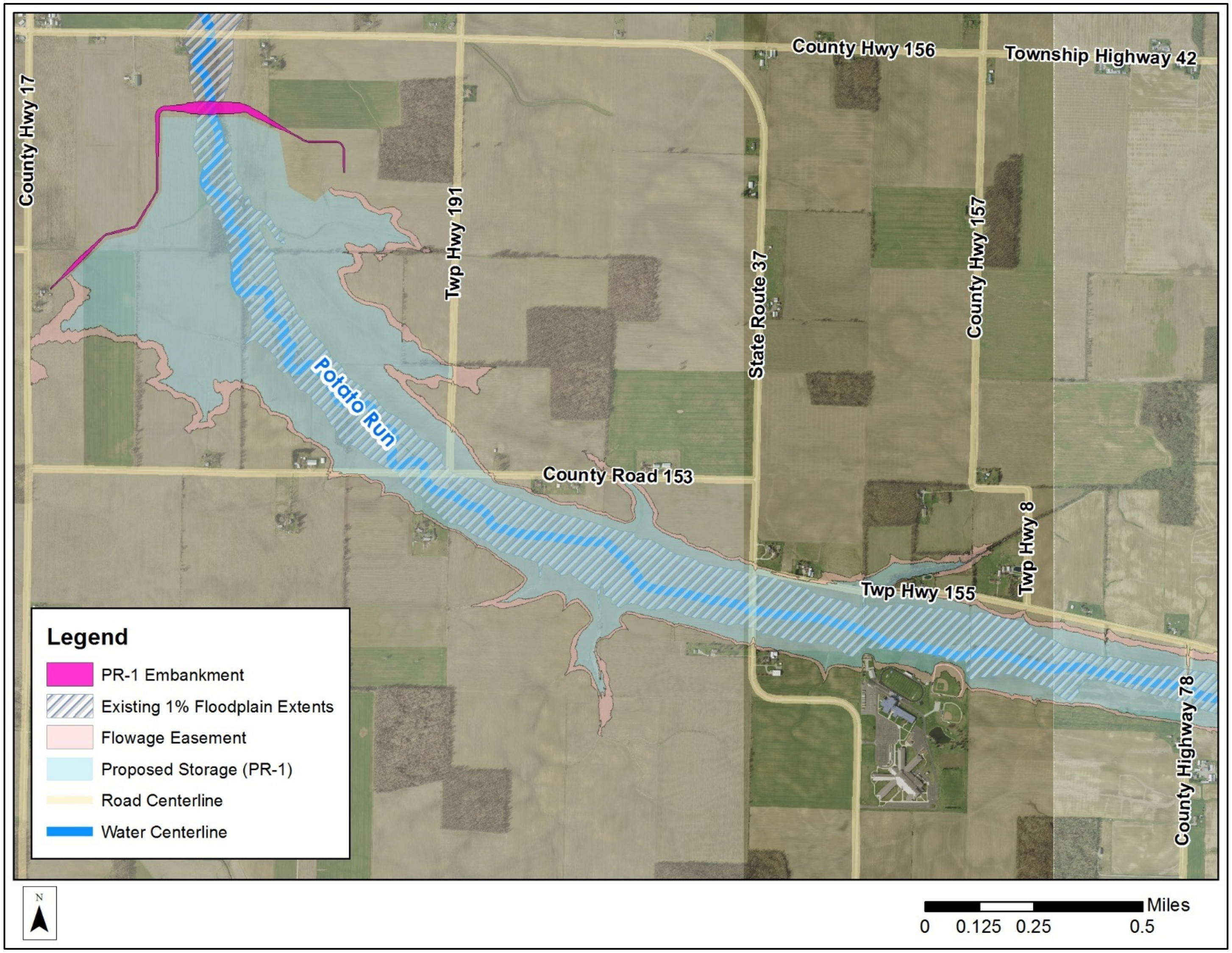
Hydrologic and hydraulic modeling results shows that the most flood risk reduction benefit is produced by the largest dam at Potato Run (PR-1). With marginally higher costs and impacts to land, Stantec recommends that the benefits outweigh the cost at this site. Further analysis of upstream transportation facilities near the dry storage basin could inform the analysis if detailed design is advanced. The layout of option PR-1 at Potato Run is comparable to the Proof of Concept option reviewed in April of 2017. Figure 35 shows the refined footprint for the proposed basin. A few potential impacts to roadways were identified when the storage basin was modeled on Potato Run, but no impacts to structures were identified.

The storage facility is sized for the 1% ACE event and has the capability to pass 100% of the PMF. Table 6 provides a comparison of the impacts associated with the Potato Run Dry Storage Basins from the April 2017 Proof of Concept Report and the refined layout recommended in the Proof of Concept update (PR-1). The cost slightly increased mainly due to the refinement of the auxiliary spillway calculations. The freeboard would allow for construction of an auxiliary spillway to pass the PMF event and to allow for wave run-up and other factors. The proposed storage areas on the Blanchard River and Potato run would intercept about 110 square miles of the watershed.

Table 6 – Comparison of the Potato Run Recommended Dry Storage Basins

Description	April 2017 Proof of Concept	June 2018 Proof of Concept Update (PR-1)
Acres Impacted by Construction	568	597
Acres Impacted Outside of Existing Floodplain	246	284
Agricultural Acres Impacted by Construction	528	556
Parcels Impacted by Construction	32	34
Structure Buyouts	0	0
TOTAL COST	**$25.6 MM**	**$27.4 MM**

Figure 35 – Potato Run Dry Storage Basin – Refined Footprint (PR-1)



4.3 ENVIRONMENTAL REVIEW

Additional literature review and assessment of publicly available information related to environmental data and the proposed HCFRR Program were completed. This review aids in the refinement of assumptions and potential impacts and mitigative measures made during the development of the recommended concepts. The high level supplemental environmental review of the flood risk reduction Program describes existing environmental conditions in the watershed and limited site-specific data in the vicinity of the proposed projects for the basis of identifying potential impacts to environmental resources. The potential impacts were broadly compared to environmental regulations. Potential mitigation measures that may apply to the projects were then identified.

Stantec's review provided insight to better define the measures that may be necessary to enable permitting of the three facilities described above in Section 4.2. Documentation of Stantec's review is found in the report titled, "*Hancock County Flood Risk Reduction Program – Preliminary Environmental Review*" which is attached as Appendix C.

4.4 CULTURAL RESOURCES REVIEW

Additional literature review and assessment of publicly available information related to cultural resources data were completed by the Mannik & Smith Group, Inc. (MSG). The review aids in the refinement of assumptions and potential impacts and mitigative measures made during the recommended concepts. MSG conducted the literature review using the Ohio State Historic Preservation Office's (OSHPO) Online Mapping website, as well as historic atlas, plat, and topographic maps and published secondary sources on local history. The purpose of the literature review was to identify the types and locations of previously recorded cultural resources within the study area and to gather information about the environmental and cultural variables likely to influence the location of other archaeological and architectural resources in this region that are not yet identified. Documentation of the MSG review is found in the memo titled, "*Cultural Resources Literature Review for Four Areas of Concern for the Hancock County Flood Risk Reduction Project, Hancock and Wyandot Counties, Ohio*" which is attached as Appendix D.

5.0 PROOF OF CONCEPT – MODELING RESULTS

The results of the HCFRR Program refinement in the following sections are considered preliminary and are subject to change as the hydrologic and hydraulic models are further refined throughout project planning and design.

The results for the conceptual alternative projects and combination of projects were generated by using the updated hydrology from the revised HEC-HMS model and the "Typical Storm" described within the Hydrology Report (Reference 6) and the refined HEC-RAS model.

5.1.1 HEC-RAS Flow Hydrographs

The 1% ACE "Typical Storm" event was simulated in the revised Stantec HEC-HMS hydrologic model. The inflows from the hydrologic HEC-HMS model were applied to each hydraulic HEC-RAS modeled alternative to simulate the hypothetical event. The 1% ACE event was used as a baseline to compare different combinations of solutions.

Figure 36 through Figure 40 show flow hydrograph results for Existing Conditions (Alternative 0) and the following four combinations of Alternatives:

1. Hydraulic Improvements & Eagle Creek (EC-2C) Storage
2. Hydraulic Improvements & Eagle Creek (EC-2C) Storage & Potato Run (PR-1) Storage
3. Hydraulic Improvements & Eagle Creek (EC-2C) Storage & Potato Run (PR-1) Storage & Smaller Blanchard River (BR-3) Storage
4. Hydraulic Improvements & Eagle Creek (EC-2C) Storage & Potato Run (PR-1) Storage & Larger Blanchard River (BR-2) Storage

Hydrographs are not shown for the Hydraulic Improvements as the construction of this project does not affect the inflow hydrographs, but the efficiency of the river. The flow hydrographs were extracted from the unsteady state hydraulic HEC-RAS model in Findlay, downstream of the Blanchard River, Eagle Creek and Lye Creek confluence. The yellow, blue, and green hydrographs represent the flow contributions from the Blanchard River (upstream), Eagle Creek, and Lye Creek respectively. These three hydrographs, when combined, create the composite hydrograph black line which represents the total flow in the Blanchard River at cross section 295930 of the hydraulic model (upstream of Main Street).

Figure 36 shows that during Existing Conditions, the second peak of Lye Creek (the green hydrograph) is cross-over flow that occurs when the Blanchard River overtops the left bank (upstream of the Findlay Water Reservoir) and is conveyed overland to the west into Lye Creek. The 1% ACE event peak flow during Existing Conditions is about 15,500 cfs. The fourth alternative with three storage basins (Figure 40) shows a peak flow reduction of about 5,500 cfs on the Blanchard River which translates to about 3.6 feet of reduction for the WSE.

The results in the following Sections are considered applicable for analyzing the conceptual, planning level alternatives based on Stantec's hydrologic risk analyses.

Figure 36 – Existing Conditions – 1% ACE Event "Typical Storm"

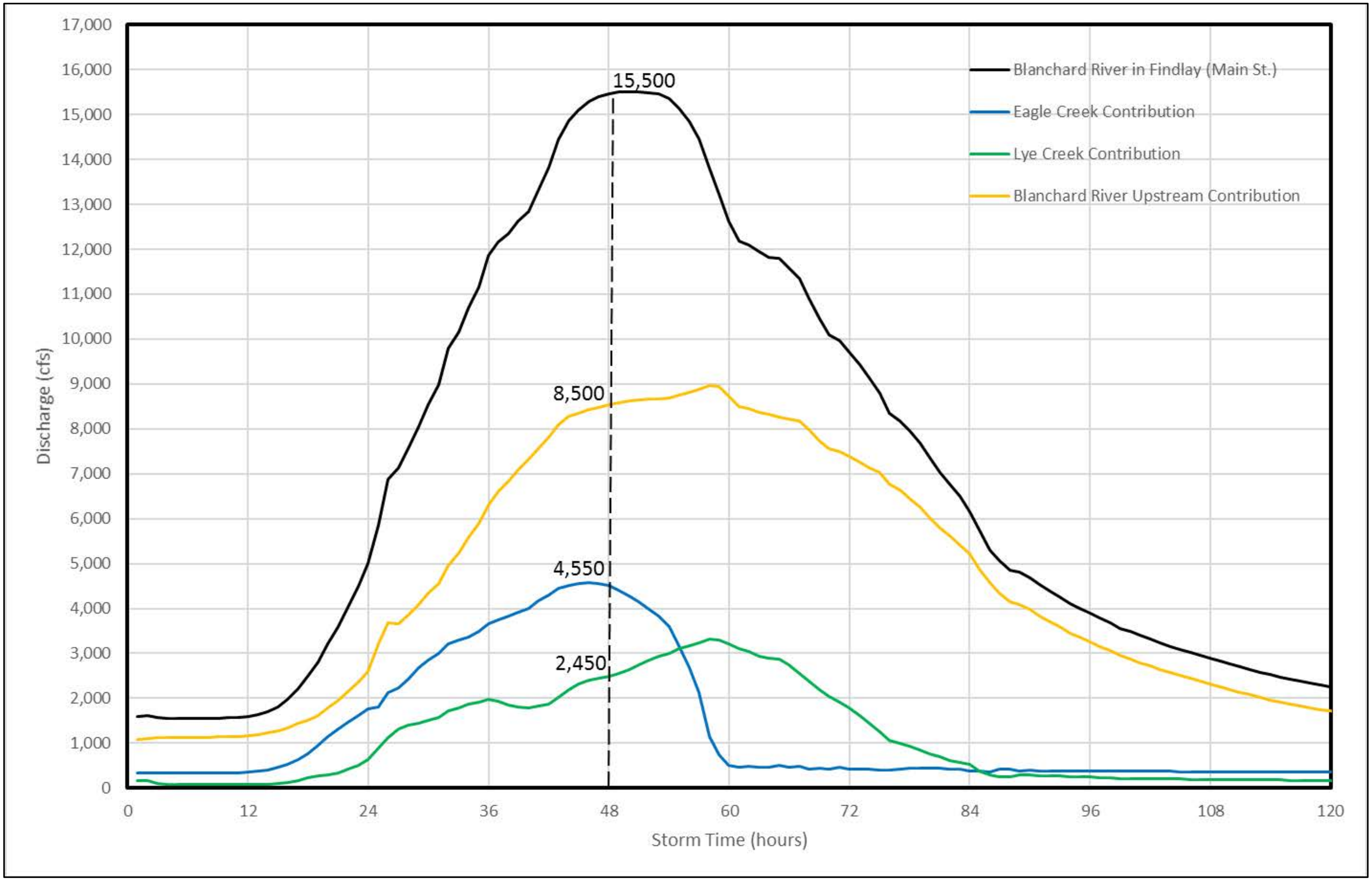


Figure 37 – Hyd. Impr. + Eagle Creek (EC-2C) Storage – 1% ACE Event "Typical Storm"

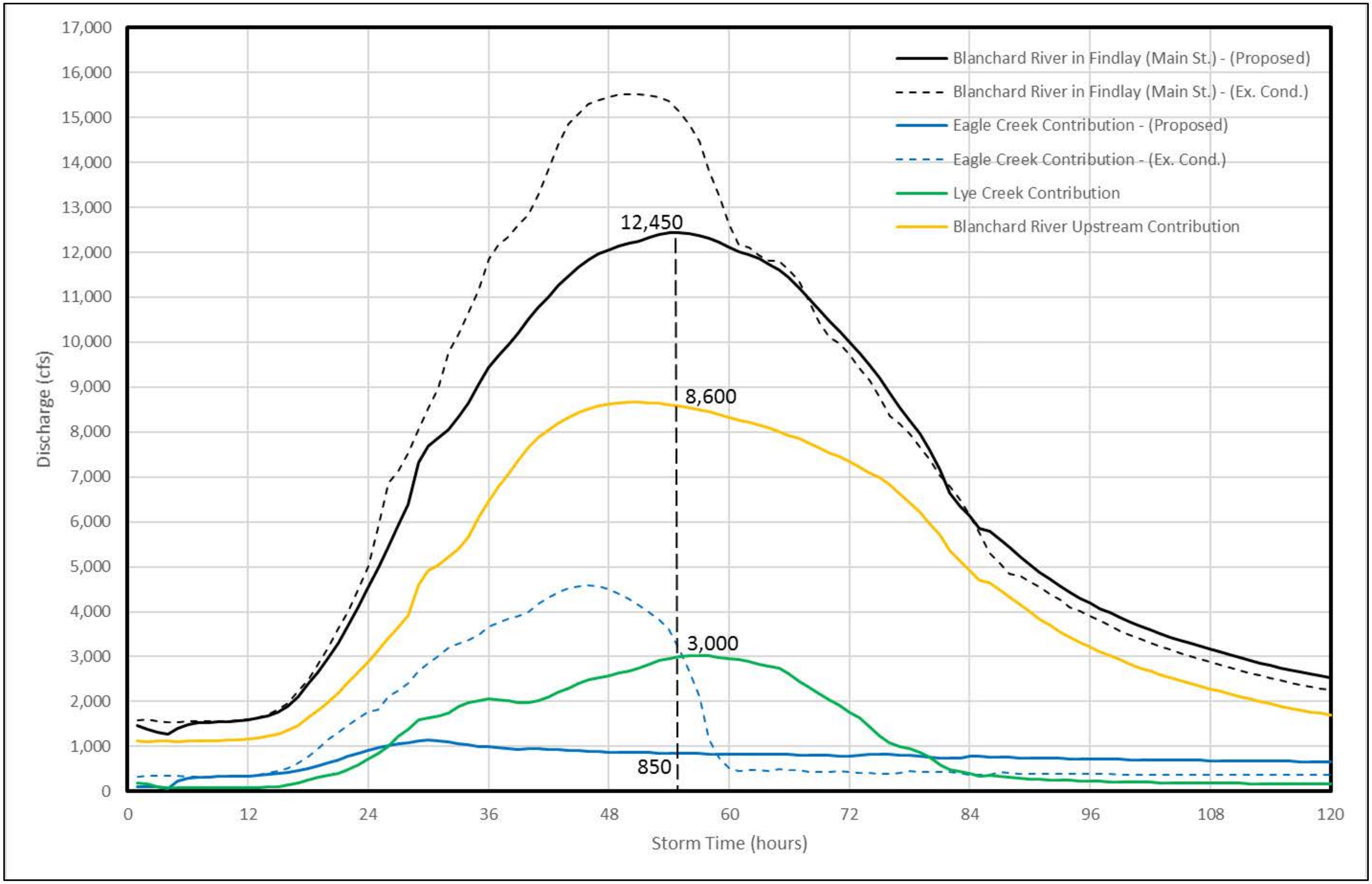


Figure 38 – Hyd. Impr. + Eagle Creek (EC-2C) & Potato Run Storage (PR-1) – 1% ACE Event "Typical Storm"

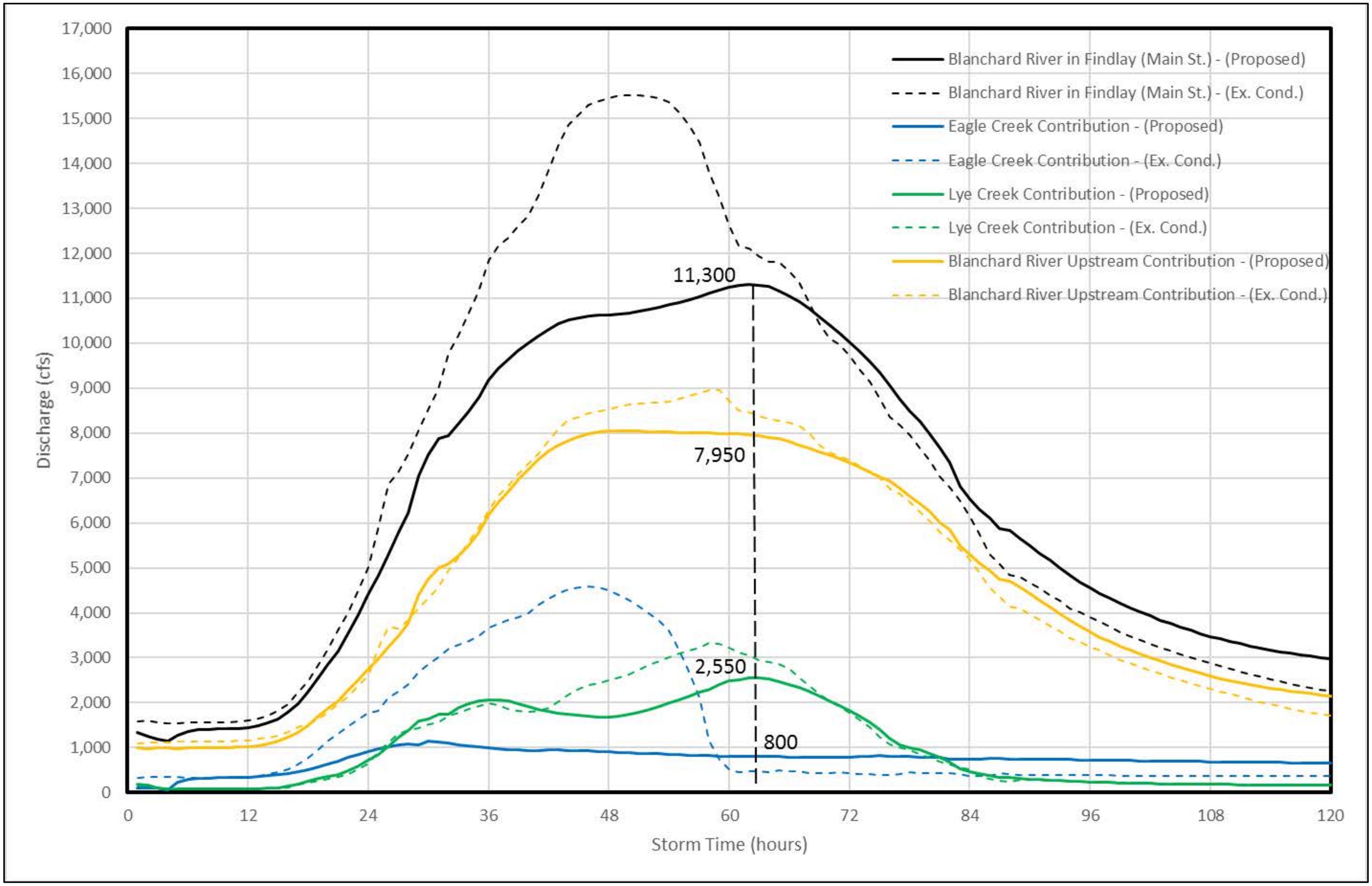


Figure 39 – Hyd. Impr. + Eagle Creek & Potato Run (PR-1) & Blanchard River (BR-3) Storage – 1% ACE Event “Typical Storm”

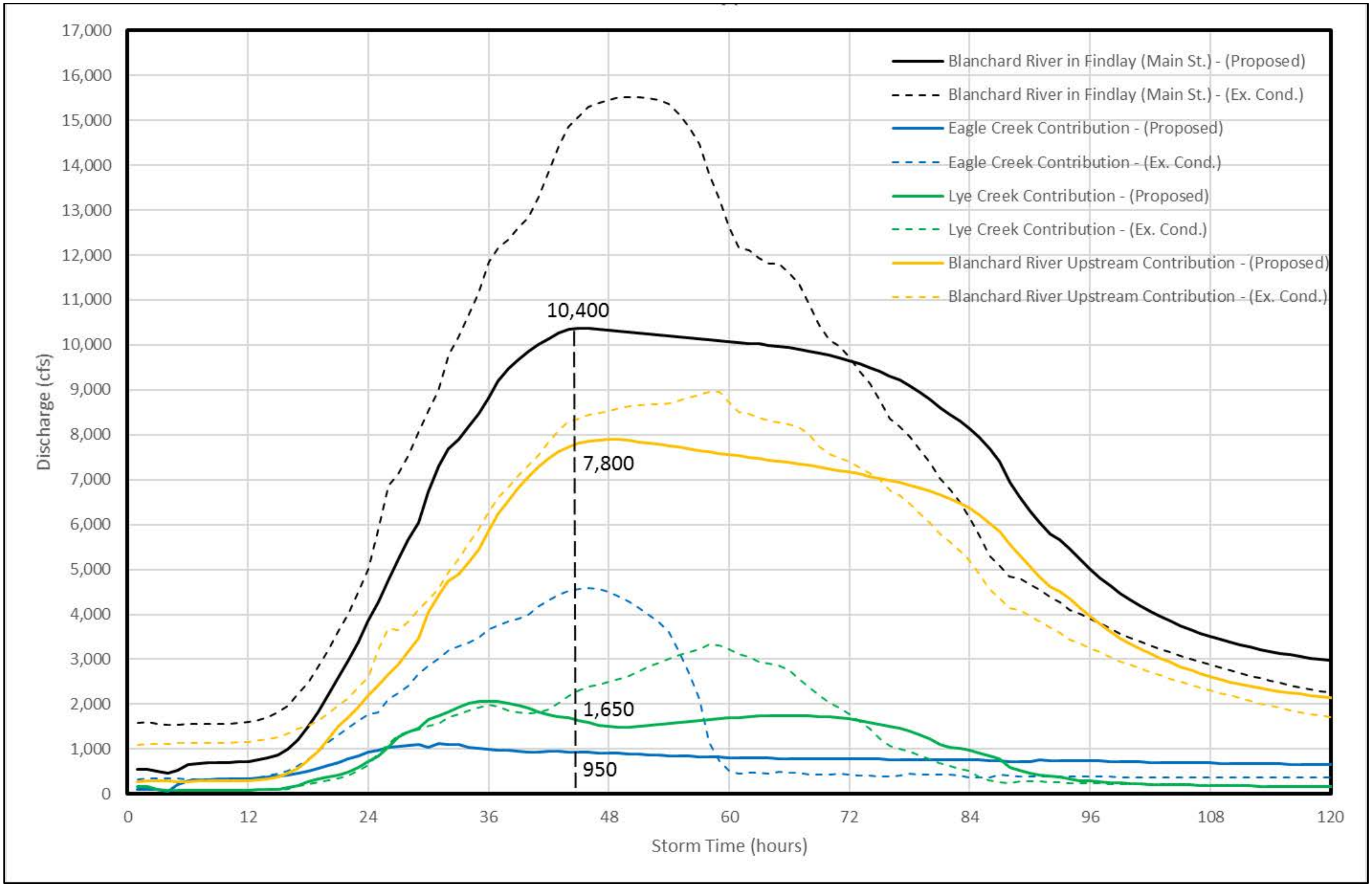
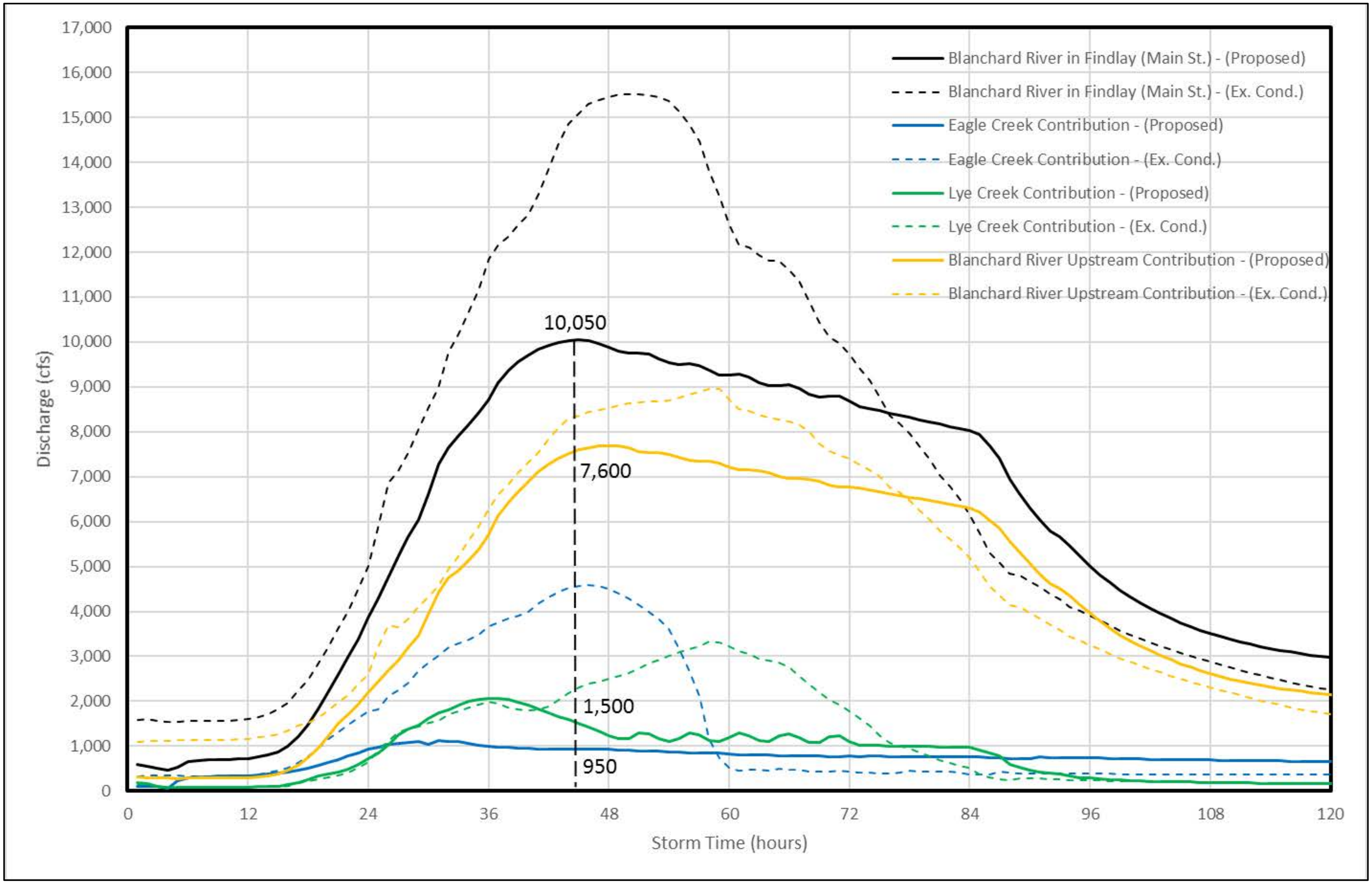


Figure 40 – Hyd. Impr. + Eagle Creek & Potato Run (PR-1) & Blanchard River (BR-2) Storage – 1% ACE Event “Typical Storm”



5.2 BENEFITS / IMPACTS SUMMARY TABLE

Stantec reviewed cumulative benefits and impacts for each alternative considered to help inform the HCFRR Program recommendation. Table 7 below highlights the benefits and costs associated with various combinations of the projects within the watershed.

Table 8 shows additional benefits and impacts from combinations of alternatives modeled. The results summarize the number of acres benefited/impacted, the number of agricultural acres benefited/impacted, and the number of parcels benefited/impacted.

Table 7 – Benefit / Impact Summary of HEC-RAS Results (1% ACE event with “Typical Storm”)

Alternative	Modeled Scenario	Blanchard River Maximum Flow at Main Street (cfs)	Blanchard River WSE at Main Street (Feet)	Reduction in WSE at Main Street (Feet)	Maximum Water Depth on Main Street (Feet)[7.]	Duration Water is 6 Inches Above Main Street (Hours)[8.]	Preliminary Opinion of Probable Cost	Preliminary Opinion of Probable Cost (With Contingency Included)
0	Existing Conditions	15,493	777.2	N/A	4.2	52	N/A	N/A
0a[1.]	Hydraulic Improvements[2.]	15,547	776.1	1.1	3.1	41	$14.3 MM	$16.2 MM
1	Hyd. Impr. + Eagle Creek Storage (EC-2C)[3.]	12,431	774.8	2.4	1.8	37	$66.6 MM	$81.6 MM
2	Hyd. Impr. + Eagle Creek Storage (EC-2C) + Potato Run Storage (PR-1)[4.]	11,291	774.3	2.9	1.3	37	$88.5 MM	$109.0 MM
3	Hyd. Impr. + Eagle Creek Storage (EC-2C) + Potato Run Storage (PR-1) + Smaller Blanchard River Storage (BR-3)[5.]	10,364	773.8	3.4	0.8	34	$124.3 MM	$153.8 MM
4	Hyd. Impr. + Eagle Creek Storage (EC-2C) + Potato Run Storage (PR-1) + Larger Blanchard River Storage (BR-2)[6.]	10,032	773.6	3.6	0.6	16	$128.8 MM	$159.4 MM

1. The Hydraulic Improvements are considered as “Alternative 0a” because Phase 1 is anticipated to be “Existing Conditions” as early as 2019
2. Hydraulic Improvements include removal of four inline dam/riffle structures, floodplain bench widening between Broad Avenue and the Norfolk Southern bridge, and widening of the Norfolk Southern Railroad bridge
3. Dry storage basin on Eagle Creek between US 68 and County Road 76 near Township Road 49 sized for the 1% ACE event
4. Dry storage basin on Potato Run south of State Route 103 and State Route 37 sized for the 1% ACE event
5. “Smaller” Dry storage basin on the Blanchard River south of State Route 103 and State Route 37 sized for the 1% ACE event
6. “Larger” Dry storage basin on the Blanchard River south of State Route 103 and State Route 37 sized for the 1% ACE event
7. The low elevation at Main Street is approximately 773.0’
8. WSE 6 inches above low elevation at Main Street is approximately 773.5’

Table 8 – Additional Benefit / Impact Summary of HEC-RAS Results (1% ACE event with "Typical Storm")

Alternative	Modeled Scenario	Total Acres Directly Impacted by Project Construction[6]	Homes Impacted	New Bridges	Area Impacted Outside of Existing Regulatory Floodplain	Acres Removed from Floodplain[7]	Agricultural Acres Directly Impacted by Project Construction[8]		Agricultural Acres Removed from Floodplain[7], [8]	Parcels Directly Impacted by Project Construction[9]	Parcels Removed from Floodplain
							Within Floodplain	Outside of Floodplain			
0	Existing Conditions	N/A	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A
0a[1]	Hydraulic Improvements[2]	47	0	0	0	223	0	0	37	5	640
DRY STORAGE BASIN	Eagle Creek Storage (EC-2C)[3]	936	6	1	596	-	161	514	-	43	-
	Potato Run Storage (PR-1)[4]	597	0	0	284	-	293	263	-	34	-
	Blanchard River Storage (BR-3)[5]	614	3	1	255	-	182	228	-	49	-
1	Hyd. Impr. + Eagle Creek Storage (EC-2C)	938	6	1	598	1,979	161	514	640	48	1,949
2	Hyd. Impr. + Eagle Creek Storage (EC-2C) + Potato Run Storage (PR-1)	1,535	6	1	882	2,778	454	777	1,246	82	2,213
3	Hyd. Impr. + Eagle Creek Storage (EC-2C) + Potato Run Storage (PR-1) + Smaller Blanchard River Storage (BR-3)	2,149	9	2	1,137	3,762	636	1,005	1,924	131	2,409

1. The Hydraulic Improvements are considered as "Alternative 0a" because Phase 1 is anticipated to be "Existing Conditions" as early as 2019
2. Hydraulic Improvements include removal of four inline dam/riffle structures, floodplain bench widening between Broad Avenue and the Norfolk Southern bridge, and widening of the Norfolk Southern Railroad bridge
3. Dry storage basin on Eagle Creek between US 68 and County Road 76 near Township Road 49 sized for the 1% ACE event
4. Dry storage basin on Potato Run south of State Route 103 and State Route 37 sized for the 1% ACE event
5. "Smaller" Dry storage basin on the Blanchard River south of State Route 103 and State Route 37 sized for the 1% ACE event
6. For storage options, acreage under berm and expected 1% ACE (100-year) floodplain extents assumed to be acquired through fee-simple purchase
7. Existing floodplain acreage within the construction footprint is included.
8. Agricultural acres include cultivated crop and hay/pasture categories within the National Land Cover Dataset
9. Number of parcels not owned by the City of Findlay or Hancock County

5.3 TRANSPORTATION BENEFITS / IMPACTS SUMMARY TABLE

Stantec reviewed transportation impacts and benefits at 27 locations across the watershed for the various combinations of projects considered. Many of the transportation impacts are expected to be reduced if combinations of the Program components are implemented. Table 9 shows the depth of flooding at multiple locations across the watershed for various alternative combinations considered.

Table 9 – Program Alternatives – Transportation Benefits and Impacts

Bridge/Intersection	Reach	1% ACE Depth above Bridge/Intersection (feet)						
		Ex. Cond.	Hyd. Improv.	EC-2C	EC-2C + PR-2	EC-2C + PR-1	EC-2C + PR-1 + BR-3	EC-2C + PR-1 + BR-2
SR 68 near TR 172	Eagle Creek	1.7	1.7	0	0	0	0	0
6th Street / Westview	Eagle Creek	0.8	0.8	0	0	0	0	0
S. Blanchard St. / E. Lincoln	Eagle Creek	3.5	2.9	0.7	0	0	0	0
E. Sandusky / S. Blanchard St.	Eagle Creek	3.0	2.3	0.3	0.2	0	0	0
SR 37 near 205	Lye Creek	0.6	0.6	0.6	0.5	0.2	0.2	0.2
CR 180 near SR 37	Lye Creek	0.8	0.8	0.8	0.7	0.1	0	0
SR37 near Williams St.	Lye Creek	1.8	1.5	1.0	0.7	0.4	0	0
Fishlock Ave. Bridge	Lye Creek	3.5	3.1	2.1	1.9	1.7	0.8	0.8
E. Sandusky Bridge	Lye Creek	5.1	4.3	3.0	2.7	2.5	1.6	1.4
SR 37 at Potato Run (W. Riverdale HS)	Potato Run	0	0	0	0.3	2.3	2.3	2.3
CR 153 / Trail 191	Potato Run	1.5	1.5	1.5	6.2	8.2	8.2	8.2
SR 37 at Potato Run (S. of Mt. Blanchard)	Potato Run	0.5	0.5	0.5	0	0	0	0
SR 37/103 at Potato/Blanchard Conf.	Blanchard River	1.1	1.1	1.1	1.1	0.9	0	0
CR 205	Blanchard River	1.3	1.3	1.3	1.3	1.3	1.0	0.8
SR 568 near CR 245	Blanchard River	0.7	0.7	0.7	0.6	0.5	0.4	0.2
SR 568 near CR 236	Blanchard River	3.5	3.3	3.0	2.7	2.5	2.3	2.1
E. Main Cross / Warrington Ave.	Blanchard River	2.0	1.4	0	0	0	0	0
S. Blanchard St. / E. High St.	Blanchard River	5.1	4.4	2.7	2.4	2.2	1.6	1.4
E. Main Cross / MLK Pkwy	Blanchard River	4.4	3.4	2.1	1.9	1.6	0.9	0.7
Main St.	Blanchard River	3.9	2.9	1.5	1.2	1.0	0.5	0.3
Defiance Ave. / Univ Townhouses	Blanchard River	4.6	4.4	3.1	2.7	2.4	1.8	1.5
Broad Ave. / Findlay St.	Blanchard River	2.4	2.2	0.7	0.3	0	0	0
Broad Ave. / Howard St.	Blanchard River	1.1	1.1	0.2	0	0	0	0
CR 223 / US 224	Blanchard River	2.8	2.8	1.6	1.2	1.0	0.6	0.4
CR 140 / US 224	Blanchard River	0.4	0.4	0	0	0	0	0
CR 139	Blanchard River	0.2	0.2	0	0	0	0	0

5.4 HCFRR PROGRAM REFINEMENT

Stantec reviewed various sizes of dry storage basins across the watershed in an attempt to balance benefits and impacts for the HCFRR Program. Ultimately, the overall flood mitigation measures recommended within this Proof of Concept Update Report are contained within Alternative 3. Alternative 3 includes constructing:

- hydraulic Improvements along the Blanchard River in Findlay (Phase 1 and 2);
- a dry storage basin on Eagle Creek with a smaller footprint than the April 2017 Proof of Concept (EC-2C);
- the “larger” dry storage basin option on Potato Run (PR-1) similar in magnitude to that of the April 2017 Proof of Concept; and
- a “smaller” dry storage basin on the Blanchard River (BR-3) that impacts fewer structures than what was recommended previously.

Figure 41 shows an overview of the watershed and where the proposed projects are located spatially. The project locations represent multiple areas across the watershed to reduce the risk of flooding by decreasing the flow rates on both Eagle Creek and the Blanchard River and by increasing the hydraulic efficiency of the Blanchard River. The projects and project sites were selected because of their limited impacts to structures, land and the environment when compared to other options available to reduce the risk of flooding for the community. Figure 42 provides a snapshot for the expected reduction in flooding during the 1% ACE event if the proposed updated HCFRR Program is completed. Figure 43 shows the expected impacts to transportation during existing conditions. Transportation impacts and detours associated with the proposed projects were considered as part of this analysis. Figure 44 shows the benefits provided by Alternative 3 (EC-2C + PR-1 + BR-3).

Figure 41 – HCFRR Program – Proposed Projects Overview

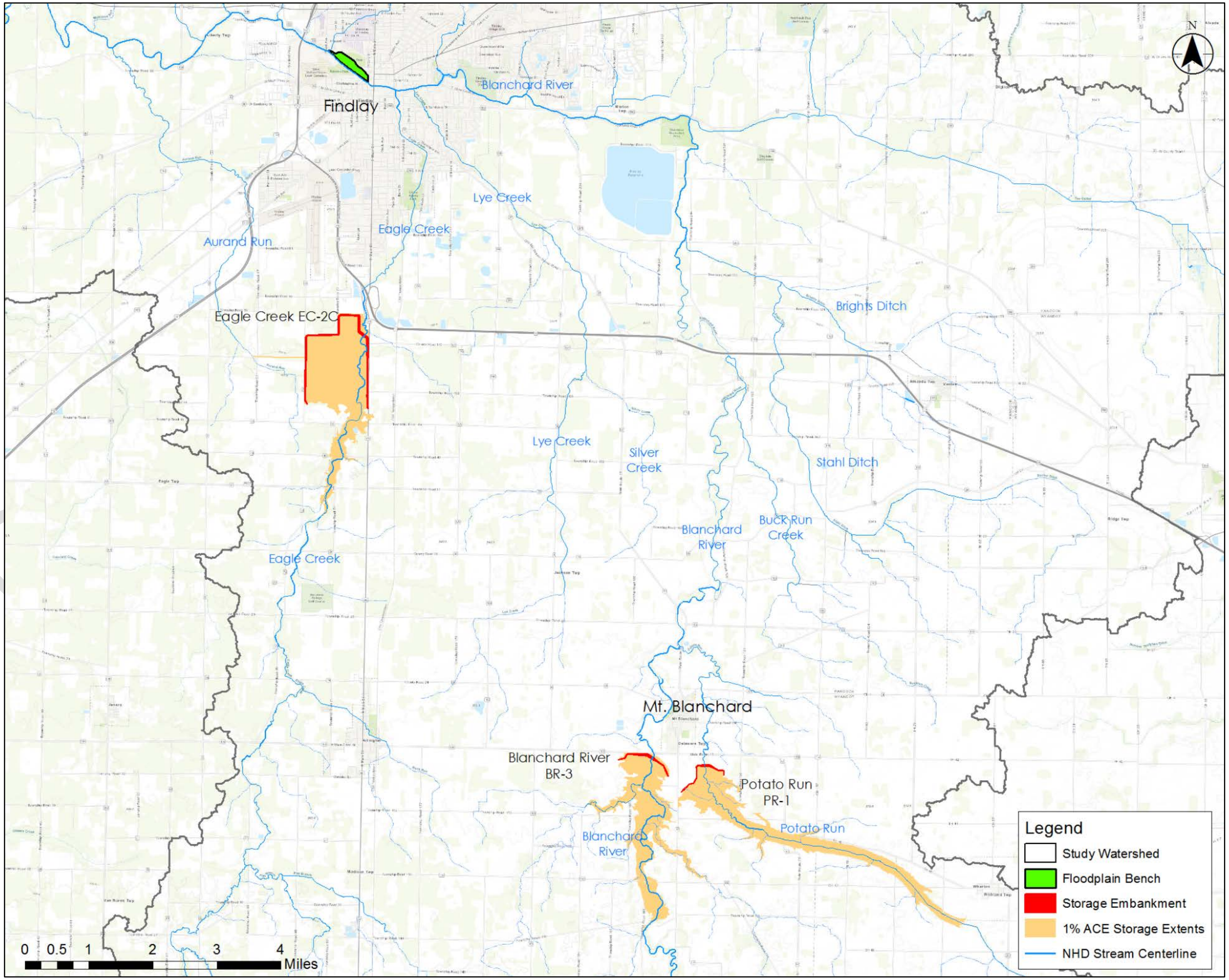


Figure 42 - Reduction of Floodplain Extents – Recommended Program

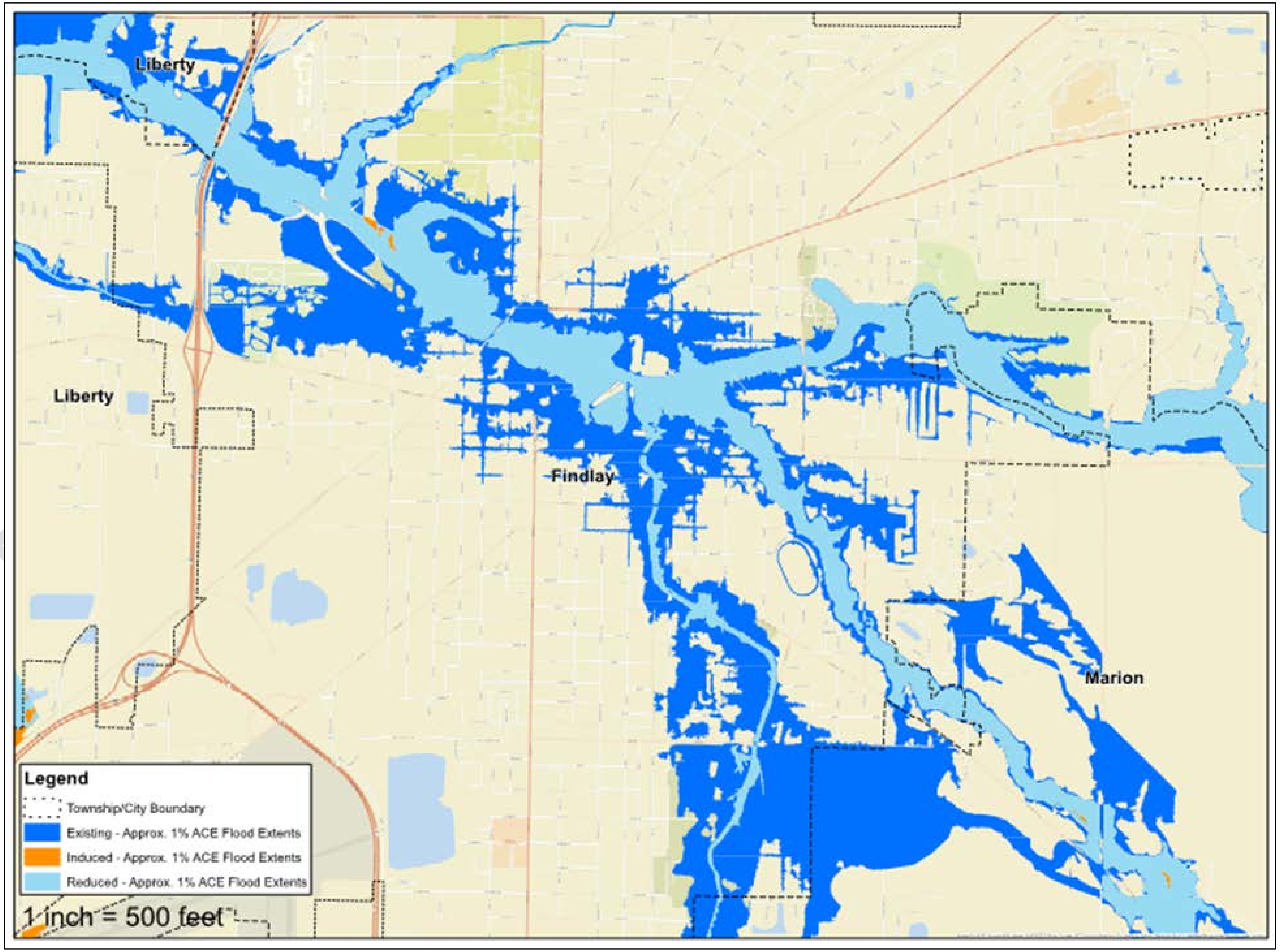


Figure 43 – Existing Conditions Simulated Transportation Impacts

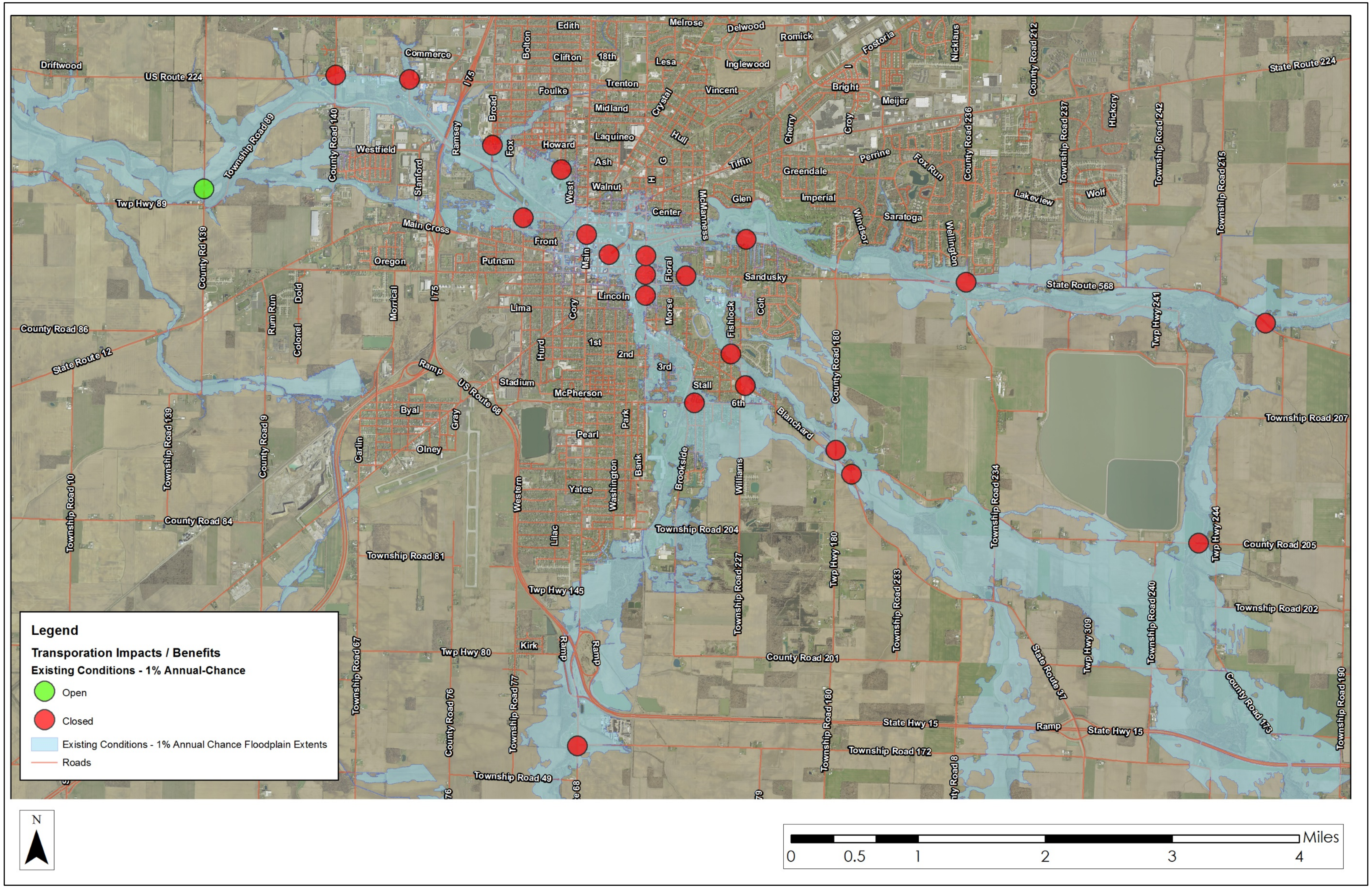
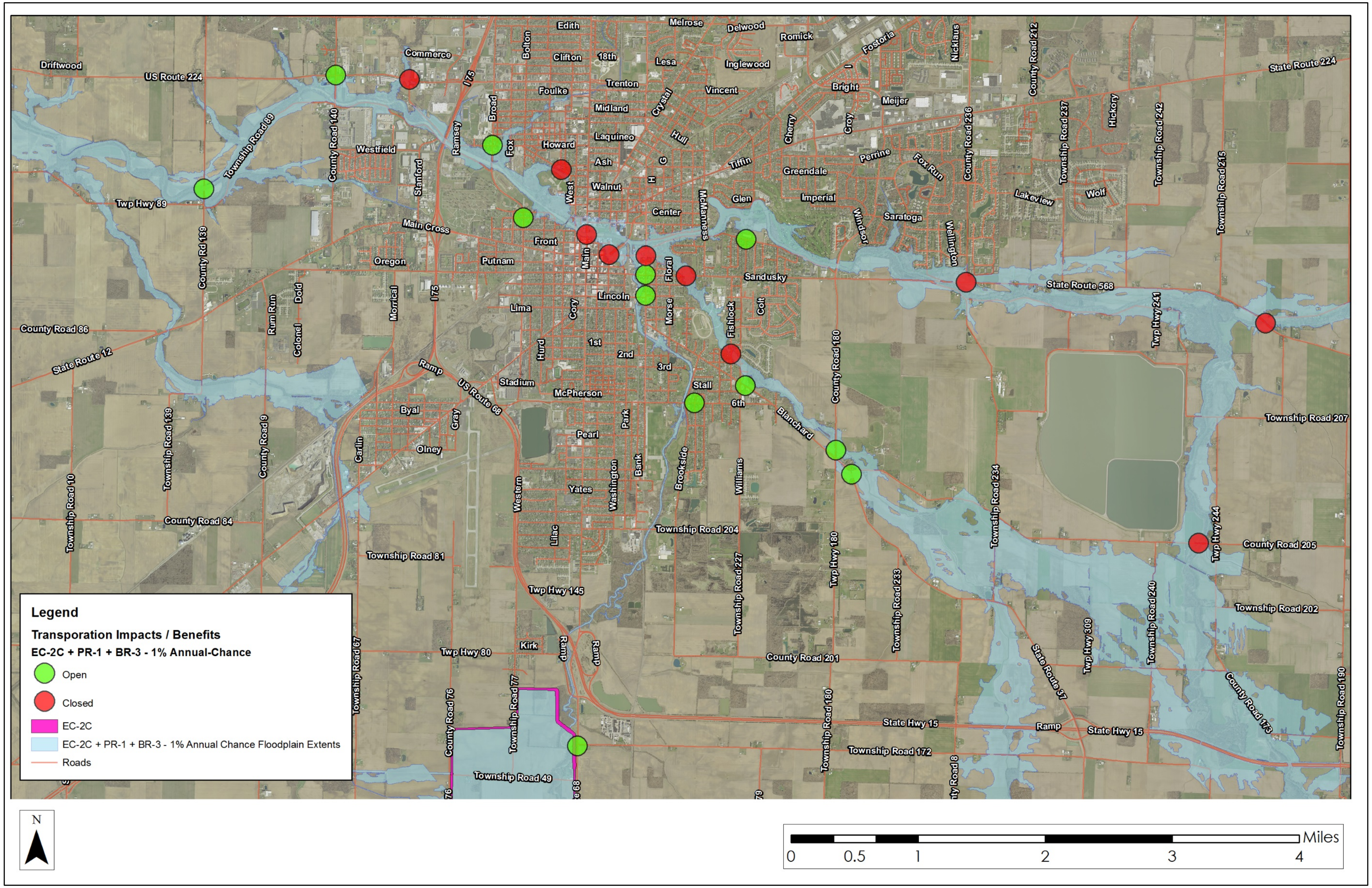


Figure 44 – Recommended Program Simulated Transportation Benefits



5.4.1 HCFRR Program Refinement Comparison

Table 10 and Table 11 provide comparisons of the benefits/impacts associated with the April 2017 Proof of Concept and the revised 2018 HCFRR Program Proof of Concept Update. The opinion of probable cost was reduced by about $6 Million after additional data were collected and Program refinements were made. The contingencies used were reduced with the refined data additional analyses performed. On one hand, the expected impacts due to construction of the proposed HCFRR Program decreases. This was one of the goals entering the Proof of Concept refinement process. Ten fewer homes and about 300 less acres of land are expected to be impacted by construction.

On the other hand, the anticipated flood risk reduction benefits generally decrease when compared to the April 2017 Proof of Concept results. One of the difference in benefits is the expected increase in flooding duration. The increase is likely a result of the proposed storage basins decreasing in footprint and storage capacity and the basin on the Blanchard River not being as effective at controlling the second peak of the flood hydrograph from the headwaters of the Blanchard River. Other decrease in benefits are that less acreage and fewer parcels are removed from the expected 1% ACE floodplain.

Table 10 – Benefit / Impact Summary of HEC-RAS Results Comparing 2017 Proof of Concept to 2018 Proof of Concept Update

Modeled Scenario	Blanchard River Maximum Flow at Main Street (cfs)	Blanchard River WSE at Main Street (Feet)	Reduction in WSE at Main Street (Feet)	Maximum Water Depth on Main Street (Feet)[1.]	Duration Water is 6 Inches Above Main Street (Hours)[2.]	Preliminary Opinion of Probable Cost	Preliminary Opinion of Probable Cost (With Contingency Included)
April 2017 Proof of Concept	11,078	774.0	3.6	1.0	15	$122.9 MM	$159.7 MM
June 2018 Proof of Concept Update	10,364	773.8	3.4	0.8	34	$124.3 MM	$153.8 MM

1. The low elevation at Main Street is approximately 773.0’
2. WSE 6 inches above low elevation at Main Street is approximately 773.5’

Table 11 – Additional Benefit / Impact Summary of HEC-RAS Results Comparing 2017 Proof of Concept to 2018 Proof of Concept Update

Modeled Scenario	Total Acres Directly Impacted by Project Construction 1.	Homes Impacted	New Bridges	Area Impacted Outside of Existing Regulatory Floodplain	Acres Removed from Floodplain 2.	Agricultural Acres Directly Impacted by Project Construction [3.]		Agricultural Acres Removed from Floodplain 2., 3.	Parcels Directly Impacted by Project Construction [4.]	Parcels Removed from Floodplain
						Within Floodplain	Outside of Floodplain			
April 2017 Proof of Concept	2,430.	19	2	1,515	5,060	1,900		2,850	135	2,850
June 2018 Proof of Concept Update	2,149	9	2	1,137	3,762	636	1,005	1,924	131	2,409

1. For storage options, acreage under berm and expected 1% ACE (100-year) floodplain extents assumed to be acquired through fee-simple purchase
2. Existing floodplain acreage within the construction footprint is included.
3. Agricultural acres include cultivated crop and hay/pasture categories within the National Land Cover Dataset
4. Number of parcels not owned by the City of Findlay or Hancock County

5.5 POTENTIAL FLOOD RISK GAP REVIEW

Stantec determined the centroid of the watershed and a 24-hour storm duration were appropriate for estimating planning level flood discharges in Findlay due to a given event during preparation of the Proof of Concept Report (April 2017) and subsequent Hydrology Report (November 2017). The centroid of the watershed was considered appropriate for a storm center location based on preliminary hydrologic modeling simulations. The 24-hour storm event was determined to be appropriate mostly due to the travel time involved with the watershed – based on observations of the simulated hypothetical design storms and historical events like those of August 2007 and July 2017. The 24-hour event duration was used by Stantec for the purposes of hydrologic and hydraulic modeling when evaluating flood mitigation measures in the watershed. Stantec was requested by MWCD to consider different storm durations for events occurring upstream of each basin and storm center locations throughout the watershed to support design efforts for the proposed basins and to address the potential “Flood Risk Gap”.

5.5.1 Storm Center Review – Existing Conditions

Storms can vary significantly within an area the size of the Upper Blanchard River watershed as the July 2017 event shows (Figure 9 – Page 2.15). MWCD requested that Stantec consider multiple storm center locations throughout the watershed to support conceptual design refinement efforts for the proposed dry storage basins and to address the question of a potential flood risk gap.

Stantec analyzed several storm center scenarios to address the flood risk gap question and determine the extent of risk involved if a storm center were to occur at various locations upstream and downstream of the proposed basins. To assess this risk of a storm center “missing” the proposed flood mitigation solutions, Stantec considered the hypothetical “Typical Storm” centered at six locations within the watershed. Those locations are shown on Figure 45 and described as follows:

1. **Findlay Main St.** – Directly over Findlay on the Blanchard River.
2. **Blanchard Upstream** – Centroid of the entire watershed upstream of Findlay. Note this location was used for the conceptual design efforts to-date.
3. **Eagle Creek Basin** – Centroid of the watershed upstream of the proposed basin on Eagle Creek.
4. **Blanchard Basin** – Centroid of the watershed upstream of the proposed basin on the Blanchard River upstream of Mt. Blanchard.
5. **Potato Run Basin** – Centroid of the watershed upstream of the proposed basin on Potato Run upstream of Mt. Blanchard.
6. **Lower Blanchard** – Centroid of the watershed upstream of Findlay, but downstream of the proposed basins. *Note: this location would represent an event that largely “misses” the three proposed basins, but still poses a significant flood potential for Findlay.*

The locations listed above were selected to generally provide the largest difference between storm event flow results and highlight key locations within the watershed. Table 12 summarizes the peak discharges at the six locations for a hypothetical 1% ACE (100-Year, 24-Hour) “Typical Storm” event based on the storm center location and “Existing Conditions” HEC-HMS geometry. The results confirm that the centroid of the watershed upstream of Findlay (Location #2), which has been used throughout conceptual design, results in the largest peak flows on the Blanchard River at Main Street in Findlay.

Figure 45 – Watershed Map with Gages and Storm Centers Considered

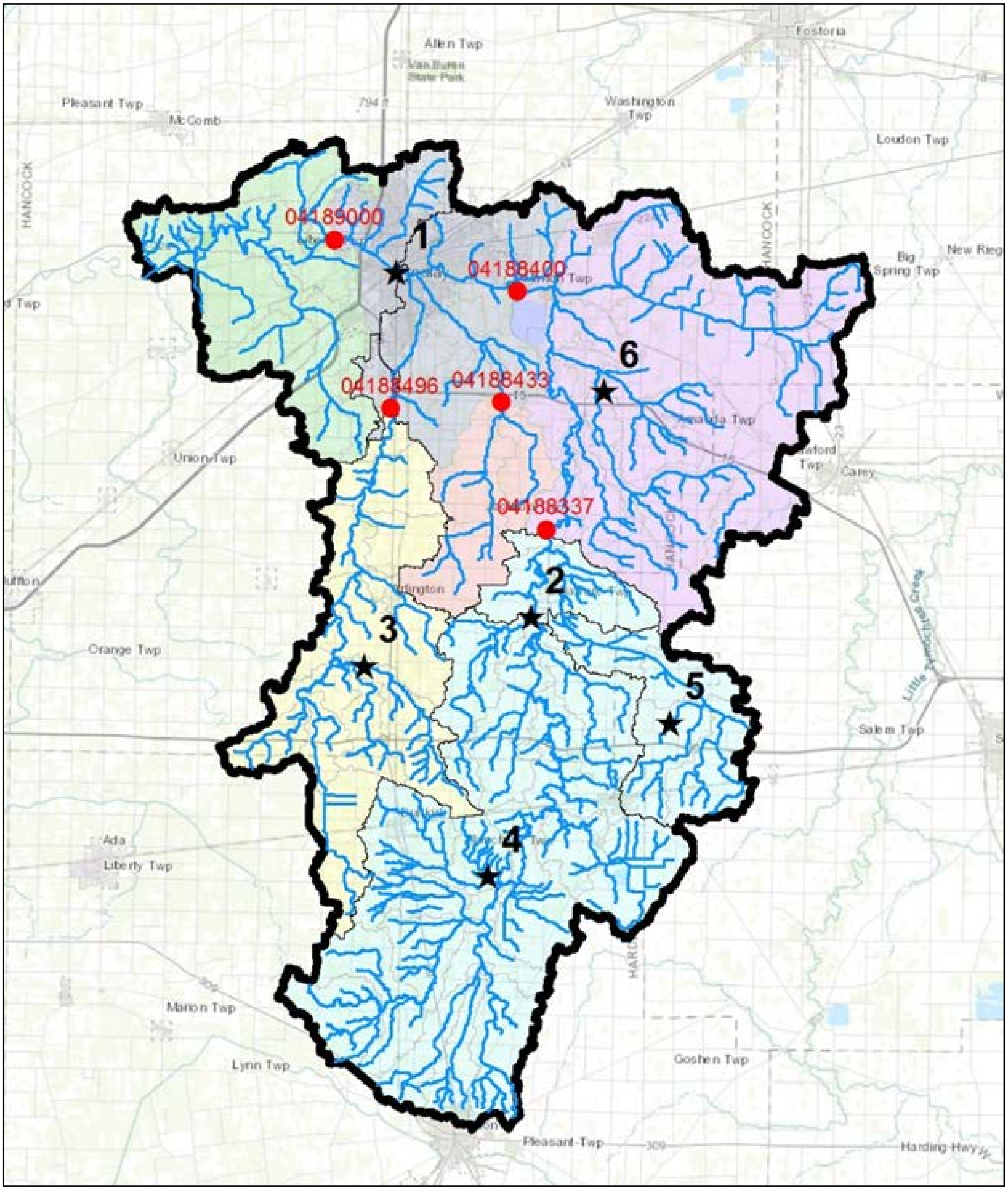


Table 12 – Peak Discharges by Storm Center (Existing Conditions – 1% ACE “Typical Storm”)

Location	**HEC-HMS Node**	**Storm Center Location**					
		1	**2**	**3**	**4**	**5**	**6**
		Findlay Main St.	**Blanchard Upstream**	**Eagle Creek Basin**	**Blanchard River Basin**	**Potato Run Basin**	**Lower Blanchard**
		Simulated Discharge (cfs)					
04189000 Blanchard River DS	J_04	14,304	15,657	15,576	14,289	15,151	15,077
04188400 Blanchard River US	J_09	7,029	7,145	7,087	7,116	7,089	7,297
04188337 Blanchard River at Mt. Blanchard	J_13	7,591	8,057	8,127	9,077	8,584	7,626
04188496 Eagle Creek	J_34	3,975	4,950	5,092	4,386	4,788	4,156
04188433 Lye Creek	J_45	1,379	1,675	1,618	1,334	1,430	1,600
Blanchard River at Main Street in Findlay	J_06	14,192	**15,661**[1.]	15,589	14,285	15,188	15,033

1.) *Note: *The storm center at Location #2 was used throughout the conceptual design process. This storm center location results in the most flow on the Blanchard River at Main Street when simulating the “Typical Storm” event.*

5.5.2 Storm Center Review – Proposed HCFRR Program

Feedback from the public meetings show concern regarding the scenario of a storm center “missing” the proposed solutions. This scenario involves an event (like that of July 2017) with a storm center that occurs downstream of the proposed flood mitigation projects. Stantec considered the potential residual flooding if the recommended HCFRR Program was implemented and the storm center occurring at different locations across the watershed. The model simulations show that for the design configuration being considered, the centroid of the watershed upstream of Findlay would result in the largest peak discharge in Findlay and was therefore appropriate for design. It is understood that whatever solution is implemented, the City of Findlay and other areas around Hancock County will still be at some level of flood risk, albeit reduced. As shown in Table 13, even if the storm event fell downstream of the three proposed basins, the overall reduction associated with the basins would be significant.

The conclusion is that although the HCFRR Program results were simulated using a “Typical Storm” centered over the watershed centroid, other storm centers still result in significant flood reductions. The risk of a 1% ACE storm event centered in such a way that it entirely misses the proposed storage basins and still yield significant flooding in Findlay is minimal. Based on the hydrologic modeling results shown in Table 13, even if a storm event is centered over the watershed downstream of the three proposed basins (at location #6), the 1% ACE discharge reduction would still be significant; reducing the flow rates at Main Street from approximately 15,000 cfs to 10,400 cfs (a WSE reduction of about 3.2 feet).

Table 13 – Peak Discharges by Storm Center (HCFRR Program – 1% ACE "Typical Storm")

Location	HEC-HMS Node	Storm Center Location					
		1	2	3	4	5	6
		Findlay Main St.	Blanchard Upstream	Eagle Creek Basin	Blanchard River Basin	Potato Run Basin	Lower Blanchard
		Simulated Discharge (cfs)					
Blanchard River at Main Street in Findlay Existing Conditions	J_06	14,192	15,661	15,589	14,285	15,188	15,033
Blanchard River at Main Street in Findlay EC-2C + PR-1 + BR-3 Storage Basins	J_06	9,822	9,866	9,686	9,005	9,360	10,442
Difference		4,370	5,795	5,903	5,280	5,826	4,591

5.5.3 Storm Duration – Proposed HCFRR Program

To support conceptual design efforts for the proposed basins, MWCD requested that Stantec consider different storm durations for events occurring upstream of each basin. The proposed flood mitigation basins have been conceptually designed using a storm with a 24-hour duration. As a part of this Proof of Concept Update, Stantec set out to determine if a different storm duration upstream of the proposed basin might change the assumptions used in the conceptual design or indicate the need for additional analyses. Stantec created a simulation of the 1% ACE (100-Year) event for durations of 3-, 6-, 12-, 24-, 48-, and 72-hours based on precipitation values from NOAA Atlas 14. Stantec then applied the storms to each location to evaluate the potential effects of storms upstream of each basin with different durations. The variable of concern was temporal variation for the duration analysis, so the storm was assumed to be uniform over the subwatershed upstream of each basin and no areal reductions were applied. The subwatersheds upstream of each proposed dry storage basin are much smaller than the overall Blanchard River watershed, making point precipitation values more applicable. Table 14 presents the peak inflow and outflow discharge values for each of the three proposed basins as indicated from the model simulations.

Table 14 – Storm Duration Analysis for Dry Storage Basins

Storm Event	Precipitation (inches)	Eagle Creek Basin		Potato Run Basin (PR-1)		Blanchard Basin (BR-3)	
		Inflow (cfs)	Outflow (cfs)	Inflow (cfs)	Outflow (cfs)	Inflow (cfs)	Outflow (cfs)
100-Year, 3-Hour	3.46	3,405	691	2,391	709	5,893	4,844
100-Year, 6-Hour	4.09	4,235	731	2,868	744	7,039	5,456
100-Year, 12-Hour	4.70	4,954	765	3,229	771	8,062	5,934
100-Year, 24-Hour	5.26	5,359	791	3,286	790	8,647	6,249
100-Year, 48-Hour	5.93	5,159	811	2,910	804	8,382	6,422
100-Year, 72-Hour	6.26	4,422	810	2,446	802	7,737	6,280

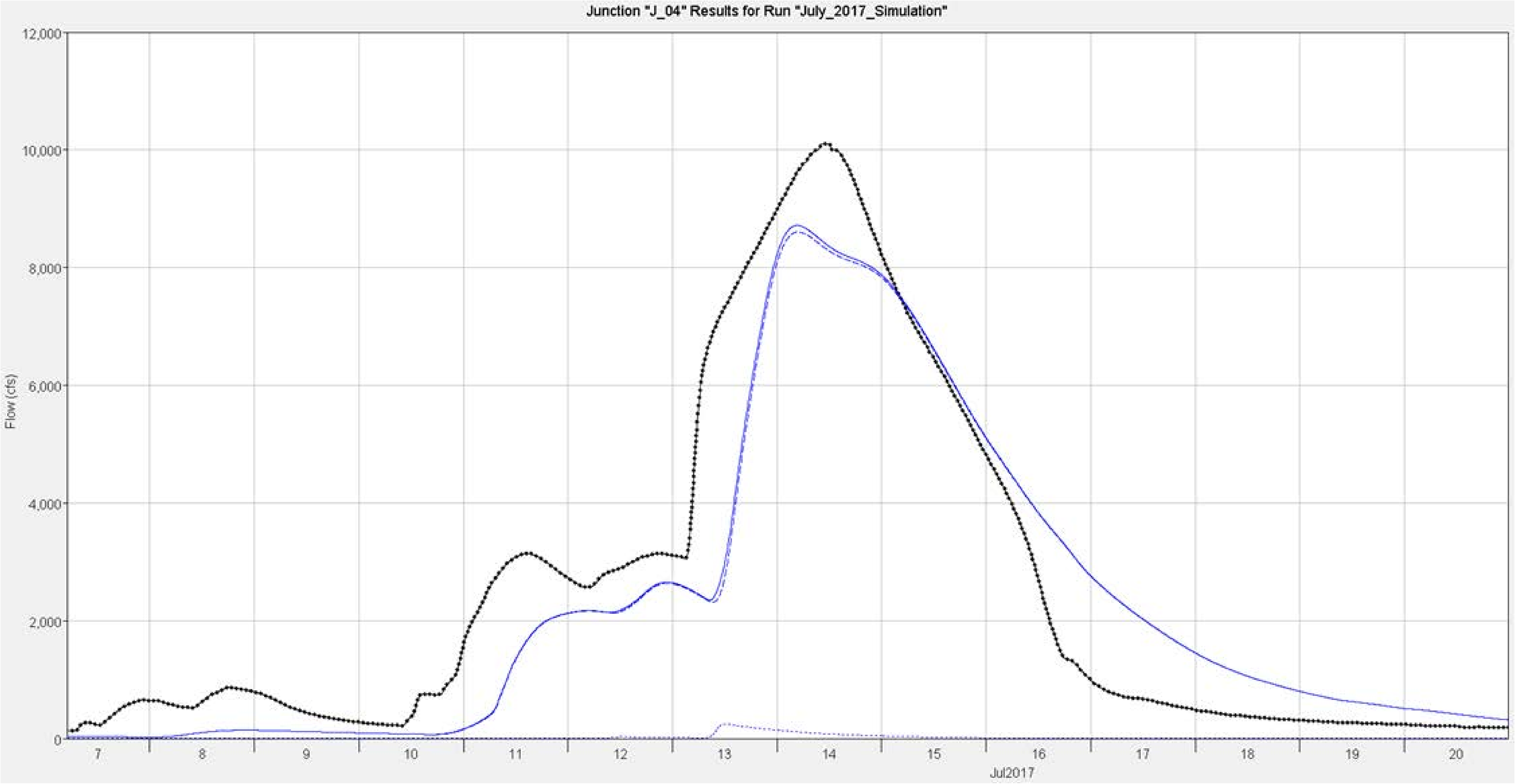
Table 14 shows the 24-hour storm duration produces the largest peak inflow for each of the three basin configurations. This indicates the 24-hour duration was a valid assumption for the conceptual design. The peak outflow discharge values are consistent for each of the durations considered for the Eagle Creek and Potato Run Basins, which indicates the conceptual outlet configurations would not change substantially based on input storm duration. For the Blanchard River basin, the 24-hour duration produces the highest inflow values, but the discharge values are more variable. Proportionately, the Blanchard River basin would pass a larger storm volume during the events than the other two basins. The Blanchard River basin would require a larger storage volume than is currently provided to reduce peak fluctuations downstream. There may be potential to further optimize the size of the outlet structure for this basin, but the overall results are consistent and indicate the storm duration considered would not substantially change the size or configuration of the structure.

5.5.4 July 2017 Model Simulation

Stantec simulated the results of the July 2017 flood event using the revised HEC-HMS model and the processed meteorological radar data from AWA. The goal was to demonstrate what would have happened during the July 2017 event if the recommended flood mitigation measures were in place.

The first step to demonstrate what would have happened was to compare the HEC-HMS model results to the gage observations for that period. The Stantec HEC-HMS model that accompanied the Hydrology Report had three calibrated geometry sets: September 2011, July 2015, and August 2007. Each geometry represents a valid calibration for the individual storm it is based on, but each also represents slightly different antecedent conditions in the watershed. For this simulation, the geometry that matches the August 2007 event seemed to produce the best match to gage observations as shown in Figure 46. The black dotted line in Figure 46 represents the observed flow over time at the USGS gage and the blue line represents the HEC-HMS simulated flow.

Figure 46 – July 2017 Model Comparison (USGS Gage #04189000) Blanchard River DS of Findlay



Though Stantec recognizes the model does not produce a perfect match with the gage observations, it is our opinion that the hydrologic geometry is sufficient for evaluation purposes, with the caveat that the predicted model discharge values are slightly lower than the observed data. For comparison purposes, results were scaled by a factor of 1.16 to represent anticipated results. An additional calibrated geometry could be created that would better replicate the July 2017 storm event observed data, but Stantec does not recommend creating an additional model geometry at this time.

The conceptual HEC-HMS model results using the July 2017 precipitation data are presented in Table 15 for various combination of Program solutions. Note the target flood elevation in Findlay is between 15.5 and 16.0 feet, which would be in the range of 9,000 to 10,000 cfs (based on the hydraulic rating curve with Hydraulic Improvements in place - Figure 15).

Table 15 – July 2017 Peak Discharge Results from HEC-HMS on the Blanchard River at Main Street in Findlay

Configuration	Model Peak Discharge (cfs)	Scaled Peak Discharge (cfs)	Peak Elevation (feet)
Existing Conditions	8,720	10,100	17.4
Hydraulic Improvements	8,720	10,100	16.3
Hydraulic Improvements + Eagle Creek Basin (“EC-2C Only”)	7,712	8,946	15.5
Hydraulic Improvements + Eagle Creek Basin + Larger Potato Run Basin (“EC-2C + PR-1”)	7,598	8,814	15.3
Hydraulic Improvements + Eagle Creek Basin + Larger Potato Run Basin + Smaller Blanchard River Basin (“EC-2C + PR-1 + BR-3”) ***Revised Recommended HCFRR Program**	7,572	8,784	15.3

Table 15 above (HEC-HMS simulated results) shows that the revised recommended HCFRR Program configuration would have resulted in a reduction in peak discharge on the Blanchard River in Findlay by about 1,315 cfs during the July 2017 event. This reduction in flow from the dry storage basins corresponds to a flood stage reduction of 2.1 feet based on the hydraulic rating curve (Figure 15) had the HCFRR Program been in place during the July 2017 event. Even though there appears to be a minimal reduction in discharge and peak WSE due to the storage basin on the Blanchard River, it should be noted that this detention facility is designed to store water during extreme events like the 2% ACE and 1% ACE events. Smaller flood flows are designed to “pass through” the proposed Blanchard River dam without storing water in order to reduce the number of impacts upstream of the dam embankment.

6.0 PROOF OF CONCEPT – BCA UPDATE

Stantec refined the opinion of probable cost for each Program component, used the updated hydrologic and hydraulic models for the HCFRR Program to generate revised water surface profiles (WSPs), and updated the elevations of the structure inventory based on the processed LiDAR data. That data and other supplemental information was provided to Jack Faucett Associates (JFA), a sub-consultant to Stantec, to update the BCA for the revised Program.

6.1 HCFRR PROGRAM REFINEMENT – OPINION OF PROBABLE COST

Preliminary, planning level opinions of probable project costs were developed for the conceptual projects identified in the revised HCFRR Program. These estimates were created based on expected quantities measured from the conceptual designs. The detail in opinions of probable cost are intended to be at a conceptual planning level for the dry storage basins. The opinion of probable cost for Phase 1 of the Hydraulic Improvements contains more detail as the project enters the final design stage.

6.1.1 Land

While details of property acquisition would occur later in any future design process, Stantec used a conservative flat rate for cost per acre for purposes of the preliminary opinions of probable cost. Stantec assumed fee-simple purchase of the permanently impacted lands and area falling within the 1% ACE event floodplain. A second, lesser unit rate was assumed for land where flowage easements were expected between the 1% ACE floodplain and the probable maximum flood extents.

6.1.2 Project Contingencies

The Proof of Concept Report (Reference 3) assumed a flat 30% contingency for each line item in the preliminary opinions of probable cost for the alternative concepts considered. While costs were reviewed for accuracy at the conceptual level, the 30% contingency covered unforeseen administrative and legal fees and obstacles that may arise during the detailed design and construction phase, such as minor utility relocations, site drainage, etc.

Stantec used several contingency factors in this Proof of Concept Update. Phase 1 of the Hydraulic Improvements had a 10% contingency since the project is at 95% design stage. Phase 2 of the Hydraulic Improvements (modifications to the Norfolk Southern railroad bridge) uses a 30% contingency because only conceptual level planning has been completed to date. Stantec used a flat 25% contingency for each line item in the dry storage basins' preliminary opinions of probable costs since additional analyses such as geotechnical explorations and hydrology refinements have been performed.

6.1.3 Mobilization, Demobilization, and Preparatory Work

Stantec applied a rate of 5% to construction costs to account for potential mobilization and demobilization. Additional costs were included for preparatory work such as survey staking and construction layout.

6.1.4 Engineering & Design and Construction Management

Stantec applied a rate of 15% for professional services (engineering, design, and permitting) and 5% for project construction and administration for the alternatives considered. An additional 2% rate was applied to the larger scale projects for construction phase services.

6.1.5 Project Quantities

Additional project quantities for the design were developed by Stantec and included: excavation volumes, embankment placement, auxiliary spillway length, access roads, clearing and grubbing, seeding and mulching, utilities, traffic control, erosion protection and sediment control measures, cultural resources preservation and environmental mitigation activities. First costs were developed based on project quantities, historical bid cost data, experience, and/or unit prices adjusted to expected project conditions.

6.1.6 Operations, Maintenance, and Repair

Preliminary project operation, maintenance, and repair (OM&R) tasks were estimated for the BCA but were not included in the preliminary opinions of probable cost. The OM&R items are likely to include: Maintenance Personnel, Equipment, Vehicles, Office/Garage, Replacement Costs, Engineering, Administration, Board of Directors, Appraisers and Conservancy Court, Legal Fees, State Dam Safety Permits, and Liability Insurance Coverage. Manual labor would include mowing, and removing obstructions such as vegetation, trash, debris, or other miscellaneous structures present within the easement area, repairing erosion and repairing or replacing riprap.

Operations and maintenance for the benching area in the Hydraulic Improvements component are estimated at $17,700 annually for mowing and occasional debris removal following flooding events. No additional OM&R costs are applied. The following calculations inform the costs:

- Mowing: 8 hours/mowing x ($25/hour (fully loaded labor rate) + $25/hour mower cost) x 1 mowing/week x 36 weeks/year = $14,400.00
- Debris Removal: 2 staff x $25/hour x 8 hours x 2 times/year + $1,000 per day for equipment x 2 days + $500 disposal = $3,300.00
- Mowing plus Debris Removal = $14,400 + $3,300 = $17,700.00

Annual operation and maintenance costs were estimated for the proposed dry storage basin projects as followings:

- $75,000 for Eagle Creek Storage Basin
- $40,000 for Blanchard River Storage Basin
- $40,000 for Potato Run Storage Basin

6.1.7 Hydraulic Improvements Phase 1 – Preliminary Opinion of Probable Cost

Table 16 provides the preliminary opinion of probable cost for Phase 1 of the Hydraulic Improvements. Phase 1 includes removing four riffle/inline structures in the Blanchard River and creating a widened floodplain bench for a portion of the Blanchard River. Most of the widening costs relate to, sewer work, excavation, and the potential need to haul material to an off-site landfill.

Table 16 – Hydraulic Improvements Phase 1 – Preliminary Opinion of Probable Cost

Description	Amount
Construction Costs	
Instream Improvements	$1,630,000
Floodplain Bench Widening Improvements	$5,608,000
Utility and Bike Path Improvements	$1,122,000
CONSTRUCTION SUBTOTAL	**$8,360,000**
Hancock County Landfill Tipping Fees	$800,000
Contingency (10%)	**$916,000**
CONSTRUCTION TOTAL	**$10,076,000**
Other Costs	
Cultural Resources	$25,000
AEP Pole Relocations	$750,000
Tree Removal (Including Debris Removal)	$150,000
Stream Wetland and T&E Mitigation	$77,250
Construction Administration	$675,000
OTHER SUBTOTAL	**$1,677,250**
TOTAL REMAINING PROJECT COSTS	**$11,760,000**

6.1.8 Hydraulic Improvements Phase 2 – Preliminary Opinion of Probable Cost

Table 17 provides the preliminary opinion of probable cost for Phase 2 of the Hydraulic Improvements. Phase 2 of the Hydraulic Improvements is modification of the railroad bridge downstream of Cory Street for addition conveyance capacity.

Table 17 – Hydraulic Improvements Phase 2 – Preliminary Opinion of Probable Cost

Description	Cost	Contingency %	Contingency $	Total Cost
Mob, Demob, & Preparatory Work	$100,000	30.0%	$30,000	$130,000
01 – Lands and Damages	$6,000	30.0%	$1,800	$7,800
02 – Relocations	$0	30.0%	$0	$0
06 – Fish and Wildlife	$0	30.0%	$0	$0
08 – Road, Railroads & Bridges	$2,500,000	30.0%	$750,000	$3,250,000
09 – Channels and Canals	$5,000	30.0%	$1,500	$6,500
15 – Floodway Control & Diversion	$3,000	30.0%	$900	$3,900
18 – Cultural Resources	$16,000	30.0%	$4,800	$20,800
30 – Engineering & Design	$400,000	30.0%	$120,000	$520,000
31 – Construction Management	$400,000	30.0%	$120,000	$520,000
TOTAL	**$3,430,000**		**$1,029,000**	**$4,459,000**

6.1.9 Eagle Creek Dry Storage Basin – Preliminary Opinion of Probable Cost

Table 18 provides the preliminary opinion of probable cost for the Eagle Creek dry storage basin (EC-2C) option sized for the 1% ACE event.

Table 18 – Eagle Creek Dry Storage Basin – Preliminary Opinion of Probable Cost

Description	Cost	Contingency %	Contingency $	Total Cost
Mob, Demob, & Preparatory Work	$1,400,000	25.0%	$350,000	$1,750,000
01 – Lands and Damages	$13,800,000	25.0%	$3,450,000	$17,250,000
02 – Relocations	$100,000	25.0%	$25,000	$125,000
06 – Fish and Wildlife	$500,000	25.0%	$125,000	$625,000
08 – Road, Railroads & Bridges	$2,100,000	25.0%	$525,000	$2,625,000
09 – Channels and Canals	$12,700,000	25.0%	$3,175,000	$15,875,000
15 – Floodway Control & Diversion	$11,900,000	25.0%	$2,975,000	$14,875,000
18 – Cultural Resources	$300,000	25.0%	$75,000	$375,000
30 – Engineering & Design	$6,400,000	25.0%	$1,600,000	$8,000,000
31 – Construction Management	$3,100,000	25.0%	$775,000	$3,875,000
TOTAL	**$52,300,000**		**$13,075,000**	**$65,375,000**

6.1.10 Blanchard River Dry Storage Basin – Preliminary Opinion of Probable Cost

Table 19 provides the preliminary opinion of probable cost for the “smaller” dry storage basin option at the Blanchard River (BR-3) sized for the 1% ACE event.

Table 19 – Blanchard River Dry Storage Basin – Preliminary Opinion of Probable Cost

Description	Cost	Contingency %	Contingency $	Total Cost
Mob, Demob, & Preparatory Work	$900,000	25.0%	$225,000	$1,125,000
01 – Lands and Damages	$9,600,000	25.0%	$2,400,000	$12,000,000
02 – Relocations	$100,000	25.0%	$25,000	$125,000
06 – Fish and Wildlife	$2,500,000	25.0%	$625,000	$3,125,000
08 – Road, Railroads & Bridges	$1,600,000	25.0%	$400,000	$2,000,000
09 – Channels and Canals	$3,300,000	25.0%	$825,000	$4,125,000
15 – Floodway Control & Diversion	$11,100,000	25.0%	$2,775,000	$13,875,000
18 – Cultural Resources	$200,000	25.0%	$50,000	$250,000
30 – Engineering & Design	$4,400,000	25.0%	$1,100,000	$5,500,000
31 – Construction Management	$2,100,000	25.0%	$525,000	$2,625,000
TOTAL	**$35,800,000**		**$8,950,000**	**$44,750,000**

6.1.11 Potato Run Dry Storage Basin – Preliminary Opinion of Probable Cost

Table 20 provides the preliminary opinion of probable cost for the “larger” dry storage basin option at Potato Run (PR-1) sized for the 1% ACE event.

Table 20 – Potato Run Dry Storage Basin – Preliminary Opinion of Probable Cost

Description	Cost	Contingency %	Contingency $	Total Cost
Mob, Demob, & Preparatory Work	$500,000	25.0%	$125,000	$625,000
01 – Lands and Damages	$9,000,000	25.0%	$2,250,000	$11,250,000
02 – Relocations	$0	25.0%	$0	$0
06 – Fish and Wildlife	$200,000	25.0%	$50,000	$250,000
08 – Road, Railroads & Bridges	$1,400,000	25.0%	$350,000	$1,750,000
09 – Channels and Canals	$2,200,000	25.0%	$550,000	$2,750,000
15 – Floodway Control & Diversion	$4,500,000	25.0%	$1,125,000	$5,625,000
18 – Cultural Resources	$100,000	25.0%	$25,000	$125,000
30 – Engineering & Design	$2,700,000	25.0%	$675,000	$3,375,000
31 – Construction Management	$1,300,000	25.0%	$325,000	$1,625,000
TOTAL	**$21,900,000**		**$5,475,000**	**$27,375,000**

6.2 BENEFIT-TO-COST ANALYSIS

Stantec developed the HCFRR Program to mitigate the risk of flooding and to increase protection for the community and their assets from periodic flooding events. Jack Faucett Associates (JFA) completed an updated evaluation of the anticipated benefit categories for the refined HCFRR Program. The research team identified the estimated damages that could be avoided if the risk of flooding was reduced in and around the City of Findlay and Hancock County.

To complete the analysis, flow hydrographs developed from the revised HEC-HMS model simulations were used as inputs into the Stantec HEC-RAS model to complete the hydraulic analyses for both “Existing Conditions” and the recommended refined HCFRR Program. Stantec developed WSPs by simulating the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year, 24-hour flood events as input to the BCA. Stantec provided JFA with WSPs for the Blanchard River, Eagle Creek, and Lye Creek for the eight different return frequencies. By combining the refined WSPs and the updated floodplain structure inventory, the team determined the expected flood damages avoided over the life of the Program.

JFA revised regional economic models and performed a BCA based upon the Proof of Concept Update for the revised HCFRR Program recommended by Stantec (described in Section 5.4). This BCA included updating the existing National Economic Development (NED) and Regional Economic Development (RED) benefits. The following is a list of key benefits identified in the development of the updated BCR by JFA:

- Structural & Content Damages
- Vehicular Damages
- Transportation Cost Impacts
- Emergency Response Cost Impacts
- National Flood Insurance Program (NFIP) Premiums and Administrative Costs
- Business Losses (Gross and Net Sales)
- Agricultural Losses
- Environmental Losses

Each of the above categories are fully defined within the JFA BCA report titled, “*Hancock County Flood Risk Reduction Program: Updated Benefit Cost Analysis*” (Reference 8 – June 2018 – Updated BCA Report). Based upon the planning level opinion of probable cost for the recommended HCFRR Program and the estimated flood control benefits derived from implementation of the refined Program, it is anticipated that the Program-wide BCR will be at least 2.21. This BCA of the HCFRR Program demonstrates that the recommended flood risk reduction measures are cost effective. The Net Present Value of the Program benefits substantially exceeds the cost, indicating that the Program components are an efficient infrastructure investment. The BCR of 2.21 reveals a substantial benefit margin over costs. This indicates that for each dollar of investment in the HCFRR Program, the community will receive $2.21 in estimated benefits. JFA also estimates that implementation of the proposed Program would produce certain environmental benefits. These environmental benefits are expected to increase the BCR to 2.94. A complete copy of the BCA and report completed by JFA is attached as Appendix E.

7.0 CONCLUSION

Reviewing the hydrology and hydraulics of the Blanchard River watershed throughout the Proof of Concept has demonstrated how the flow contributions from Eagle Creek, Lye Creek, and the headwaters of the Blanchard River combine to create the flooding conditions experienced by the community. It is evident when studying the hydrology that there are two distinct flow peaks of concern in the Upper Blanchard River Watershed due to the conveyance timing. The first and largest peak flow is comprised of contributions from Eagle Creek, Lye Creek, and the Blanchard sub-basins closer to the downtown area of Findlay. The second peak is almost entirely from the upper headwaters of the Blanchard River watershed. Both peaks cause substantial flooding conditions across Hancock County.

A singular project is not expected to provide enough flood risk reduction benefit to meet the needs of the community. A multi-faceted approach that seeks to address the various sources of flooding in the watershed will provide the most benefit and reduce the risk of flooding from spatially varying storm events.

Feedback from the community and project stakeholders, the revised hydrology model, and additional data collection were key elements in the refinement of the April 2017 Proof of Concept and the HCFRR Program. The study refinement that occurred since the Proof of Concept Report was finalized in April of 2017 was focused on responding to concerns that have been made known by the community while maintaining similar flood risk reduction benefits. Updated survey data, geotechnical exploration, a revised hydrology model, and public outreach have led to the refined analysis of the HCFRR Program.

The processed LiDAR data confirmed that the storage facility locations analyzed during the Proof of Concept Report were once again the locations determined to be the most viable options. The LiDAR data also provided the information necessary to refine the structure inventory used in the BCA.

Project refinements were made to the Eagle Creek dry storage basin. Two of the refinements made included reducing the footprint and typical dam embankment cross section of the storage facility. The cost was reduced from $69.9 MM in the April 2017 Proof of Concept Report to $65.4 MM for the Proof of Concept Update. Fewer structures and less acreage are impacted with the Proof of Concept Update changes incorporated.

Project refinements were also made to the Blanchard River and Potato Run dry storage basins. The basins' footprints were reviewed to reduce impacts to the local community. The revised dams result in fewer impacts, but also provide less benefit during the 1% ACE event. Storage options upstream of Mt. Blanchard can reduce the peak flow on the Blanchard River such that the crossover flows and depths to Lye Creek would be minimal even without the construction of a cutoff levee.

A combination of projects can reduce the WSE on the Blanchard River near Main Street in Findlay by about 3.6 feet during the 1% ACE flood event. Alternative 3 is expected to be a cost-effective option to reduce the risk of flooding in the community by providing a spatial spread of projects while also considering a reduction in site-specific impacts. The projects distributed across the watershed assists in the management of flood risk. This alternative includes projects on the Blanchard River through the City of Findlay (floodplain bench widening, railroad bridge modifications, and riffle/low dam removals), and dry storage basins on the Blanchard River and Potato Run upstream of Mt. Blanchard, and on Eagle Creek.

The proposed HCFRR Program and Proof of Concept Update is expected to be $153.8 Million based on the preliminary opinion of probable cost, a reduction of about $6 Million from the April 2017 Proof of Concept. The Program's baseline Benefit-to-Cost Ratio was calculated as 2.21 by JFA based on the expected reduction in damages for flood control alone if the Program was implemented.

Analysis of the July 2017 flood event shows that the proposed Program would have resulted in a WSE near Main Street in Findlay of about 2.1 feet. Model simulations show that even though the storm center occurred downstream of the proposed dry storage facilities, the reduction in flow and flood depths would have significantly decreased the damages observed during this event.

7.1 RECOMMENDATION

Stantec understands there is a balance that must be achieved between benefit to the local community and the potential for adverse impacts associated with the cost and construction of improvements. Stantec reviewed several project combinations seeking a social and environmentally friendly, cost-effective solution to this complex problem.

Based on Stantec's review of the existing conditions modeling and various project refinements that were made during the Proof of Concept Update, Stantec again recommends that a combination of Blanchard River Hydraulic Improvements within downtown Findlay and upstream dry storage basins on Eagle Creek, the Blanchard River, and Potato Run produces the most effective results in terms of reducing impacts from construction and reducing the risk of flooding in and around the City of Findlay and Hancock County for both flood peaks experienced in the Upper Blanchard River watershed.

Stantec once again recommends the Eagle Creek dry storage basin option over the larger Western Diversion of Eagle Creek option because of preliminary opinions of probable cost ($65.4 million for Eagle Creek storage compared to $105.8 million for the 100-year diversion channel), reduction in number of parcels impacted, and a similar estimated water surface elevation.

The total opinion of probable cost for the three storage options would be approximately $137.6 Million. This option, combining the three dry storage basins, is estimated to be about $56.4 million less expensive than a comparatively sized diversion channel extension project, which includes the Western Diversion sized for the 1% ACE event flows from Eagle Creek ($137.6 million versus $194 million).

The components of the proposed HCFRR Program update (Alternative 3) may be constructed in any order. Stantec recommends finalizing design of the hydraulic improvements on the Blanchard River and completing construction. Stantec then recommends proceeding with the Eagle Creek dry storage basin, and then the Blanchard River and Potato Run dry basins. The storage detention basins are anticipated to remain dry a majority of the time with the exception of providing increased flood protection during certain storm events. These types of facilities have less impacts on habitat, aquatic and terrestrial species, and other environmental concerns compared to a typical retention water reservoir. Another benefit of the dry basins is that agricultural land upstream of the storage berms may remain in use and would not be permanently removed from production. In the case of a storm event with a 1% chance of happening each year, durations of storage would last for a couple of days with depths of water varying based on the distance from the watercourse and the embankment.

The recommended plan will benefit several locations across the community including these specific locations:

- Reduced flooding through large stretches of residential areas along Eagle Creek and the Blanchard River;
- Reduced flooding of large areas of suburban and agricultural properties between the dry storage basins and the City of Findlay;
- Reduced flooding of agricultural properties downstream of the City of Findlay;
- Reduced overtopping/closure of SR-15 at Eagle Creek and along US-68;
- Reduced closure of US-224 between County Road 140 and Interstate 75;
- Reduced flooding for major intersections and business in downtown Findlay;
- Reduced flooding near the Hunter’s Creek Subdivision and County Fairgrounds along Lye Creek;
- Reduced closure of the Martin Luther King Parkway just east of downtown Findlay;
- Reduced time of temporary inundation of agricultural lands near SR-15 along the Blanchard River; and
- Reduced flooding of the public park and local parcels within the Village of Mt. Blanchard.

7.1.1 Next Steps

This Proof of Concept Update Report and the refined HCFRR Program will be reviewed by the Maumee Watershed Conservancy District and other key stakeholders (The City of Findlay, Hancock County, local residents, businesses, and the agricultural community among others).

Stantec anticipates the community will immediately benefit from reduced flooding during storm events as soon the Hydraulic Improvements project is completed. The project is expected to be beneficial and cost effective while having limited impacts.

The planning level costs presented in this report are given for comparative purposes and should not be used for capital planning. Additional work in advancing the recommended projects to Stage 1 plans (30% design) should begin. This work would include site survey, geotechnical exploration, and preliminary design to better refine the planning level costs.

8.0 REFERENCES

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2. DRAFT - U.S. Army Corps of Engineers, Buffalo District. (March 2016). “Interim Report in Response to the Western Lake Erie Basin (WLEB) Blanchard River Watershed Study, Section 441 of the Water Resource Development Act of 1999, General Investigations, Feasibility Study/Final Environmental Impact Statement”; (DRAFT - USACE Feasibility Report/Final EIS).

3. Stantec Consulting Services Inc., (April 2017). “Hancock County Flood Risk Reduction Program Final Report: Data Review, Gap Analysis, USACE Plan and Alternatives Review, and Program Recommendation.” (Proof of Concept)

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7. Stantec Consulting Services Inc., (April 2018). “Report of Geotechnical Exploration – Hancock County Flood Risk Reduction Program – Dams Preliminary”, (Geotechnical Report).

8. Jack Faucett Associates, (June 2018). “Hancock County Flood Risk Reduction Program: Updated Benefit Cost Analysis”, (Updated BCA Report).

9.0 STANTEC INTERNAL QA/QC PROCESS

Stantec employs a Project Management (PM) Framework containing a list of tasks to be completed in conformance with our ISO9001:2008 registered Quality Management System. Specifically, the PM Framework sets the expectations for the quality assurance processes to be completed for all projects. The intent is that final documents will be affixed with a professional seal and signature of the licensed professional taking responsibility for a final document. The PM Framework requirements for signing final documents are the minimum requirements for work completed within Stantec to provide a level of quality assurance and quality control (QA/QC).

Final documents must also have an independent technical review (ITR) conducted and signed by the independent reviewer prior to issuance. The independent review of the final documents is completed by a qualified professional not directly associated with the development of the documents. For larger or more complex assignments, multiple independent reviews and independent reviewers may be required to meet the intent of this requirement.

For this Proof of Concept Update Report and supporting appendices, multiple QA/QC and ITR reviews were conducted by various professionals examining the individual technical aspects of the various chapters and report sections, as well as overall report content. QA/QC reviews were completed by the following professionals:

- Scott Peyton, PE – Technical Project Manager
- Erman Caudill, PE – H&H Technical Lead
- Kyle Blakely, PE – Geotechnical Lead
- Cody Fleece – Permitting Lead

ITRs were completed by the following professionals:

- Stan Harris, PE, Stantec Consulting Services Inc.
- Laura LaRiviere, PE, Stantec Consulting Services Inc.
- David Hayson, PE, SI Stantec Consulting Services Inc.
- Adam Hoff, PE, Hoff Consulting Services, LLC

APPENDICES

Appendix A – HYDROLOGIC EVALUATION OF THE BLANCHARD RIVER

Hydrologic Evaluation of the Blanchard River

Hancock County Flood Risk Reduction Program

Prepared for:
Maumee Watershed
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November 8, 2017

Revision	Description	Author		Quality Check		Independent Review	
0	FINAL	E. Caudill	Nov. 8, 2017	SP	11/8		

Sign-off Sheet

This document entitled Hydrologic Evaluation of the Blanchard River was prepared by Stantec Consulting Services Inc. (“Stantec”) for the account of Maumee Watershed Conservancy District (the “Client”). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec’s professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by Erman Caudill
(signature)

Erman Caudill, PE (KY #23451), CFM

Reviewed by ______________________________
(signature)

David Hayson, PE

Approved by ______________________________
(signature)

Scott Peyton, PE

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Executive Summary

The Blanchard River system near the City of Findlay, in Hancock County, Ohio floods often. When intense convective storms move over the watershed, or rain falls on areas with sparse vegetation that may still have snow cover or wet/frozen ground, runoff from the predominantly agricultural watershed quickly fills the river and tributaries beyond the channel's capacity. Overbank flooding can lead to significant damages and economic impacts to the community, similar to the near flood of record that happened to the City of Findlay in August 2007.

The 2007 event renewed interest in flood mitigation for the area, and the U.S. Army Corps of Engineers Buffalo District (USACE) studied the river system and proposed a 9.2-mile long flood diversion channel upstream of Findlay to help reduce the impacts of future floods. The diversion channel was to connect Eagle Creek to the Blanchard River and divert potential flood flows to the south and west around Findlay. As USACE completed preliminary engineering and design, it became apparent the proposed Federal project was becoming an increasingly expensive undertaking with a marginal benefit-cost ratio.

In 2016, the local community accepted responsibilities for the project from USACE. The Maumee Watershed Conservancy District (MWCD), in cooperation with the Hancock County Commissioners and the City of Findlay, tasked Stantec Consulting Services Inc. (Stantec) with reviewing the USACE proposed project and continuing the planning and design efforts. Stantec's work was described in a conceptual report entitled: "*Final Report: Data Review, Gap Analysis, USACE Plan and Alternatives Review, and Program Recommendation*" dated April 3, 2017, referenced herein as the *Stantec Concept Report*. Stantec identified a number of gaps or questions from the prior USACE efforts and identified several areas where additional data was necessary for the project. After further reviewing the function and conceptual design of the proposed diversion channel, Stantec recommended alternate flood mitigation measures consisting of channel improvements to the Blanchard River within the City of Findlay and dry storage basins at three upstream locations (Eagle Creek, Blanchard River, and Potato Run).

Several portions of the *Stantec Concept Report* discussed gaps or questions from the hydrologic analyses performed by USACE. The following hydrologic data gaps have been addressed and resolved by Stantec as explained and documented herein:

Gage Frequency Analyses – Prior documentation for gage-based flood flow frequency analyses of the Blanchard River system was limited. Stantec performed an updated statistical frequency analysis for the USGS stream gage on the Blanchard River a short distance downstream of Findlay to determine peak discharge values for a variety of recurrence intervals. Methodology and results of those analyses are presented herein. The results indicate, from a strictly statistical perspective, the 100-year, 24-hour flood discharge at the gage location could range from about 12,040 to 16,120 cubic feet per second (cfs), within a 95-percent confidence limit, with a recommended value of about 13,700 cfs.

Spatial Storm Patterns – Previous hydrologic simulations of hypothetical events conservatively assumed a single point precipitation value over the entire watershed. Storms that occur over an area larger than about 10-square miles seldom have uniform precipitation over their spatial extent and often resemble an elliptical shape. Procedures outlined in publications by NOAA, including: *Atlas 2*, *Atlas 14*, and *HMR-52*, describe common spatial patterns and areal reduction factors used to account for larger scale spatial variability. Stantec worked with a meteorological consulting group, Applied Weather Associates (AWA), to study spatial and temporal patterns from actual large historic storms that have occurred throughout the United States and which could reasonably be transposed to the Blanchard River location. Characteristics such as storm orientation, major to minor axis variability, and areal reduction factors, were used to model the spatial variability that would likely occur across the Blanchard River watershed. As an example, the central 10-square mile portion of the watershed may experience a full point-precipitation value of 5.26-inches for a 100-year, 24-hour storm event as predicted by *NOAA Atlas 14*; however, the outer portions of the approximate 350-square mile watershed may experience only about 80-percent of that value, or 4.18-inches based on the spatial variation observed from the historic storms.

Storm Centering – When areal reduction factors are applied to a geographically fixed storm, the center of the storm becomes an important factor in runoff simulations. Four different locations were considered as the center of the storm to determine critical placement for the purposes of runoff simulations. A storm centered over the centroid of the upstream watershed, near the headwaters of Lye Creek and middle of Eagle Creek and the Blanchard River watersheds, was determined to result in the greatest average peak discharge and runoff volume in Findlay. Conversely, a storm centered over Main Street in Findlay produced the lowest peak discharges and volumes of the four locations considered.

Temporal Pattern - Previous hydrologic simulations of hypothetical events assumed an SCS Type II storm distribution. The SCS Type II event is valid, but more recent studies indicate it may be overly conservative, as it results in more runoff during the intense middle portion of the storm. Publications such as *NOAA Atlas 14* and *Bulletin 71* include additional analyses of historic precipitation gage records that indicate a less intense storm pattern that is more evenly spread over the duration of the storm is more common to the Blanchard River watershed geographic area. AWA reviewed the temporal patterns of the historic storm events and derived a custom temporal distribution that was similar to that of a less intense, more uniform Huff 3rd Quartile event. Stantec applied the custom temporal pattern to hypothetical model simulations to simulate storm timing.

HEC-HMS Model Updates – Stantec refined and updated the USACE HEC-HMS model to the extent possible. The watershed delineation was verified based on LiDAR based topographic mapping from the Ohio Statewide Imagery Program (OSIP). Subbasins were created based on dividing the watershed at locations significant to the flood risk reduction project and areas of 10 square-miles or smaller. Model parameters were selected to support calibration and for correlation with the updated and revised HEC-RAS model, which was completed during development of the previously submitted *Stantec Concept Report*.

Calibration Storms – Stantec reviewed historic stream and precipitation records for the area to identify events that were hydrologically similar to the August 2007 flood with sufficient data available for calibration purposes. Events in September 2011 and June 2015 were identified as calibration events. Stantec worked with AWA to obtain calibrated radar data for those events (and the August 2007 event) which were then used to create individual calibration geometries in the HEC-HMS model for all three events.

Based on the calibration and gage frequency results, Stantec determined the September 2011 geometry adequately represents typical conditions in the watershed. The HEC-HMS model using the September 2011 geometry with hypothetical grid-based precipitation patterns produces a reasonable approximation of the watershed's hydrologic response (hydrograph shapes and durations) to various return period events and predicts peak discharge values at the USGS Gage 04189000 location similar to the gage frequency estimates.

Note storms with a duration of 24-hours and point precipitation values from *NOAA Atlas 14* were previously discussed and recommended as a part of the *Stantec Concept Report*. Those values were retained for the simulations described herein.

The HEC-HMS model was used to simulate hypothetical events for various annual chance of exceedances (recurrence intervals). Peak discharge values at Main Street in Findlay and the five USGS gage locations are presented in Table E-1.

The HEC-HMS model that was developed as a part of this study and discharges listed in Table E-1 are based on more analyses than previous hydrologic studies of the area. The magnitude and trends predicted by the results are consistent with prior efforts and, therefore, do not invalidate the previous hydrologic modeling. Stantec does not recommend updating the *Concept Report, which was a* planning level document, but would recommend this revised and updated hydrologic model and results presented herein be used for future flood mitigation planning and design efforts in the area to the extent applicable.

Table E1 – Peak Flood Discharge Values

	Average Recurrence Interval (Years)							
Location	**2**	**5**	**10**	**25**	**50**	**100**	**200**	**500**
Main Street in Findlay	5,680	7,643	9,321	11,634	13,595	15,652	17,902	21,130
USGS Gage 04189000 Blanchard River DS of Findlay	5,730	7,715	9,413	11,734	13,574	15,652	17,951	21,106
Gage Analyses (-/+ 5% Confidence)	*5,086* *6,020*	*7,319* *8,918*	*8,625* *10,788*	*10,111* *13,037*	*11,113* *14,619*	*12,039* *16,120*	*12,903* *17,552*	*13,964* *19,351*
USGS Gage 04188400 Blanchard River US of Findlay	3,825	4,650	5,218	5,997	6,578	7,148	7,743	8,633
USGS Gage 04188337 Blanchard River DS of Mt. Blanchard	3,356	4,249	4,988	6,186	7,094	8,008	8,991	10,489
USGS Gage 04188496 Eagle Creek Above Findlay	1,741	2,323	2,839	3,577	4,223	4,915	5,690	6,732
USGS Gage 04188433 Lye Creek Above Findlay	533	752	942	1,217	1,451	1,699	1,967	2,344

Notes:

- Discharges are reported in cubic feet per second (cfs).
- Values from HEC-HMS model simulations using the September 2011 calibration geometry developed by Stantec.
- Gage Frequency Estimates for USGS Gage 04189000 are provided for comparison purposes.

Abbreviations

ACE	Annual Chance Exceedance
AC-FT	Acre Feet
ARCGIS	ESRI geographic information system software (version 10.5)
AWA	Applied Weather Associates
CFS	Cubic Feet per Second
DDF	Depth - Duration - Frequency
GIS	Geographic Information System
HEC-HMS	USACE Hydrologic Engineering Center Hydrologic Modeling System Software (version 4.2)
HEC-RAS	USACE Hydrologic Engineering Center River Analysis System Software (version 5.0.3)
HEC-GeoHMS	USACE Hydrologic Engineering Center Geospatial Hydrologic Modeling Extension for ArcGIS
HEC-GridUtil	USACE Hydrologic Engineering Center Grid Utility Software Package (version 2.0)
HEC-SSP	USACE Hydrologic Engineering Center Statistical Software Package (version 2.1)
IDF	Intensity - Duration - Frequency
LiDAR	Light Detection and Ranging
MWCD	Maumee Watershed Conservancy District
NOAA	U.S. Department of Commerce, National Oceanic and Atmospheric Administration
NRCS	U.S. Department of Agriculture, Natural Resources Conservation Service
OGRIP	Ohio Geographically Referenced Information Program
OSIP	Ohio Statewide Imagery Program
SCS	U.S. Department of Agriculture, Soil Conservation Service (now the NRCS)
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WSEL	Water Surface Elevation
YR	Year as in return period.

1.0 INTRODUCTION & BACKGROUND

The Blanchard River system drains an area of about 343 square miles as it flows through the City of Findlay, in Hancock County, Ohio. Except for the area around Findlay and some smaller upstream communities, the majority of the watershed is characterized by agricultural (row-crop) land uses with a smaller percentage being urbanized or having stands of deciduous trees. When intense convective storms move over the watershed or when rain and snow melt runs off from frozen and sparsely vegetated ground, runoff from the predominantly agricultural area quickly fills the river and tributaries beyond the channel capacity. Overbank flooding occurs frequently and can lead to significant damages and economic impacts to the community.

In August 2007, a large flood impacted the City of Findlay and resulted in a great deal of interest in flood mitigation for the area. The U.S. Army Corps of Engineers Buffalo District (USACE) studied the river system and proposed a 9.2-mile long flood diversion channel upstream of Findlay to help reduce future adverse flood impacts. The diversion channel was to connect Eagle Creek to the Blanchard River and divert potential flood flows to the south and west around Findlay. As USACE completed preliminary engineering and design of the diversion channel, it became apparent the proposed Federal project was going to be an increasingly expensive undertaking with a marginal benefit cost ratio. Hancock County, the City of Findlay, and the Maumee Watershed Conservancy District (MWCD) agreed to take over and continue the project as it changed from one guided by Federal interests and economic measures to one led by the local community.

In July 2016, Hancock County retained Stantec Consulting Services Inc. (Stantec) to perform a gap analysis on the USACE work and complete design and permitting for the Western Diversion of Eagle Creek project recommended by the USACE. In Phase 1, Stantec reviewed existing data and analyses completed by USACE and identified potential data gaps and further analyses necessary to support the design work. Phase 2 was administered by the MWCD and attempted to resolve a number of those data gaps and questions. Findings were outlined in the Stantec report entitled: "*Final Report: Data Review, Gap Analysis, USACE Plan and Alternatives Review, and Program Recommendation*" dated April 3, 2017, referenced herein as the *Stantec Concept Report*.

Several key data gaps related to the proposed diversion channel were identified as described in the *Stantec Concept Report,* including: a poorly defined flood mitigation/management objective, incomplete economic evaluation of benefits, technical questions related to the hydrologic and hydraulic analyses, and an incomplete assessment of residual risk associated with the proposed diversion channel.

On the residual risk issue, USACE did not provide a complete accounting of the risks involved with the construction and operation of the Eagle Creek diversion channel. There was a recognized, yet significant, risk that the proposed channel would not appreciably reduce flood risk in Findlay if the source of flooding was from Lye Creek or the upstream portion of the

Blanchard River. Eagle Creek at the diversion location drains about 15-percent of the watershed area upstream of Findlay, but USACE had not estimated the reliability of the proposed diversion for flood control purposes.

Additionally, the recommended operating range for the diversion was up to and including the 4-percent annual-chance-exceedance (ACE) or 25-year average return period event. For floods larger than that, the ones that cause extensive damages in Findlay, a large portion of the flood discharge would bypass the diversion structure and could still potentially cause flooding downstream and in Findlay.

The initial hydrologic and hydraulic analyses performed by USACE in support of the diversion channel were conceptual and conservative. More analyses were needed to support the design. Stantec performed additional hydrologic and hydraulic modeling to resolve some of the identified gaps and questions with the USACE modeling.

After further reviewing the initial design for the proposed diversion channel, its economic benefits and costs, and hydrologic and hydraulic results, Stantec ultimately recommended alternate flood mitigation measures consisting of channel improvements to the Blanchard River within the City of Findlay and dry storage basins at three upstream locations (Eagle Creek, Blanchard River, and Potato Run). The recommendations were supported by a revised HEC-RAS hydraulic model as described in the *Stantec Concept Report,* but also included preliminary results from the hydrologic modeling. The final results from the hydrologic modeling are presented in greater detail herein and should be used for future work on the project, as described in section 6.1.

1.1 HYDROLOGIC DATA GAPS

Several portions of the *Stantec Concept Report* discussed gaps in the hydrologic analyses. The purpose of this report is to further explain and document how Stantec has addressed hydrologic gaps associated with the following topics:

- Observations & predictions of flood discharges based on area stream gage data
- Spatial variability in storms and differences in results based on where they might occur over the watershed
- Timing of storm accumulation

Also discussed are revisions and updates to the USACE HEC-HMS model and more complete documentation of the calibration of the revised model.

2.0 STATISTICAL ANALYSIS OF STREAM GAGE DATA

The U.S. Geological Survey (USGS) operates five stream gages in the portion of the Blanchard River watershed that is a part of the current study:

- Gage 04189000 – Blanchard River Downstream of Findlay
- Gage 04188400 – Blanchard River Upstream of Findlay
- Gage 04188337 – Blanchard River Downstream of Mt. Blanchard
- Gage 04188496 – Eagle Creek Above Findlay
- Gage 04188433 – Lye Creek Above Findlay

Figure 1 illustrates the locations of active USGS stream gages in the watershed.

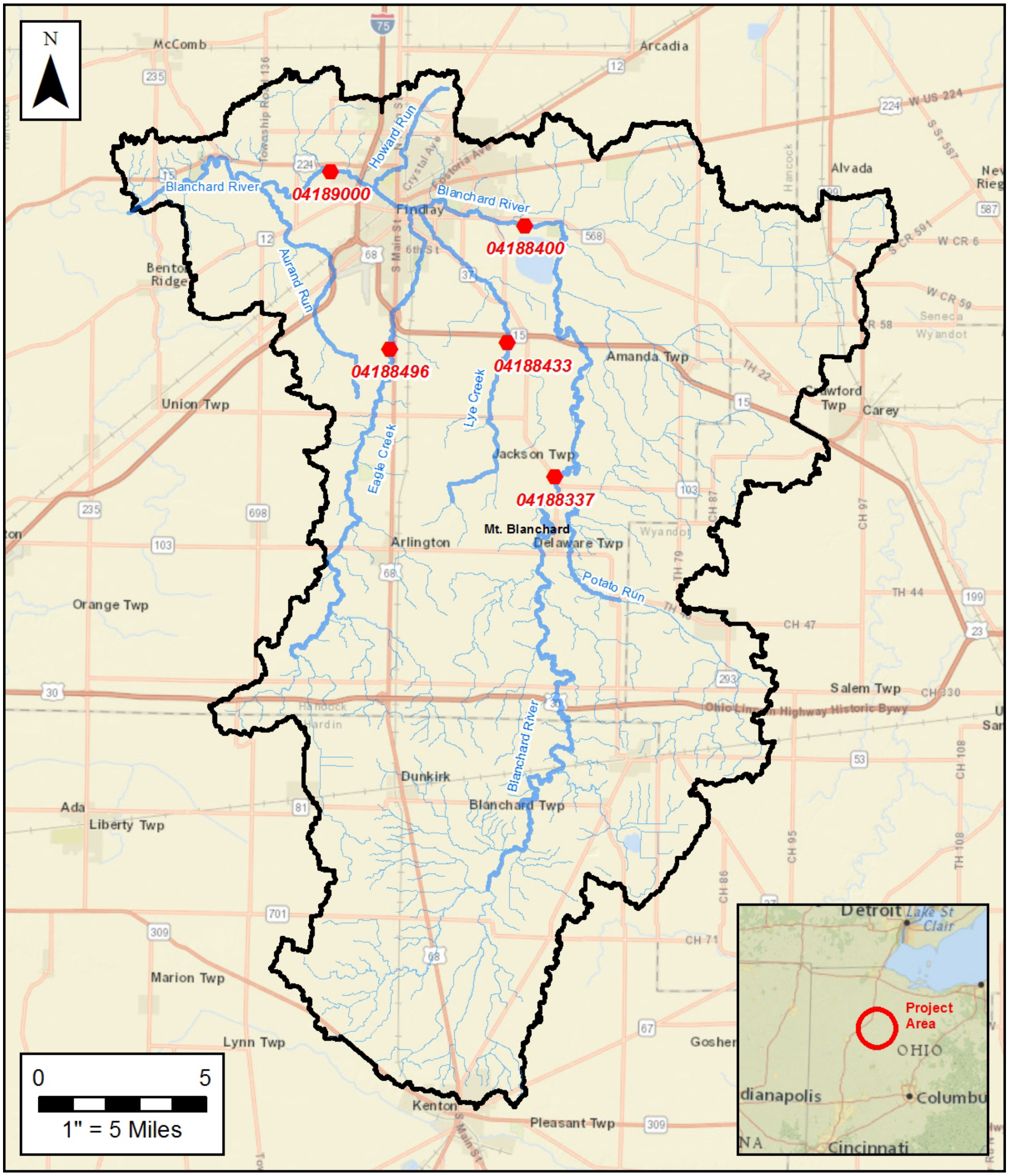
A minimum of 10-15 years of continuous data is typically recommended to perform a statistically valid flood frequency analysis. Gage 04189000 is located on the Blanchard River a short distance downstream of Findlay, approximately 2 miles west, on the upstream side of the County Road 140 bridge. This gage has been in nearly continuous operation since October 1923, with a short data gap of 5 years between December 1935 and October 1940. A total of 89 years of reliable stage-discharge data suitable for this type of analysis is available. Unfortunately, the other four gages weren't established until after the 2007 flood event. Data from those gages isn't sufficient for flood flow frequency analyses, but records of events occurring since 2007 are useful for validating and calibrating the hydrologic model.

Procedures described in the "*Guidelines for Determining Flood Flow Frequency – Bulletin 17B*" from the U.S. Department of the Interior Geological Survey Interagency Advisory Committee on Water Data (1981) were used to perform a flood flow frequency analysis for Gage 04189000. Application of procedures from that document, referred to here as *Bulletin 17B*, are further described in a technical memo included in Appendix A. Stantec used the USACE Hydrologic Engineering Center Statistical Software Package (HEC-SSP) as a tool to perform the study and evaluate sensitivity to parameters such as data skew, hydrologic modifications in the watershed, and varied lengths of the period of records.

Note these analyses were completed prior to the flooding that occurred along the Blanchard River on July 13, 2017. Inclusion of that data point would likely skew the results slightly toward higher discharges on a more frequent basis (the 1% annual chance discharge estimate would be higher).

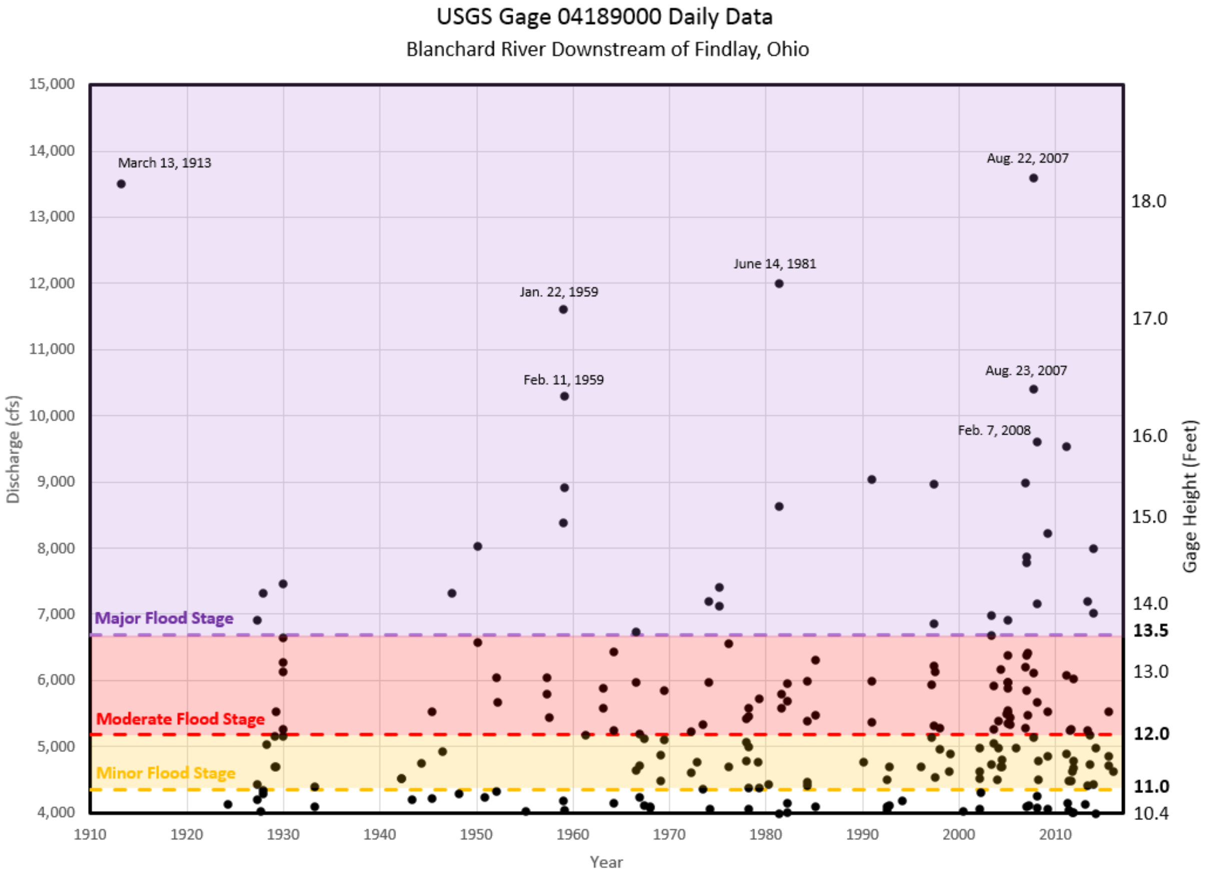
Figure 2 illustrates a trace of the historic observations from USGS Gage 04189000, while Figure 3 illustrates the frequency of various discharge values graphically. Lastly, Table 1 presents a summary of the results of the *Bulletin 17B* flood flow frequency analyses for USGS Gage 04189000.

Figure 1 - USGS Stream Gage Location Map



Data Sources: ESRI Online Map Services, USGS NHD Streams, USGS Gage Locations

Figure 2 - USGS Gage # 04189000 Historic Data



** Flood Stages identified by the National Weather Service.*

Figure 3 - USGS Gage # 04189000 Data Trends

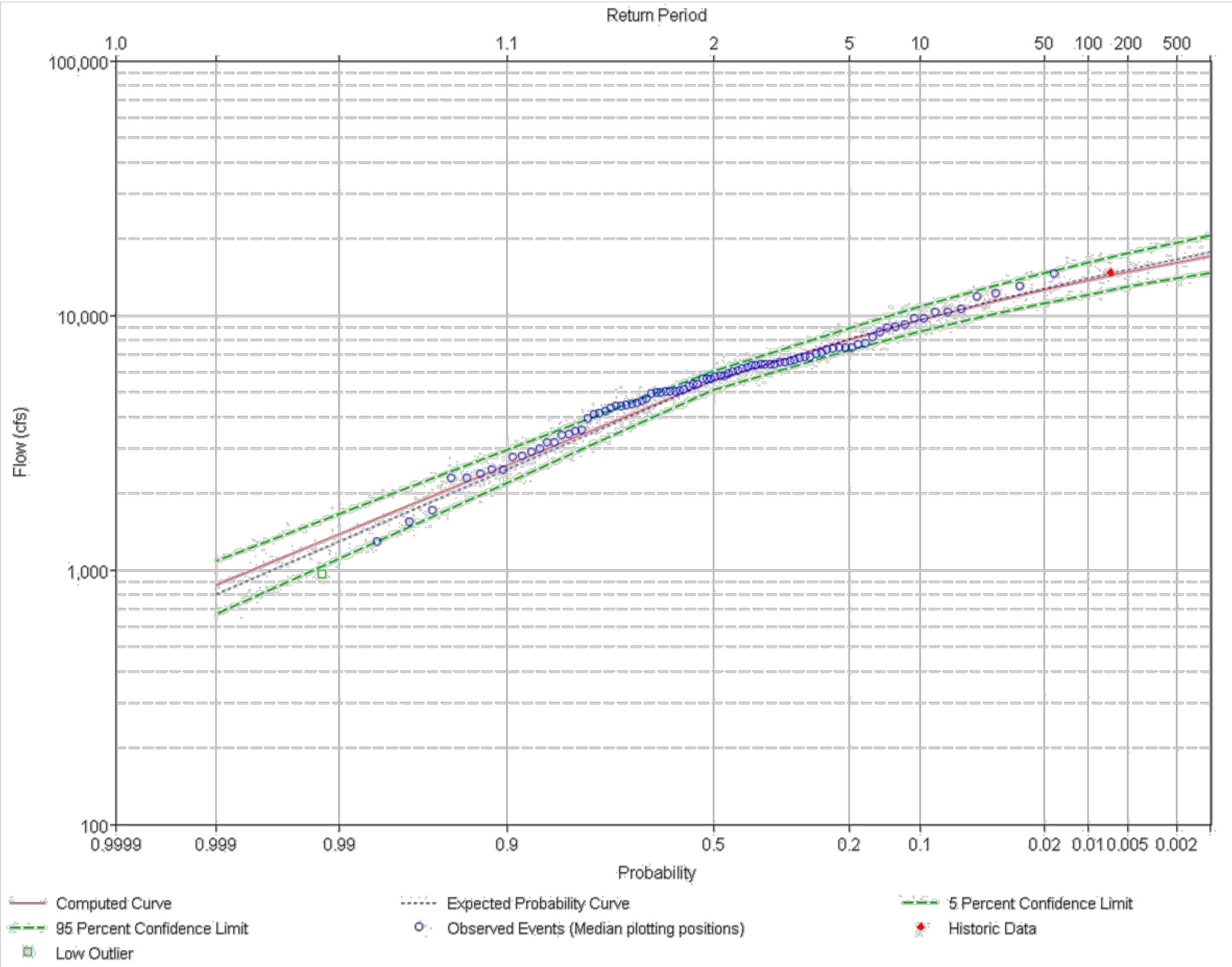


Table 1 – USGS Gage 04189000 Bulletin 17B Flood Frequency Analysis Results

Percent Chance Exceedance	Average Recurrence Interval (years)	Computed Discharge (cfs)	Confidence Limits 0.05	0.95
0.1	1000	17,117	20,649	14,715
0.2	500	16,156	19,351	13,964
0.5	200	14,811	17,552	12,903
1.0	***100***	***13,727***	16,120	12,039
2.0	50	12,576	14,619	11,113
4.0	25	11,346	13,037	10,111
10.0	10	9,559	10,788	8,625
20.0	5	8,028	8,918	7,319
50.0	2	5,530	6,020	5,086
99.9	1	875	1,084	667

An interesting trend was noted during the flood flow frequency analyses. As discussed in the memo in Appendix A, by limiting the period of record from the 89 years of available data, to only the last 40 years, and finally only the last 20 years, it would appear that the magnitude and frequency of flood discharges on the Blanchard River are increasing as a trend. Whether or not this increase is attributable to modifications to the hydrologic conditions within the watershed, changes to land use, or changes to the regional precipitation patterns cannot be determined from these analyses. Resolving that question is beyond the scope of the current study.

Refer to Appendix A for additional information pertaining to the Flood Flow Frequency Analyses for the USGS gage data.

3.0 SPATIAL DISTRIBUTION

In the initial planning and design efforts for the proposed Eagle Creek diversion channel, USACE developed a simulation of hydrologic conditions in the watershed using a HEC-HMS model. The HEC-HMS model included simulations for hypothetical events representing the 50%-, 20%-, 10%-, 4%-, 2%-, 1%-, 0.4%-, and 0.2%-annual-chance-exceedance (ACE) (2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year average recurrence interval) storms.

For the hypothetical storm simulations, the USACE HEC-HMS model used the Frequency Storm approach and point precipitation depths obtained from *NOAA Atlas 14*. For the Frequency Storm approach, USACE assumed a storm area of 100-square miles for each of the subbasins. This resulted in an areal reduction factor of approximately 95% of the *NOAA Atlas 14* point based precipitation depth. The resulting precipitation depth was then applied uniformly to all of the subbasins in the watershed. Spatial variation was not considered. *NOAA Atlas 14* and publications such as *NOAA's Atlas 2* and *HMR 52* indicate for storms having a spatial area greater than about 10 square miles, a spatial or areal reduction factor should be applied. *HMR*

52 relates the areal reduction factors to a spatial pattern having an elliptical shape. This assumption of a storm's spatial pattern is well correlated to historic data and simplifies implementation in a GIS-based modeling environment. A typical example of such a storm is shown in Figure 4. By not applying the full areal reduction factors and not considering spatial variability of the hypothetical storms, the USACE simulations were overly conservative in terms of how much precipitation the watershed would receive for a given hypothetical storm event.

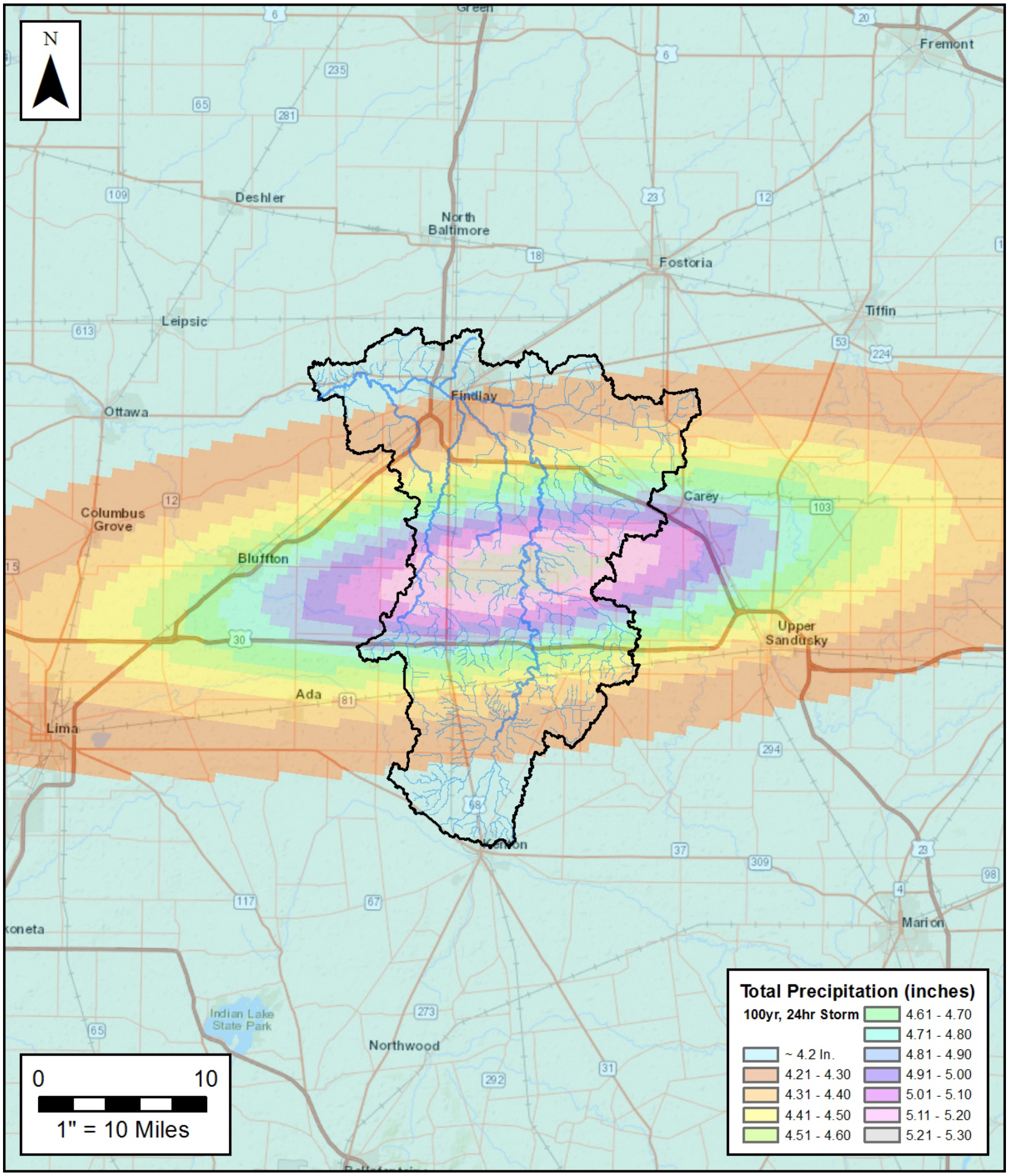
For the present hydrologic study updates, Stantec accounted for the spatial variability in the watershed. To understand how the hypothetical storms might occur, Stantec worked with a meteorological consulting group, Applied Weather Associates (AWA), to study actual large historic storms that have occurred throughout the United States and which could reasonably be transposed to the Blanchard River location. Based on 22 actual storm events, AWA developed spatial characteristics of storms that could occur in this area such as orientation, major to minor axis variability, and point rainfall reduction factors as a function of storm area. AWA found the historic storms fit relatively well to an ellipsoid type pattern commonly assumed. The average orientation of the ellipse pattern was about 262-degrees based on a north azimuth of 0-degrees for the major axis and clockwise angle measurement. The ratio of major to minor axis dimensions was found to average 3.82.

AWA also analyzed the spatial variability of the historic storms by studying the radar data and observed precipitation accumulations at various locations. AWA compared the precipitation at the center of the storm to the outer bands and developed spatial reduction factors based on proximity to the center. These "areal" reduction factors were based on the area of the ellipsoid pattern through a given point located away from the center of the storm. The *NOAA Atlas 14* point based precipitation values shown in Table 2 are applicable to a given storm that occurs within the Blanchard River watershed; however, the areal reduction factors shown in Figure 5 and elliptical geometric characteristics described above were applied to create more accurate storm simulations similar to the one shown in Figure 4. Of note, the minimum recommended areal reduction factor is 0.795 based on AWA's analyses, so all of the watershed receives at least 79.5% of the *NOAA Atlas 14* point precipitation value for a given storm event.

The composite precipitation accumulation pattern for each storm simulation was applied to the HEC-HMS model using gridded precipitation input files. In order to create the gridded precipitation files, a temporal pattern was applied to disaggregate the storm into a series of time steps. Temporal patterns are discussed further in Section 4 of this report. The process of creating the precipitation gridsets required extensive geoprocessing and data manipulation using the *ESRI ArcGIS* software application. Geoprocessing steps included developing a custom Python script to create the ellipsoid pattern on a grid basis, dissecting the precipitation into a series of time steps, setting values for the grid cells for each of those time steps, reprojecting the data into the correct Standard Hydrologic Grid (SHG) projection used by HEC and NOAA, then exporting the data in an acceptable ASCII file format that can be imported into a HEC-DSS database file. The HEC-HMS model also required a grid cell parameter file that related the subbasin locations in coordinate space to the precipitation grid locations. This file was created in ArcGIS using the HEC-GeoHMS extension and a series of geoprocessing routines and a custom Python script that

Stantec created to format the file. Lastly, the HEC-DSS Vue and HEC-GridUtil programs were used to help visualize and organize the data.

Figure 4 - Typical Storm Pattern



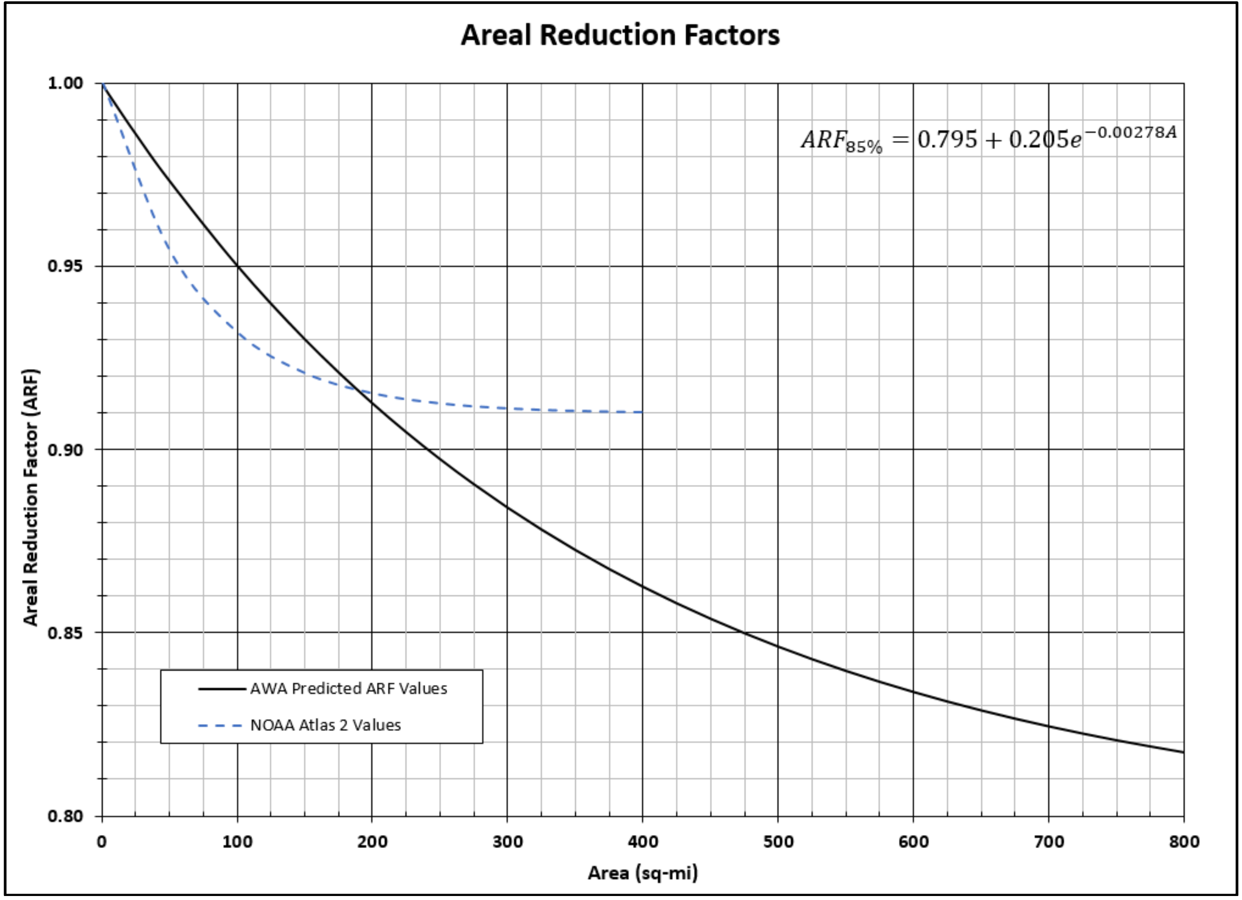
Data Sources: ESRI Online Map Services, USGS NHD Streams, USGS Gage Locations

Table 2 - NOAA Atlas 14 Point Precipitation Values

Average Recurrence Interval (years)	90% Confidence Interval (inches)		Recommended Value (inches)
1	1.90	2.20	***2.04***
2	2.28	2.64	***2.44***
5	2.81	3.25	***3.01***
10	3.23	3.75	***3.48***
25	3.83	4.46	***4.14***
50	4.32	5.05	***4.69***
100	4.82	5.68	***5.26***
200	5.33	6.34	***5.87***
500	6.04	7.30	***6.72***
1000	6.61	8.08	***7.42***

All events are 24-hour duration.

Figure 5 - Areal Reduction Factors



Graph adapted from Applied Weather Associates

3.1 STORM CENTERING

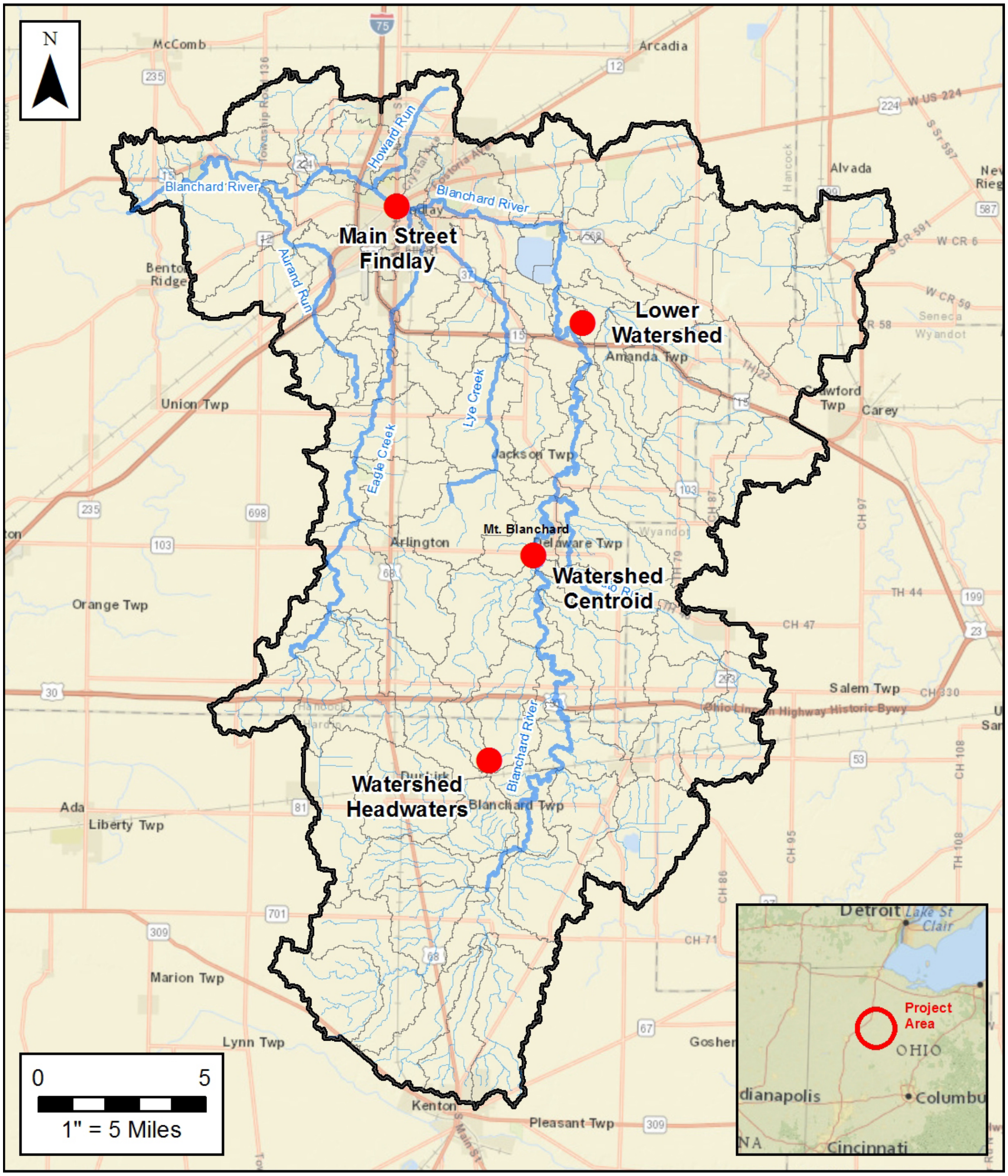
When areal reduction factors and a spatial storm distribution are applied to a geographically fixed storm simulation, the location of the storm in relation to the watershed, the center of the ellipse, becomes an important factor in the hydrologic modeling. Four different locations were considered as the center of the storm to determine the appropriate placement for the purposes of runoff simulations. These locations are illustrated in Figure 6.

A storm centered over the centroid of the upstream watershed, near the top of Lye Creek and middle of Eagle Creek and the Blanchard River watershed, was determined to result in larger average peak discharges and larger volume of discharge. Conversely, a storm centered over Main Street in Findlay produced the lowest peak discharges and volumes for the four locations considered. Table 3 summarizes the simulation results at select locations based on storm center assuming Stantec's calibrated September 2011 geometry and a 100-year, 24-hour storm event.

Table 3 – 100-Year, 24-Hour Simulation Results based on Storm Center

Location / Storm Center	Discharge (cfs)	Volume (ac-ft)
Blanchard River at Main Street in Findlay		
Watershed Centroid	15,652	70,927
Headwaters	14,945	70,352
Lower Watershed	14,985	70,432
Over Main Street	14,192	67,627
Eagle Creek Outlet		
Watershed Centroid	4,797	12,235
Headwaters	4,588	11,718
Lower Watershed	4,245	11,387
Over Main Street	4,048	10,770
Lye Creek Outlet		
Watershed Centroid	3,398	12,582
Headwaters	3,325	12,552
Lower Watershed	3,039	11,799
Over Main Street	2,650	10,643

Figure 6 - Storm Centers Considered



Data Sources: ESRI Online Map Services, USGS NHD Streams, USGS Gage Locations

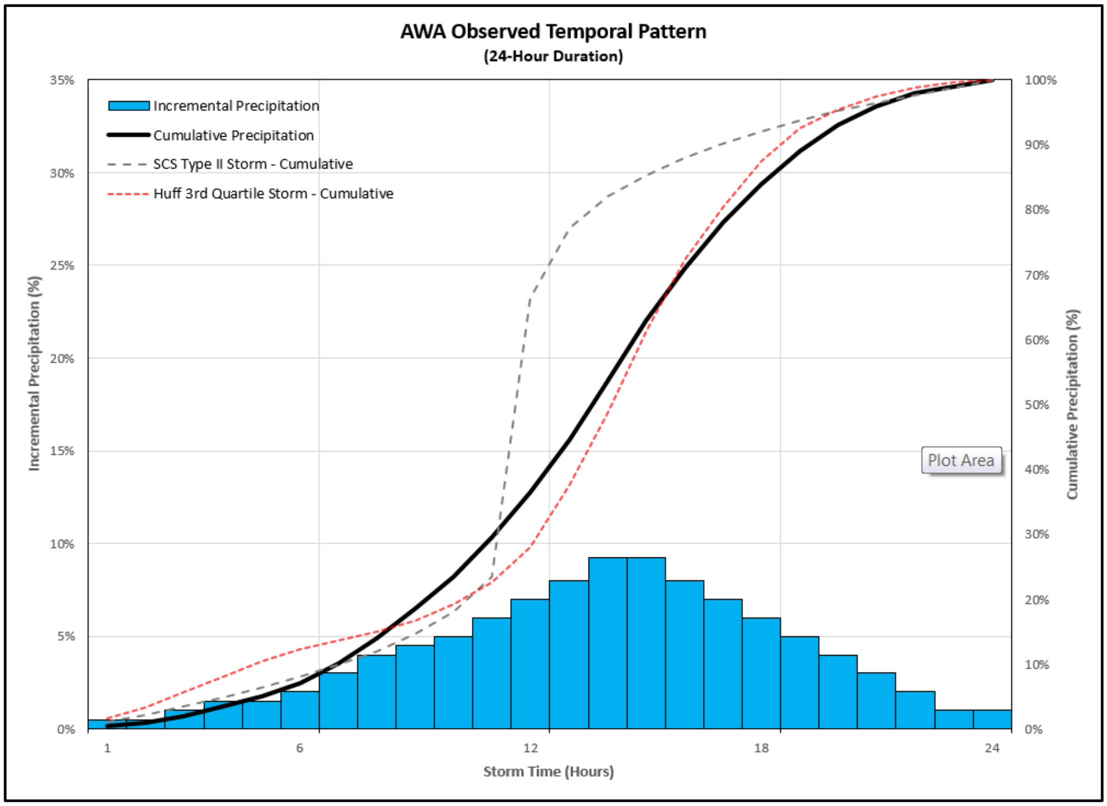
4.0 TEMPORAL PATTERNS

Previous hydrologic simulations of hypothetical events by both Stantec and USACE assumed an SCS Type II storm distribution. The SCS Type II temporal pattern is a synthetic rainfall event first identified by the Natural Resources Conservation Service (NRCS) as a result of "*Technical Publication 40, Rainfall Frequency Atlas of the United States"* (TP-40) that was published in 1961 and followed by "*Technical Publication 149, A Method for Estimating Volume and Rate of Runoff in Small Watersheds*" in 1968. SCS Type II events have been used for engineering analyses in the eastern U.S. for many years.

The "*NOAA Rainfall Frequency Atlas of the Midwest, Bulletin 71"* was an initial update to TP-40 with the goal of identifying rainfall patterns specific to the Midwest. The "*NOAA Atlas 14 Rainfall Frequency Atlas of the United States*" is a newer update that takes into account approximately 40 years of additional precipitation records throughout the U.S. *NOAA Atlas 14* includes precipitation estimates and temporal patterns for various hypothetical frequency (return period) based storms and various durations. The *Bulletin 71* Huff Quartile Temporal Distributions and *NOAA Atlas 14* Temporal Distributions, which are also presented on a quartile basis, have rainfall more evenly distributed throughout the duration of the storm. Stantec's observations from using the *NOAA Atlas 14* temporal pattern indicates it is a less conservative approach than the SCS Type II rainfall, but more appropriate for simulating storms in a watershed of this size and in this geographic region for the purposes of flood mitigation.

Stantec asked AWA to review the temporal patterns associated with the historic storms used in the spatial analyses. AWA found most of the storms closely resembled that of a Huff 3rd Quartile storm from *Bulletin 71* or a NOAA 3rd Quartile storm from *Atlas 14*. Stantec applied the average temporal pattern determined by AWA to hypothetical model simulations used in the HEC-HMS model. Figure 7 illustrates the storm patterns described here.

Figure 7 - Storm Temporal Pattern



Graph adapted from Applied Weather Associates

5.0 HEC-HMS MODEL UPDATES

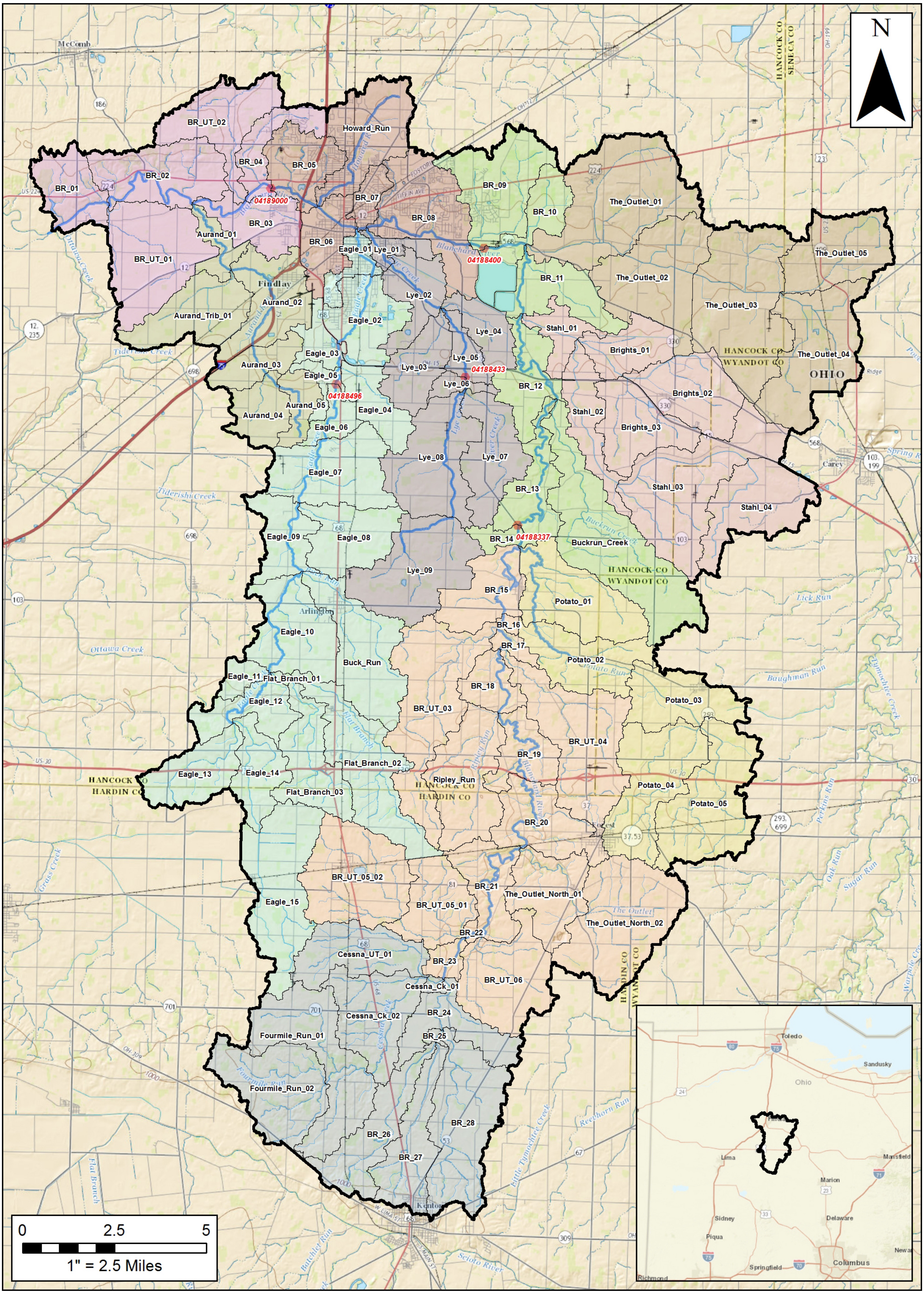
In order to simulate potential flood mitigation measures in the Blanchard River watershed, Stantec implemented a number of changes and updates to the USACE HEC-HMS model. First the watershed boundary and subbasin delineations were modified to fit the extent of the study and areas of interest for the proposed flood mitigation measures. Watershed and subbasin delineations were accomplished using the HEC-GeoHMS and ArcHydro plugins for ESRI ArcGIS. Terrain data used in the analyses was based on LiDAR based topographic mapping from the Ohio Statewide Imagery Program (OSIP). Subbasins were created based on dividing the watershed at locations significant to the flood risk reduction project and areas of 10 square-miles or smaller. Stream data used in the analyses was based on the USGS National Hydrologic Dataset (NHD). Figure 8 illustrates the watershed and subbasin delineation. Appendix B contains tabular summaries of the subbasin and reach parameters used in the HEC-HMS model.

Subbasin runoff was modeled in HEC-HMS using the SCS Curve Number approach applied on a grid basis. The SCS Curve Number approach was selected based on data availability and common acceptance within the industry for this type of modeling. More robust soil moisture accounting methods or Green-Ampt soil infiltration methods could have been used, but those methods introduce additional model uncertainty and are more appropriate to longer term simulations. The curve number grid was created using landcover data from the USGS National Land Cover Database (NLCD) and soils data from the NRCS SSURGO soils database. Land cover and soil hydrologic groups were linked to SCS Curve Number values by selecting compatible pairs from the NRCS "*TR-55 Urban Hydrology for Small Watersheds*". The initial abstraction ratio and retention factors were used as calibration parameters as described below.

The selected subbasin transform method was the ModClark grid method. The ModClark grid method was used because it was one of the only methods compatible with the gridded precipitation inputs and produces results with a finer resolution. Associated parameters with that approach are the time of concentration and subbasin retention storage coefficient, which were both determined initially using HEC-GeoHMS, then used as calibration parameters. Time of concentration was initially determined using the TR-55 segmental approach (overland, shallow concentrated, channel flow) with assumed velocities for channel segments. The velocities were cross-checked against reach routing velocities as applicable.

The selected baseflow methodology was recession baseflow. Recession baseflow was selected because it could be used to simulate conditions leading up to the modeled historic storm events and the trailing limb of the discharge hydrographs after the events occurred. Parameters used in the recession baseflow included the initial discharge per unit area, recession constant, and discharge limb threshold ratio to peak. The recession constant was not changed, but the other two parameters were used as calibration values.

Figure 8 - Subbasin Delineation



Data Sources: ESRI Online Map Services, USGS NHD Streams, USGS Gage Locations

Reach routing was accomplished using Modified Puls storage-discharge functions in areas with cross sections common to the HEC-RAS model. The storage-discharge data was calculated from rating curves developed from the HEC-RAS model. Note the HEC-RAS model updates were previously described in the *Stantec Concept Report*. Routing times and reach attenuation was compared to the HEC-RAS routing results for validation.

For areas that did not have cross sections in the HEC-RAS model, simple lag routing was applied. Initial values for the lag were calculated using an assumed velocity for the length of the stream calculated from the NHD stream data. These lag times, with reasonable limits on velocities, were later used as model calibration parameters.

5.1 CALIBRATION EVENTS

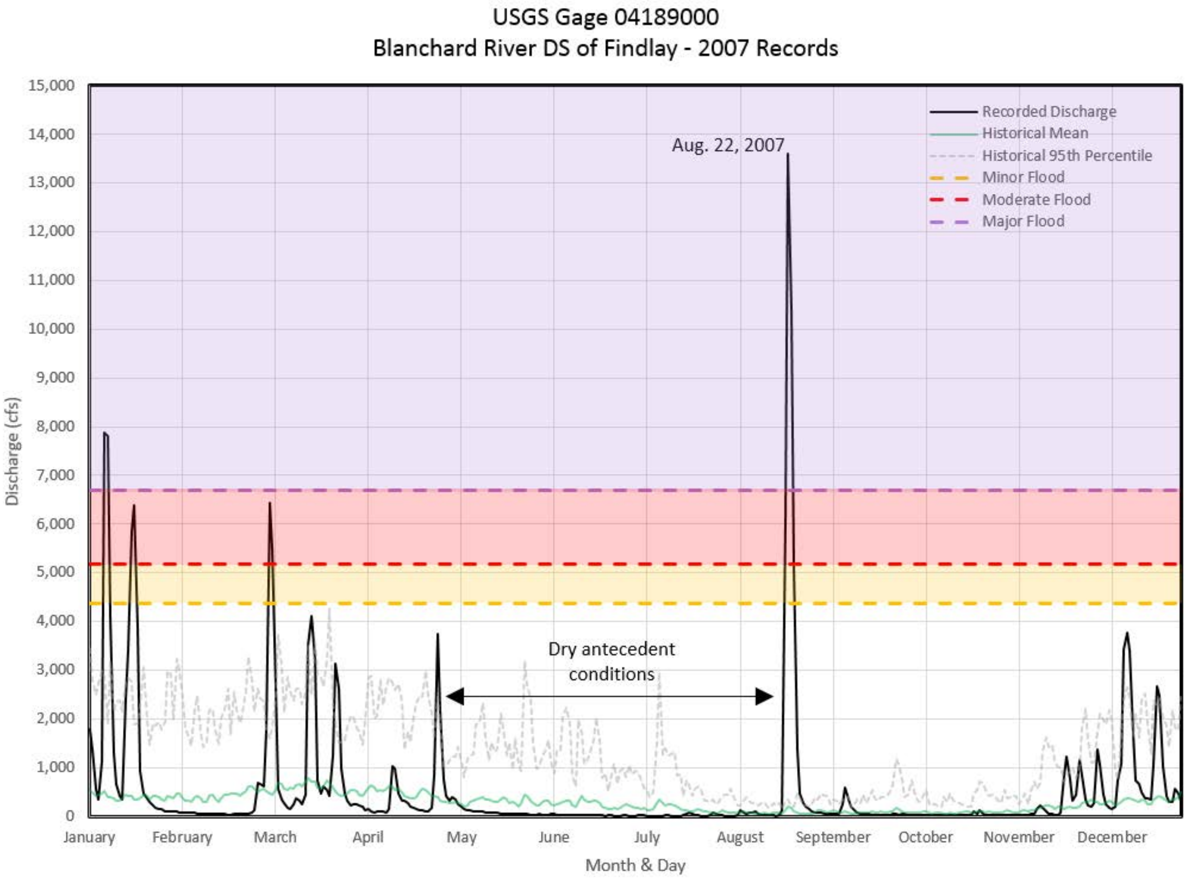
As a part of the initial gap analysis for the USACE hydrologic study, Stantec noted the calibration approach for the hydrologic model was not well documented. Gridded precipitation records for a number of historic storm events were included in the USACE HEC-HMS model, but it appears USACE calibrated the model to a single event that occurred in October 2011.

After Stantec further refined and updated the HEC-HMS model, the model results for the October 2011 event did not seem to correlate well to gage based discharge observations. The timing of the storms and runoff did not correctly align and the volume of runoff seemed different. The USACE model parameters also seemed inconsistent and varied widely between adjacent subbasins and reaches. Upon further investigation, it appears USACE used raw NEXRAD radar data from NOAA and did not correct the data using precipitation gage data. NEXRAD radar data captures reflectivity, which doesn’t necessarily result in a correct estimate of direct rainfall. To best use the radar data, the resulting precipitation estimates must be compared and scaled on a time-step basis to precipitation gages in the area. The result from the USACE model was a model geometry that reasonably replicated gage results, but that was based on an uncalibrated October 2011 input storm and inconsistent calibration parameters. Stantec sought to recalibrate the updated model using precipitation corrected radar data.

The first assumption in model calibration was that the model geometry should represent an “average” antecedent condition where the ground was not overly saturated, frozen, or covered with snow accumulation. The model results would thus reflect runoff commensurate with those conditions. In addition, since the USGS Gage 04189000 has an abundance of reliable data, the model should also reasonably replicate the results of the gage frequency analyses.

Stantec started by reviewing stream discharge records for the USGS gage 04189000 prior to the August 2007 event. A trace of daily mean discharges is shown in Figure 9. One observation from Figure 9 was there was nearly four months of drier than normal conditions, as the stream discharge was well below the historical mean values for the gage published by USGS.

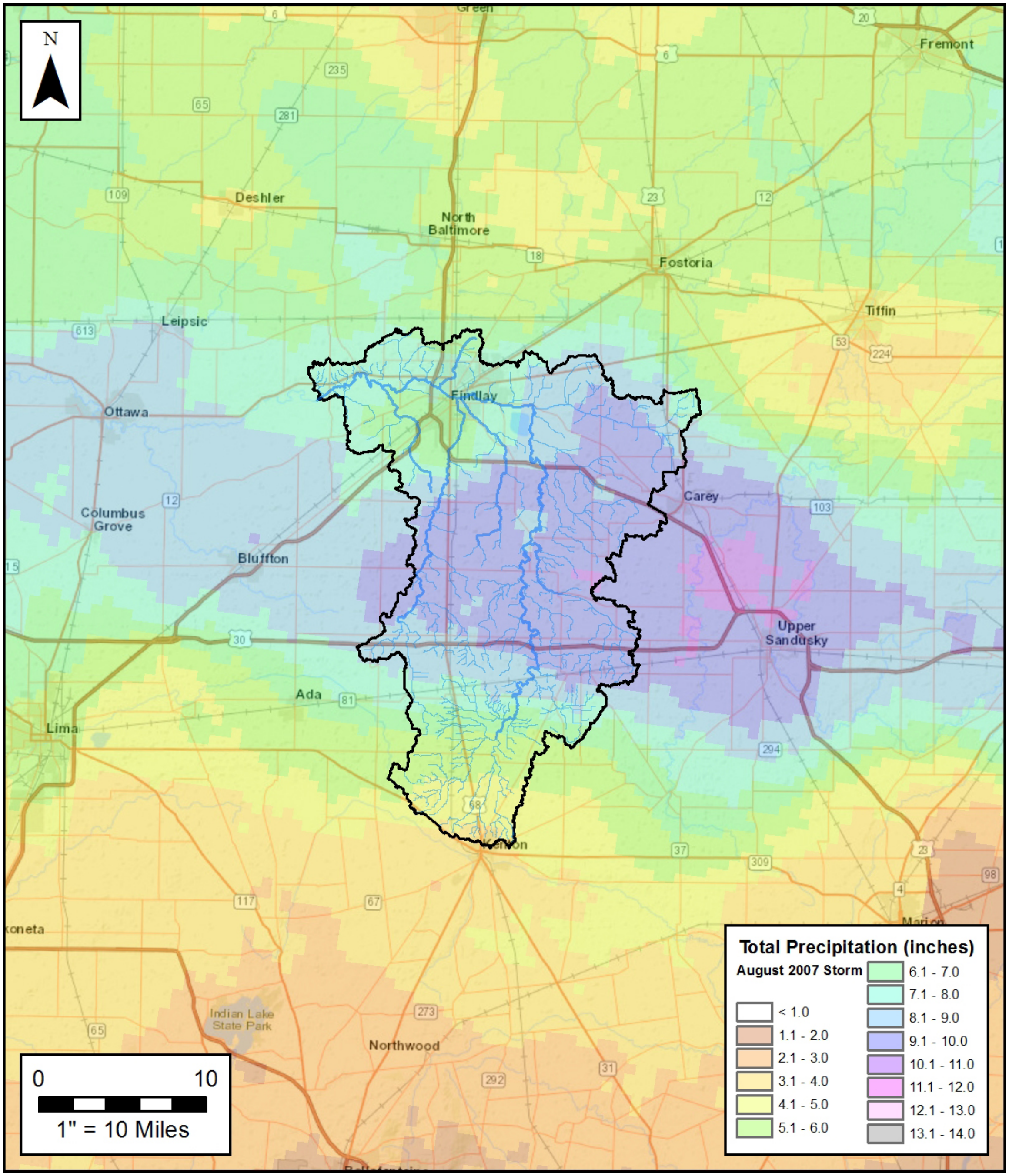
Figure 9 - August 2007 Storm Preceding Conditions



To further evaluate the August 2007 event, Stantec reviewed precipitation gages in the area and found very little accumulation during that preceding 4-month period. Not only was the stream discharge low, the watershed was also relatively dry. Stantec worked with AWA to obtain precipitation gage corrected radar data for the August 2007 storm. Total precipitation accumulations for the period between August 18 and August 22 of 2007 are shown in Figure 10. Note portions of the watershed received over 11 inches of rainfall during that time, making it an extremely abnormal hydrologic event. In fact, the Annual Chance of Exceedance (ACE) for a storm event with a depth and duration similar to the one in August 2007 was estimated to be less than 0.2% (greater than a 500-year return period) for much of the watershed. The intense rainfall with significant volume falling onto a dry watershed led to what would nearly approximate the flood of record for the City of Findlay.

Also note from Figure 10 the nearly elliptical shape of the storm and spatial distribution outward from a central precipitation band. These patterns are additional validation for the assumptions on spatial storm distribution and areal reduction described in Section 3 above.

Figure 10 - August 2007 Storm Spatial Pattern



Data Sources: ESRI Online Map Services, USGS NHD Streams, USGS Gage Locations

For calibration purposes, Stantec sought to identify one or more storm events that were independent and distinct occurrences; that were not affected by saturated conditions, frozen ground, or snow accumulation; and which produced large discharges in Findlay like the August 2007 event. The calibration events were limited to the availability of stream gage records on all five USGS gages, which meant the events must occur after 2007.

A few larger runoff events were noted during 2011. One particularly promising event in March 2011 produced a large discharge in Findlay; however, upon further review of the precipitation gage data and temperature data for the area, it was found to be partially due to snow melt. Additionally, runoff from much of the watershed would have been affected by frozen ground with limited crop and tree cover. For that reason, the focus was placed mainly on events occurring between late spring and fall that were more similar to the August 2007 event.

Early June of 2011 indicated another significant runoff event, but that spring was particularly wet and antecedent conditions did not represent typical conditions in the watershed. An event was identified on September 22 of 2011 that met most of the criteria. It was a late summer convective storm, with a uniform and distinct rainfall, falling on a relatively dry watershed that had not received a great deal of rain in the preceding 3-4 months, and vegetative cover would have been similar to 2007. Figure 11 shows the trace of runoff during 2011, while Figure 12 shows the precipitation gage corrected radar for the September 2011 event.

Using the same process, Stantec identified another similar event in June 2015. A trace of the runoff during 2015 and precipitation gage corrected radar data for the June 2015 event are included in Figures 13 and 14 respectively.

Observed runoff hydrographs at the USGS 04189000 gage for all three storm events are illustrated in Figure 15.

Figure 11 - September 2011 Storm Preceding Conditions

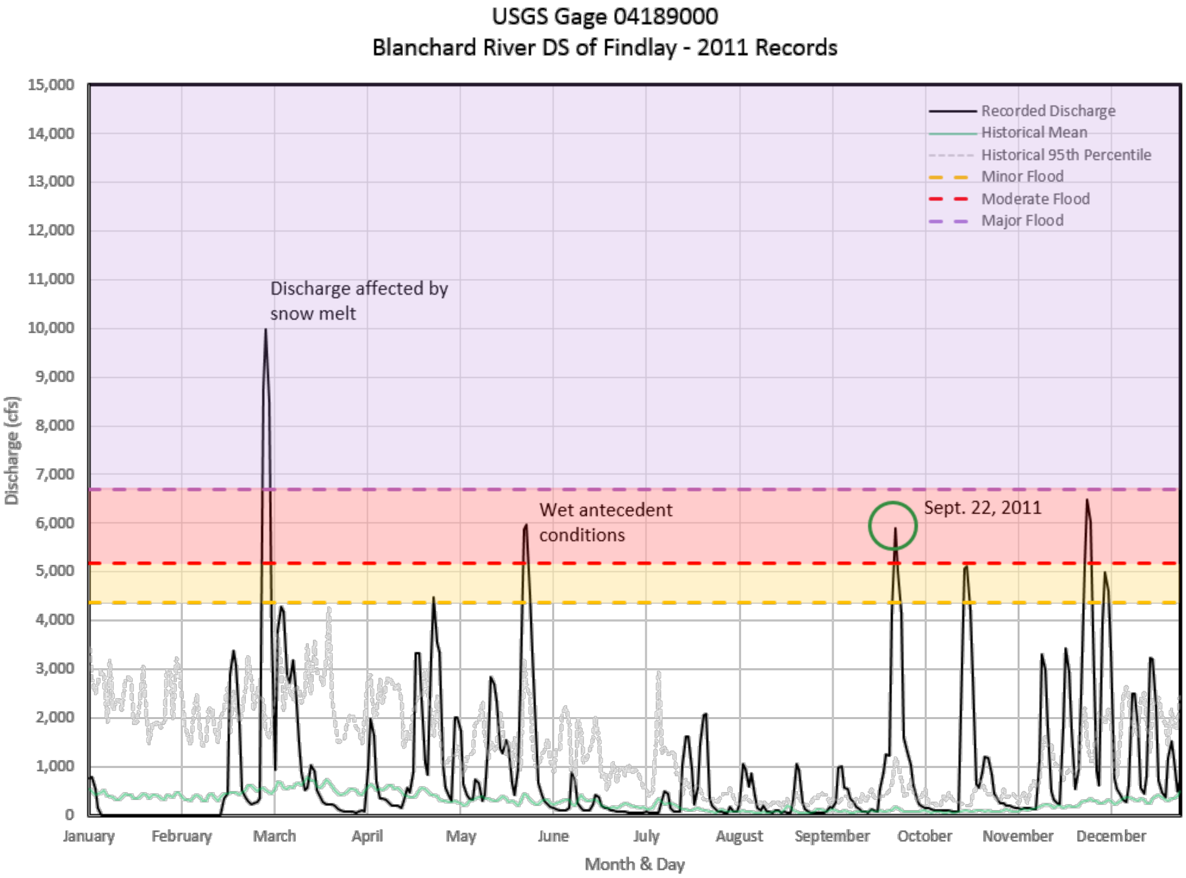
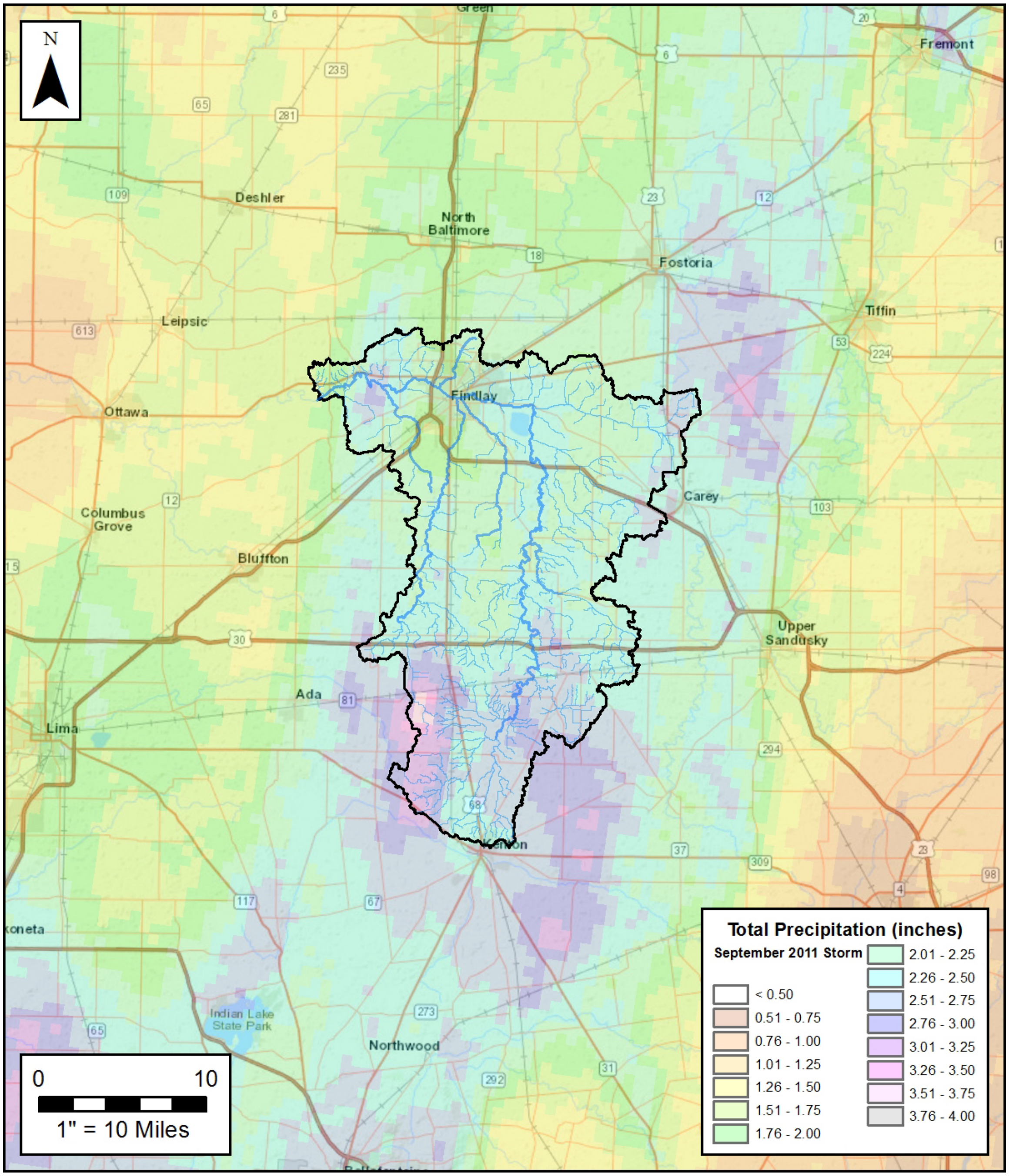


Figure 12 - September 2011 Storm Spatial Pattern



Data Sources: ESRI Online Map Services, USGS NHD Streams, USGS Gage Locations

Figure 13 - June 2015 Storm Preceding Conditions

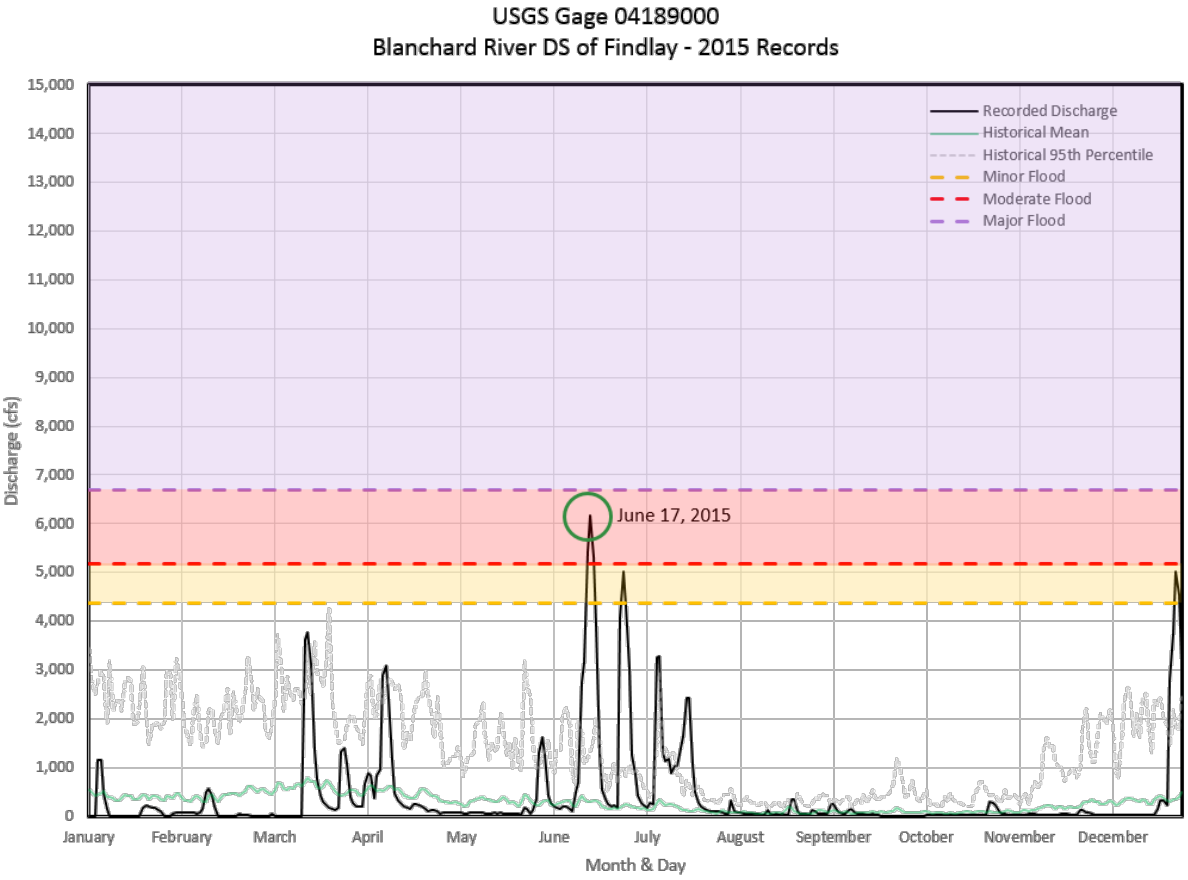
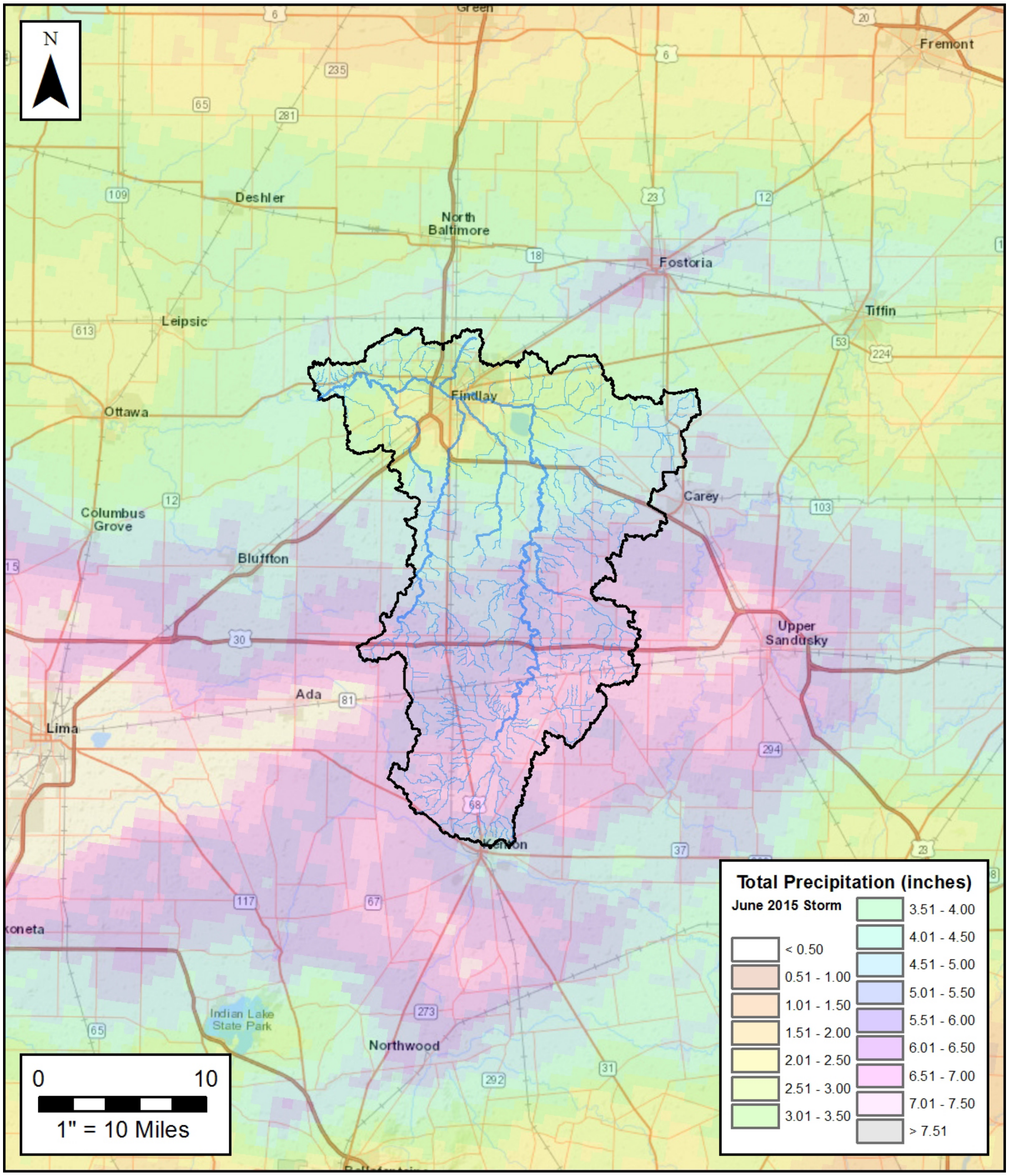
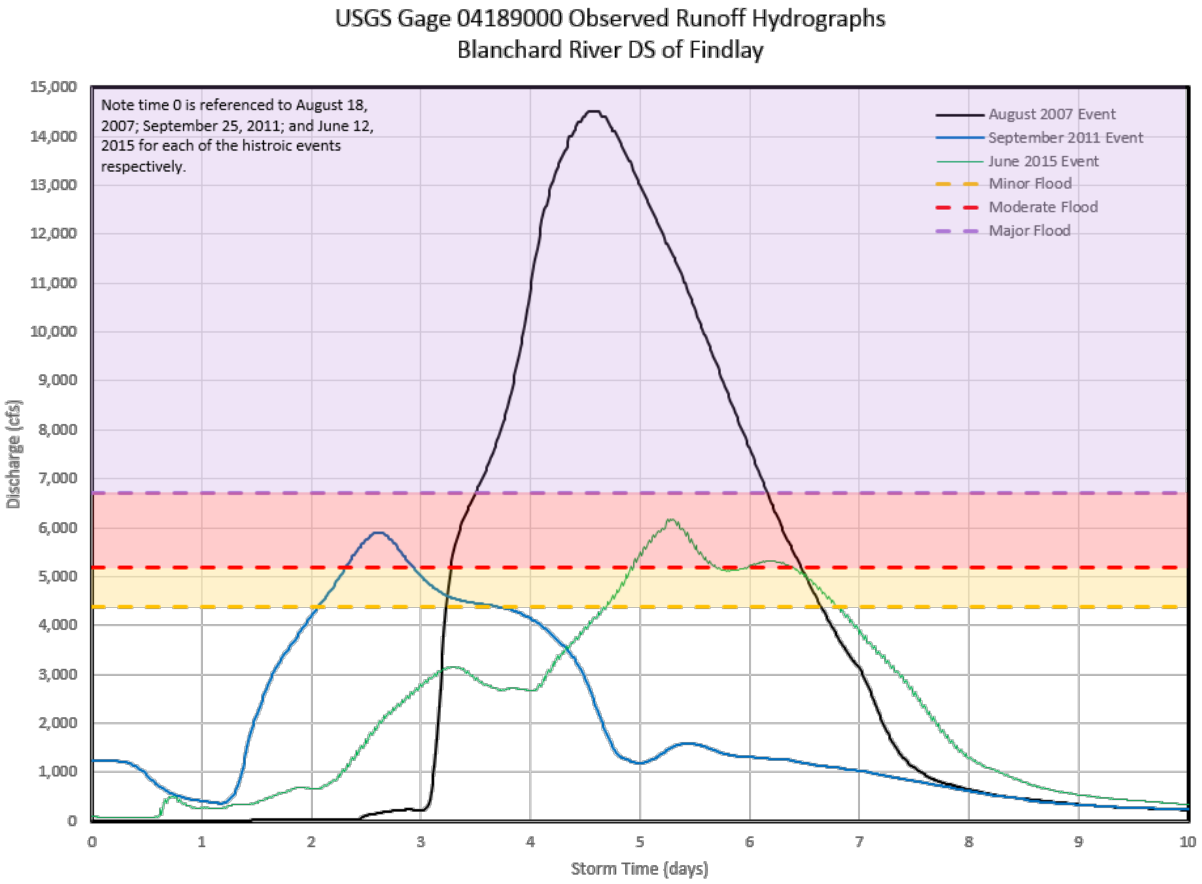


Figure 14 - June 2015 Storm Spatial Pattern



Data Sources: ESRI Online Map Services, USGS NHD Streams, USGS Gage Locations

Figure 15 - USGS Gage 04189000 Hydrographs



5.2 HEC-HMS MODEL CALIBRATION APPROACH

To calibrate the HEC-HMS model, Stantec started by creating calibrated geometry datasets for each of the September 2011 and June 2015 events. USGS gage data was available at five locations for these events. To accomplish the calibration, Computation Points were assigned to the nodes in the HEC-HMS model that represented the five USGS gage locations. Subbasins and reaches upstream of each gage (Computation Point) were then divided into 2-3 zones based on approximate travel time to the gage locations. The Forecast Analysis tools in HEC-HMS were then used to uniformly vary parameters within the zones. Lastly, parameter groupings and adjustments were checked for consistency between zones and within nearby spatial areas using GIS and an Excel spreadsheet.

Using the adjustments made for the September 2011 and June 2015 calibration events as a guide, Stantec then used the base model geometry to create a third calibration geometry dataset that simulated the result of the August 2007 flood event. The geometries for each of these three calibration events were somewhat different due to variations in antecedent conditions.

Stantec then used the three calibrated geometries to simulate hypothetical storm events in the watershed. The September 2011 geometry produced results in Findlay for various return period events that were within the acceptable range of values determined from the gage frequency analyses at the USGS Gage 04189000 location. The September 2011 geometry was therefore deemed more appropriate for simulation purposes.

The base geometry and calibration adjustments are included in Appendix C. Some additional notes on specific calibration parameters and results follow.

5.2.1 Subbasin Losses - SCS Curve Number Grid Adjustment

Typically, SCS Curve Numbers originally computed using procedures in TR-55 would be transformed into area weighted composite values for each subbasin and then slightly adjusted to account for antecedent moisture conditions (AMC). Table 10.1 in the NRCS National Engineering Handbook, Part 4, Hydrology (NEH 4) and Table 3 in NRCS Technical Publication 149 (TP-149) describes adjustments to the curve number for antecedent conditions. As an example, a watershed with an average curve number of 85 under AMC II (average) conditions can have a curve number that ranges from 70 for AMC I (dry conditions) to 94 for AMC III (wet conditions).

When using the gridded curve number approach in HEC-HMS, the grid values are direct representations of average curve number for each grid cell, assuming AMC II conditions. Runoff is calculated on a cell by cell basis and then accumulated at the subbasin outlet. The curve number grid is not typically adjusted to account for antecedent conditions. Instead, the initial abstraction and retention factors are adjusted individually for each subbasin. A 1-square-kilometer curve number grid was used to match the radar based precipitation grid data sets.

The calculation of runoff using the SCS Curve Numbers is described in Equations 2-1 to 2-4 from TR-55.

$$Q = \frac{(P-I_a)^2}{(P-I_a)+S} \text{ (Eq. 2-1)} \qquad I_a = 0.2S \text{ (Eq. 2-2)} \qquad S = \frac{1000}{CN} - 10 \text{ (Eq. 2-4)}$$

Where Q is the direct runoff, P is the precipitation for a given time period, I_a is a term describing the initial abstraction or precipitation loss, and S is a term defining the potential maximum retention.

In the HEC-HMS solution scheme for a gridded curve number approach, the 0.2 factor in Eq. 2-2 is replaced with a variable Abstraction Ratio. This allows for changes to the initial loss rates due to antecedent conditions, without artificially modifying the curve number grid. For calibration purposes, this value was adjusted within the range of 0.05 to 0.30, with an average of about 0.09.

In addition, the S in equation 2-1 is replaced in the HEC-HMS solution scheme with a term that has a multiplier Retention Factor that can account for additional (or less) subbasin storage that wouldn't otherwise be apparent with the curve number. This factor was adjusted within the range of 0.3 to 2.5 during calibration, with an average of about 0.79.

5.2.2 Subbasin Transform – ModClark Time Parameters

Two factors are included in the ModClark transform method: time of concentration and storage coefficient. Time of concentration (Tc) was initially calculated using the segmental approach (overland, shallow concentrated, and channel flow) described in TR-55. For calibration purposes, the times of concentrations were multiplied by a factor that ranged from 0.7 to 1.9 with a maximum variation of 3 hours from the calculated value. The 3-hour limiting value was chosen based on the expected possible error in the initial time of concentration calculation. The average adjusted value was about 90% of the original determination.

The ModClark storage coefficient (R) was calculated based on a ratio to the time of concentration. Many references, including the *HEC-HMS Technical Reference Manual* and *USGS Water-Resources Investigations Report 00-4184* indicate the ratio of R / (Tc + R) is nearly constant for an area. For calibration purposes, this ratio was initially assumed as 0.6, then assumed to be relatively fixed for given group of subbasins assigned to a common computation point and forecast zone.

5.2.3 Subbasin Recession Baseflow

The initial discharge per unit area ratio and ratio of the recession threshold to peak discharge were adjusted during calibration based on hydrograph observations. Initial discharge varied from 0.1 to 1.5, while the recession ratio varied from 0.01 to 0.05. The average values were 0.93 and 0.026 respectively.

5.2.4 Reach Lag Times

The lower reaches of the Blanchard River watershed were previously included in the updated HEC-RAS model. For those reaches, the Modified Puls storage routing method was applied using storage discharge rating curves developed from the HEC-RAS model. The assumed number of subreaches was set to 1 to produce the maximum amount of attenuation within the reaches. No other parameters were included with those reaches and they were not included in the calibration process.

For upstream reaches and larger tributaries that were not included in the HEC-RAS model, simple lag time routing was applied within the HEC-HMS model. Lag time routing does not replicate attenuation within a reach, but allows for adjustments of timing of runoff from various parts of the watershed. Lag time was initially calculated by assuming a fixed velocity of 2 feet per second over the length of the reach as calculated from the NHD stream centerlines. During calibration, the velocity values were modified within the range of 0.9 to 2 feet per second and lag times calculated accordingly. The average selected velocity was about 2.0 feet per second.

5.3 CALIBRATION RESULTS

Peak discharge and volumetric results for the HEC-HMS calibration are summarized in Table 4. Graphical hydrograph comparisons are provided in Appendix C.

Table 4 - USGS Gage Observation Comparison – “Calibrated” Geometries

	September 2011		June 2015		August 2007	
Location	**Peak Q (cfs)**	**Volume (ac-ft)**	**Peak Q (cfs)**	**Volume (ac-ft)**	**Peak Q (cfs)**	**Volume (ac-ft)**
USGS Gage 04189000 Blanchard River DS of Findlay	**6,232**	**33,499**	**8,277**	**53,392**	**14,290**	**77,809**
	5,900	*38,258*	*6,180*	*46,256*	*14,500*	*74,412*
USGS Gage 04188400 Blanchard River US of Findlay	**4,556**	**25,646**	**5,105**	**36,485**	**7,320**	**46,820**
	4,440	*29,809*	*5,400*	*38,006*	*N/A*	*N/A*
USGS Gage 04188337 Blanchard River DS of Mt. Blanchard	**4,571**	**18,073**	**5,670**	**28,438**	**6,215**	**29,179**
	4,720	*20,143*	*5,830*	*28,112*	*N/A*	*N/A*
USGS Gage 04188496 Eagle Creek Above Findlay	**2,010**	**4,264**	**2,808**	**9,154**	**3,361**	**13,427**
	2,090	*5,997*	*2,760*	*10,988*	*N/A*	*N/A*
USGS Gage 04188433 Lye Creek Above Findlay	**519**	**1,150**	**699**	**2,948**	**1,497**	**5,139**
	520	*1,471*	*682*	*3,173*	*N/A*	*N/A*

Notes:

- *Values in small typeface and italics are gage observations.*
- *Gage data not available for the August 2007 event except for gage 04189000*

After completing calibration and comparing the model geometries calibrated from the September 2011 and June 2015 storm events, Stantec observed the two events were slightly different hydrologically.

For the September 2011 event, a separate small rainfall event occurred about two days prior. The results of the calibration indicate less initial abstraction and retention storage. Runoff occurs more slowly as times of concentration are longer and the velocities are slower. The storage coefficients are lower as much of the retention storage is thought to be partially filled from the prior rainfall event.

For the June 2015 event, the preceding period was very dry. The results of the calibration indicate a higher initial abstraction and more retention storage. Runoff occurs more rapidly though as the times of concentration and velocities are shorter. The storage coefficients are higher as more of the retention storage is available.

These trends were used to create a separate geometry specific to the August 2007 event that reasonably replicated gage observations from USGS gage 04189000 during that event. The antecedent conditions for the August 2007 event were drier than normal. Calibration parameters were therefore adjusted accordingly within a reasonable range based on the input data.

For the purposes of modeling hypothetical storm events, the September 2011 geometry was found to produce results similar to the frequency analyses for USGS gage 04189000 and was therefore deemed appropriate for the simulations. Results are reflected in Section 6 of this report.

6.0 RESULTS

The HEC-HMS model was used with the September 2011 calibration geometry to simulate several storm events using the spatial and temporal patterns described herein. The upstream watershed centroid was assumed as the center of the storm events. Peak discharge values at Main Street in Findlay and the five USGS gage locations for various return periods (recurrence intervals) are presented in Table 5.

6.1 APPLICABILITY AND RECOMMENDATIONS

The HEC-HMS model that was developed as a part of this study and discharges listed in Table 5 are based on more analyses than previous hydrologic studies of the area. The magnitude and trends predicted by the results are consistent with prior efforts and, therefore, do not invalidate the previous hydrologic modeling. Stantec does not recommend updating the *Concept Report, which was a* planning level document, but would recommend this revised and updated hydrologic model and results presented herein be used for future flood mitigation planning, benefit to cost ratio work, and design efforts in the area to the extent applicable.

Based on review of historic gage data and hydrologic modeling of historic storm events, the results of these analyses show that antecedent conditions will factor substantially into the resulting runoff volumes and peak discharges within the Blanchard River watershed. Stantec recommends that subsequent users of this model thoroughly review antecedent conditions and exercise caution when applying the model to varied hydrologic events.

Table 5 – Peak Flood Discharges

	Average Recurrence Interval (Years)							
Location	**2**	**5**	**10**	**25**	**50**	**100**	**200**	**500**
Main Street in Findlay	5,680	7,643	9,321	11,634	13,595	15,652	17,902	21,130
USGS Gage 04189000 Blanchard River DS of Findlay	5,730	7,715	9,413	11,734	13,574	15,652	17,951	21,106
Gage Analyses (-/+ 5% Confidence)	*5,086* *6,020*	*7,319* *8,918*	*8,625* *10,788*	*10,111* *13,037*	*11,113* *14,619*	*12,039* *16,120*	*12,903* *17,552*	*13,964* *19,351*
USGS Gage 04188400 Blanchard River US of Findlay	3,825	4,650	5,218	5,997	6,578	7,148	7,743	8,633
USGS Gage 04188337 Blanchard River DS of Mt. Blanchard	3,356	4,249	4,988	6,186	7,094	8,008	8,991	10,489
USGS Gage 04188496 Eagle Creek Above Findlay	1,741	2,323	2,839	3,577	4,223	4,915	5,690	6,732
USGS Gage 04188433 Lye Creek Above Findlay	533	752	942	1,217	1,451	1,699	1,967	2,344

Notes:

- Discharges are reported in cubic feet per second (cfs).
- Values from HEC-HMS model simulations using the September 2011 calibration geometry developed by Stantec.
- Gage Frequency Estimates for USGS Gage 04189000 are provided for comparison purposes.

7.0 REFERENCES

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USGS Gage Data: United States Geological Survey, Gage ID #'s 0418900, 04188400, 04188337, 04188496, 0418433. Refer to https://waterdata.usgs.gov/nwis/rt to access individual sites.

USGS NHD: United States Geological Survey National Hydrography Dataset. Refer to https://nhd.usgs.gov/data.html for data access.

NOAA NEXRAD Radar Data: National Centers for Environmental Information, National Oceanic and Atmospheric Administration. Refer to https://www.ncdc.noaa.gov/data-access/radar-data/nexrad for data access.

National Land Cover Database (NLCD): Multi-Resolution Land Characteristics Consortium. Refer to https://www.mrlc.gov/ for data access.

SSURGO NRCS Soils Database: USDA Natural Resources Conservation Service. Refer to https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/survey/ for data access.

Ohio Statewide Imagery Program (OSIP) and Ohio Geographically Referenced Information Program (OGRIP): Refer to http://ogrip.oit.ohio.gov/Home.aspx for additional information and data access.

Appendix A GAGE ANALYSIS SUPPORT DATA

Stantec

Memo

To: Project Files
Cincinnati, Ohio
From: Matthew Armstrong, Erman Caudill
Lexington, KY
File: 174316204
Date: June 16, 2017

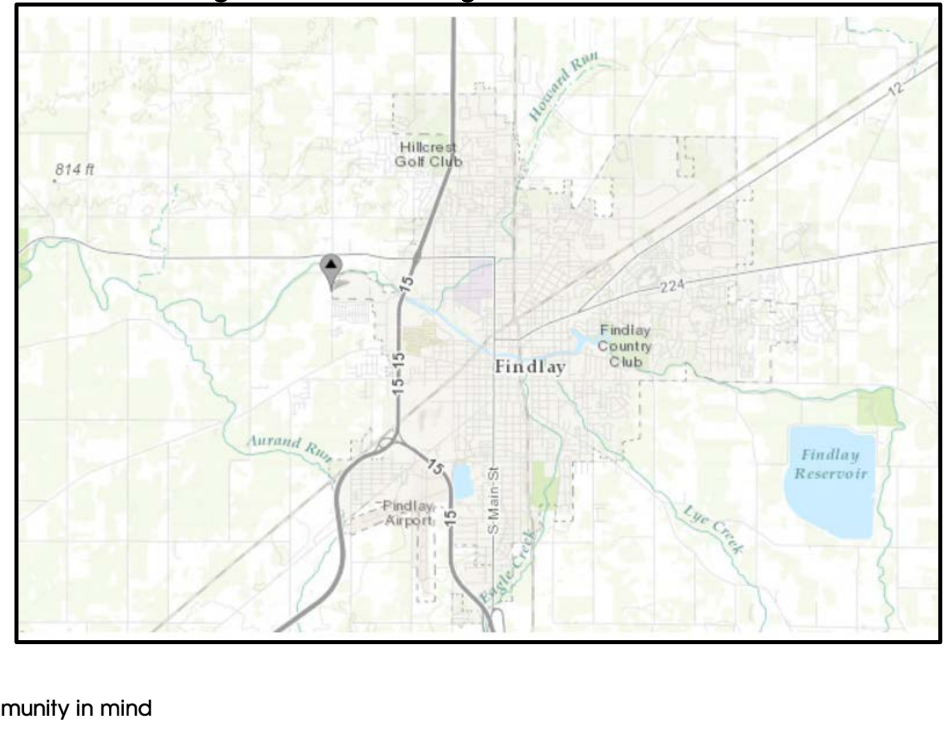
Reference: **Stream Gage Frequency Analyses**
USGS Gage # 04189000 Blanchard River
Hancock County Flood Risk Reduction Program

Stantec has completed a hydrologic study for the Blanchard River and its tributaries in the vicinity of Hancock County and the City of Findlay, Ohio. As part of the study, Stantec completed a flood flow frequency analysis using many years of data from a stream gage located a short distance downstream of Findlay on the Blanchard River. This memo summarizes the flood flow frequency analysis and results.

Stream gage 04189000 on the Blanchard River is operated cooperatively by the U.S. Geologic Survey (USGS), the City of Findlay, and the U.S. Army Corps of Engineers (USACE). It is located approximately 2 miles west of the City of Findlay, on the upstream side of County Road 140 bridge. The gage location has 346 square miles of contributing watershed area. The gage's period of record includes daily mean discharges since October 1923; however, there is a gap in the data between December 1935 and October 1940. Instantaneous readings on a 30-minute interval have also been collected since the early 2000's. Lastly, a historical peak height/discharge value has been appended to the gage record: in March 1913, a gage height of 18.5 feet was reported and a discharge of 22,000 cubic-feet-per-second (cfs) was estimated.

Figure 1 from the USGS website for the gage illustrates the gage location.

Figure 1 – USGS Gage 04189000 Location



1.0 METHODOLOGY

The methods used to perform this analysis are outlined in "*Guidelines for Determining Flood Flow Frequency – Bulletin 17B*" from the U.S. Department of the Interior Geological Survey Interagency Advisory Committee on Water Data (USDOI, 1981). This document is abbreviated herein as *Bulletin 17B*.

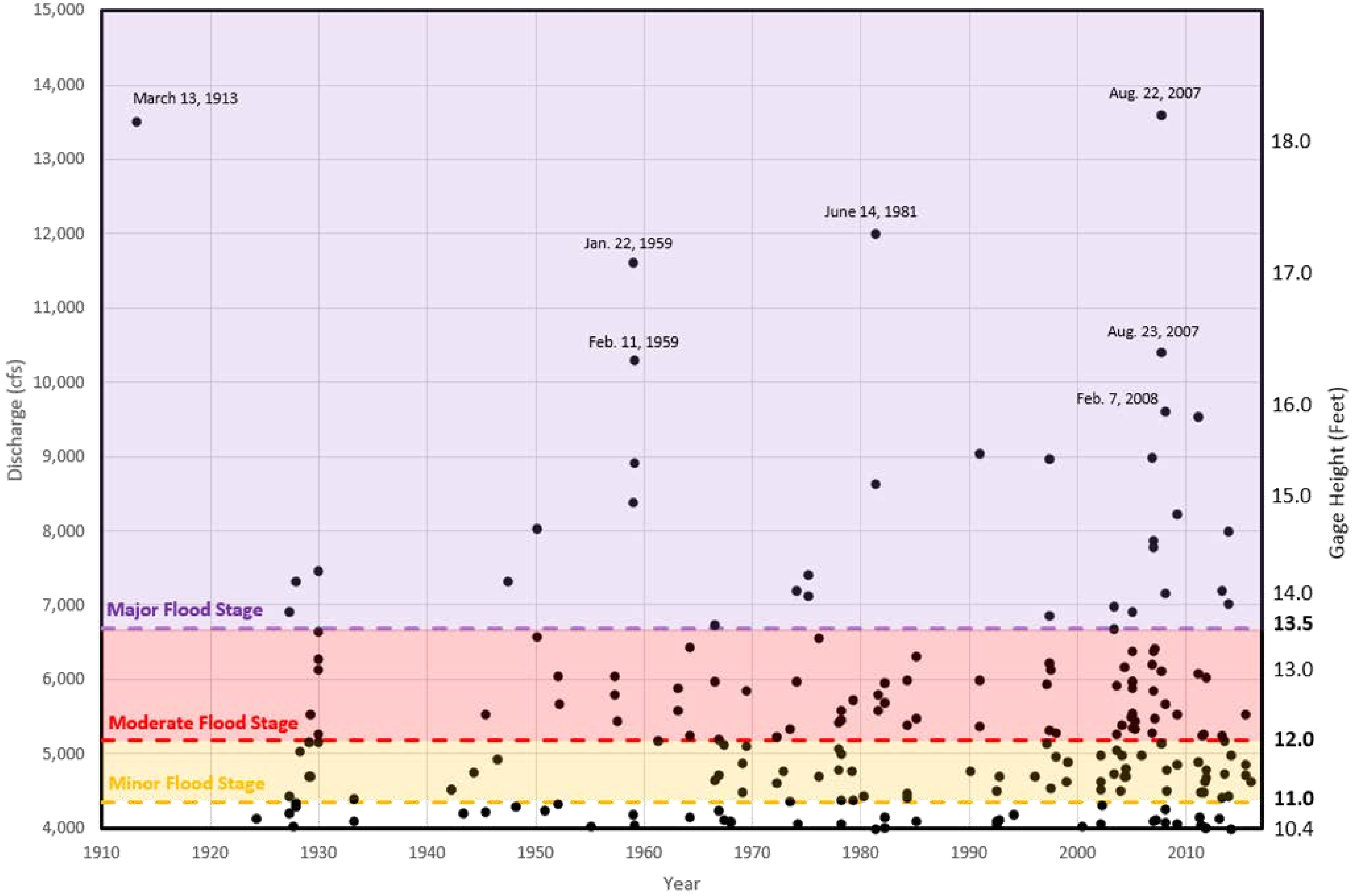
1.1 SOURCE DATA

Stream gage data consisting of daily mean discharge values was obtained from the USGS (USGS, 2017). The gage's daily data includes two time windows: October 1, 1923 to December 31, 1935 and October 1, 1940 to the present. (January 25, 2017 was the date of the download.) Annual maximum daily discharge values, on a water year basis, were also obtained for the *Bulletin 17B* analyses. The largest annual peak occurred on August 22, 2007 with a discharge of about 14,500 cubic feet per second (cfs). The lowest annual peak occurred on January 2, 1941 with a discharge of 958 cfs. The average daily value for the available period of record is about 280 cfs. One additional historical peak discharge is included with the gage data. A large event occurred around March 1913 that was estimated to have a magnitude of 22,000 cfs with a similar gage height as the August 2007 event. A listing of the annual peaks is included in the attached HEC-SSP output (see below), but Figure 2 shows a general plot of larger historic daily peaks from the gage.

1.2 GENERALIZED SKEW

In the *Bulletin 17B* procedure, the skew variable is used to account for the tendency of the data to vary from the mean. This skew or "spread" is similar to the standard deviation in classical statistical analyses. A "station skew" can be calculated directly from the input data; however, this can be inaccurate if there isn't a sufficient population of data or the data is not well represented due to one or more atypical events. To formulate a better estimate of the skew coefficient, the station skew can be combined with a generalized skew factor to create a weighted skew value. The generalized skew is based on other gage data from the region and was previously pre-computed and published in map form in *Bulletin 17B*. For this analysis, a generalized skew factor of -0.4 and mean skew error of 0.302 from *Bulletin 17B* (Interagency Advisory Committee on Water Data, 1982) were used to produce a weighted skew value. The sensitivity of the analyses to the skew coefficient selection was also evaluated.

Figure 2 – USGS Gage 04189000 Daily Peaks



1.3 HISTORICAL PERIOD DATA

Historical period data is defined in the *Bulletin 17B* procedure as flood information outside of the continuous or systematic record. It is used to extend the range of the largest events at a gage, but can introduce uncertainty in the frequency aspect of the results because it omits the lower annual peak events that may have occurred between when the historic event happened and the continuous period of record began.

When including flood information outside of the systematic record it is important to evaluate the reliability of the data. Erroneous historic data will lead to errors in the flood flow frequency curve. For the March 1913 event a gage height of 18.5 feet was estimated with a corresponding discharge of 22,000 cfs. This value was estimated based on extrapolation from a rating curve with a previous peak discharge of 9,500 cfs (Weld, Asselstine, & Johnson, 1959). A similar gage height was recorded in August 2007, 18.46 feet; however, the recorded discharge during that event was only 14,500 cfs. For analysis purposes, the March 1913 discharge value was corrected to 14,590 cfs to be more consistent with the rating curve for the gage and 2007 observations.

Figure 3 illustrates the current rating curve for the gage that was obtained from the USGS and the relationship between the reported and corrected 1913 peak discharge values.

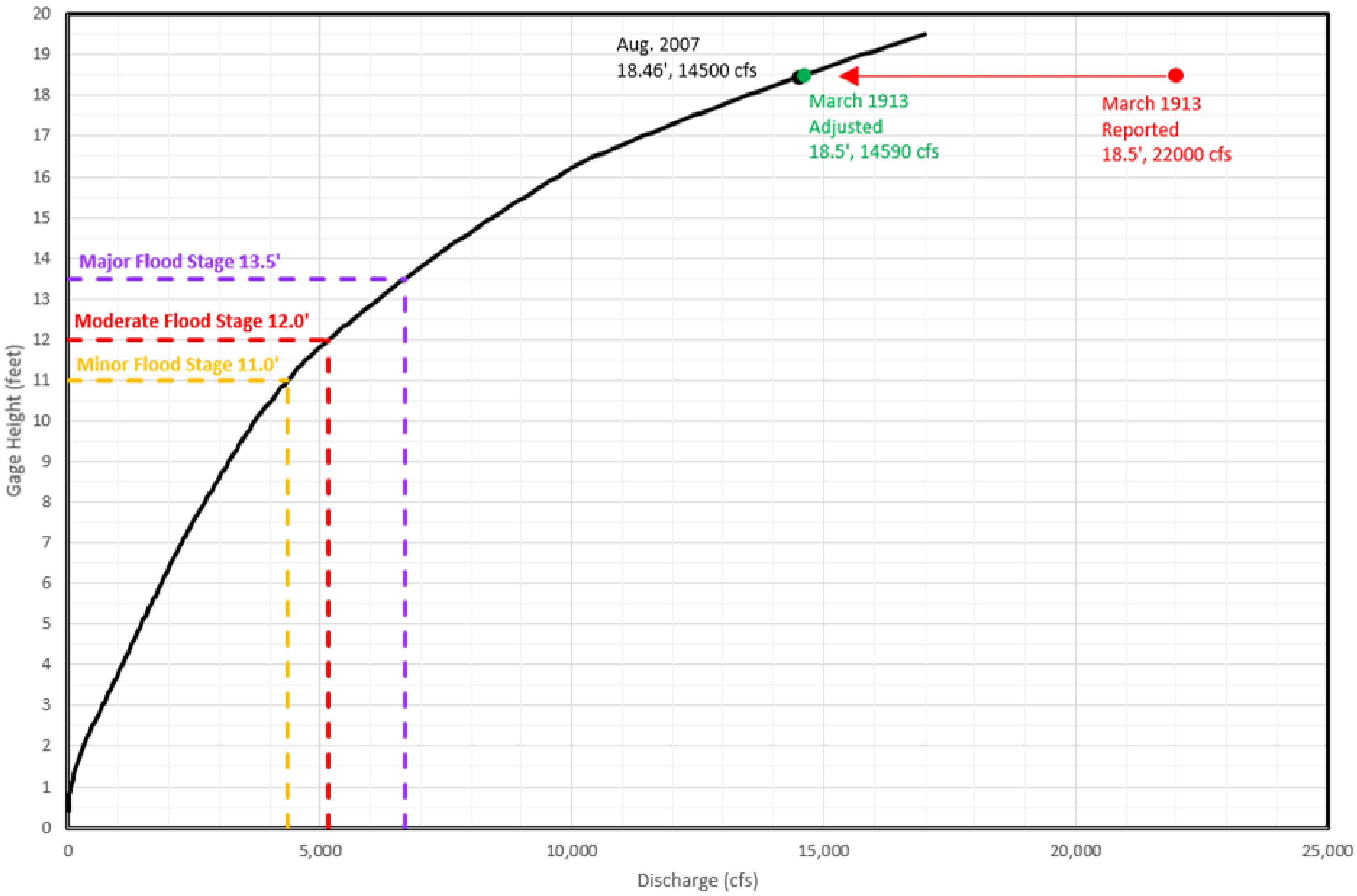
1.4 HYDROLOGIC MODIFICATIONS

One of the most important assumptions of flood flow frequency guidance is that no major hydrologic changes have occurred during the period of record used. Incremental increase in urbanization over time and discharge modification due to storage can have a significant impact on the runoff characteristics of the watershed. Urbanization, for the purpose of this analysis, is creation of new impervious area within the watershed that is not directly offset with mitigation measures (i.e. designed detention). Only records which represent relatively constant hydrologic conditions in the watershed should be used to perform a frequency analysis.

Historical records of impervious areas were not available for most of the 89 years of gage records; but based on current landuse in the watershed, development appears to be limited to the Findlay area and is not occurring over a large percentage of the watershed. For the analyses it was assumed that the percent of impervious area within the watershed was constant. To further test this assumption, three data subsets were evaluated to see if there may be changes in response during certain periods of time using:

1. The entire gage record
2. The most recent 40-years of gage records (about ½ the available data)
3. The most recent 20-years of gage records (about ¼ the available data)

Figure 3 – USGS Gage 04189000 Rating Curve



1.5 MODELING SOFTWARE

The analyses were performed using the USACE Hydrologic Engineering Center Statistical Software Package (HEC-SSP) v2.1 (USACE, 2016). Unless noted, the model parameter settings used during the analyses were:

- Bulletin 17B Methods
- Use Station Skew or Weighted Skew (depending on the simulation)
- Regional Skew = -0.4, Reg. Skew MSE = 0.302
- Compute expected probability curve
- Low Outlier Test – Single Grubbs-Beck
- Plotting Position - Median
- Confidence Limits – Default (0.05, 0.95)
- Time Window Modification Start Date – Checked, set to 01JAN1924
- Historic Period Data – Checked, 1913 to 1914, Corrected Value
- Frequencies Computed: 99.9%, 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, 0.2%, 0.1%

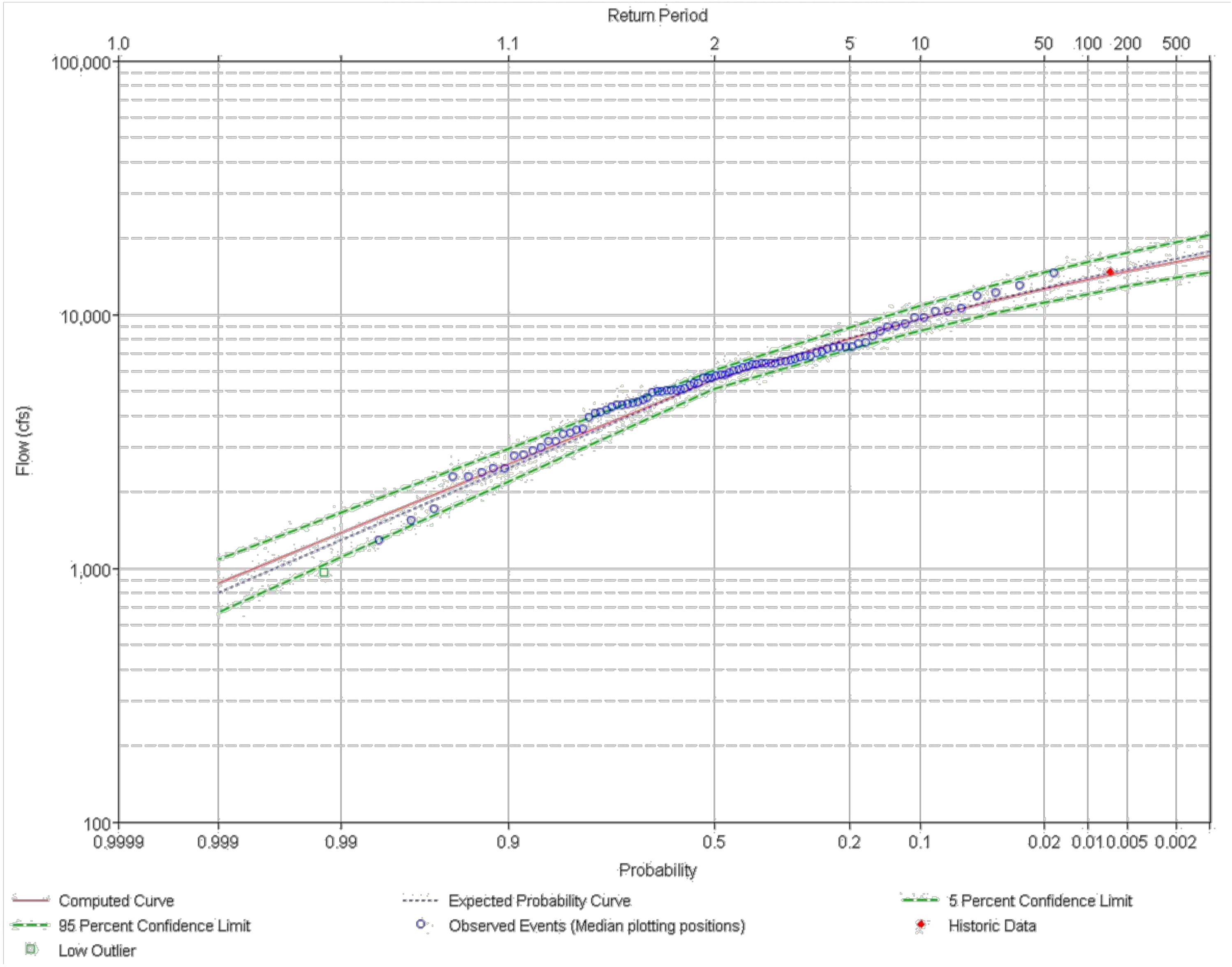
2.0 RESULTS

Table 1 summarizes the computed discharges for various probabilities based on the weighted skew factor, corrected historical discharge value in 1913, and using all of the available data. Figure 4 presents the results graphically. Lastly, a detailed HEC-SSP output is included as an attachment. Further discussion of the skew factor and potential hydrologic modifications is discussed in terms of sensitivity in section 2.1.

Table 1 – Flood Flow Frequency Analysis Results

USGS Gage 04189000 Blanchard River Downstream of Findlay, Ohio					
Percent Chance Exceedance	Avg. Recurrence Interval (years)	Computed Curve Flow (cfs)	Expected Flow (cfs)	Confidence Limits	
				0.05	0.95
0.1	1000	17116.5	17627.6	20649.2	14715.0
0.2	500	16156.2	16576.7	19351.4	13964.1
0.5	200	14810.6	15119.5	17552.0	12902.8
1.0	***100***	***13726.8***	13964.6	16120.2	12039.4
2.0	50	12576.4	12749.5	14619.1	11113.4
4.0	25	11346.2	11464.9	13037.1	10110.5
10.0	10	9558.6	9618.5	10787.9	8625.4
20.0	5	8027.7	8055.9	8918.1	7319.4
50.0	2	5530.2	5530.2	6020.3	5085.9
99.9	1	874.5	804.9	1083.6	667.1

Figure 4 – USGS Gage 04189000 Flood Flow Frequency Analysis Results



2.1 SENSITIVITY

As part of the analyses the sensitivity of the results to three variables were evaluated in order to quantify their impact on the flood flow frequency curve. The three variables evaluated were:

- Station Skew -vs- Weighted Skew
- Hydrologic Modifications
- Draft Bulletin 17C Procedural Guidance

2.1.1 Skew

As a basis of comparison, the 1-percent-chance exceedance (100-year recurrence) interval discharge in Table 1 above was calculated as 13726.8 cfs. This value assumed a weighted skew factor based on regional data previously published. If the “station skew” factor is selected instead, the calculated value is 13869.1, a difference of only +142.3 cfs or 0.01%. Other frequencies had similar results leading us to conclude using the weighted skew values do not significantly affect the results. This is also valid intuitively as the 04189000 gage has many years of data to support computing an accurate station based skew coefficient.

2.1.2 Hydrologic Modifications

To test the assumption that the hydrologic conditions in the watershed have remained relatively constant over the period of record, the analyses were split into 3 subsets: the entire record, the last 40 years, and the last 20 years. The 1913 event was omitted from the shorter duration simulations.

Again as a basis of comparison, the 1-percent-chance exceedance (100-year recurrence) interval discharge in Table 1 above was calculated as 13726.8 cfs using the entire period of record. If the data is limited to the last 40 years, the calculated value is 14694.1 cfs. If limited to the last 20 years, the calculated value is 15154.9 cfs. Table 2 summarizes the results for each of the frequencies.

Table 2 – Flood Flow Frequency Analysis Results Using Partial Records

USGS Gage 04189000 Blanchard River Downstream of Findlay, Ohio				
		Calculated Discharges (cfs)		
Percent Chance Exceedance	Avg. Recurrence Interval (years)	Entire Period of Record	Last 40 Years of Records	Last 20 Years of Records
0.1	1000	17116.5	19482.5	18273.9
0.2	500	16156.2	18035.8	17410.0
0.5	200	14810.6	16132.5	16173.3
1.0	100	13726.8	14694.1	15154.9
2.0	50	12576.4	13249.8	14051.7
4.0	25	11346.2	11789.5	12845.5
10.0	10	9558.6	9804.1	11042.7
20.0	5	8027.7	8213.5	9448.4
50.0	2	5530.2	5789.1	6736.8
99.9	1	874.5	1408.3	1184.3

From Table 2, it would appear that the magnitude and frequency of flood discharges on the Blanchard River are increasing as a trend. Whether or not this increase is attributable to modifications to the hydrologic conditions within the watershed or changes to the regional precipitation patterns cannot be determined from these analyses and are beyond the scope of this study. Further study of historic trends may be warranted. For now the entire period of record is used for the flood flow frequency analysis results.

2.1.3 Draft Bulletin 17C Guidance

The procedures described in *Bulletin 17B* were last updated in 1981. In 2016 the USGS released a draft version of proposed revisions termed *Bulletin 17C* (England Jr., et al., 2016). The new *Bulletin 17C* guidance includes a number of changes to the *Bulletin 17B* process.

One of the changes in *Bulletin 17C* is the generalized skew factor isoline map is no longer available to support weighting the station skew. The new guidance discontinues the country-wide map and directs the user to either generate their own regional skew factor or utilize regional skew data developed by others. The USGS has not published a regional skew analysis for this region or the state of Ohio. From the discussion in Section 2.1.1 above, this particular gage has sufficient data such that using only the station skew does not appear to significantly alter the results.

A second change centers around filling in gaps in systematic gage records using perception thresholds. *Bulletin 17C* discusses statistically valid ways to synthetically generate data that make the data sets more complete and lead to better frequency estimates.

HEC-SSP has implemented the DRAFT *Bulletin 17C* guidance and was used to compare the results. For the *Bulletin 17C* analysis the following modeling parameters were used as recommended in the *HEC-SSP Users Manual* (USACE 2016):

- Use Station Skew (no weighted skew)
- Low Outlier Test – Multiple Grubbs-Beck
- Plotting Position – Hirsch/Stedinger
- Confidence Limits – Default (0.05, 0.95)
- Frequencies Computed: 99.9%, 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, 0.2%, 0.1%
- Perception Thresholds:
  - 1913 to 1924 and 1935 to 1940: Low Threshold = 4,365 cfs (discharge at minor flood stage) and High Threshold = 14,590 cfs (discharge during 1913 event)

Results of the *Bulletin 17C* analyses are slightly lower in that the 1-percent-chance exceedance (100-year recurrence) interval discharge was calculated as 12614.8 cfs, as opposed to the 13726.8 cfs in Table 1 above. The values in Table 1 are within the confidence limits of the *Bulletin 17C* results as shown in Table 3.

Table 3 – Flood Flow Frequency Analysis Results Using Bulletin 17C

USGS Gage 04189000 Blanchard River Downstream of Findlay, Ohio					
		Calculated Discharges (cfs)			
Percent Chance Exceedance	Avg. Recurrence Interval (years)	Bulletin 17B Results	Bulletin 17C Results	Bulletin 17C 0.05 Confidence	Bulletin 17C 0.95 Confidence
0.1	1000	17116.5	14685.1	19260.5	12312.5
0.2	500	16156.2	14140.4	17889.4	12085.4
0.5	200	14810.6	13322.0	16110.6	11692.2
1.0	100	13726.8	12614.8	14779.5	11297.3
2.0	50	12576.4	11815.9	13447.7	10781.3
4.0	25	11346.2	10904.9	12094.8	10092.2
10.0	10	9558.6	9473.9	10236.8	8820.5
20.0	5	8027.7	8144.8	8754.3	7563.9
50.0	2	5530.2	5768.1	6256.5	5305.2
99.9	1	874.5	793.2	1209.3	290.3

Since the *Bulletin 17C* guidance is still in DRAFT form at this point, values predicted using Bulletin 17B are within the confidence limits, and more conservative, the Bulletin 17B values in Table 1 are recommended.

3.0 CONCLUSION & RECOMMENDATIONS

Flood flow frequency analyses for USGS gage 04189000 were carried out using procedures in *Bulletin 17B*. The gage data was found to be sufficient to support the analyses and results are shown in Table 1 and Figure 1.

Sensitivity analyses were carried out for skew coefficient, hydrologic modifications, and the draft *Bulletin 17C* guidance.

- Using the station skew coefficient in-lieu of a weighted skew coefficient was found to have limited impact on the analyses.
- Considering partial periods of record as a surrogate for hydrologic modifications indicated there is an increasing trend in terms of frequency and magnitude of flood events; however, additional study is necessary to adequately characterize the changes. For now using the entire period of record is recommended.
- The Bulletin 17C guidance results in a slightly lower prediction of flood flow frequency values, but the Bulletin 17B values are within the confidence levels of the analysis and considered appropriate.

At this time Stantec recommends the results of the Bulletin 17B analyses described in Table 1 and Figure 1 be used for planning and design efforts as applicable. Should additional analysis of regional trends be performed by the USGS or others, this analysis may need to be reviewed and revised as necessary.

4.0 REFERENCES

England Jr., J. F., Cohn, T. A., Faber, B. A., Stedinger, J. R., Thomas Jr., W. O., Veilleux, A. G., . . . Mason, R. R. (2016). “*DRAFT Guidelines for Determining Flood Flow Frequency – Bulletin 17C*”: U.S. Geological Survey Techniques and. US Department of the Interior, US Geological Survey, Reston. Retrieved from http://dx.doi.org/10.3133/tm4–BXX/

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Attachment: HEC-SSP Output File

```
-------------------------------
Bulletin 17B Frequency Analysis
    16 Jun 2017   12:14 PM
-------------------------------


--- Input Data ---

Analysis Name: Stream Gage Frequency Analysis
Description: USGS Gage 04189000 Blanchard River downstream of Findlay, Ohio
LOCATION.--Lat 41°03'21", long 83°41'17", Hancock County, OH, Hydrologic
Unit 04100008, on left bank at upstream side of county road bridge, 2 mi west
of Findlay, 3 mi downstream from Eagle Creek, and 3 mi upstream from Aurand Run.
DRAINAGE AREA.--346 mi2.
PERIOD OF RECORD.--October 1923 to December 1935, October 1940 to current year.
Monthly discharge only for October 1923, published in WSP 1307.
REVISED RECORDS.--WSP 974: 1942. WSP 1054: 1927-1930, 1933(M), 1945. WSP 1387: 1926,
1928(M), 1930(M), 1952. WSP 1912: Drainage area. WDR-OH-81-2: 1959, 1975(M).
WDR-OH-97-2: 1996(M).
REMARKS.--Water is diverted upstream from station into Findlay Reservoir. All water
returns to stream upstream from station. Water quality and sediment data previously
collected at this site.

Data Set Name: Blanchard River-Findlay OH-FLOW-ANNUAL PEAK
DSS File Name:
C:\Users\ecaudill\Documents\Project_Files\HEC_SSP\Blanchard_River_near_Findlay_OH\Blanchard_River
_near_Findlay_OH.dss
DSS Pathname: /Blanchard River/Findlay OH/FLOW-ANNUAL PEAK/01jan1900/IR-CENTURY/USGS/

Report File Name:
C:\Users\ecaudill\Documents\Project_Files\HEC_SSP\Blanchard_River_near_Findlay_OH\Bulletin17Resul
ts\Stream_Gage_Frequency_Analysis\Stream_Gage_Frequency_Analysis.rpt
XML File Name:
C:\Users\ecaudill\Documents\Project_Files\HEC_SSP\Blanchard_River_near_Findlay_OH\Bulletin17Resul
ts\Stream_Gage_Frequency_Analysis\Stream_Gage_Frequency_Analysis.xml

Start Date: 01 Jan 1924
End Date:

Skew Option: Use Weighted Skew
Regional Skew: -0.4
Regional Skew MSE: 0.302

Plotting Position Type: Median

Upper Confidence Level: 0.05
Lower Confidence Level: 0.95

Use Historic Data
Historic Period Start Year: 1913
Historic Period End Year: 1914
Year: 1913   Value: 14,590

Use non-standard frequencies
Frequency: 99.9
Frequency: 50.0
Frequency: 20.0
Frequency: 10.0
Frequency: 4.0
Frequency: 2.0
Frequency: 1.0
Frequency: 0.5
Frequency: 0.2
Frequency: 0.1

Display ordinate values using 1 digits in fraction part of value

--- End of Input Data ---
```

```
--- Preliminary Results ---

<< Plotting Positions >>
Blanchard River-Findlay OH-FLOW-ANNUAL PEAK
--------------------------------------------------------------------
|     Events Analyzed       |            Ordered Events            |
|                     FLOW  |          Water        FLOW   Median  |
| Day Mon Year         CFS  |  Rank     Year         CFS  Plot Pos |
|---------------------------|--------------------------------------|
|  30 Mar 1924     4,280.0  |    1      2007    14,500.0    0.78   |
|  19 Dec 1924     2,980.0  |    2      1981    13,000.0    1.90   |
|  05 Sep 1926     4,380.0  |    3      1959    12,100.0    3.02   |
|  21 Mar 1927     7,460.0  |    4      1928    11,800.0    4.14   |
|  01 Dec 1927    11,800.0  |    5      2008    10,500.0    5.26   |
|  19 Jan 1929     6,010.0  |    6      2011    10,200.0    6.38   |
|  15 Jan 1930     8,580.0  |    7      1950    10,200.0    7.49   |
|  03 Apr 1931     1,290.0  |    8      1991     9,670.0    8.61   |
|  18 Jan 1932     3,400.0  |    9      1997     9,630.0    9.73   |
|  14 Mar 1933     5,760.0  |   10      2014     9,110.0   10.85   |
|  29 Mar 1934     1,700.0  |   11      2009     8,930.0   11.97   |
|  04 May 1935     2,900.0  |   12      1975     8,860.0   13.09   |
|  27 Feb 1936     6,660.0  |   13      1930     8,580.0   14.21   |
|  02 Jan 1941       958.0  |   14      1947     8,160.0   15.32   |
|  10 Apr 1942     5,760.0  |   15      2003     7,710.0   16.44   |
|  18 May 1943     4,520.0  |   16      1963     7,660.0   17.56   |
|  12 Apr 1944     5,340.0  |   17      1927     7,460.0   18.68   |
|  20 Jun 1945     6,140.0  |   18      1974     7,410.0   19.80   |
|  18 Jun 1946     6,400.0  |   19      1966     7,410.0   20.92   |
|  08 Jun 1947     8,160.0  |   20      2013     7,350.0   22.04   |
|  22 Mar 1948     4,930.0  |   21      2005     7,290.0   23.15   |
|  16 Feb 1949     3,900.0  |   22      1976     7,070.0   24.27   |
|  15 Feb 1950    10,200.0  |   23      1952     7,020.0   25.39   |
|  21 Nov 1950     4,900.0  |   24      1973     6,850.0   26.51   |
|  27 Jan 1952     7,020.0  |   25      1964     6,830.0   27.63   |
|  18 May 1953     2,370.0  |   26      2004     6,750.0   28.75   |
|  17 Apr 1954     2,470.0  |   27      1936     6,660.0   29.87   |
|  04 Mar 1955     5,100.0  |   28      1957     6,580.0   30.98   |
|  26 Feb 1956     4,700.0  |   29      1984     6,510.0   32.10   |
|  06 Apr 1957     6,580.0  |   30      2012     6,480.0   33.22   |
|  07 Dec 1957     2,470.0  |   31      1969     6,410.0   34.34   |
|  11 Feb 1959    12,100.0  |   32      1978     6,400.0   35.46   |
|  11 Feb 1960     3,370.0  |   33      1946     6,400.0   36.58   |
|  26 Apr 1961     5,620.0  |   34      1985     6,380.0   37.70   |
|  27 Jan 1962     4,380.0  |   35      1982     6,320.0   38.81   |
|  06 Mar 1963     7,660.0  |   36      1979     6,300.0   39.93   |
|  22 Apr 1964     6,830.0  |   37      2015     6,180.0   41.05   |
|  05 Mar 1965     2,290.0  |   38      1945     6,140.0   42.17   |
|  13 Jul 1966     7,410.0  |   39      1929     6,010.0   43.29   |
|  08 May 1967     5,710.0  |   40      1998     5,990.0   44.41   |
|  30 Jan 1968     4,590.0  |   41      1972     5,850.0   45.53   |
|  19 May 1969     6,410.0  |   42      1942     5,760.0   46.64   |
|  05 Mar 1970     4,180.0  |   43      1933     5,760.0   47.76   |
|  23 Feb 1971     3,540.0  |   44      1967     5,710.0   48.88   |
|  23 Apr 1972     5,850.0  |   45      1961     5,620.0   50.00   |
|  27 May 1973     6,850.0  |   46      1992     5,610.0   51.12   |
|  20 Jan 1974     7,410.0  |   47      2002     5,590.0   52.24   |
|  24 Feb 1975     8,860.0  |   48      1996     5,340.0   53.36   |
|  17 Feb 1976     7,070.0  |   49      1944     5,340.0   54.47   |
|  17 Sep 1977     3,150.0  |   50      2006     5,260.0   55.59   |
|  17 Mar 1978     6,400.0  |   51      1955     5,100.0   56.71   |
|  14 Apr 1979     6,300.0  |   52      1999     5,060.0   57.83   |
|  22 Mar 1980     4,980.0  |   53      1993     5,020.0   58.95   |
|  14 Jun 1981    13,000.0  |   54      2016     5,010.0   60.07   |
|  13 Mar 1982     6,320.0  |   55      1980     4,980.0   61.19   |
|  03 May 1983     3,140.0  |   56      1990     4,960.0   62.30   |
|  23 Apr 1984     6,510.0  |   57      1948     4,930.0   63.42   |
|  24 Feb 1985     6,380.0  |   58      1951     4,900.0   64.54   |
|  05 Feb 1986     4,060.0  |   59      1956     4,700.0   65.66   |
|  03 Dec 1986     2,780.0  |   60      1968     4,590.0   66.78   |
|  02 Feb 1988     1,530.0  |   61      1943     4,520.0   67.90   |
```

```
|  26 May 1989     4,080.0  |   62      2000     4,450.0   69.02   |
|  17 Feb 1990     4,960.0  |   63      1994     4,420.0   70.13   |
|  31 Dec 1990     9,670.0  |   64      1962     4,380.0   71.25   |
|  15 Jul 1992     5,610.0  |   65      1926     4,380.0   72.37   |
|  13 Nov 1992     5,020.0  |   66      1924     4,280.0   73.49   |
|  29 Jan 1994     4,420.0  |   67      1970     4,180.0   74.61   |
|  12 Apr 1995     3,480.0  |   68      1989     4,080.0   75.73   |
|  20 Jan 1996     5,340.0  |   69      1986     4,060.0   76.85   |
|  02 Jun 1997     9,630.0  |   70      1949     3,900.0   77.96   |
|  08 Jan 1998     5,990.0  |   71      1971     3,540.0   79.08   |
|  24 Jan 1999     5,060.0  |   72      1995     3,480.0   80.20   |
|  19 Jun 2000     4,450.0  |   73      1932     3,400.0   81.32   |
|  21 Apr 2001     2,290.0  |   74      1960     3,370.0   82.44   |
|  01 Feb 2002     5,590.0  |   75      1977     3,150.0   83.56   |
|  10 May 2003     7,710.0  |   76      1983     3,140.0   84.68   |
|  22 May 2004     6,750.0  |   77      1925     2,980.0   85.79   |
|  13 Jan 2005     7,290.0  |   78      1935     2,900.0   86.91   |
|  03 Jan 2006     5,260.0  |   79      1987     2,780.0   88.03   |
|  22 Aug 2007    14,500.0  |   80      2010     2,750.0   89.15   |
|  07 Feb 2008    10,500.0  |   81      1958     2,470.0   90.27   |
|  09 Mar 2009     8,930.0  |   82      1954     2,470.0   91.39   |
|  11 Mar 2010     2,750.0  |   83      1953     2,370.0   92.51   |
|  01 Mar 2011    10,200.0  |   84      2001     2,290.0   93.62   |
|  30 Nov 2011     6,480.0  |   85      1965     2,290.0   94.74   |
|  12 Apr 2013     7,350.0  |   86      1934     1,700.0   95.86   |
|  23 Dec 2013     9,110.0  |   87      1988     1,530.0   96.98   |
|  17 Jun 2015     6,180.0  |   88      1931     1,290.0   98.10   |
|  29 Dec 2015     5,010.0  |   89      1941       958.0*  99.22   |
|---------------------------|---------------------------------------|
                                                        * Outlier
<< Skew Weighting >>
-----------------------------------------------------------------
Based on 89 events, mean-square error of station skew =      0.11
Mean-square error of regional skew =                        0.302
-----------------------------------------------------------------

<< Frequency Curve >>
Blanchard River-Findlay OH-FLOW-ANNUAL PEAK
-------------------------------------------------------------------
|  Computed    Expected   |   Percent    |    Confidence Limits    |
|    Curve    Probability |   Chance     |        0.05       0.95 |
|        FLOW, CFS        | Exceedance  |        FLOW, CFS        |
|-------------------------|-------------|-------------------------|
|     15,324.8    15,646.1 |     0.1     |    18,335.9    13,247.9 |
|     14,691.6    14,970.0 |     0.2     |    17,489.1    12,748.4 |
|     13,749.2    13,967.3 |     0.5     |    16,239.0    12,000.1 |
|     12,943.1    13,121.1 |     1.0     |    15,179.8    11,354.9 |
|     12,041.4    12,177.9 |     2.0     |    14,006.7    10,626.9 |
|     11,024.1    11,123.5 |     4.0     |    12,699.6     9,796.9 |
|      9,449.8     9,503.4 |    10.0     |    10,715.5     8,490.7 |
|      8,013.4     8,040.0 |    20.0     |     8,953.2     7,269.8 |
|      5,511.0     5,511.0 |    50.0     |     6,029.7     5,046.1 |
|        655.6       591.3 |    99.9     |       835.9       481.9 |
|-------------------------|-------------|-------------------------|

<< Systematic Statistics >>
Blanchard River-Findlay OH-FLOW-ANNUAL PEAK
----------------------------------------------------------------
|        Log Transform:         |                               |
|          FLOW, CFS            |       Number of Events        |
|------------------------------|-------------------------------|
|  Mean                  3.716  |  Historic Events          0  |
|  Standard Dev          0.219  |  High Outliers         0     |
|  Station Skew         -0.809  |  Low Outliers          0     |
|  Regional Skew        -0.400  |  Zero Events           0     |
|  Weighted Skew        -0.700  |  Missing Events        0     |
|  Adopted Skew         -0.700  |  Systematic Events       89  |
|------------------------------|-------------------------------|

--- End of Preliminary Results ---
```

```
Note: High outlier threshold is set to lowest historic value.

----------------------
<< Low Outlier Test >>
----------------------
 Based on 89 events, 10 percent outlier test deviate K(N) = 2.977
                       Computed low outlier test value = 1,155.82

         1 low outlier(s) identified below test value of 1,155.82


     Statistics and frequency curve adjusted for 1 low outlier(s)


<< Systematic Statistics >>
Blanchard River-Findlay OH-FLOW-ANNUAL PEAK
----------------------------------------------------------------
|        Log Transform:         |                               |
|          FLOW, CFS            |       Number of Events        |
|-------------------------------|-------------------------------|
|  Mean                  3.729  |  Historic Events           1  |
|  Standard Dev          0.210  |  High Outliers          0     |
|  Station Skew         -0.506  |  Low Outliers           1     |
|  Regional Skew        -0.400  |  Zero Events            0     |
|  Weighted Skew        -0.700  |  Missing Events         0     |
|  Adopted Skew         -0.700  |  Systematic Events        89  |
|                               |  Historic Period         104  |
|-------------------------------|-------------------------------|


-----------------------
<< High Outlier Test >>
-----------------------
 Based on 88 events, 10 percent outlier test deviate K(N) = 2.973
                     Computed high outlier test value = 22,559.21

     0 high outlier(s) identified above input threshold of 14,590

    Statistics and frequency curve adjusted for 0 high outlier(s)
                                          and 1 historic event(s)


<< Systematic Statistics >>
Blanchard River-Findlay OH-FLOW-ANNUAL PEAK
----------------------------------------------------------------
|        Log Transform:         |                               |
|          FLOW, CFS            |       Number of Events        |
|-------------------------------|-------------------------------|
|  Mean                  3.728  |  Historic Events           1  |
|  Standard Dev          0.209  |  High Outliers          0     |
|  Station Skew         -0.514  |  Low Outliers           1     |
|  Regional Skew        -0.400  |  Zero Events            0     |
|  Weighted Skew        -0.700  |  Missing Events         0     |
|  Adopted Skew         -0.700  |  Systematic Events        89  |
|                               |  Historic Period         104  |
|-------------------------------|-------------------------------|


Note: Statistics and frequency curve were modified
using conditional probablity adjustment.
```

```
--- Final Results ---

<< Plotting Positions >>
Blanchard River-Findlay OH-FLOW-ANNUAL PEAK
--------------------------------------------------------------------
|     Events Analyzed       |          Ordered Events            |
|                     FLOW  |          Water          FLOW   Median  |
| Day Mon Year         CFS  |  Rank     Year          CFS  Plot Pos |
|---------------------------|--------------------------------------|
|  01 Jan 1913    14,590.0  |    1      1913    14,590.0    0.67   |
|  30 Mar 1924     4,280.0  |    2      2007    14,500.0    1.70   |
|  19 Dec 1924     2,980.0  |    3      1981    13,000.0    2.81   |
|  05 Sep 1926     4,380.0  |    4      1959    12,100.0    3.92   |
|  21 Mar 1927     7,460.0  |    5      1928    11,800.0    5.03   |
|  01 Dec 1927    11,800.0  |    6      2008    10,500.0    6.14   |
|  19 Jan 1929     6,010.0  |    7      2011    10,200.0    7.25   |
|  15 Jan 1930     8,580.0  |    8      1950    10,200.0    8.35   |
|  03 Apr 1931     1,290.0  |    9      1991     9,670.0    9.46   |
|  18 Jan 1932     3,400.0  |   10      1997     9,630.0   10.57   |
|  14 Mar 1933     5,760.0  |   11      2014     9,110.0   11.68   |
|  29 Mar 1934     1,700.0  |   12      2009     8,930.0   12.79   |
|  04 May 1935     2,900.0  |   13      1975     8,860.0   13.90   |
|  27 Feb 1936     6,660.0  |   14      1930     8,580.0   15.01   |
|  02 Jan 1941       958.0  |   15      1947     8,160.0   16.11   |
|  10 Apr 1942     5,760.0  |   16      2003     7,710.0   17.22   |
|  18 May 1943     4,520.0  |   17      1963     7,660.0   18.33   |
|  12 Apr 1944     5,340.0  |   18      1927     7,460.0   19.44   |
|  20 Jun 1945     6,140.0  |   19      1974     7,410.0   20.55   |
|  18 Jun 1946     6,400.0  |   20      1966     7,410.0   21.66   |
|  08 Jun 1947     8,160.0  |   21      2013     7,350.0   22.77   |
|  22 Mar 1948     4,930.0  |   22      2005     7,290.0   23.87   |
|  16 Feb 1949     3,900.0  |   23      1976     7,070.0   24.98   |
|  15 Feb 1950    10,200.0  |   24      1952     7,020.0   26.09   |
|  21 Nov 1950     4,900.0  |   25      1973     6,850.0   27.20   |
|  27 Jan 1952     7,020.0  |   26      1964     6,830.0   28.31   |
|  18 May 1953     2,370.0  |   27      2004     6,750.0   29.42   |
|  17 Apr 1954     2,470.0  |   28      1936     6,660.0   30.53   |
|  04 Mar 1955     5,100.0  |   29      1957     6,580.0   31.63   |
|  26 Feb 1956     4,700.0  |   30      1984     6,510.0   32.74   |
|  06 Apr 1957     6,580.0  |   31      2012     6,480.0   33.85   |
|  07 Dec 1957     2,470.0  |   32      1969     6,410.0   34.96   |
|  11 Feb 1959    12,100.0  |   33      1978     6,400.0   36.07   |
|  11 Feb 1960     3,370.0  |   34      1946     6,400.0   37.18   |
|  26 Apr 1961     5,620.0  |   35      1985     6,380.0   38.29   |
|  27 Jan 1962     4,380.0  |   36      1982     6,320.0   39.39   |
|  06 Mar 1963     7,660.0  |   37      1979     6,300.0   40.50   |
|  22 Apr 1964     6,830.0  |   38      2015     6,180.0   41.61   |
|  05 Mar 1965     2,290.0  |   39      1945     6,140.0   42.72   |
|  13 Jul 1966     7,410.0  |   40      1929     6,010.0   43.83   |
|  08 May 1967     5,710.0  |   41      1998     5,990.0   44.94   |
|  30 Jan 1968     4,590.0  |   42      1972     5,850.0   46.04   |
|  19 May 1969     6,410.0  |   43      1942     5,760.0   47.15   |
|  05 Mar 1970     4,180.0  |   44      1933     5,760.0   48.26   |
|  23 Feb 1971     3,540.0  |   45      1967     5,710.0   49.37   |
|  23 Apr 1972     5,850.0  |   46      1961     5,620.0   50.48   |
|  27 May 1973     6,850.0  |   47      1992     5,610.0   51.59   |
|  20 Jan 1974     7,410.0  |   48      2002     5,590.0   52.70   |
|  24 Feb 1975     8,860.0  |   49      1996     5,340.0   53.80   |
|  17 Feb 1976     7,070.0  |   50      1944     5,340.0   54.91   |
|  17 Sep 1977     3,150.0  |   51      2006     5,260.0   56.02   |
|  17 Mar 1978     6,400.0  |   52      1955     5,100.0   57.13   |
|  14 Apr 1979     6,300.0  |   53      1999     5,060.0   58.24   |
|  22 Mar 1980     4,980.0  |   54      1993     5,020.0   59.35   |
|  14 Jun 1981    13,000.0  |   55      2016     5,010.0   60.46   |
|  13 Mar 1982     6,320.0  |   56      1980     4,980.0   61.56   |
|  03 May 1983     3,140.0  |   57      1990     4,960.0   62.67   |
|  23 Apr 1984     6,510.0  |   58      1948     4,930.0   63.78   |
|  24 Feb 1985     6,380.0  |   59      1951     4,900.0   64.89   |
|  05 Feb 1986     4,060.0  |   60      1956     4,700.0   66.00   |
```

```
|  03 Dec 1986     2,780.0  |   61      1968     4,590.0   67.11   |
|  02 Feb 1988     1,530.0  |   62      1943     4,520.0   68.22   |
|  26 May 1989     4,080.0  |   63      2000     4,450.0   69.32   |
|  17 Feb 1990     4,960.0  |   64      1994     4,420.0   70.43   |
|  31 Dec 1990     9,670.0  |   65      1962     4,380.0   71.54   |
|  15 Jul 1992     5,610.0  |   66      1926     4,380.0   72.65   |
|  13 Nov 1992     5,020.0  |   67      1924     4,280.0   73.76   |
|  29 Jan 1994     4,420.0  |   68      1970     4,180.0   74.87   |
|  12 Apr 1995     3,480.0  |   69      1989     4,080.0   75.98   |
|  20 Jan 1996     5,340.0  |   70      1986     4,060.0   77.08   |
|  02 Jun 1997     9,630.0  |   71      1949     3,900.0   78.19   |
|  08 Jan 1998     5,990.0  |   72      1971     3,540.0   79.30   |
|  24 Jan 1999     5,060.0  |   73      1995     3,480.0   80.41   |
|  19 Jun 2000     4,450.0  |   74      1932     3,400.0   81.52   |
|  21 Apr 2001     2,290.0  |   75      1960     3,370.0   82.63   |
|  01 Feb 2002     5,590.0  |   76      1977     3,150.0   83.73   |
|  10 May 2003     7,710.0  |   77      1983     3,140.0   84.84   |
|  22 May 2004     6,750.0  |   78      1925     2,980.0   85.95   |
|  13 Jan 2005     7,290.0  |   79      1935     2,900.0   87.06   |
|  03 Jan 2006     5,260.0  |   80      1987     2,780.0   88.17   |
|  22 Aug 2007    14,500.0  |   81      2010     2,750.0   89.28   |
|  07 Feb 2008    10,500.0  |   82      1958     2,470.0   90.39   |
|  09 Mar 2009     8,930.0  |   83      1954     2,470.0   91.49   |
|  11 Mar 2010     2,750.0  |   84      1953     2,370.0   92.60   |
|  01 Mar 2011    10,200.0  |   85      2001     2,290.0   93.71   |
|  30 Nov 2011     6,480.0  |   86      1965     2,290.0   94.82   |
|  12 Apr 2013     7,350.0  |   87      1934     1,700.0   95.93   |
|  23 Dec 2013     9,110.0  |   88      1988     1,530.0   97.04   |
|  17 Jun 2015     6,180.0  |   89      1931     1,290.0   98.15   |
|  29 Dec 2015     5,010.0  |   90      1941       958.0*  99.25   |
|---------------------------|---------------------------------------|
|      Note: Plotting positions based on historic period (H) = 104 |
|             Number of historic events plus high outliers (Z) = 1 |
|              Weighting factor for systematic events (W) = 1.1573 |
--------------------------------------------------------------------
                                                          * Outlier


<< Skew Weighting >>
-----------------------------------------------------------------
Based on 104 events, mean-square error of station skew =    0.076
Mean-square error of regional skew =                        0.302
-----------------------------------------------------------------


<< Frequency Curve >>
Blanchard River-Findlay OH-FLOW-ANNUAL PEAK
-------------------------------------------------------------------
|  Computed    Expected   |   Percent    |    Confidence Limits    |
|    Curve    Probability |   Chance     |        0.05       0.95 |
|        FLOW, CFS        | Exceedance   |        FLOW, CFS        |
|-------------------------|--------------|-------------------------|
|    17,116.5    17,627.6 |      0.1     |    20,649.2    14,715.0 |
|    16,156.2    16,576.7 |      0.2     |    19,351.4    13,964.1 |
|    14,810.6    15,119.5 |      0.5     |    17,552.0    12,902.8 |
|    13,726.8    13,964.6 |      1.0     |    16,120.2    12,039.4 |
|    12,576.4    12,749.5 |      2.0     |    14,619.1    11,113.4 |
|    11,346.2    11,464.9 |      4.0     |    13,037.1    10,110.5 |
|     9,558.6     9,618.5 |     10.0     |    10,787.9     8,625.4 |
|     8,027.7     8,055.9 |     20.0     |     8,918.1     7,319.4 |
|     5,530.2     5,530.2 |     50.0     |     6,020.3     5,085.9 |
|       874.5       804.9 |     99.9     |     1,083.6       667.1 |
|-------------------------|--------------|-------------------------|
```

```
<< Synthetic Statistics >>
Blanchard River-Findlay OH-FLOW-ANNUAL PEAK
----------------------------------------------------------------
|        Log Transform:         |                               |
|          FLOW, CFS            |       Number of Events        |
|------------------------------|-------------------------------|
|  Mean                  3.726  |  Historic Events           1  |
|  Standard Dev          0.208  |  High Outliers          0     |
|  Station Skew         -0.490  |  Low Outliers           1     |
|  Regional Skew        -0.400  |  Zero Events            0     |
|  Weighted Skew        -0.472  |  Missing Events         0     |
|  Adopted Skew         -0.472  |  Systematic Events        89  |
|                               |  Historic Period         104  |
|------------------------------|-------------------------------|

--- End of Analytical Frequency Curve ---
```

Appendix B HEC-HMS MODEL SUPPORT DATA

Table 6 - HEC-HMS Model NLCD/TR55 Landuse Linkage

NLCD Landuse		TR-55 Landuse Translation	% of Watershed	SCS Curve Number Hydrologic Soil Group			
Code	**Description**	**Description**		**A**	**B**	**C**	**D**
11	Open Water	Impervious Area	0.6%	98	98	98	98
21	Developed, Open Space	Open Space, Poor Condition	6.9%	68	79	86	89
22	Developed, Low Intensity	Residential, 1/2 acre lots	3.7%	54	70	80	85
23	Developed, Medium Intensity	Residential, 1/4 acre lots	1.3%	61	75	83	87
24	Developed, High Intensity	Residential, 1/8 acre lots	0.6%	77	85	90	92
31	Barren Land (Rock/Sand/Clay)	Newly Graded Areas	0.1%	77	86	91	94
41	Deciduous Forest	Woods, Fair Condition	6.1%	36	60	73	79
42	Evergreen Forest	Woods, Good Condition	0.0%	30	55	70	77
43	Mixed Forest	Woods, Poor Condition	0.0%	45	66	77	83
71	Grassland / Herbaceous	Pasture, Good Condition	1.8%	39	61	74	80
81	Pasture / Hay	Pasture, Fair Condition	1.5%	49	69	79	84
82	Cultivated Crops	Row Crops, Straight, Good Condition	76.9%	67	78	85	89
90	Woody Wetlands	Brush, Poor Condition	0.1%	48	67	77	83
95	Emergent Herbaceous Wetlands	Brush, Poor Condition	0.3%	48	67	77	83
			% of Watershed	0.6%	0.6%	2.8%	96.1%

Table 7 - HEC-HMS Model Parameter Summary – Subbasins (Hypothetical Geometry)

		Loss Method		Transform Method		Baseflow Method		
		SCS CN (Grid)		ModClark		Recession - Discharge / Unit Area		
Subbasin	Area (sq-mi)	Ratio	Factor	Time of Concentration (hours)	Storage Coefficient (hours)	Initial Discharge Ratio	Recession Constant	Ratio to Peak
Aurand_Trib_01	4.49456	0.100	0.800	7.5	15.8	0.90	0.90	0.02
Aurand_01	1.35477	0.100	0.800	5.0	10.6	0.90	0.90	0.02
Aurand_02	4.65369	0.100	0.800	8.1	17.0	0.90	0.90	0.02
Aurand_03	2.05036	0.100	0.800	8.0	16.9	0.90	0.90	0.02
Aurand_04	2.48329	0.100	0.800	7.0	14.9	0.90	0.90	0.02
Aurand_05	1.61275	0.100	0.800	7.7	16.3	0.90	0.90	0.02
Brights_01	2.83366	0.100	0.800	6.6	32.9	1.50	0.90	0.05
Brights_02	4.58726	0.100	0.800	6.7	33.7	1.50	0.90	0.05
Brights_03	4.16126	0.100	0.800	4.7	23.6	1.50	0.90	0.05
BR_UT_01	6.87143	0.100	0.800	11.6	24.5	0.90	0.90	0.02
BR_UT_02	4.71974	0.100	0.800	9.9	20.9	0.90	0.90	0.02
BR_UT_03	8.47815	0.050	0.250	10.0	23.3	1.00	0.90	0.01
BR_UT_04	7.87170	0.050	0.250	8.2	19.2	1.00	0.90	0.01
BR_UT_05_01	3.90651	0.050	0.250	4.1	10.8	1.00	0.90	0.01
BR_UT_05_02	6.97983	0.050	0.250	5.8	15.4	1.00	0.90	0.01
BR_UT_06	5.80165	0.050	0.250	6.3	16.9	1.00	0.90	0.01
BR_01	3.33344	0.100	0.800	7.1	14.9	0.90	0.90	0.02
BR_02	5.43133	0.100	0.800	9.8	20.6	0.90	0.90	0.02
BR_03	3.17725	0.100	0.800	8.8	18.5	0.90	0.90	0.02
BR_04	2.49105	0.100	0.800	11.8	25.0	0.90	0.90	0.02
BR_05	3.40561	0.200	1.500	6.4	9.6	0.50	0.90	0.05
BR_06	2.85738	0.200	1.500	8.2	12.3	0.50	0.90	0.05
BR_07	1.12919	0.200	1.500	7.2	10.7	0.50	0.90	0.05
BR_08	6.34916	0.200	1.500	9.9	14.9	0.50	0.90	0.05
BR_09	5.75170	0.200	1.500	8.7	13.1	0.50	0.90	0.05
BR_10	3.55180	0.100	0.800	3.5	17.6	1.50	0.90	0.05
BR_11	3.79895	0.100	0.800	5.9	29.5	1.50	0.90	0.05
BR_12	3.33920	0.100	0.800	4.0	19.8	1.50	0.90	0.05
BR_13	3.41588	0.050	1.200	10.1	53.6	1.50	0.90	0.05
BR_14	0.86954	0.050	0.250	3.5	8.1	1.00	0.90	0.01
BR_15	3.63388	0.050	0.250	6.4	14.8	1.00	0.90	0.01
BR_16	0.25546	0.050	0.250	1.0	2.4	1.00	0.90	0.01
BR_17	0.64167	0.050	0.250	2.7	6.2	1.00	0.90	0.01

		Loss Method		**Transform Method**		**Baseflow Method**		
		SCS CN (Grid)		ModClark		Recession - Discharge / Unit Area		
Subbasin	Area (sq-mi)	Ratio	Factor	Time of Concentration (hours)	Storage Coefficient (hours)	Initial Discharge Ratio	Recession Constant	Ratio to Peak
BR_18	2.01279	0.050	0.250	2.6	6.0	1.00	0.90	0.01
BR_19	2.79108	0.050	0.250	4.9	11.5	1.00	0.90	0.01
BR_20	4.31911	0.050	0.250	5.6	13.1	1.00	0.90	0.01
BR_21	3.30564	0.050	0.250	6.4	17.2	1.00	0.90	0.01
BR_22	0.20520	0.050	0.250	1.2	3.2	1.00	0.90	0.01
BR_23	0.91675	0.050	0.250	2.8	7.4	1.00	0.90	0.01
BR_24	3.39536	0.050	0.250	6.5	17.4	1.00	0.90	0.01
BR_25	0.18619	0.050	0.250	1.6	4.2	1.00	0.90	0.01
BR_26	4.41753	0.050	0.250	6.7	19.0	1.00	0.90	0.01
BR_27	4.19643	0.050	0.250	5.4	15.3	1.00	0.90	0.01
BR_28	7.30912	0.050	0.250	7.3	20.6	1.00	0.90	0.01
Buckrun_Creek	9.87749	0.050	1.200	15.1	90.6	1.50	0.90	0.05
Buck_Run	5.86944	0.050	1.200	12.8	4.3	0.70	0.90	0.01
Cessna_Ck_01	0.23087	0.050	0.250	1.3	3.4	1.00	0.90	0.01
Cessna_Ck_02	5.09014	0.050	0.250	4.3	11.6	1.00	0.90	0.01
Cessna_UT_01	4.41856	0.050	0.250	5.5	14.6	1.00	0.90	0.01
Eagle_01	1.29007	0.200	1.500	8.7	13.0	0.50	0.90	0.05
Eagle_02	3.82090	0.200	1.500	9.5	14.2	0.50	0.90	0.05
Eagle_03	1.38015	0.200	1.500	7.6	11.5	0.50	0.90	0.05
Eagle_04	2.47872	0.200	1.500	8.3	12.4	0.50	0.90	0.05
Eagle_05	0.78482	0.200	1.500	7.2	10.8	0.50	0.90	0.05
Eagle_06	1.28442	0.050	1.000	2.6	3.8	0.70	0.90	0.01
Eagle_07	5.65467	0.050	1.000	5.3	8.0	0.70	0.90	0.01
Eagle_08	3.99742	0.050	1.000	4.6	6.8	0.70	0.90	0.01
Eagle_09	2.98628	0.050	1.000	4.3	6.5	0.70	0.90	0.01
Eagle_10	5.16309	0.050	1.000	6.1	9.2	0.70	0.90	0.01
Eagle_11	0.93828	0.050	1.000	2.7	4.1	0.70	0.90	0.01
Eagle_12	2.83092	0.050	1.200	7.4	2.5	0.70	0.90	0.01
Eagle_13	3.64121	0.050	1.200	8.1	2.7	0.70	0.90	0.01
Eagle_14	2.96949	0.050	1.200	8.1	2.7	0.70	0.90	0.01
Eagle_15	7.29972	0.050	1.200	11.5	3.8	0.70	0.90	0.01
Flat_Branch_01	0.14956	0.050	1.200	1.2	1.8	0.70	0.90	0.01
Flat_Branch_02	6.67580	0.050	1.200	13.1	4.4	0.70	0.90	0.01
Flat_Branch_03	4.21592	0.050	1.200	10.0	3.4	0.70	0.90	0.01

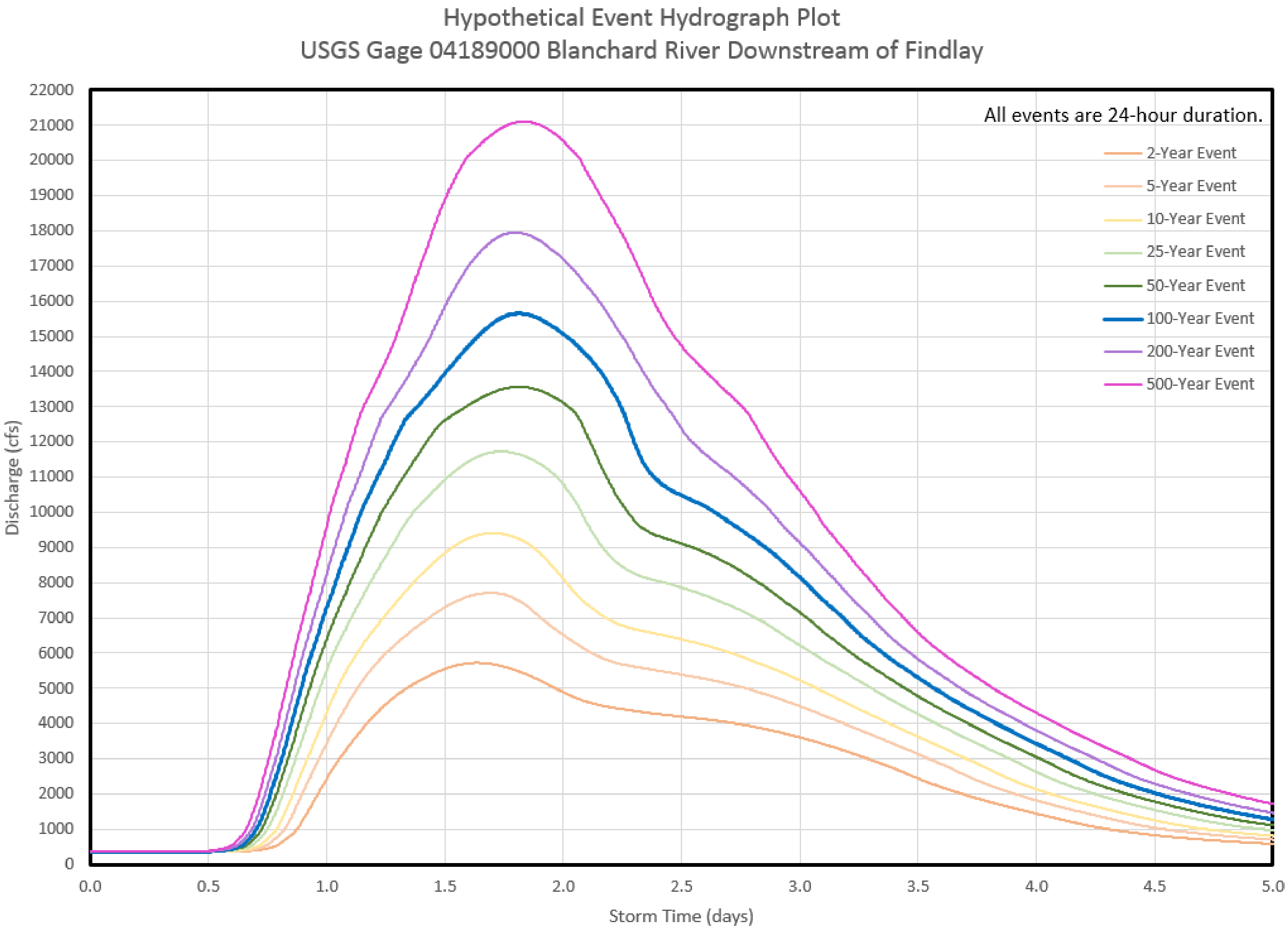
		Loss Method		Transform Method		Baseflow Method		
		SCS CN (Grid)		ModClark		Recession - Discharge / Unit Area		
Subbasin	Area (sq-mi)	Ratio	Factor	Time of Concentration (hours)	Storage Coefficient (hours)	Initial Discharge Ratio	Recession Constant	Ratio to Peak
Fourmile_Run_01	7.23825	0.050	0.250	6.8	19.3	1.00	0.90	0.01
Fourmile_Run_02	6.23404	0.050	0.250	4.9	13.9	1.00	0.90	0.01
Howard_Run	5.13442	0.200	1.500	7.9	11.8	0.50	0.90	0.05
Lye_01	0.98623	0.200	1.500	12.4	18.7	0.50	0.90	0.05
Lye_02	2.93308	0.200	1.500	11.4	17.0	0.50	0.90	0.05
Lye_03	3.09764	0.200	1.500	8.8	13.1	0.50	0.90	0.05
Lye_04	2.14784	0.200	1.500	10.1	15.2	0.50	0.90	0.05
Lye_05	1.38881	0.200	1.500	7.9	11.8	0.50	0.90	0.05
Lye_06	0.71725	0.100	1.000	3.8	12.8	0.50	0.90	0.03
Lye_07	4.26122	0.100	1.000	9.1	26.3	0.50	0.90	0.03
Lye_08	6.10663	0.100	1.000	6.8	19.6	0.50	0.90	0.03
Lye_09	6.76232	0.200	1.500	9.7	3.2	0.50	0.90	0.03
Potato_01	5.84167	0.050	0.250	7.4	17.3	1.00	0.90	0.01
Potato_02	4.48842	0.050	0.250	5.4	12.6	1.00	0.90	0.01
Potato_03	4.12563	0.050	0.250	4.7	11.0	1.00	0.90	0.01
Potato_04	6.36293	0.050	0.250	5.2	12.0	1.00	0.90	0.01
Potato_05	7.16129	0.050	0.250	5.8	13.6	1.00	0.90	0.01
Ripley_Run	5.73986	0.050	0.250	5.3	12.4	1.00	0.90	0.01
Stahl_01	1.75367	0.100	0.800	3.8	18.8	1.50	0.90	0.05
Stahl_02	3.20619	0.100	0.800	6.3	31.6	1.50	0.90	0.05
Stahl_03	8.99017	0.050	1.200	9.4	48.0	1.50	0.90	0.05
Stahl_04	5.29128	0.050	1.200	9.4	47.9	1.50	0.90	0.05
The_Outlet_North_01	4.19666	0.050	0.250	5.8	15.4	1.00	0.90	0.01
The_Outlet_North_02	8.31070	0.050	0.250	6.1	16.3	1.00	0.90	0.01
The_Outlet_01	9.77788	0.100	0.800	6.8	33.8	1.50	0.90	0.05
The_Outlet_02	6.95405	0.100	0.800	5.9	29.5	1.50	0.90	0.05
The_Outlet_03	9.67070	0.100	0.800	5.0	25.2	1.50	0.90	0.05
The_Outlet_04	7.30965	0.100	0.800	4.6	23.1	1.50	0.90	0.05
The_Outlet_05	4.96085	0.100	0.800	6.2	31.0	1.50	0.90	0.05

Table 8 - HEC-HMS Model Parameter Summary – Reaches (Hypothetical Geometry)

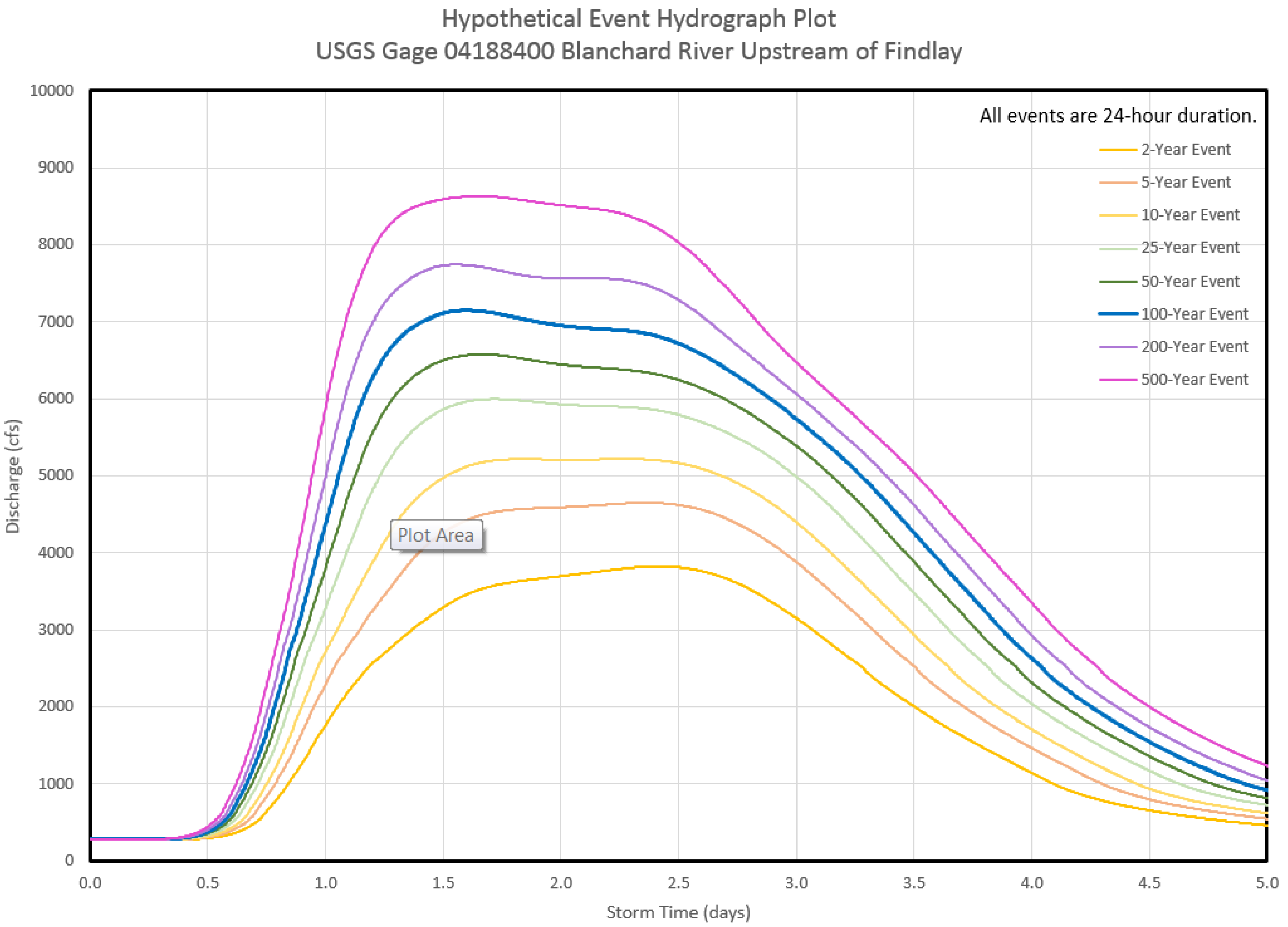
Reach	Name	Length	Slope	Routing Method	Velocity	Lag Time
R_01	Blanchard River	10,800	0.0001	Modified Puls	N/A	N/A
R_02	Blanchard River	25,400	0.0001	Modified Puls	N/A	N/A
R_03	Blanchard River	11,000	0.0003	Modified Puls	N/A	N/A
R_04	Blanchard River	4,900	0.0003	Modified Puls	N/A	N/A
R_05	Blanchard River	7,900	0.0001	Modified Puls	N/A	N/A
R_06	Blanchard River	6,700	0.0012	Modified Puls	N/A	N/A
R_07	Blanchard River	1,500	0.0004	Modified Puls	N/A	N/A
R_08	Blanchard River	18,600	0.0001	Modified Puls	N/A	N/A
R_09	Blanchard River	2,100	0.0004	Modified Puls	N/A	N/A
R_10	Blanchard River	6,200	0.0004	Modified Puls	N/A	N/A
R_11	Blanchard River	11,700	0.0001	Modified Puls	N/A	N/A
R_12	Blanchard River	20,400	0.0001	Modified Puls	N/A	N/A
R_13	Blanchard River	31,600	0.0001	Modified Puls	N/A	N/A
R_14	Blanchard River	3,300	0.0006	Modified Puls	N/A	N/A
R_15	Blanchard River	19,100	0.0001	Modified Puls	N/A	N/A
R_16	Blanchard River	2,200	0.0009	Modified Puls	N/A	N/A
R_17	Blanchard River	5,500	0.001	Modified Puls	N/A	N/A
R_18	Blanchard River	12,700	0.0012	Modified Puls	N/A	N/A
R_19	Blanchard River	22,600	0.0001	Lag	1.05	360
R_20	Blanchard River	18,800	0.0005	Lag	1.03	305
R_21	Blanchard River	27,000	0.0003	Lag	1.02	440
R_22	Blanchard River	2,900	0.0001	Lag	1.93	25
R_23	Blanchard River	8,300	0.0006	Lag	1.02	135
R_24	Cessna Creek	3,000	0.0029	Lag	2.00	25
R_25	Cessna Creek	20,900	0.0004	Lag	1.07	325
R_26	Fourmile Run	12,100	0.0004	Lag	1.06	190
R_27	Aurand Run	14,400	0.0015	Modified Puls	N/A	N/A
R_28	Aurand Run	17,700	0.0012	Modified Puls	N/A	N/A
R_29	Aurand Run	4,600	0.0002	Modified Puls	N/A	N/A
R_30	Aurand Run	2,800	0.0009	Modified Puls	N/A	N/A
R_31	Eagle Creek	8,400	0.0012	Modified Puls	N/A	N/A
R_32	Eagle Creek	12,000	0.0008	Modified Puls	N/A	N/A
R_33	Eagle Creek	4,000	0.0014	Modified Puls	N/A	N/A
R_34	Eagle Creek	3,200	0.0001	Modified Puls	N/A	N/A
R_35	Eagle Creek	10,200	0.0001	Modified Puls	N/A	N/A

Reach	Name	Length	Slope	Routing Method	Velocity	Lag Time
R_36	Eagle Creek	12,000	0.0003	Modified Puls	N/A	N/A
R_37	Eagle Creek	12,900	0.001	Lag	1.26	170
R_38	Eagle Creek	21,500	0.0009	Lag	1.30	275
R_39	Eagle Creek	14,400	0.0015	Lag	0.79	305
R_40	Eagle Creek	21,700	0.0005	Lag	0.79	455
R_41	Flat Branch	5,300	0.0012	Lag	0.80	110
R_42	Lye Creek	6,900	0.0007	Modified Puls	N/A	N/A
R_43	Lye Creek	10,100	0.0002	Modified Puls	N/A	N/A
R_44	Lye Creek	12,100	0.0011	Modified Puls	N/A	N/A
R_45	Lye Creek	1,600	0.0002	Lag	0.59	45
R_46	Lye Creek	21,500	0.0004	Lag	N/A	N/A
R_47	The Outlet	15,700	0.0001	Lag	0.62	580
R_48	The Outlet	10,700	0.0001	Lag	2.38	110
R_49	The Outlet	13,000	0.0001	Lag	2.38	75
R_50	Stahl Run	9,300	0.0003	Lag	2.41	90
R_51	Stahl Run	25,500	0.0011	Lag	2.38	65
R_52	Stahl Run	21,600	0.0005	Lag	2.36	180
R_53	Brights Run	8,900	0.0001	Lag	2.32	155
R_54	Potato Run	19,200	0.0002	Modified Puls	2.47	60
R_55	Potato Run	18,300	0.0003	Lag	N/A	N/A
R_56	Potato Run	13,300	0.0005	Lag	1.36	225
R_57	The Outlet (North)	21,300	0.0013	Lag	1.34	165
R_58	Unnamed Trib 05	13,000	0.0001	Lag	1.31	270
R_59	Blanchard River	11,400	0.0005	Lag	1.31	165
R_60	Blanchard River	2,400	0.0021	Lag	1.27	150

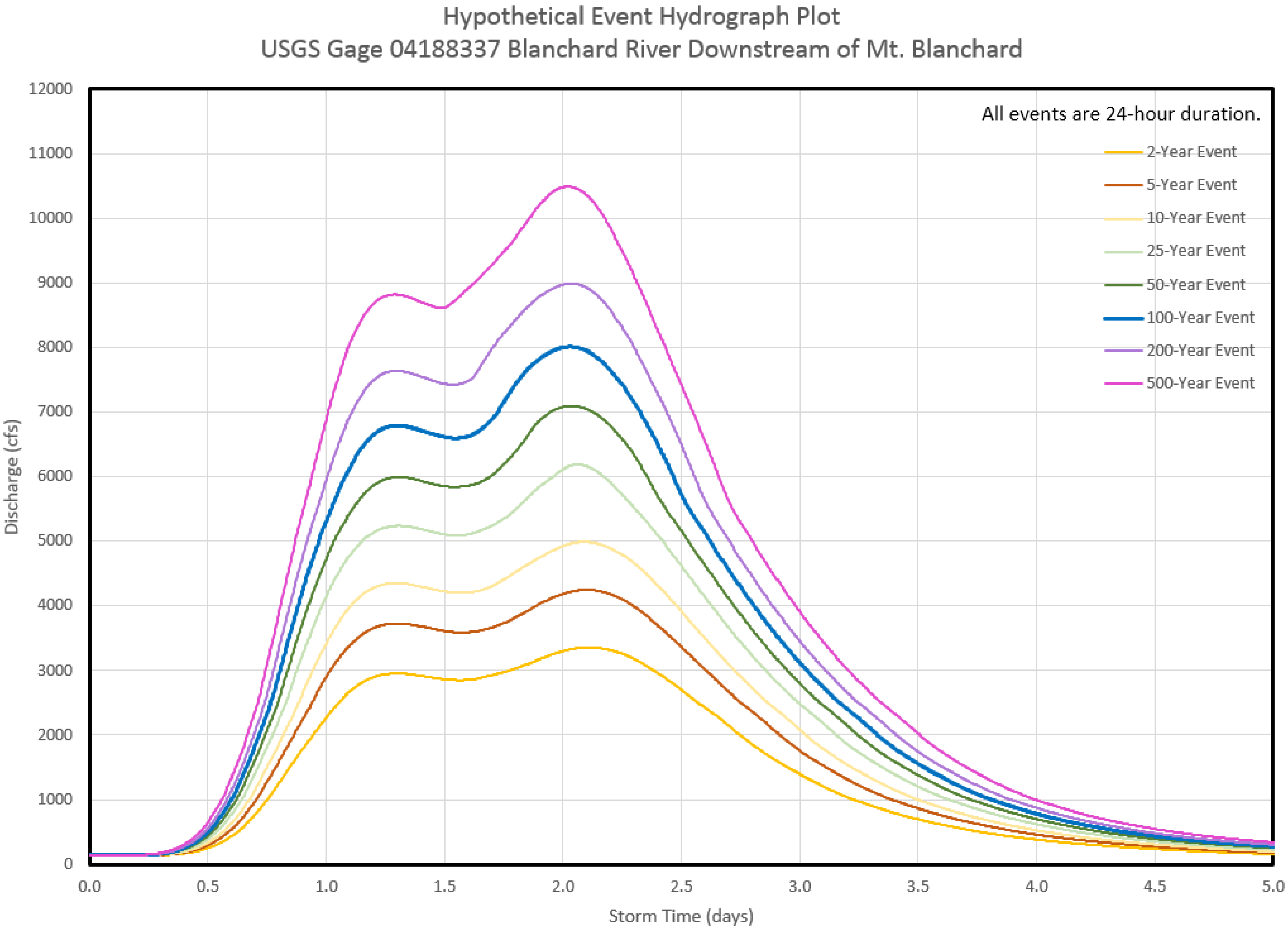
USGS Gage 04189000 Blanchard River Downstream of Findlay (Using September 2011 Calibrated Geometry)



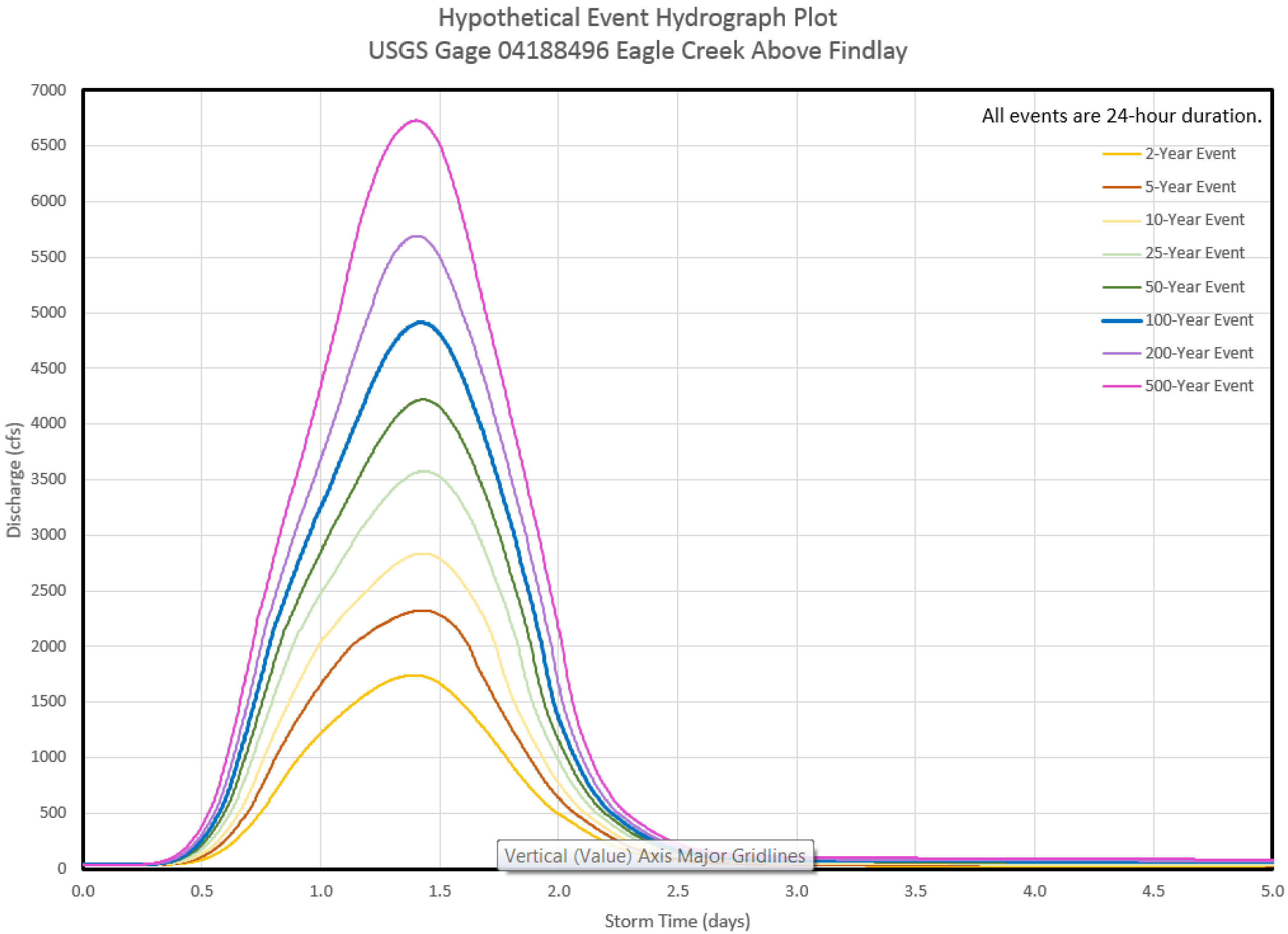
USGS Gage 04188400 Blanchard River Upstream of Findlay (Using September 2011 Calibrated Geometry)



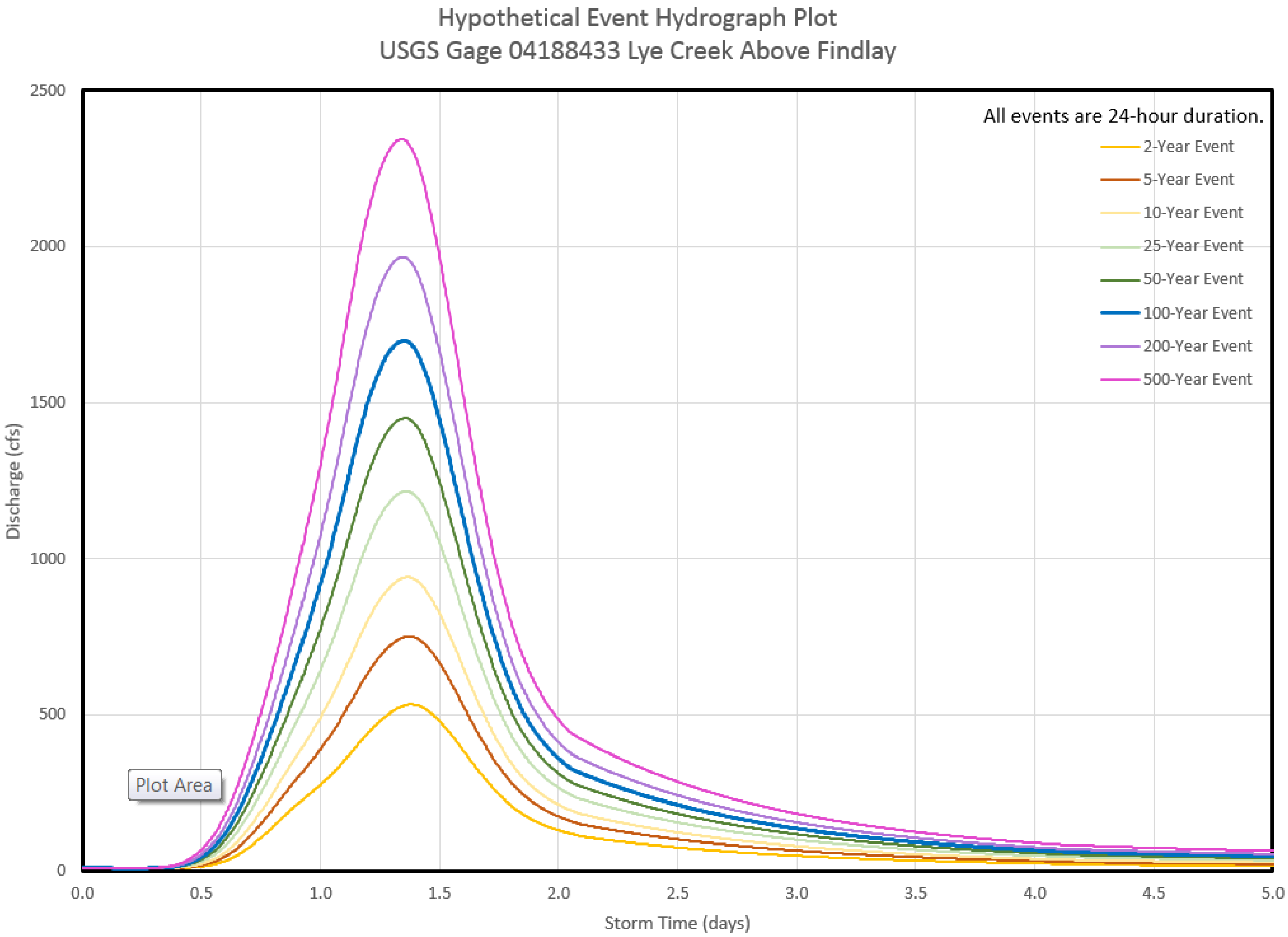
USGS Gage 04188337 Blanchard River Downstream of Mt. Blanchard (Using September 2011 Calibrated Geometry)



USGS Gage 04188496 Eagle Creek Above Findlay (Using September 2011 Calibrated Geometry)



USGS Gage 04188433 Lye Creek Above Findlay (Using September 2011 Calibrated Geometry)



Appendix C CALIBRATION DATA

Subbasin Parameter Calibration – September 2011

	Original Values							September 2011 Calibration						
	Loss (Gridded CN)		Transform		Baseflow			Loss (Gridded CN)		Transform		Baseflow		
Subbasin	Ratio	Factor	Time of Concentration	Storage Coefficient	Initial Discharge Ratio	Recession Constant	Ratio to Peak	Ratio	Factor	Tc Multiplier	R Multiplier	Initial Discharge Ratio	Recession Constant	Ratio to Peak
Average	0.20	1.00			0.50	0.90	0.05	0.09	0.79	1.14	1.81	0.93	0.90	0.026
Aurand_Trib_01	0.20	1.0	5.53	8.30	0.5	0.9	0.05	0.10	0.8	1.35	1.90	0.9	0.9	0.02
Aurand_01	0.20	1.0	3.72	5.58	0.5	0.9	0.05	0.10	0.8	1.35	1.90	0.9	0.9	0.02
Aurand_02	0.20	1.0	5.98	8.97	0.5	0.9	0.05	0.10	0.8	1.35	1.90	0.9	0.9	0.02
Aurand_03	0.20	1.0	5.93	8.90	0.5	0.9	0.05	0.10	0.8	1.35	1.90	0.9	0.9	0.02
Aurand_04	0.20	1.0	5.21	7.82	0.5	0.9	0.05	0.10	0.8	1.35	1.90	0.9	0.9	0.02
Aurand_05	0.20	1.0	5.73	8.60	0.5	0.9	0.05	0.10	0.8	1.35	1.90	0.9	0.9	0.02
Brights_01	0.20	1.0	7.32	10.98	0.5	0.9	0.05	0.10	0.80	0.90	3.00	1.5	0.9	0.05
Brights_02	0.20	1.0	7.48	11.22	0.5	0.9	0.05	0.10	0.80	0.90	3.00	1.5	0.9	0.05
Brights_03	0.20	1.0	5.24	7.86	0.5	0.9	0.05	0.10	0.80	0.90	3.00	1.5	0.9	0.05
BR_UT_01	0.20	1.0	8.59	12.89	0.5	0.9	0.05	0.10	0.8	1.35	1.90	0.9	0.9	0.02
BR_UT_02	0.20	1.0	7.34	11.01	0.5	0.9	0.05	0.10	0.8	1.35	1.90	0.9	0.9	0.02
BR_UT_03	0.20	1.0	11.07	16.61	0.5	0.9	0.05	0.05	0.25	0.90	1.40	1.0	0.9	0.01
BR_UT_04	0.20	1.0	9.16	13.74	0.5	0.9	0.05	0.05	0.25	0.90	1.40	1.0	0.9	0.01
BR_UT_05_01	0.20	1.0	4.51	6.77	0.5	0.9	0.05	0.05	0.25	0.90	1.60	1.0	0.9	0.01
BR_UT_05_02	0.20	1.0	6.40	9.60	0.5	0.9	0.05	0.05	0.25	0.90	1.60	1.0	0.9	0.01
BR_UT_06	0.20	1.0	7.03	10.55	0.5	0.9	0.05	0.05	0.25	0.90	1.60	1.0	0.9	0.01
BR_01	0.20	1.0	5.23	7.85	0.5	0.9	0.05	0.10	0.8	1.35	1.90	0.9	0.9	0.02
BR_02	0.20	1.0	7.24	10.86	0.5	0.9	0.05	0.10	0.8	1.35	1.90	0.9	0.9	0.02
BR_03	0.20	1.0	6.50	9.75	0.5	0.9	0.05	0.10	0.8	1.35	1.90	0.9	0.9	0.02
BR_04	0.20	1.0	8.75	13.13	0.5	0.9	0.05	0.10	0.8	1.34	1.90	0.9	0.9	0.02
BR_05	0.20	1.0	3.42	5.13	0.5	0.9	0.05	0.20	1.50	1.88	1.88	0.5	0.9	0.05
BR_06	0.20	1.0	5.19	7.79	0.5	0.9	0.05	0.20	1.50	1.58	1.58	0.5	0.9	0.05
BR_07	0.20	1.0	4.16	6.24	0.5	0.9	0.05	0.20	1.50	1.72	1.72	0.5	0.9	0.05
BR_08	0.20	1.0	6.91	10.37	0.5	0.9	0.05	0.20	1.50	1.43	1.43	0.5	0.9	0.05
BR_09	0.20	1.0	5.70	8.55	0.5	0.9	0.05	0.20	1.50	1.53	1.53	0.5	0.9	0.05
BR_10	0.20	1.0	3.91	5.87	0.5	0.9	0.05	0.10	0.80	0.90	3.00	1.5	0.9	0.05
BR_11	0.20	1.0	6.56	9.84	0.5	0.9	0.05	0.10	0.80	0.90	3.00	1.5	0.9	0.05
BR_12	0.20	1.0	4.40	6.60	0.5	0.9	0.05	0.10	0.80	0.90	3.00	1.5	0.9	0.05
BR_13	0.20	1.0	7.14	10.71	0.5	0.9	0.05	0.05	1.20	1.42	5.00	1.5	0.9	0.05

	Original Values							September 2011 Calibration						
	Loss (Gridded CN)		Transform		Baseflow			Loss (Gridded CN)		Transform		Baseflow		
Subbasin	Ratio	Factor	Time of Concentration	Storage Coefficient	Initial Discharge Ratio	Recession Constant	Ratio to Peak	Ratio	Factor	Tc Multiplier	R Multiplier	Initial Discharge Ratio	Recession Constant	Ratio to Peak
BR_14	0.20	1.0	3.87	5.81	0.5	0.9	0.05	0.05	0.25	0.90	1.40	1.0	0.9	0.01
BR_15	0.20	1.0	7.06	10.59	0.5	0.9	0.05	0.05	0.25	0.90	1.40	1.0	0.9	0.01
BR_16	0.20	1.0	1.14	1.71	0.5	0.9	0.05	0.05	0.25	0.90	1.40	1.0	0.9	0.01
BR_17	0.20	1.0	2.97	4.46	0.5	0.9	0.05	0.05	0.25	0.90	1.40	1.0	0.9	0.01
BR_18	0.20	1.0	2.87	4.31	0.5	0.9	0.05	0.05	0.25	0.90	1.40	1.0	0.9	0.01
BR_19	0.20	1.0	5.49	8.24	0.5	0.9	0.05	0.05	0.25	0.90	1.40	1.0	0.9	0.01
BR_20	0.20	1.0	6.23	9.35	0.5	0.9	0.05	0.05	0.25	0.90	1.40	1.0	0.9	0.01
BR_21	0.20	1.0	7.16	10.74	0.5	0.9	0.05	0.05	0.25	0.90	1.60	1.0	0.9	0.01
BR_22	0.20	1.0	1.34	2.01	0.5	0.9	0.05	0.05	0.25	0.90	1.60	1.0	0.9	0.01
BR_23	0.20	1.0	3.10	4.65	0.5	0.9	0.05	0.05	0.25	0.90	1.60	1.0	0.9	0.01
BR_24	0.20	1.0	7.26	10.89	0.5	0.9	0.05	0.05	0.25	0.90	1.60	1.0	0.9	0.01
BR_25	0.20	1.0	1.76	2.64	0.5	0.9	0.05	0.05	0.25	0.90	1.60	1.0	0.9	0.01
BR_26	0.20	1.0	7.44	11.16	0.5	0.9	0.05	0.05	0.25	0.90	1.70	1.0	0.9	0.01
BR_27	0.20	1.0	6.00	9.00	0.5	0.9	0.05	0.05	0.25	0.90	1.70	1.0	0.9	0.01
BR_28	0.20	1.0	8.07	12.11	0.5	0.9	0.05	0.05	0.25	0.90	1.70	1.0	0.9	0.01
Buckrun_Creek	0.20	1.0	12.08	18.12	0.5	0.9	0.05	0.05	1.20	1.25	5.00	1.5	0.9	0.05
Buck_Run	0.20	1.0	9.84	14.76	0.5	0.9	0.05	0.05	1.00	1.30	0.29	0.7	0.9	0.01
Cessna_Ck_01	0.20	1.0	1.43	2.15	0.5	0.9	0.05	0.05	0.25	0.90	1.60	1.0	0.9	0.01
Cessna_Ck_02	0.20	1.0	4.82	7.23	0.5	0.9	0.05	0.05	0.25	0.90	1.60	1.0	0.9	0.01
Cessna_UT_01	0.20	1.0	6.09	9.14	0.5	0.9	0.05	0.05	0.25	0.90	1.60	1.0	0.9	0.01
Eagle_01	0.20	1.0	5.67	8.51	0.5	0.9	0.05	0.20	1.50	1.53	1.53	0.5	0.9	0.05
Eagle_02	0.20	1.0	6.48	9.72	0.5	0.9	0.05	0.20	1.50	1.46	1.46	0.5	0.9	0.05
Eagle_03	0.20	1.0	4.63	6.95	0.5	0.9	0.05	0.20	1.50	1.65	1.65	0.5	0.9	0.05
Eagle_04	0.20	1.0	5.29	7.94	0.5	0.9	0.05	0.20	1.50	1.57	1.57	0.5	0.9	0.05
Eagle_05	0.20	1.0	4.19	6.29	0.5	0.9	0.05	0.20	1.50	1.72	1.71	0.5	0.9	0.05
Eagle_06	0.20	1.0	2.84	4.26	0.5	0.9	0.05	0.05	1.00	0.90	0.90	0.7	0.9	0.01
Eagle_07	0.20	1.0	5.91	8.87	0.5	0.9	0.05	0.05	1.00	0.90	0.90	0.7	0.9	0.01
Eagle_08	0.20	1.0	5.05	7.58	0.5	0.9	0.05	0.05	1.00	0.90	0.90	0.7	0.9	0.01
Eagle_09	0.20	1.0	4.82	7.23	0.5	0.9	0.05	0.05	1.00	0.90	0.90	0.7	0.9	0.01
Eagle_10	0.20	1.0	6.82	10.23	0.5	0.9	0.05	0.05	1.00	0.90	0.90	0.7	0.9	0.01
Eagle_11	0.20	1.0	3.04	4.56	0.5	0.9	0.05	0.05	1.00	0.90	0.90	0.7	0.9	0.01
Eagle_12	0.20	1.0	4.42	6.63	0.5	0.9	0.05	0.05	1.00	1.68	0.37	0.7	0.9	0.01
Eagle_13	0.20	1.0	5.13	7.70	0.5	0.9	0.05	0.05	1.00	1.58	0.35	0.7	0.9	0.01
Eagle_14	0.20	1.0	5.13	7.70	0.5	0.9	0.05	0.05	1.00	1.58	0.35	0.7	0.9	0.01
Eagle_15	0.20	1.0	8.49	12.74	0.5	0.9	0.05	0.05	1.00	1.35	0.30	0.7	0.9	0.01

	Original Values							September 2011 Calibration						
	Loss (Gridded CN)		Transform		Baseflow			Loss (Gridded CN)		Transform		Baseflow		
Subbasin	Ratio	Factor	Time of Concentration	Storage Coefficient	Initial Discharge Ratio	Recession Constant	Ratio to Peak	Ratio	Factor	Tc Multiplier	R Multiplier	Initial Discharge Ratio	Recession Constant	Ratio to Peak
Flat_Branch_01	0.20	1.0	1.32	1.98	0.5	0.9	0.05	0.05	1.00	0.90	0.90	0.7	0.9	0.01
Flat_Branch_02	0.20	1.0	10.05	15.08	0.5	0.9	0.05	0.05	1.00	1.30	0.29	0.7	0.9	0.01
Flat_Branch_03	0.20	1.0	7.04	10.56	0.5	0.9	0.05	0.05	1.00	1.43	0.32	0.7	0.9	0.01
Fourmile_Run_01	0.20	1.0	7.55	11.33	0.5	0.9	0.05	0.05	0.25	0.90	1.70	1.0	0.9	0.01
Fourmile_Run_02	0.20	1.0	5.44	8.16	0.5	0.9	0.05	0.05	0.25	0.90	1.70	1.0	0.9	0.01
Howard_Run	0.20	1.0	4.87	7.31	0.5	0.9	0.05	0.20	1.50	1.62	1.61	0.5	0.9	0.05
Lye_01	0.20	1.0	9.43	14.15	0.5	0.9	0.05	0.20	1.50	1.32	1.32	0.5	0.9	0.05
Lye_02	0.20	1.0	8.36	12.54	0.5	0.9	0.05	0.20	1.50	1.36	1.36	0.5	0.9	0.05
Lye_03	0.20	1.0	5.75	8.63	0.5	0.9	0.05	0.20	1.50	1.52	1.52	0.5	0.9	0.05
Lye_04	0.20	1.0	7.12	10.68	0.5	0.9	0.05	0.20	1.50	1.42	1.42	0.5	0.9	0.05
Lye_05	0.20	1.0	4.85	7.28	0.5	0.9	0.05	0.20	1.50	1.62	1.62	0.5	0.9	0.05
Lye_06	0.20	1.0	3.41	5.12	0.5	0.9	0.05	0.10	1.00	1.10	2.50	0.5	0.9	0.03
Lye_07	0.20	1.0	7.01	10.52	0.5	0.9	0.05	0.10	1.00	1.30	2.50	0.5	0.9	0.03
Lye_08	0.20	1.0	5.22	7.83	0.5	0.9	0.05	0.10	1.00	1.30	2.50	0.5	0.9	0.03
Lye_09	0.20	1.0	6.69	10.04	0.5	0.9	0.05	0.20	1.50	1.45	0.32	0.5	0.9	0.03
Potato_01	0.20	1.0	8.24	12.36	0.5	0.9	0.05	0.05	0.25	0.90	1.40	1.0	0.9	0.01
Potato_02	0.20	1.0	5.99	8.99	0.5	0.9	0.05	0.05	0.25	0.90	1.40	1.0	0.9	0.01
Potato_03	0.20	1.0	5.23	7.85	0.5	0.9	0.05	0.05	0.25	0.90	1.40	1.0	0.9	0.01
Potato_04	0.20	1.0	5.72	8.58	0.5	0.9	0.05	0.05	0.25	0.90	1.40	1.0	0.9	0.01
Potato_05	0.20	1.0	6.47	9.71	0.5	0.9	0.05	0.05	0.25	0.90	1.40	1.0	0.9	0.01
Ripley_Run	0.20	1.0	5.89	8.84	0.5	0.9	0.05	0.05	0.25	0.90	1.40	1.0	0.9	0.01
Stahl_01	0.20	1.0	4.17	6.26	0.5	0.9	0.05	0.10	0.80	0.90	3.00	1.5	0.9	0.05
Stahl_02	0.20	1.0	7.02	10.53	0.5	0.9	0.05	0.10	0.80	0.90	3.00	1.5	0.9	0.05
Stahl_03	0.20	1.0	6.40	9.60	0.5	0.9	0.05	0.05	1.20	1.47	5.00	1.5	0.9	0.05
Stahl_04	0.20	1.0	6.38	9.57	0.5	0.9	0.05	0.05	1.20	1.47	5.00	1.5	0.9	0.05
The_Outlet_North_01	0.20	1.0	6.42	9.63	0.5	0.9	0.05	0.05	0.25	0.90	1.60	1.0	0.9	0.01
The_Outlet_North_02	0.20	1.0	6.77	10.16	0.5	0.9	0.05	0.05	0.25	0.90	1.60	1.0	0.9	0.01
The_Outlet_01	0.20	1.0	7.51	11.27	0.5	0.9	0.05	0.10	0.80	0.90	3.00	1.5	0.9	0.05
The_Outlet_02	0.20	1.0	6.55	9.83	0.5	0.9	0.05	0.10	0.80	0.90	3.00	1.5	0.9	0.05
The_Outlet_03	0.20	1.0	5.59	8.39	0.5	0.9	0.05	0.10	0.80	0.90	3.00	1.5	0.9	0.05
The_Outlet_04	0.20	1.0	5.14	7.71	0.5	0.9	0.05	0.10	0.80	0.90	3.00	1.5	0.9	0.05
The_Outlet_05	0.20	1.0	6.88	10.32	0.5	0.9	0.05	0.10	0.80	0.90	3.00	1.5	0.9	0.05

Subbasin Parameter Calibration – June 2015

	Original Values							June 2015 Calibration						
	Loss (Gridded CN)		Transform		Baseflow			Loss (Gridded CN)		Transform		Baseflow		
Subbasin	Ratio	Factor	Time of Concentration	Storage Coefficient	Initial Discharge Ratio	Recession Constant	Ratio to Peak	Ratio	Factor	Tc Multiplier	R Multiplier	Initial Discharge Ratio	Recession Constant	Ratio to Peak
Average	0.20	1.00			0.50	0.90	0.05	0.20	1.68	1.20	2.12	0.32	0.90	0.025
Aurand_Trib_01	0.20	1.0	5.53	8.30	0.5	0.9	0.05	0.20	1.70	1.30	2.20	0.3	0.9	0.02
Aurand_01	0.20	1.0	3.72	5.58	0.5	0.9	0.05	0.20	1.70	1.30	2.20	0.3	0.9	0.02
Aurand_02	0.20	1.0	5.98	8.97	0.5	0.9	0.05	0.20	1.70	1.30	2.20	0.3	0.9	0.02
Aurand_03	0.20	1.0	5.93	8.90	0.5	0.9	0.05	0.20	1.70	1.30	2.20	0.3	0.9	0.02
Aurand_04	0.20	1.0	5.21	7.82	0.5	0.9	0.05	0.20	1.70	1.30	2.20	0.3	0.9	0.02
Aurand_05	0.20	1.0	5.73	8.60	0.5	0.9	0.05	0.20	1.70	1.30	2.20	0.3	0.9	0.02
Brights_01	0.20	1.0	7.32	10.98	0.5	0.9	0.05	0.20	2.00	1.41	3.00	0.5	0.9	0.05
Brights_02	0.20	1.0	7.48	11.22	0.5	0.9	0.05	0.20	2.00	1.40	3.00	0.5	0.9	0.05
Brights_03	0.20	1.0	5.24	7.86	0.5	0.9	0.05	0.20	2.00	1.50	3.00	0.5	0.9	0.05
BR_UT_01	0.20	1.0	8.59	12.89	0.5	0.9	0.05	0.20	1.70	1.30	2.20	0.3	0.9	0.02
BR_UT_02	0.20	1.0	7.34	11.01	0.5	0.9	0.05	0.20	1.70	1.30	2.20	0.3	0.9	0.02
BR_UT_03	0.20	1.0	11.07	16.61	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
BR_UT_04	0.20	1.0	9.16	13.74	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
BR_UT_05_01	0.20	1.0	4.51	6.77	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
BR_UT_05_02	0.20	1.0	6.40	9.60	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
BR_UT_06	0.20	1.0	7.03	10.55	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
BR_01	0.20	1.0	5.23	7.85	0.5	0.9	0.05	0.20	1.70	1.30	2.20	0.3	0.9	0.02
BR_02	0.20	1.0	7.24	10.86	0.5	0.9	0.05	0.20	1.70	1.30	2.20	0.3	0.9	0.02
BR_03	0.20	1.0	6.50	9.75	0.5	0.9	0.05	0.20	1.70	1.30	2.20	0.3	0.9	0.02
BR_04	0.20	1.0	8.75	13.13	0.5	0.9	0.05	0.20	1.70	1.30	2.20	0.3	0.9	0.02
BR_05	0.20	1.0	3.42	5.13	0.5	0.9	0.05	0.20	1.50	1.88	1.88	0.5	0.9	0.05
BR_06	0.20	1.0	5.19	7.79	0.5	0.9	0.05	0.20	1.50	1.58	1.58	0.5	0.9	0.05
BR_07	0.20	1.0	4.16	6.24	0.5	0.9	0.05	0.20	1.50	1.72	1.72	0.5	0.9	0.05
BR_08	0.20	1.0	6.91	10.37	0.5	0.9	0.05	0.20	1.50	1.43	1.43	0.5	0.9	0.05
BR_09	0.20	1.0	5.70	8.55	0.5	0.9	0.05	0.20	1.50	1.53	1.53	0.5	0.9	0.05
BR_10	0.20	1.0	3.91	5.87	0.5	0.9	0.05	0.20	2.00	0.80	0.80	0.5	0.9	0.05
BR_11	0.20	1.0	6.56	9.84	0.5	0.9	0.05	0.20	2.00	0.80	0.80	0.5	0.9	0.05
BR_12	0.20	1.0	4.40	6.60	0.5	0.9	0.05	0.20	2.00	0.80	0.80	0.5	0.9	0.05
BR_13	0.20	1.0	7.14	10.71	0.5	0.9	0.05	0.20	2.00	1.42	8.00	0.5	0.9	0.05

	Original Values							June 2015 Calibration						
	Loss (Gridded CN)		Transform		Baseflow			Loss (Gridded CN)		Transform		Baseflow		
Subbasin	Ratio	Factor	Time of Concentration	Storage Coefficient	Initial Discharge Ratio	Recession Constant	Ratio to Peak	Ratio	Factor	Tc Multiplier	R Multiplier	Initial Discharge Ratio	Recession Constant	Ratio to Peak
BR_14	0.20	1.0	3.87	5.81	0.5	0.9	0.05	0.20	1.40	0.90	2.50	0.1	0.9	0.01
BR_15	0.20	1.0	7.06	10.59	0.5	0.9	0.05	0.20	1.40	0.90	2.50	0.1	0.9	0.01
BR_16	0.20	1.0	1.14	1.71	0.5	0.9	0.05	0.20	1.40	0.90	2.50	0.1	0.9	0.01
BR_17	0.20	1.0	2.97	4.46	0.5	0.9	0.05	0.20	1.40	0.90	2.50	0.1	0.9	0.01
BR_18	0.20	1.0	2.87	4.31	0.5	0.9	0.05	0.20	1.40	0.90	2.50	0.1	0.9	0.01
BR_19	0.20	1.0	5.49	8.24	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
BR_20	0.20	1.0	6.23	9.35	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
BR_21	0.20	1.0	7.16	10.74	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
BR_22	0.20	1.0	1.34	2.01	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
BR_23	0.20	1.0	3.10	4.65	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
BR_24	0.20	1.0	7.26	10.89	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
BR_25	0.20	1.0	1.76	2.64	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
BR_26	0.20	1.0	7.44	11.16	0.5	0.9	0.05	0.20	1.40	0.90	1.80	0.1	0.9	0.01
BR_27	0.20	1.0	6.00	9.00	0.5	0.9	0.05	0.20	1.40	0.90	1.80	0.1	0.9	0.01
BR_28	0.20	1.0	8.07	12.11	0.5	0.9	0.05	0.20	1.40	0.90	1.80	0.1	0.9	0.01
Buckrun_Creek	0.20	1.0	12.08	18.12	0.5	0.9	0.05	0.20	2.00	1.25	8.00	0.5	0.9	0.05
Buck_Run	0.20	1.0	9.84	14.76	0.5	0.9	0.05	0.20	1.60	1.40	0.60	0.5	0.9	0.01
Cessna_Ck_01	0.20	1.0	1.43	2.15	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
Cessna_Ck_02	0.20	1.0	4.82	7.23	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
Cessna_UT_01	0.20	1.0	6.09	9.14	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
Eagle_01	0.20	1.0	5.67	8.51	0.5	0.9	0.05	0.20	1.50	1.53	1.53	0.5	0.9	0.05
Eagle_02	0.20	1.0	6.48	9.72	0.5	0.9	0.05	0.20	1.50	1.46	1.46	0.5	0.9	0.05
Eagle_03	0.20	1.0	4.63	6.95	0.5	0.9	0.05	0.20	1.50	1.65	1.65	0.5	0.9	0.05
Eagle_04	0.20	1.0	5.29	7.94	0.5	0.9	0.05	0.20	1.50	1.57	1.57	0.5	0.9	0.05
Eagle_05	0.20	1.0	4.19	6.29	0.5	0.9	0.05	0.20	1.50	1.72	1.71	0.5	0.9	0.05
Eagle_06	0.20	1.0	2.84	4.26	0.5	0.9	0.05	0.20	1.80	1.60	0.60	0.5	0.9	0.01
Eagle_07	0.20	1.0	5.91	8.87	0.5	0.9	0.05	0.20	1.80	1.51	0.60	0.5	0.9	0.01
Eagle_08	0.20	1.0	5.05	7.58	0.5	0.9	0.05	0.20	1.80	1.59	0.60	0.5	0.9	0.01
Eagle_09	0.20	1.0	4.82	7.23	0.5	0.9	0.05	0.20	1.80	1.60	0.60	0.5	0.9	0.01
Eagle_10	0.20	1.0	6.82	10.23	0.5	0.9	0.05	0.20	1.80	1.44	0.60	0.5	0.9	0.01
Eagle_11	0.20	1.0	3.04	4.56	0.5	0.9	0.05	0.20	1.80	1.60	0.60	0.5	0.9	0.01
Eagle_12	0.20	1.0	4.42	6.63	0.5	0.9	0.05	0.20	1.60	1.40	0.60	0.5	0.9	0.01
Eagle_13	0.20	1.0	5.13	7.70	0.5	0.9	0.05	0.20	1.60	1.40	0.60	0.5	0.9	0.01
Eagle_14	0.20	1.0	5.13	7.70	0.5	0.9	0.05	0.20	1.60	1.40	0.60	0.5	0.9	0.01
Eagle_15	0.20	1.0	8.49	12.74	0.5	0.9	0.05	0.20	1.60	1.40	0.60	0.5	0.9	0.01

	Original Values							June 2015 Calibration						
	Loss (Gridded CN)		Transform		Baseflow			Loss (Gridded CN)		Transform		Baseflow		
Subbasin	Ratio	Factor	Time of Concentration	Storage Coefficient	Initial Discharge Ratio	Recession Constant	Ratio to Peak	Ratio	Factor	Tc Multiplier	R Multiplier	Initial Discharge Ratio	Recession Constant	Ratio to Peak
Flat_Branch_01	0.20	1.0	1.32	1.98	0.5	0.9	0.05	0.20	1.80	1.60	0.60	0.5	0.9	0.01
Flat_Branch_02	0.20	1.0	10.05	15.08	0.5	0.9	0.05	0.20	1.60	1.40	0.60	0.5	0.9	0.01
Flat_Branch_03	0.20	1.0	7.04	10.56	0.5	0.9	0.05	0.20	1.60	1.40	0.60	0.5	0.9	0.01
Fourmile_Run_01	0.20	1.0	7.55	11.33	0.5	0.9	0.05	0.20	1.40	0.90	1.80	0.1	0.9	0.01
Fourmile_Run_02	0.20	1.0	5.44	8.16	0.5	0.9	0.05	0.20	1.40	0.90	1.80	0.1	0.9	0.01
Howard_Run	0.20	1.0	4.87	7.31	0.5	0.9	0.05	0.20	1.50	1.62	1.61	0.5	0.9	0.05
Lye_01	0.20	1.0	9.43	14.15	0.5	0.9	0.05	0.20	1.50	1.32	1.32	0.5	0.9	0.05
Lye_02	0.20	1.0	8.36	12.54	0.5	0.9	0.05	0.20	1.50	1.36	1.36	0.5	0.9	0.05
Lye_03	0.20	1.0	5.75	8.63	0.5	0.9	0.05	0.20	1.50	1.52	1.52	0.5	0.9	0.05
Lye_04	0.20	1.0	7.12	10.68	0.5	0.9	0.05	0.20	1.50	1.42	1.42	0.5	0.9	0.05
Lye_05	0.20	1.0	4.85	7.28	0.5	0.9	0.05	0.20	1.50	1.62	1.62	0.5	0.9	0.05
Lye_06	0.20	1.0	3.41	5.12	0.5	0.9	0.05	0.15	1.00	1.10	1.80	0.1	0.9	0.01
Lye_07	0.20	1.0	7.01	10.52	0.5	0.9	0.05	0.15	1.00	0.70	1.90	0.1	0.9	0.01
Lye_08	0.20	1.0	5.22	7.83	0.5	0.9	0.05	0.15	1.00	0.70	1.90	0.1	0.9	0.01
Lye_09	0.20	1.0	6.69	10.04	0.5	0.9	0.05	0.15	1.20	1.45	1.20	0.1	0.9	0.01
Potato_01	0.20	1.0	8.24	12.36	0.5	0.9	0.05	0.20	1.40	0.90	2.50	0.1	0.9	0.01
Potato_02	0.20	1.0	5.99	8.99	0.5	0.9	0.05	0.20	1.40	0.90	2.50	0.1	0.9	0.01
Potato_03	0.20	1.0	5.23	7.85	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
Potato_04	0.20	1.0	5.72	8.58	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
Potato_05	0.20	1.0	6.47	9.71	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
Ripley_Run	0.20	1.0	5.89	8.84	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
Stahl_01	0.20	1.0	4.17	6.26	0.5	0.9	0.05	0.20	2.00	0.80	0.80	0.5	0.9	0.05
Stahl_02	0.20	1.0	7.02	10.53	0.5	0.9	0.05	0.20	2.00	1.43	3.00	0.5	0.9	0.05
Stahl_03	0.20	1.0	6.40	9.60	0.5	0.9	0.05	0.20	2.00	1.47	8.00	0.5	0.9	0.05
Stahl_04	0.20	1.0	6.38	9.57	0.5	0.9	0.05	0.20	2.00	1.47	8.00	0.5	0.9	0.05
The_Outlet_North_01	0.20	1.0	6.42	9.63	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
The_Outlet_North_02	0.20	1.0	6.77	10.16	0.5	0.9	0.05	0.20	1.80	0.90	2.50	0.1	0.9	0.01
The_Outlet_01	0.20	1.0	7.51	11.27	0.5	0.9	0.05	0.20	2.00	0.80	0.80	0.5	0.9	0.05
The_Outlet_02	0.20	1.0	6.55	9.83	0.5	0.9	0.05	0.20	2.00	0.80	0.80	0.5	0.9	0.05
The_Outlet_03	0.20	1.0	5.59	8.39	0.5	0.9	0.05	0.20	2.00	1.50	3.00	0.5	0.9	0.05
The_Outlet_04	0.20	1.0	5.14	7.71	0.5	0.9	0.05	0.20	2.00	1.50	3.00	0.5	0.9	0.05
The_Outlet_05	0.20	1.0	6.88	10.32	0.5	0.9	0.05	0.20	2.00	1.44	3.00	0.5	0.9	0.05

Subbasin Parameter Calibration – August 2007

	Original Values							August 2007 Calibration						
	Loss (Gridded CN)		Transform		Baseflow			Loss (Gridded CN)		Transform		Baseflow		
Subbasin	Ratio	Factor	Time of Concentration	Storage Coefficient	Initial Discharge Ratio	Recession Constant	Ratio to Peak	Ratio	Factor	Tc Multiplier	R Multiplier	Initial Discharge Ratio	Recession Constant	Ratio to Peak
Average	0.20	1.00			0.50	0.90	0.05	0.30	2.50	1.00	3.90	0.10	0.01	0.01
Aurand_Trib_01	0.20	1.0	5.53	8.30	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01
Aurand_01	0.20	1.0	3.72	5.58	0.5	0.9	0.05	0.30	2.50	0.99	3.91	0.1	0.01	0.01
Aurand_02	0.20	1.0	5.98	8.97	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Aurand_03	0.20	1.0	5.93	8.90	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01
Aurand_04	0.20	1.0	5.21	7.82	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Aurand_05	0.20	1.0	5.73	8.60	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01
Brights_01	0.20	1.0	7.32	10.98	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Brights_02	0.20	1.0	7.48	11.22	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Brights_03	0.20	1.0	5.24	7.86	0.5	0.9	0.05	0.30	2.50	0.99	3.91	0.1	0.01	0.01
BR_UT_01	0.20	1.0	8.59	12.89	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
BR_UT_02	0.20	1.0	7.34	11.01	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01
BR_UT_03	0.20	1.0	11.07	16.61	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
BR_UT_04	0.20	1.0	9.16	13.74	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
BR_UT_05_01	0.20	1.0	4.51	6.77	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
BR_UT_05_02	0.20	1.0	6.40	9.60	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
BR_UT_06	0.20	1.0	7.03	10.55	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
BR_01	0.20	1.0	5.23	7.85	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01
BR_02	0.20	1.0	7.24	10.86	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01
BR_03	0.20	1.0	6.50	9.75	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
BR_04	0.20	1.0	8.75	13.13	0.5	0.9	0.05	0.30	2.50	1.01	3.90	0.1	0.01	0.01
BR_05	0.20	1.0	3.42	5.13	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01
BR_06	0.20	1.0	5.19	7.79	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
BR_07	0.20	1.0	4.16	6.24	0.5	0.9	0.05	0.30	2.50	1.01	3.89	0.1	0.01	0.01
BR_08	0.20	1.0	6.91	10.37	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
BR_09	0.20	1.0	5.70	8.55	0.5	0.9	0.05	0.30	2.50	1.00	3.89	0.1	0.01	0.01
BR_10	0.20	1.0	3.91	5.87	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
BR_11	0.20	1.0	6.56	9.84	0.5	0.9	0.05	0.30	2.50	1.01	3.90	0.1	0.01	0.01
BR_12	0.20	1.0	4.40	6.60	0.5	0.9	0.05	0.30	2.50	1.00	3.89	0.1	0.01	0.01
BR_13	0.20	1.0	7.14	10.71	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01

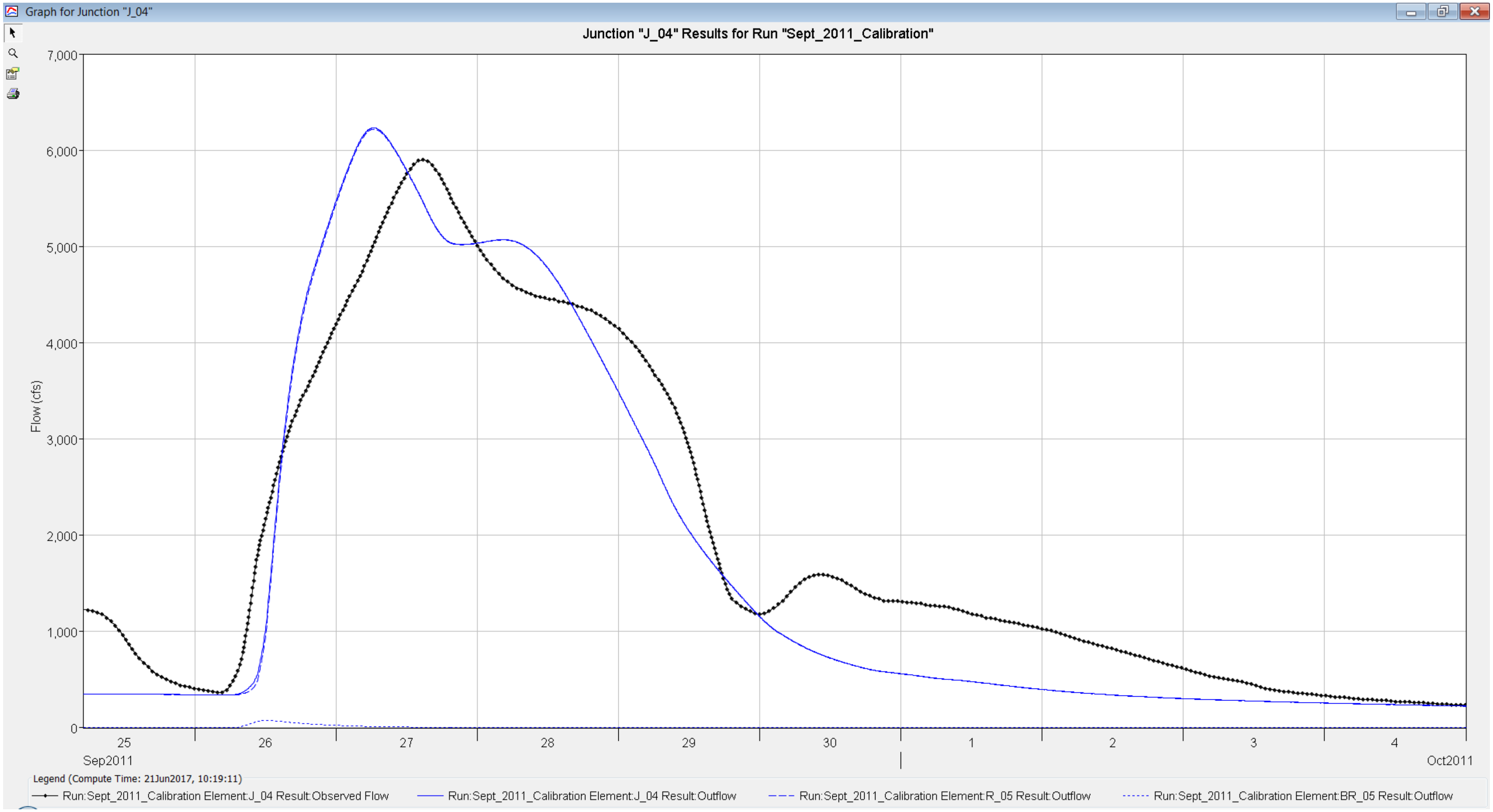
	Original Values							August 2007 Calibration						
	Loss (Gridded CN)		Transform		Baseflow			Loss (Gridded CN)		Transform		Baseflow		
Subbasin	Ratio	Factor	Time of Concentration	Storage Coefficient	Initial Discharge Ratio	Recession Constant	Ratio to Peak	Ratio	Factor	Tc Multiplier	R Multiplier	Initial Discharge Ratio	Recession Constant	Ratio to Peak
BR_14	0.20	1.0	3.87	5.81	0.5	0.9	0.05	0.30	2.50	1.01	3.91	0.1	0.01	0.01
BR_15	0.20	1.0	7.06	10.59	0.5	0.9	0.05	0.30	2.50	1.01	3.90	0.1	0.01	0.01
BR_16	0.20	1.0	1.14	1.71	0.5	0.9	0.05	0.30	2.50	0.96	3.92	0.1	0.01	0.01
BR_17	0.20	1.0	2.97	4.46	0.5	0.9	0.05	0.30	2.50	1.01	3.90	0.1	0.01	0.01
BR_18	0.20	1.0	2.87	4.31	0.5	0.9	0.05	0.30	2.50	1.01	3.90	0.1	0.01	0.01
BR_19	0.20	1.0	5.49	8.24	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
BR_20	0.20	1.0	6.23	9.35	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
BR_21	0.20	1.0	7.16	10.74	0.5	0.9	0.05	0.30	2.50	1.01	3.90	0.1	0.01	0.01
BR_22	0.20	1.0	1.34	2.01	0.5	0.9	0.05	0.30	2.50	0.97	3.88	0.1	0.01	0.01
BR_23	0.20	1.0	3.10	4.65	0.5	0.9	0.05	0.30	2.50	1.00	3.89	0.1	0.01	0.01
BR_24	0.20	1.0	7.26	10.89	0.5	0.9	0.05	0.30	2.50	1.01	3.90	0.1	0.01	0.01
BR_25	0.20	1.0	1.76	2.64	0.5	0.9	0.05	0.30	2.50	1.02	3.90	0.1	0.01	0.01
BR_26	0.20	1.0	7.44	11.16	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01
BR_27	0.20	1.0	6.00	9.00	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
BR_28	0.20	1.0	8.07	12.11	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Buckrun_Creek	0.20	1.0	12.08	18.12	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Buck_Run	0.20	1.0	9.84	14.76	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Cessna_Ck_01	0.20	1.0	1.43	2.15	0.5	0.9	0.05	0.30	2.50	0.98	3.91	0.1	0.01	0.01
Cessna_Ck_02	0.20	1.0	4.82	7.23	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Cessna_UT_01	0.20	1.0	6.09	9.14	0.5	0.9	0.05	0.30	2.50	1.00	3.89	0.1	0.01	0.01
Eagle_01	0.20	1.0	5.67	8.51	0.5	0.9	0.05	0.30	2.50	1.01	3.90	0.1	0.01	0.01
Eagle_02	0.20	1.0	6.48	9.72	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Eagle_03	0.20	1.0	4.63	6.95	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01
Eagle_04	0.20	1.0	5.29	7.94	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Eagle_05	0.20	1.0	4.19	6.29	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Eagle_06	0.20	1.0	2.84	4.26	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01
Eagle_07	0.20	1.0	5.91	8.87	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Eagle_08	0.20	1.0	5.05	7.58	0.5	0.9	0.05	0.30	2.50	1.01	3.91	0.1	0.01	0.01
Eagle_09	0.20	1.0	4.82	7.23	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Eagle_10	0.20	1.0	6.82	10.23	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Eagle_11	0.20	1.0	3.04	4.56	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01
Eagle_12	0.20	1.0	4.42	6.63	0.5	0.9	0.05	0.30	2.50	1.00	3.91	0.1	0.01	0.01
Eagle_13	0.20	1.0	5.13	7.70	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01
Eagle_14	0.20	1.0	5.13	7.70	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01
Eagle_15	0.20	1.0	8.49	12.74	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01

	Original Values							August 2007 Calibration						
	Loss (Gridded CN)		Transform		Baseflow			Loss (Gridded CN)		Transform		Baseflow		
Subbasin	Ratio	Factor	Time of Concentration	Storage Coefficient	Initial Discharge Ratio	Recession Constant	Ratio to Peak	Ratio	Factor	Tc Multiplier	R Multiplier	Initial Discharge Ratio	Recession Constant	Ratio to Peak
Flat_Branch_01	0.20	1.0	1.32	1.98	0.5	0.9	0.05	0.30	2.50	0.98	3.89	0.1	0.01	0.01
Flat_Branch_02	0.20	1.0	10.05	15.08	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Flat_Branch_03	0.20	1.0	7.04	10.56	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01
Fourmile_Run_01	0.20	1.0	7.55	11.33	0.5	0.9	0.05	0.30	2.50	1.01	3.90	0.1	0.01	0.01
Fourmile_Run_02	0.20	1.0	5.44	8.16	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01
Howard_Run	0.20	1.0	4.87	7.31	0.5	0.9	0.05	0.30	2.50	1.01	3.90	0.1	0.01	0.01
Lye_01	0.20	1.0	9.43	14.15	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Lye_02	0.20	1.0	8.36	12.54	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Lye_03	0.20	1.0	5.75	8.63	0.5	0.9	0.05	0.30	2.50	1.01	3.90	0.1	0.01	0.01
Lye_04	0.20	1.0	7.12	10.68	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Lye_05	0.20	1.0	4.85	7.28	0.5	0.9	0.05	0.30	2.50	1.01	3.90	0.1	0.01	0.01
Lye_06	0.20	1.0	3.41	5.12	0.5	0.9	0.05	0.30	2.50	1.00	3.91	0.1	0.01	0.01
Lye_07	0.20	1.0	7.01	10.52	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Lye_08	0.20	1.0	5.22	7.83	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Lye_09	0.20	1.0	6.69	10.04	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Potato_01	0.20	1.0	8.24	12.36	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Potato_02	0.20	1.0	5.99	8.99	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Potato_03	0.20	1.0	5.23	7.85	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01
Potato_04	0.20	1.0	5.72	8.58	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Potato_05	0.20	1.0	6.47	9.71	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Ripley_Run	0.20	1.0	5.89	8.84	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Stahl_01	0.20	1.0	4.17	6.26	0.5	0.9	0.05	0.30	2.50	1.01	3.90	0.1	0.01	0.01
Stahl_02	0.20	1.0	7.02	10.53	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Stahl_03	0.20	1.0	6.40	9.60	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
Stahl_04	0.20	1.0	6.38	9.57	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
The_Outlet_North_01	0.20	1.0	6.42	9.63	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
The_Outlet_North_02	0.20	1.0	6.77	10.16	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
The_Outlet_01	0.20	1.0	7.51	11.27	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
The_Outlet_02	0.20	1.0	6.55	9.83	0.5	0.9	0.05	0.30	2.50	1.01	3.90	0.1	0.01	0.01
The_Outlet_03	0.20	1.0	5.59	8.39	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01
The_Outlet_04	0.20	1.0	5.14	7.71	0.5	0.9	0.05	0.30	2.50	0.99	3.90	0.1	0.01	0.01
The_Outlet_05	0.20	1.0	6.88	10.32	0.5	0.9	0.05	0.30	2.50	1.00	3.90	0.1	0.01	0.01

Reach Parameter Calibration

			Original Values		Sept. 2011 Calibration			June 2015 Calibration			August 2007 (Stantec)		
Reach	Length	Slope	Lag Time	Velocity	Lag Time	Velocity	Multiplier	Lag Time	Velocity	Multiplier	Lag Time	Velocity	Multiplier
			Average	2.01		1.49	1.49		1.80	1.15		2.03	1.00
R_19	22600	0.0001	190	1.98	360	1.05	1.89	190	1.98	1.00	190	1.98	1.00
R_20	18800	0.0005	160	1.96	305	1.03	1.91	160	1.96	1.00	160	1.96	1.00
R_21	27000	0.0003	230	1.96	440	1.02	1.91	230	1.96	1.00	230	1.96	1.00
R_22	2900	0.0001	20	2.42	25	1.93	1.25	25	1.93	1.25	20	2.42	1.00
R_23	8300	0.0006	70	1.98	135	1.02	1.93	70	1.98	1.00	70	1.98	1.00
R_24	3000	0.0029	25	2.00	25	2.00	1.00	25	2.00	1.00	30	1.67	1.20
R_25	20900	0.0004	170	2.05	325	1.07	1.91	170	2.05	1.00	170	2.05	1.00
R_26	12100	0.0004	100	2.02	190	1.06	1.90	100	2.02	1.00	100	2.02	1.00
R_37	12900	0.001	108	1.99	170	1.26	1.57	110	1.95	1.02	110	1.95	1.02
R_38	21500	0.0009	179	2.00	275	1.30	1.54	180	1.99	1.01	180	1.99	1.01
R_39	14400	0.0015	120	2.00	305	0.79	2.54	120	2.00	1.00	120	2.00	1.00
R_40	21700	0.0005	181	2.00	455	0.79	2.51	180	2.01	0.99	180	2.01	0.99
R_41	5300	0.0012	44	2.01	110	0.80	2.50	45	1.96	1.02	40	2.21	0.91
R_45	1600	0.0002			45	0.59		15	1.78		10	2.67	
R_46	21500	0.0004			580	0.62		215	1.67		180	1.99	
R_47	15700	0.0001	131	2.00	110	2.38	0.84	195	1.34	1.49	130	2.01	0.99
R_48	10700	0.0001	89	2.00	75	2.38	0.84	135	1.32	1.52	90	1.98	1.01
R_49	13000	0.0001	108	2.01	90	2.41	0.83	160	1.35	1.48	110	1.97	1.02
R_50	9300	0.0003	78	1.99	65	2.38	0.83	120	1.29	1.54	80	1.94	1.03
R_51	25500	0.0011	213	2.00	180	2.36	0.85	320	1.33	1.50	210	2.02	0.99
R_52	21600	0.0005	180	2.00	155	2.32	0.86	270	1.33	1.50	180	2.00	1.00
R_53	8900	0.0001	74	2.00	60	2.47	0.81	110	1.35	1.49	70	2.12	0.95
R_55	18300	0.0003	150	2.03	225	1.36	1.50	150	2.03	1.00	150	2.03	1.00
R_56	13300	0.0005	110	2.02	165	1.34	1.50	110	2.02	1.00	110	2.02	1.00
R_57	21300	0.0013	180	1.97	270	1.31	1.50	180	1.97	1.00	180	1.97	1.00
R_58	13000	0.0001	110	1.97	165	1.31	1.50	110	1.97	1.00	110	1.97	1.00
R_59	11400	0.0005	100	1.90	150	1.27	1.50	100	1.90	1.00	100	1.90	1.00
R_60	2400	0.0021	20	2.00	20	2.00	1.00	20	2.00	1.00	20	2.00	1.00

September 2011 Event – USGS Gage 04189000 Blanchard River Downstream of Findlay (Using Sept. 2011 Calibrated Geometry)



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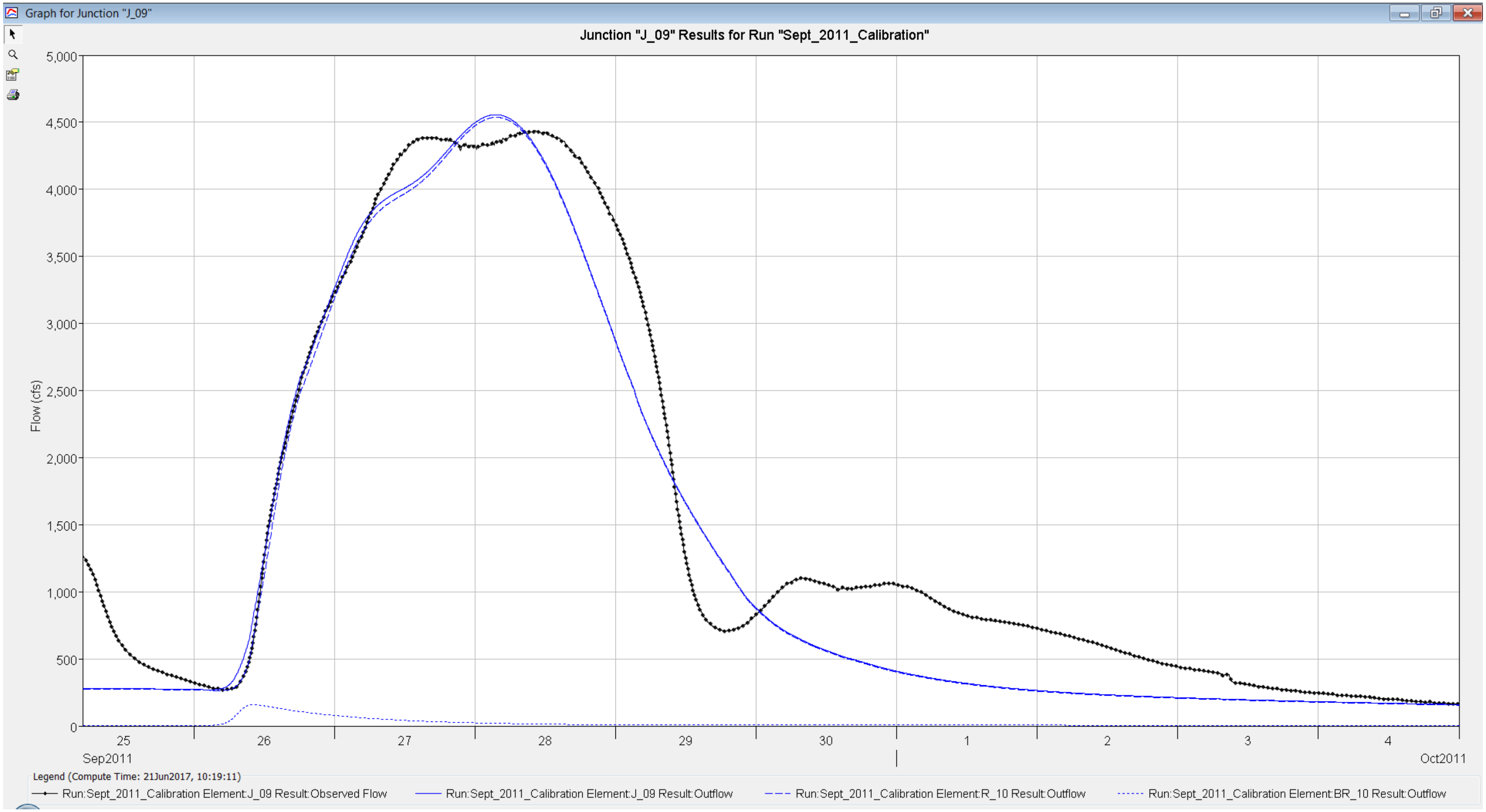
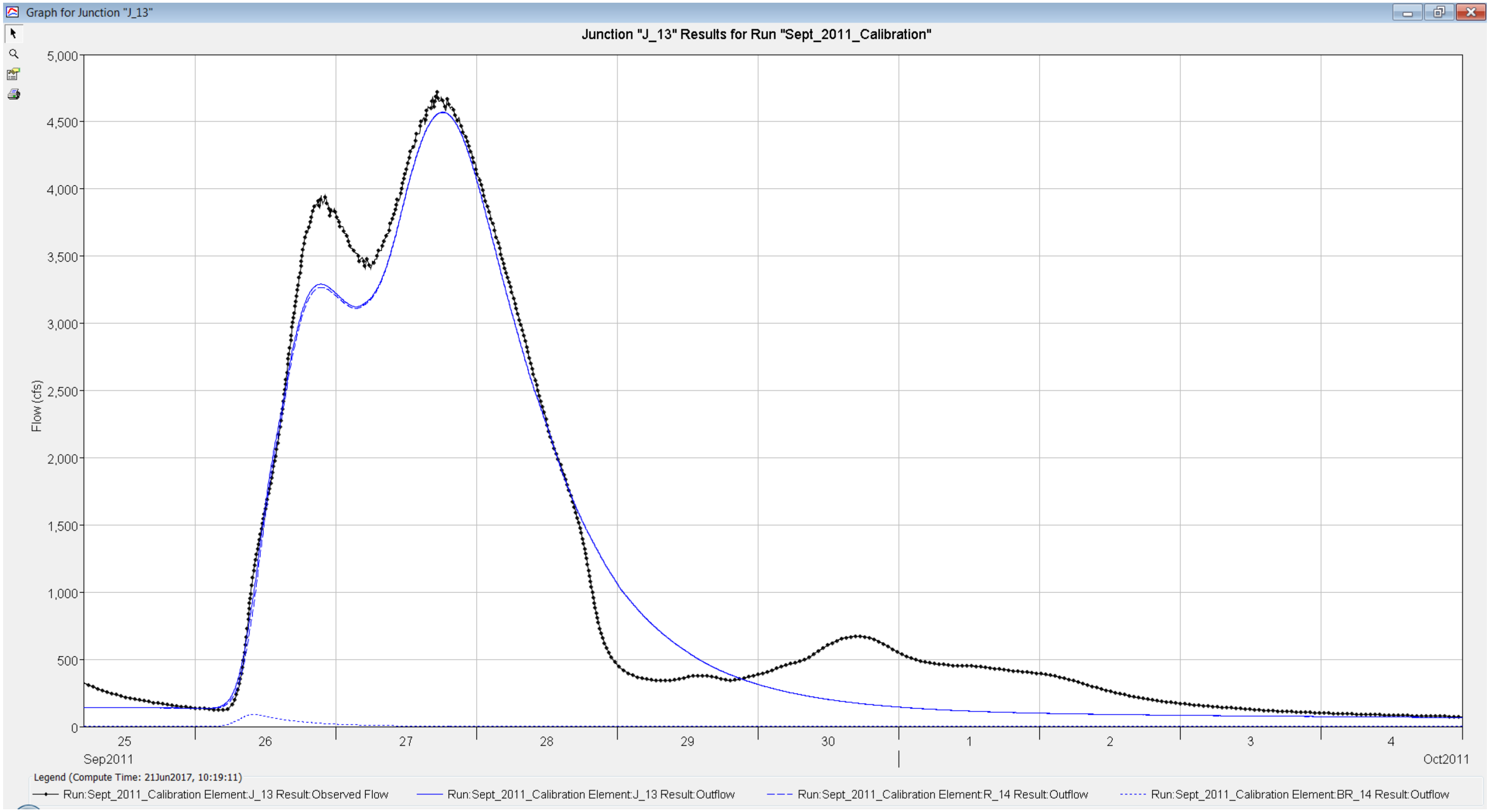
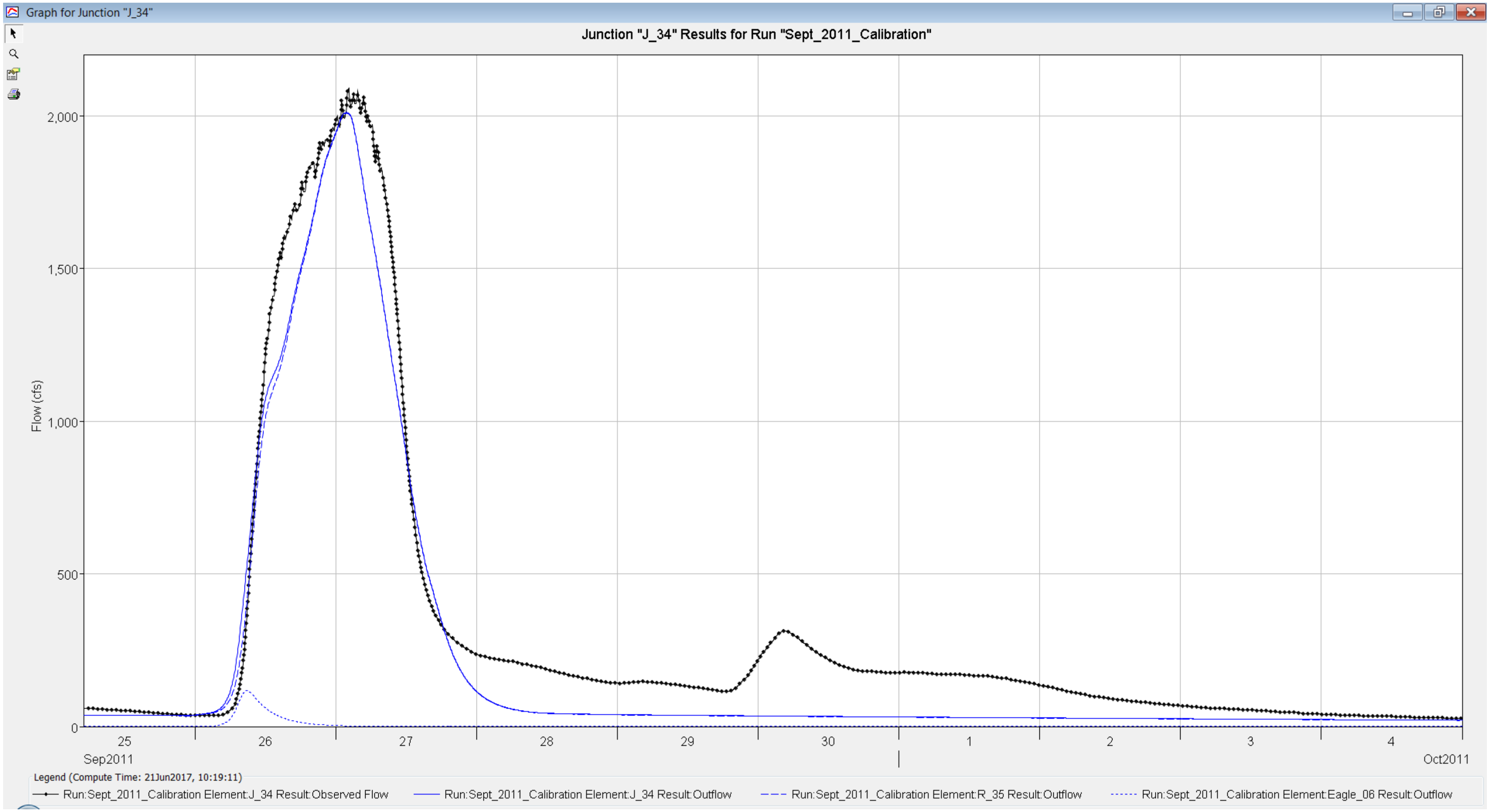


September 2011 Event – USGS Gage 04188337 Blanchard River Downstream of Mt. Blanchard (Using Sept. 2011 Calibrated Geometry)



September 2011 Event – USGS Gage 04188496 Eagle Creek Above Findlay (Using Sept. 2011 Calibrated Geometry)



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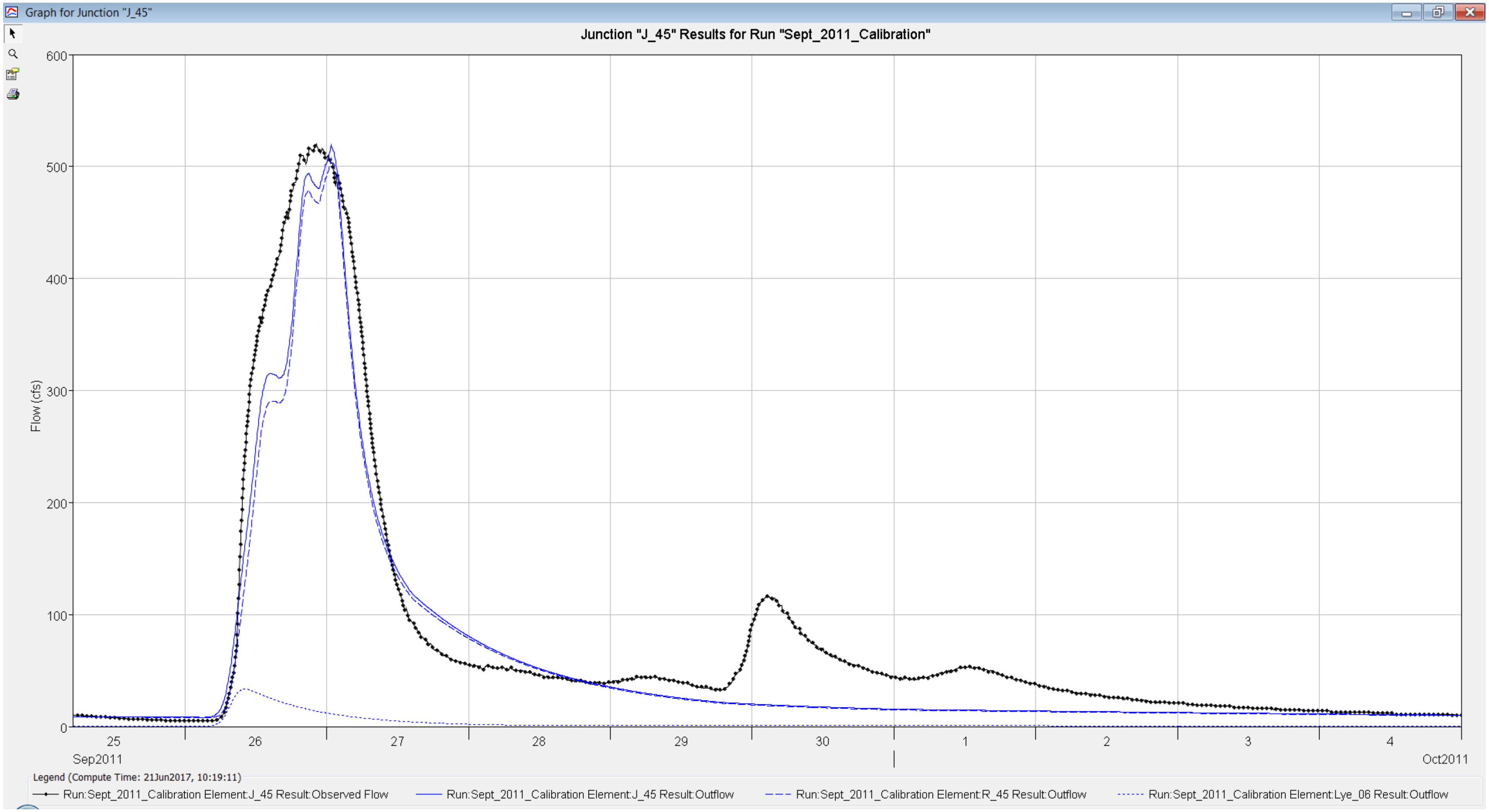
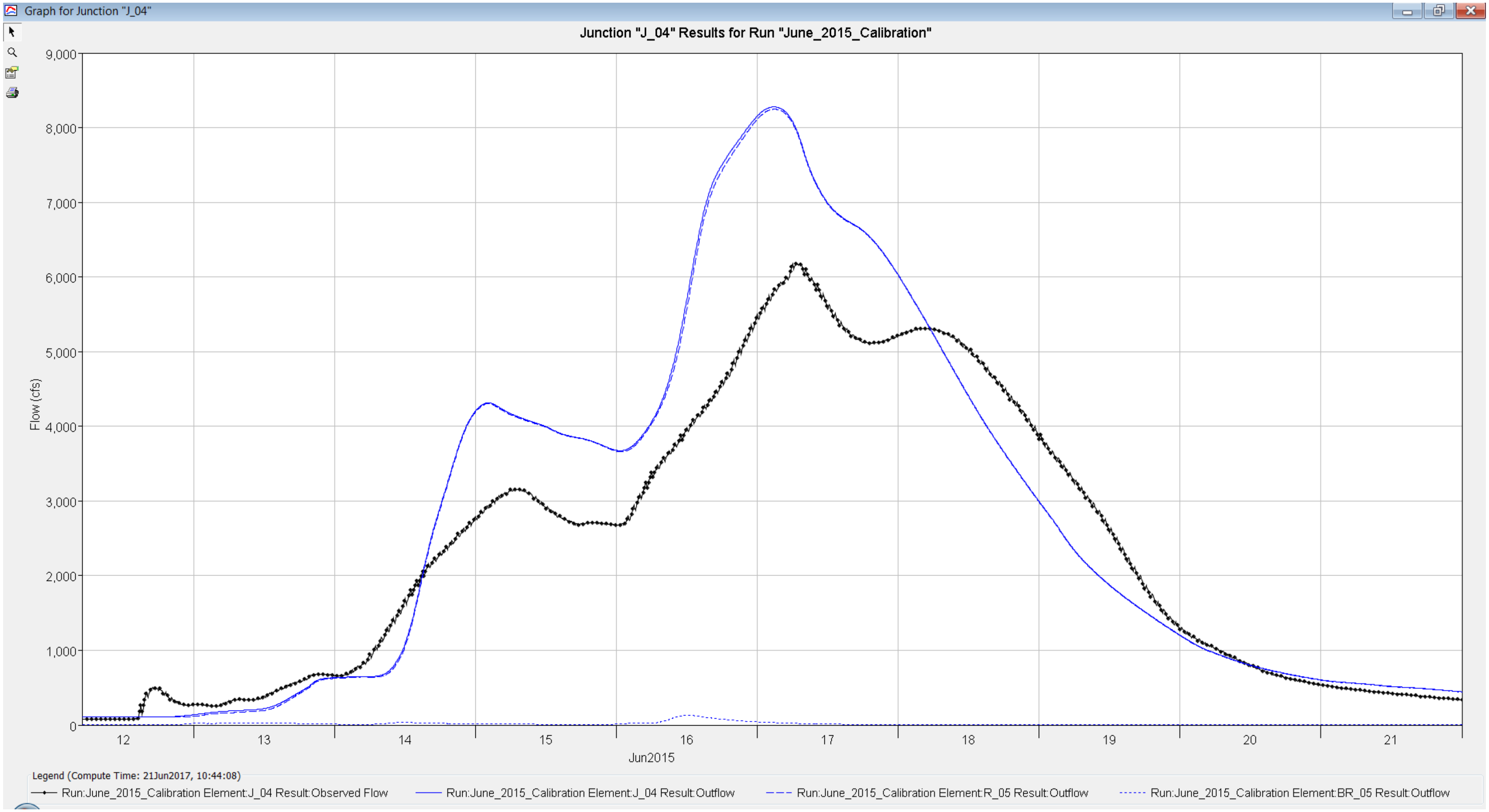
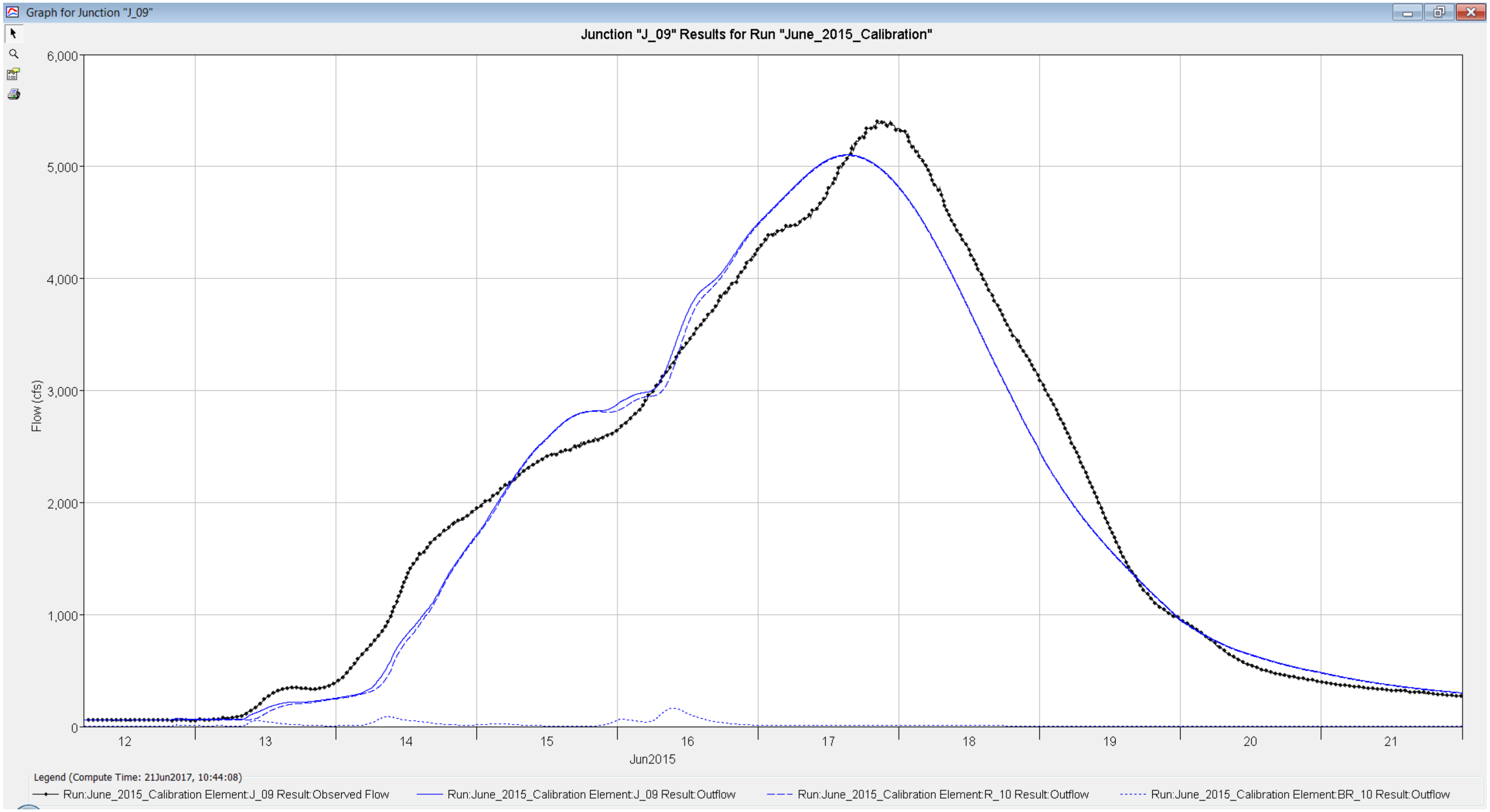


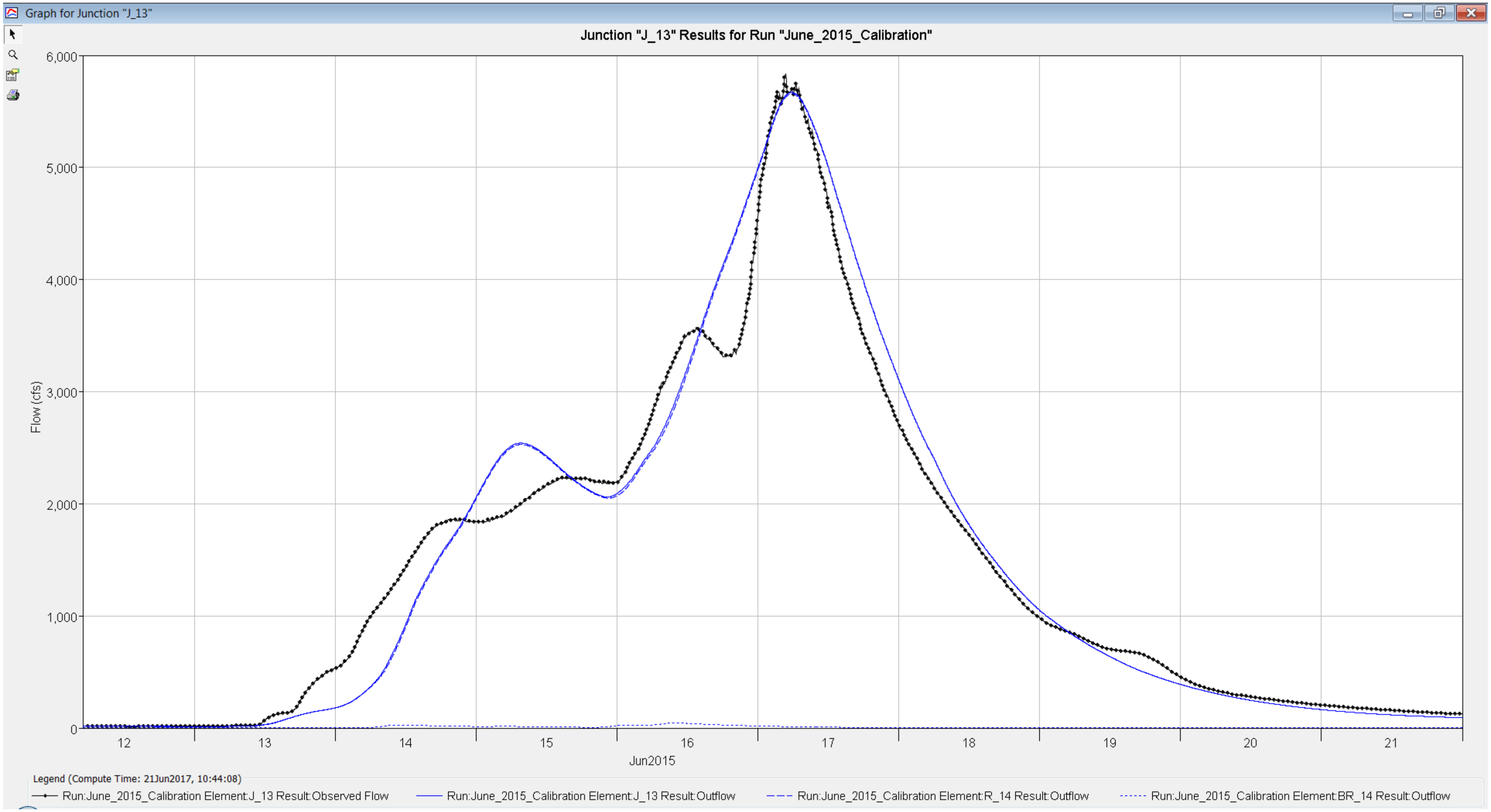
June 2015 Event – USGS Gage 04189000 Blanchard River Downstream of Findlay (Using June 2015 Calibrated Geometry)



June 2015 Event – USGS Gage 04188400 Blanchard River Upstream of Findlay (Using June 2015 Calibrated Geometry)



June 2015 Event – USGS Gage 04188337 Blanchard River Downstream of Mt. Blanchard (Using June 2015 Calibrated Geometry)



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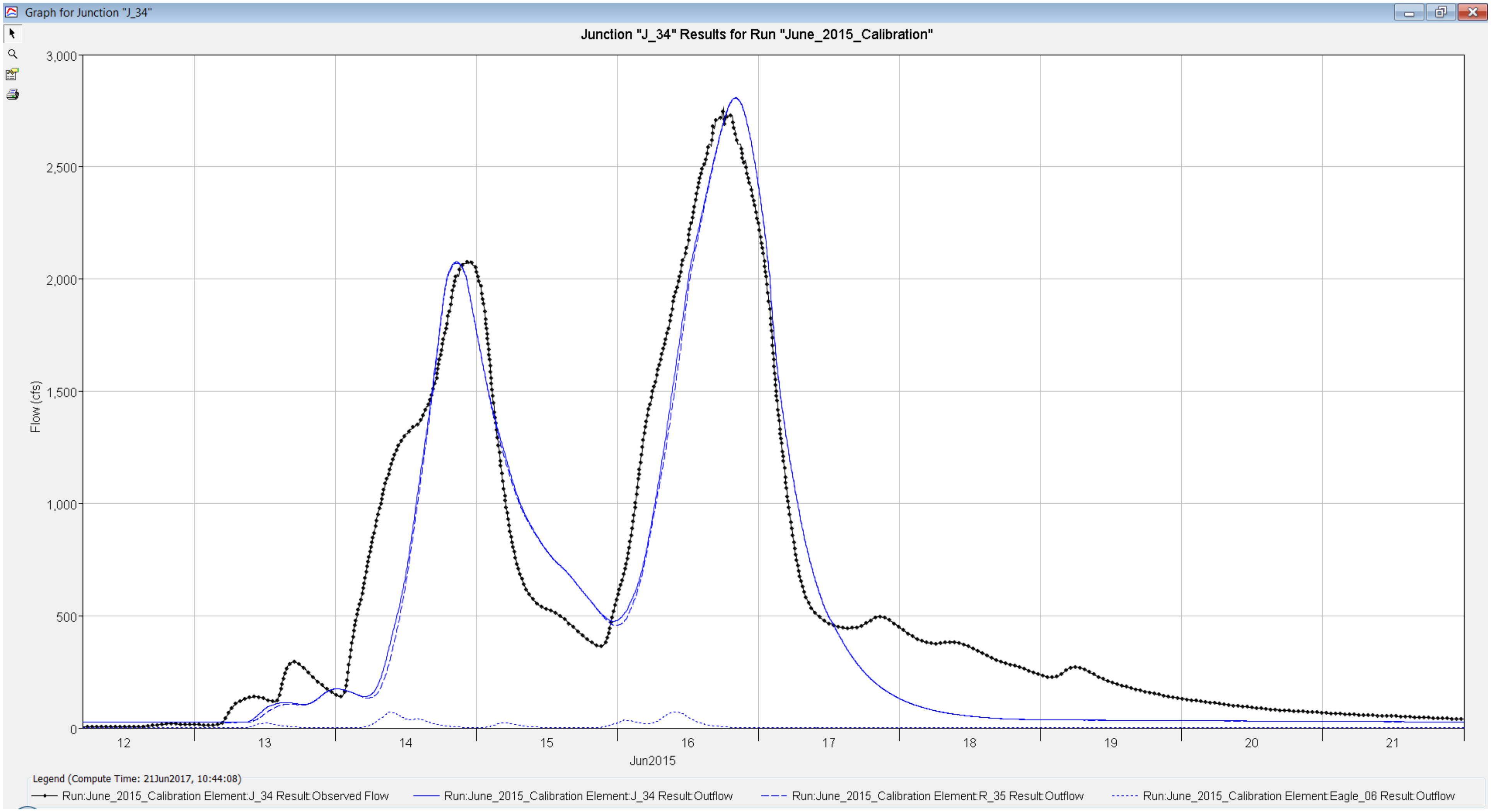

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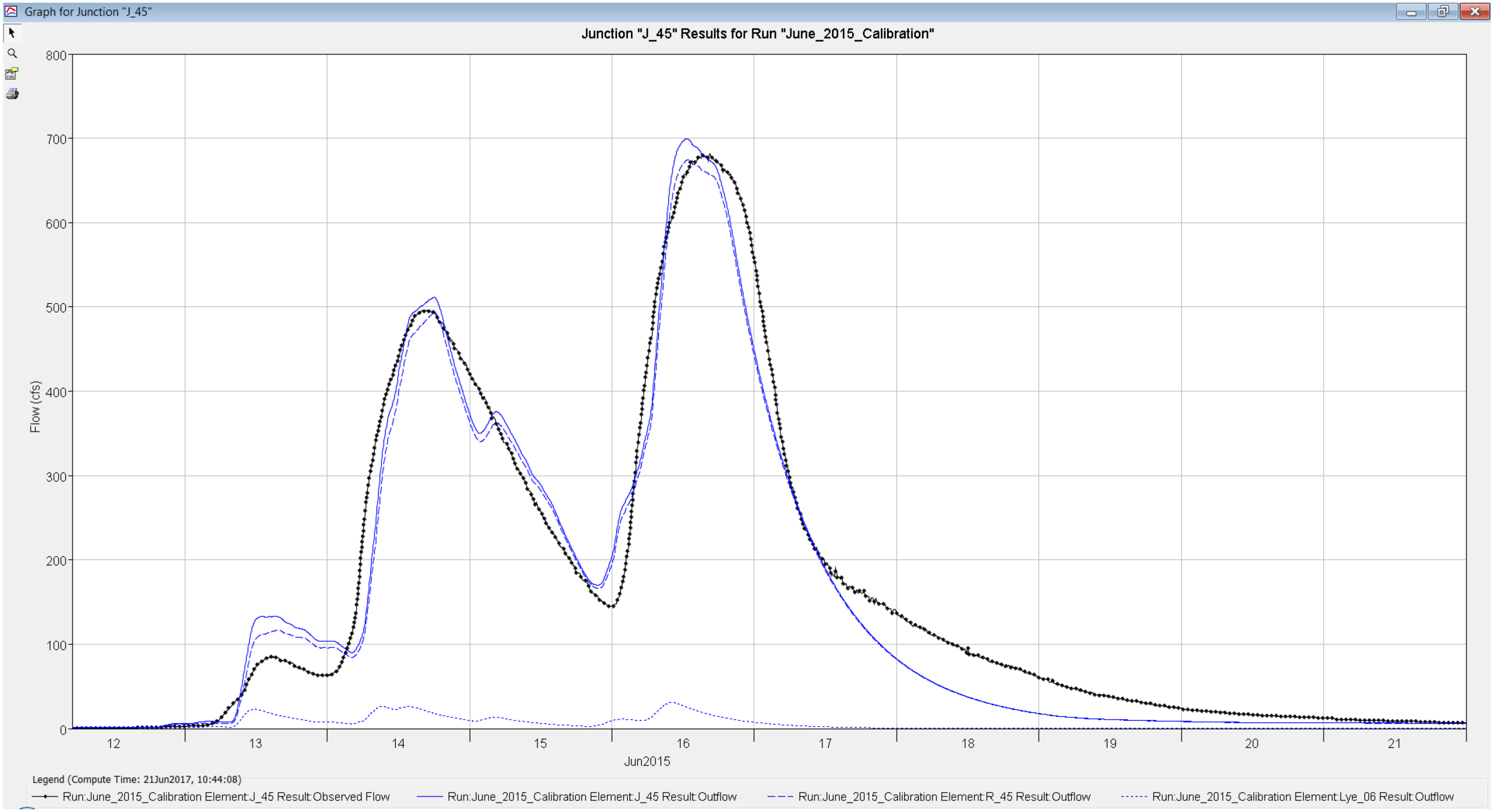
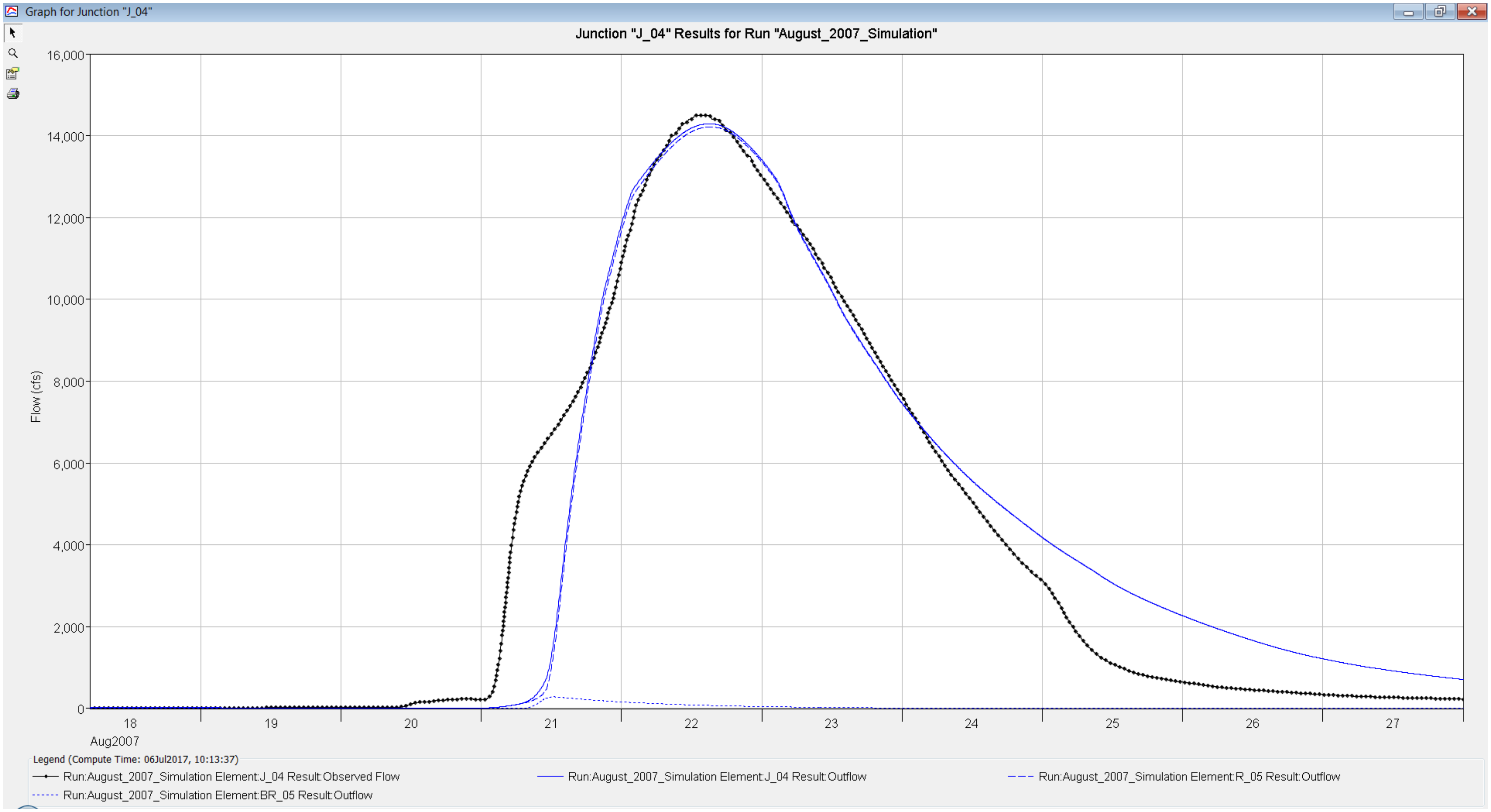


August 2007 Event – USGS Gage 04189000 Blanchard River Downstream of Findlay (Using August 2007 Calibrated Geometry)



Appendix B – REPORT OF GEOTECHNICAL EXPLORATION

Report of Geotechnical Exploration

Hancock County Flood Risk Reduction Program – Dams Preliminary

April 2, 2018

Prepared for:

Maumee Watershed Conservancy District
Defiance, Ohio

Prepared by:

Stantec Consulting Services Inc.
Cincinnati, Ohio

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Executive Summary

As part of the Hancock County Flood Risk Reduction Program, Maumee Watershed Conservancy District (MWCD) is evaluating three potential dam alignments (Eagle Creek Dam, Blanchard River Dam, and Potato Run Dam) near Findlay, Ohio. The three dams are proposed to be earth detention dams, only detaining pools during flood events. Stantec Consulting Services Inc. (Stantec) was contracted by MWCD to perform engineering and design services for the program, including the preliminary geotechnical exploration for the proposed dams.

The proposed Eagle Creek dam alignment is approximately 4.2 miles long and 4 miles south of Findlay. The proposed Blanchard River and Potato Run Dams are approximately 10 miles south and 5 miles east of Findlay, near Mt. Blanchard, Ohio. The proposed Blanchard River and Potato Run Dam alignments are approximately 1.4 miles and 0.7 miles long, respectively.

Four borings were advanced by TTL Associates and supervised by Stantec to obtain preliminary geotechnical data for the proposed dams. Borings B-101 and B-102 were advanced near County Road (CR) 77 and through US Route (US) 68, respectively, near the proposed alignment for Eagle Creek Dam. Borings B-103 and B-104 were advanced through Township Road (TR) 187 and State Route (SR) 103, respectively, to provide subsurface information for the proposed Blanchard River Dam. Property access was not available for explorations along the proposed dam alignment across Potato Run. In this report, conditions for the Potato Run Dam are assumed to be similar to conditions at the Blanchard River Dam.

Disturbed and undisturbed soil samples were collected through the soil overburden. Upon encountering bedrock, 20 to 25 feet of rock coring was performed. Soil and rock samples obtained from the borings were logged in the field by a geotechnical engineer, then returned to the laboratory for testing and storage. Laboratory testing included natural moisture content determinations, soil classifications including particle size analysis and Atterberg limits, specific gravity testing, unit weight testing, hydraulic conductivity testing, and triaxial compression testing.

Soils encountered in B-101 and B-102 for the Eagle Creek Dam consisted of alternating layers of fine- and coarse-grained materials. Laboratory testing classified the fine-grained soils as Lean Clay with Sand (CL), Sandy Lean Clay (CL), or Silty Clay with Sand (CL-ML). These soils were described as moist, medium stiff to very stiff, and having varying amounts of sand and gravel. Fine-grained soils were encountered near the ground surface, and again deeper in the profile between two layers of coarse-grained soils. The coarse-grained materials were visually described as poorly graded sand with some gravel or mechanically classified as Poorly Graded Gravel with Clay and Sand (GP-GC). These soils were described as moist and dense to very dense. The coarse-grained materials were encountered at depths of about 11 to 12 feet, and again at depths of about 16 to 22 feet, above the top of bedrock. The groundwater table was measured during drilling, and typically coincided with the upper coarse-grained soil layer. Bedrock was encountered at depths of 19.8 feet (elevation 779.7 feet) in B-101 and 22.1 feet (elevation 773.4 feet) in B-102. The bedrock was described as gray dolomite, slightly weathered, fractured to moderately fractured, slightly rough, and thin to medium bedded.

Soils encountered in B-103 and B-104 near the Blanchard River Potato Run Dam alignments consisted of fine-grained fill materials, underlain by natural fine- and coarse-grained soils. The natural fine-grained material was encountered below the fill in B-103, and classified as Lean Clay with Sand (CL). This material was described as moist and very stiff. Coarse-grained materials were encountered below fill or natural fine-grained soils, and classified as

Clayey Sand (SC) and Silty Sand (SM). These soils were described as moist and loose to medium dense. Bedrock was encountered at depths of 18.9 feet (elevation 824.2 feet) in B-103 and 12.7 feet (elevation 823.3 feet) in B-104. The bedrock was described as gray dolomite, slightly weathered, fractured to moderately fractured, slightly rough, and thin to medium bedded.

Seepage and slope stability analyses were performed for the Eagle Creek Dam and Blanchard River Dam sites. For the purpose of these preliminary analyses, the Potato Run Dam site was assumed to be similar to the Blanchard River. Two cross sections were considered for each of the two evaluated sites. One cross section considered the maximum height of the proposed structures, requiring mid-slope benches in the dam embankment. The second cross section considered reaches of the dams where the height would be a maximum (16 feet) before requiring a mid-slope bench. Material parameters for analysis models were estimated from laboratory testing or typical published values.

The stability analyses results met the minimum factor of safety requirements according to United States Army Corps of Engineers (USACE) except for one load case for the proposed Eagle Creek Dam. The case that did not meet the minimum factor of safety requirement considered steady-state seepage at the elevated flood pool. It is unlikely that steady-state seepage would develop at the flood level because the dam is proposed to be used for detention only.

The following recommendations should be considered as the project moves to detailed design:

1. Additional exploration, including but not limited to, drilling, sampling, instrumentation, in-situ testing, and laboratory testing should be performed to further define the borrow sources and foundation soil and rock near the proposed dam locations.
    a. A borrow source study should be performed to determine the available quantity of site specific fill materials. The study should include laboratory testing to determine design parameters of the potential borrow soil.
    b. Conduct additional geotechnical explorations at regularly spaced intervals to adequately characterize subsurface conditions. Explorations should include locations along the dam alignments and at select cross sections, and should obtain information to adequately design the foundation treatment and/or necessary seepage control measures for the sites.
    c. Install temporary piezometers and/or groundwater wells to establish groundwater levels and boundary conditions appropriate for detailed seepage design models.
    d. Perform in-situ hydraulic conductivity testing of foundation soils and bedrock to develop site specific parameters for seepage design models.
2. If the dams will be designed for steady-state seepage at flood levels, then an internal drainage system (chimney/blanket drain, finger drains, outlet pipes, etc.) should be considered for final design.
3. Design of the principal outlet conduits through the dams should include a filter diaphragm to intercept preferential seepage paths along the conduits.
4. The proposed structures will likely be classified as high hazard dams, and would therefore require special investigations to determine liquefaction potential and the presence of nearby faults. These seismic analysis requirements should be considered when developing the detailed explorations prior to final design.

1.0 INTRODUCTION

As part of the Hancock County Flood Risk Reduction Program, the Maumee Watershed Conservancy District (MWCD) is evaluating three potential dam alignments near Findlay, Ohio. The three dams are proposed to be earth detention dams, only detaining pools during flood events. Stantec Consulting Services Inc. (Stantec) was contracted by MWCD to perform engineering and design services for the program, including the preliminary geotechnical exploration for the proposed dams.

Figure 1 shows the site vicinity and preliminary alignment of the proposed Eagle Creek Dam. Eagle Creek runs south to north, flowing into the Blanchard River in the eastern portion of the City of Findlay. The proposed dam is located approximately 4 miles south of the City of Findlay with an approximate embankment length of 4.2 miles.

Figure 2 shows the site vicinity and preliminary alignment of the proposed Blanchard River and Potato Run Dams. South of Findlay, the Blanchard River runs south to north, then flows east to west through the City of Findlay. Potato Run flows south to north, entering the Blanchard River approximately 1.2 miles north of Mt. Blanchard. The proposed Blanchard River Dam alignment is approximately 1.4 miles long, and the proposed Potato Run Dam is approximately 0.7 miles long. The proposed dams are approximately 10 miles south and 5 miles east of the City of Findlay, near Mt. Blanchard.

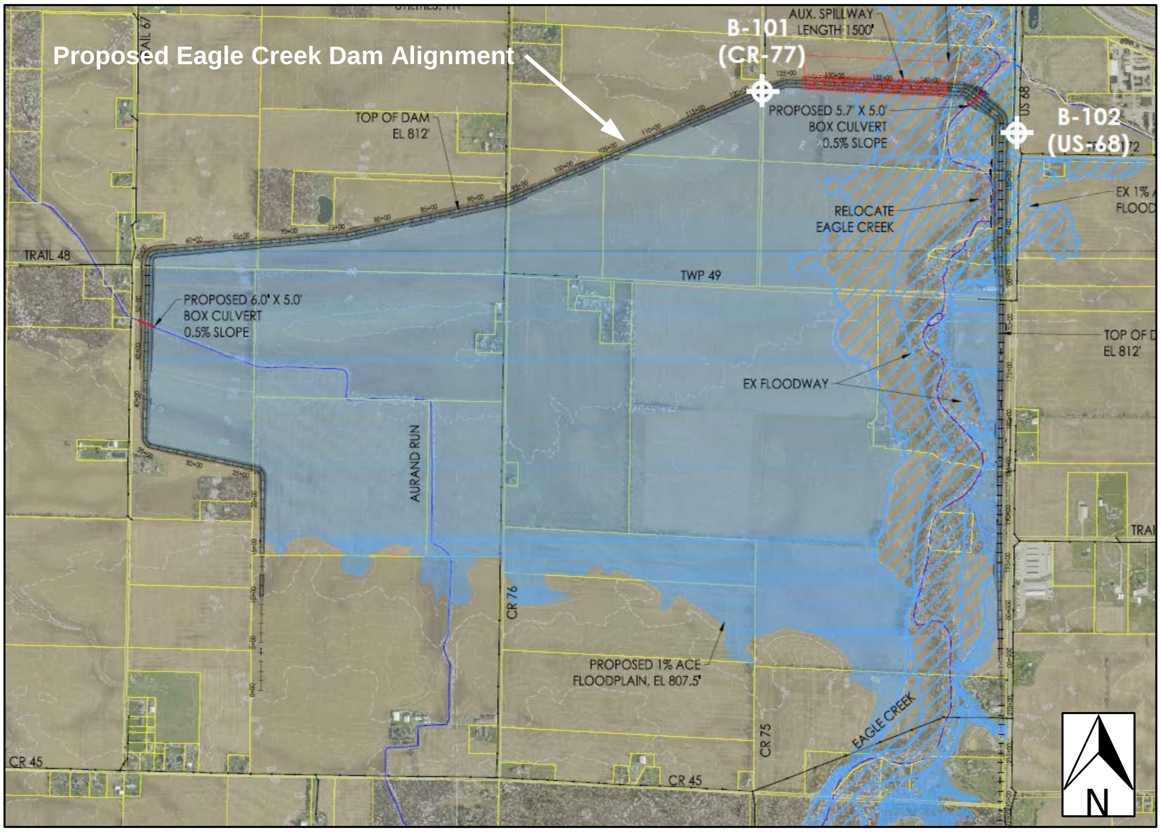

Figure 1. Eagle Creek Dam Site Vicinity Map

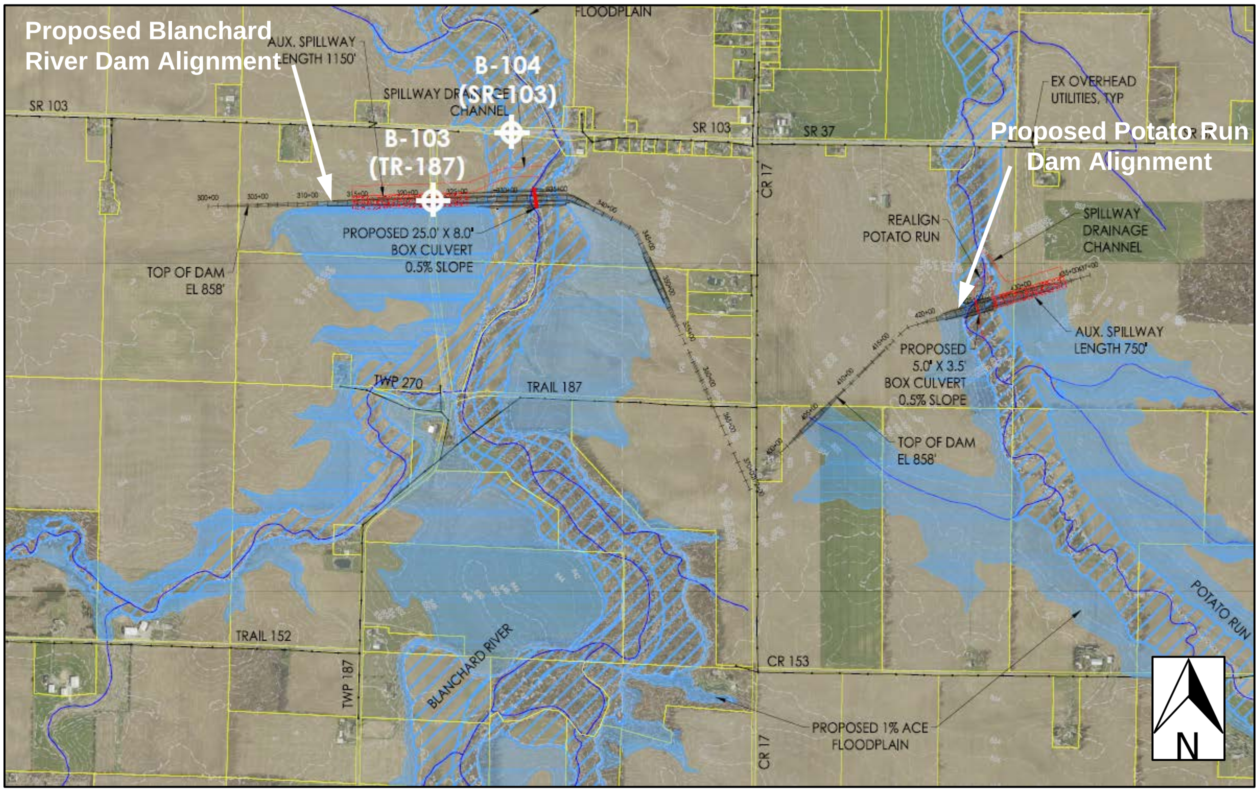

Figure 2. Blanchard River Dam and Potato Run Dam Site Vicinity Map

2.0 GEOLOGY AND OBSERVATIONS

2.1 GENERAL

The *Physiographic Regions of Ohio* map (Ohio Department of Natural Resources (ODNR), 1998) indicates that the proposed dam sites are located in the Central Ohio Clayey Till Plain. The Central Ohio Clayey Till Plain has a surface of clayey till, and contains well-defined moraines with intervening flat-lying ground moraine and intermorainal lake basins. This region contains a few large streams and has moderate relief (100 feet) with elevations of 700 to 1,150 feet. According to the map, the Columbus Escarpment is approximately one to two miles north of the proposed Eagle Creek dam site.

2.2 SOIL GEOLOGY

According to the *Quaternary Geology of Ohio* map (ODNR, 1999), the sites are predominantly underlain by clayey till deposited during the Late Wisconsinan Age. The clayey till originated as flat to gently undulating ground moraine.

The soil survey (*Web Soil Survey of Hancock County, Ohio*, United States Department of Agriculture (USDA), 2017) indicates that the sites are underlain predominantly by Blount silt loam. These soils consist of silt loam, silty clay, and clay loam with low to moderately high capacities to transmit water.

The *Drift Thickness Map of Ohio* (ODNR, 2004) suggests a range of soil cover at the project sites between 0 and 50 feet.

2.3 BEDROCK GEOLOGY

Bedrock mapping *(Reconnaissance Bedrock Geology of the Arlington, Ohio Quadrangle*, ODNR, 1999 and *Reconnaissance Bedrock Geology of the Blanchard, Ohio Quadrangle*, ODNR, 1998) and Descriptions of Geologic Map Units (ODNR, 2000) indicate that overburden soils at the proposed dam sites are underlain by sedimentary bedrock from the Tymochtee Dolomite Formation of the Silurian System. The Tymochtee Dolomite Formation is composed of olive gray to yellowish brown dolomite with shale laminae. This bedrock is described as thin to massively bedded, with thicknesses ranging from 0 to 140 feet.

According to the Abandoned Underground Mine Locator (ODNR, 2015), mapped underground mines have not been identified in the project vicinity.

The *Ohio Karst Areas* map (ODNR, 2007) does not indicate known karst areas in the vicinity of the sites. Probable karst areas are located east of the project sites in Wyandot and Seneca Counties.

2.4 SEISMIC

A review of the seismic data available in the project vicinity included the OhioSeis database developed by the ODNR, Division of Geological Survey. The review was performed using the internet mapping service (rev. 2012) at the following website: https://gis.ohiodnr.gov/website/dgs/earthquakes/.

Overall, Ohio has a relatively limited amount of seismic activity. However, within a 100-km (approximately 62 miles) radius of the proposed dam sites, there have been 75 earthquake epicenters with magnitudes ranging between 2.0 to 5.4. The available data included events that occurred from 1804 to present day.

The proposed structures will likely be classified as high hazard dams. According to the NRCS Technical Release Number 60 (TR-60), the project sites are in Seismic Zone 2, and will therefore require special investigations to determine liquefaction potential and the presence of nearby faults.

2.5 HYDROLOGY

The project is located in the Blanchard River Watershed. South of Findlay, Ohio, the Blanchard River runs south to north, then flows east to west through the City of Findlay. Eagle Creek runs south to north, flowing into the Blanchard River in the eastern portion of the City of Findlay. Potato Run runs south to north, flowing into the Blanchard River approximately 1.2 miles north of Mt. Blanchard.

2.6 HYDROGEOLOGY

Groundwater migrates by both primary and secondary porosity at the site. The soils in the area range from silts and clays to zones with sands and gravels. Surface water seeps into the soil overburden, particularly within the coarser zones. Perched water will often concentrate in the coarser soils and along the soil-top of bedrock interface. The groundwater will then primarily migrate downward through secondary porosity features such as the existing fractures, joints, and bedding planes, and to a lesser extent by primary porosity through the bedrock matrix. Groundwater follows the path of greater transmissivity downward and laterally until it intercepts the ground surface at seeps or springs, or intercepts the primary water table at varying depths within the bedrock. Regionally, groundwater generally flows in the direction of the surface drainage and intercepts channels and streams at lower elevations in the surrounding watersheds.

2.7 RECONNAISSANCE

Stantec representatives visited the site on November 1, 2017 to stake the boring locations. During this preliminary phase of work, borings were advanced on roadways within public right-of-way. The borings were marked with paint on the existing roadway pavement or staked in the right-of-way beyond the pavement. The areas immediately surrounding the boring locations were described as rural/agricultural, with some residential structures in the vicinity. In general, the existing pavement appeared to be in good condition. The boring locations were chosen to limit potential for interaction with existing utilities, guard rails, or other obstructions.

3.0 EXPLORATION

3.1 HISTORICAL EXPLORATION PROGRAMS

The ODOT Transportation Information Management System (TIMS) indicates that several geotechnical explorations have been performed in the vicinity of the dam sites. An exploration was performed in 1962 for the existing alignment of US-68/SR-15, which is approximately 0.5 miles north of the proposed Eagle Creek Dam site. The majority of the soils encountered were classified as silt and clay (ODOT Classification A-6a) or silty clay (A-4a). Bedrock encountered was described as hard gray dolomite. The top of bedrock elevation was reported at approximately 780 feet near the intersection of US-68/SR-15 with Eagle Creek.

Thirteen soundings were advanced for a 1954 exploration, just north of the proposed Blanchard River Dam site, along SR-103 for the bridge crossing the Blanchard River. The top of bedrock was reported at elevations ranging from 821.0 to 824.1 feet. Limited information on the soil and rock types is available in the documentation.

A search of the ODNR Ohio Oil & Gas Well Locator (2017) indicates that no wells have been drilled within the footprints of the proposed dam sites. Several wells have been drilled in the vicinity of the project sites, but the well reports include limited information to define subsurface conditions.

A search was also performed using the ODNR Ohio Water Wells Map (2017). According to the map, several wells have been drilled in the vicinity of the project sites. The water wells indicate that the overburden materials are typically clay, and bedrock was usually encountered at depths between 15 and 25 feet.

3.2 PROJECT EXPLORATION PROGRAM

Four borings were advanced by TTL Associates with boring logging performed by Stantec to obtain preliminary geotechnical data for the proposed dams. A summary of the borings advanced for this project is shown in Table 1. Boring logs are provided in Appendix A. Borings to investigate the existing conditions at the proposed dam structure along Potato Run were not advanced due to property access restrictions. In this report, conditions are assumed to be similar to those encountered in Borings B-103 and B-104.

Table 1. Boring Summary

Boring No.	Location	Ground Surface Elevation (ft)	Top of Bedrock Elevation (ft)	Bottom of Boring Elevation (ft)
B-101	CR-77 (Eagle Creek Dam Centerline)	799.5	779.7	754.5
B-102	US-68 (Eagle Creek Dam Downstream)	795.5	773.4	747.7
B-103	TR-187 (Blanchard River Dam Centerline)	843.1	824.2	803.6
B-104	SR-103 (Blanchard River Dam Downstream)	836.0	823.3	801.2

The borings were completed with a CME 550 or CME 75 drill rig using 3¼-inch inside diameter (ID) hollow stem augers to advance through soil. Standard penetration test (SPT) and undisturbed Shelby tube (ST) sampling was performed at continuous intervals until bedrock was encountered in the borings. The energy ratios (ER) of the drill rigs' automatic hammer and drill rod systems were measured on previous TTL Associates projects. The ER values are reported in Table 2.

Table 2. Drill Rig Summary

Drill Rig	Borings Drilled	Automatic Hammer Energy Ratio (ER)	Date of Measurement
CME 550	B-101	80.3	January 10, 2017
CME 75	B-102, B-103, B-104	74.5	December 29, 2015

The SPT sampling was performed in accordance with ASTM D1586, without the use of liners. The SPT samples were driven with an automatic hammer, and consisted of repeatedly dropping a 140-pound hammer from a height of 30 inches to drive a split-spoon sampler a distance of 18-inches. The number of hammer blows needed to advance the sampler was recorded over three 6-inch increments. The blow count from the first 6-inch increment was discarded due to ground disturbance at the bottom of the borehole. The sum of the blow counts from the second and third 6-inch increments is called the field N-value (N_{field}). The field N-value is corrected to an equivalent rod energy ratio of 60 percent (N_{60}) according to the equation below.

$$N_{60} = N_{field}\left(\frac{ER}{60}\right)$$

The depths/elevations of the SPTs with the corresponding blow counts are shown on the boring logs in Appendix A.

Upon encountering bedrock, rock coring was performed in the borings using NQ-size equipment. Recovery, core loss, and rock quality designation (RQD) values were recorded as percentages for the core runs. The recovery is a measurement of the core sample obtained from a core run. The loss is the difference between the core run and the recovery length. The RQD is measured by dividing the sum of all pieces of intact rock core within a core run that were longer than four inches by the total length of the core run. These values are shown on the boring logs in Appendix A.

The materials encountered were logged by a geotechnical engineer, with particular attention given to soil type, consistency, and moisture content. The borings were checked for the presence of groundwater during and after drilling with the depth of water recorded on the boring logs.

Borings were sealed using a cement/bentonite grout. A tremie pipe was lowered to the bottom of the borehole and grout was injected as the drilling tools were removed to displace water, drilling mud, and remaining soil cuttings, providing an appropriate seal within the boring. Quantities of the materials used in the grout mix are shown on the boring logs in Appendix A. Borings that were advanced through the existing pavement were backfilled with asphalt cold patch at the pavement surface.

The soil samples obtained from the borings were returned to the laboratory for visual classification and tested for water content. Engineering classification testing was performed on disturbed SPT and undisturbed Shelby tube samples reflecting the main soil horizons. The engineering classification tests included sieve and hydrometer analysis (ASTM D 422) and Atterberg limits (ASTM D 4318). Consolidated undrained triaxial compression testing (ASTM D 4767) and falling head hydraulic conductivity testing (ASTM D 5084) were performed on undisturbed Shelby tube samples. The results of the laboratory testing are provided in Appendix B.

4.0 FINDINGS

4.1 EAGLE CREEK DAM

Borings B-101 and B-102 were advanced to provide preliminary subsurface information for the proposed Eagle Creek Dam site. Boring B-101 was advanced adjacent to CR-77 along the proposed Eagle Creek Dam alignment, west of Eagle Creek. Boring B-102 was advanced through US-68, approximately 200 feet east of the proposed Eagle Creek Dam alignment, and east of Eagle Creek.

Surface materials consisted of 0.3 feet of topsoil in B-101 and 0.9 feet of asphalt pavement in B-102. A 1.8-foot thick layer of fill was encountered below the pavement in B-102.

Below the surface materials, an 8.5- to 9.8-foot layer of fine-grained material was encountered in the borings above the groundwater tables This fine-grained soil extended down to approximate elevations 788 feet (Boring B-101) and 784 feet (Boring B-102). This soil classified as Lean Clay with Sand (CL) and is described as having varying amounts of sand and gravel, moist, and medium stiff to stiff. Blow counts ranged from 8 to 22 blows per foot within this layer, and was generally stiffer with depth. In the seepage and stability analysis models, this layer was named “Upper Fine-Grained”.

Coarse-grained material was encountered below the “Upper Fine-Grained” material. Thin sand seams (1 to 2 inches thick) were encountered in B-101 between approximate elevations 787 feet and 788 feet. A 1.9-foot layer of moist, dense, poorly graded sand with some gravel was visually classified in B-102 between elevations 782.2 feet and 784.1 feet. The elevations correspond to similar locations (relative to the top of bedrock) within the profile of the two borings. The depth of this coarse-grained material generally corresponds the location of the groundwater table as measured within the boreholes during drilling. The groundwater table was encountered at a depth of 11.5 feet (El. 788.0 feet) in B-101 and 11.4 feet (El. 784.1 feet) in B-102. This material was assigned the name “Upper Coarse-Grained” for use in seepage and stability analyses.

A lower layer of fine-grained material was encountered in the borings below the “Upper Coarse-Grained” material. This layer was 4.9 to 5.5 feet thick and classified as Sandy Lean Clay (CL) or Silty Clay with Sand (CL-ML). These soils were encountered between elevations 783.5 and 789 feet in B-101, and between elevations 777.3 and 782.2 feet in B-102. The material was described as moist and medium stiff to very stiff. In the seepage and stability analysis models, this layer was named “Lower Fine-Grained”.

Below the “Lower Fine-Grained” material, a 3.8- to 3.9-foot layer of coarse-grained material was encountered above the top of bedrock. This material classified as a Poorly Graded Gravel with Clay and Sand (GP-GC). The GP-GC soils were encountered between elevations 779.7 and783.5 feet in B-101 and between elevations 773.4 and 777.3 feet in B-102. This material was described as moist and dense to very dense, with a fairly strong hydro-carbon odor noted in B-102. This layer is called “Lower Coarse-Grained” material in the seepage and stability analyses.

Bedrock was encountered at a depth of 19.8 feet (El. 779.7 feet) in B-101 and 22.1 feet (El. 773.4 feet) in B-102. The bedrock was described as gray dolomite, slightly weathered, fractured to moderately fractured, slightly rough, and thin to medium bedded. Recovery of the rock core runs ranged from 90 to 100 percent with RQD ranging from 33 to 87 percent. Fractured zones and water loss were noted in the bedrock until the termination depths. Therefore, bedrock was modeled as “Fractured Bedrock” in the seepage and stability analyses.

Laboratory testing performed on samples obtained from B-101 and B-102 is summarized in Table 3. Results of laboratory testing are provided in Appendix B. Refer to sections 6.1.2.2 and 6.1.3.1 for discussion on material parameters selected for the seepage and stability analyses.

Table 3. Summary of Laboratory Testing for Eagle Creek Dam

Laboratory Test	Number of Tests
Natural Moisture Content	33
Particle Size Analysis	7
Atterberg Limits	7
Soil Classifications	7
Specific Gravity	10
Unit Weight	9
Triaxial Compression	6
Hydraulic Conductivity	3

4.2 BLANCHARD RIVER AND POTATO RUN DAMS

Borings B-103 and B-104 were advanced to provide preliminary subsurface information for the proposed Blanchard River and Potato Run Dams. Boring B-103 was advanced through TR-187 along the proposed Blanchard River Dam alignment. Boring B-104 was advanced through SR-103, downstream of the proposed Blanchard River Dam alignment. Both borings were drilled west of the Blanchard River.

Surface materials consisted of 0.4 to 0.9 feet of roadway pavement and 0.4 feet of granular base material. Fill visually described as lean clay with sand was encountered to depths of 3.7 feet (El. 839.4 feet) in B-103 and 7.9 feet (El. 828.1 feet) in B-104.

A 12.8-foot layer of cohesive material was encountered below the fill in B-103 between elevations 826.6 and 839.4 feet. The soil classified as Clayey Sand (SC) and Lean Clay with Sand (CL). The soil was described as moist and medium dense or very stiff. Blow counts ranged from 16 to 25 blows per foot in this layer. This material was not encountered in B-104. For the seepage and stability analyses, this material was named “Fine-Grained” material.

Below the “Fine-Grained” material in B-103 and the fill material in B-104, a 2.4- to 4.8-foot layer of coarse-grained material was encountered above the top of bedrock. This material classified as non-plastic Silty Sand (SM) and was described as moist and loose to medium dense. A fairly strong hydro-carbon odor was noted in B-104. The silty sand material was encountered between elevations 824.2 and 826.6 feet in B-103, and between elevations 823.3 and 828.1 feet in B-104. This layer is called “Coarse-Grained” material in the seepage and stability analyses.

Bedrock was encountered at a depth of 18.9 feet (El. 824.2 feet) in B-103 and 12.7 feet (El. 823.3 feet) in B-104. The bedrock was described as gray dolomite, slightly weathered, fractured to moderately fractured, slightly rough, and thin to medium bedded. Recovery of the rock core runs ranged from 88 to 100 percent with RQD ranging from 13 to 100 percent. RQD was lower in the first approximately 10 feet of rock core runs, ranging from 13 to 20 percent. In the seepage and stability analysis models, bedrock was modeled as “Fractured Bedrock” in the upper 10 feet and “Bedrock” below.

Laboratory testing performed on samples obtained from B-103 and B-104 is summarized in Table 4. Results of laboratory testing are provided in Appendix B. Refer to sections 6.2.2.2 and 6.2.3.1 for discussion on material parameters selected for the seepage and stability analyses.

Table 4. Summary of Laboratory Testing for Blanchard River and Potato Run Dams

Laboratory Test	Number of Tests
Natural Moisture Content	27
Particle Size Analysis	5
Atterberg Limits	5
Soil Classifications	5
Specific Gravity	7
Unit Weight	6
Triaxial Compression	4
Hydraulic Conductivity	2

5.0 ANALYSIS METHODOLOGY

5.1 SEEPAGE ANALYSES

5.1.1 Software Employed in Seepage Analyses

Seepage analyses were completed in GeoStudio SEEP/W 2016, finite element software tailored for modeling two-dimensional groundwater seepage problems in soil and rock. SEEP/W is distributed by GEO-SLOPE International, Ltd. of Calgary, Alberta, Canada (www.geo-slope.com). SEEP/W 2016, version 8.16, is used for the analyses described herein.

SEEP/W uses problem geometry, boundary conditions, and soil properties defined by the user to compute the total hydraulic head at nodal points within the modeled cross section (GEO-SLOPE 2015a). Among other features, SEEP/W includes a graphical user interface, semi-automated mesh generation routines, iterative algorithms for solving unconfined flow problems, specialized boundary conditions (seepage faces, etc.), capabilities for steady-state or transient analyses, and features for visualizing model predictions. The software also includes material models that allow the simulation of both saturated and unsaturated flow, including the transition in seepage characteristics as soils become saturated or unsaturated during the problem simulation.

For the numerical analysis, the cross section is modeled as a mesh of elements, consisting of first-order quadrilateral and triangular finite elements. For seepage problems, where the primary unknown (hydraulic head) is a scalar quantity, first-order elements provide efficient and effective modeling. Given appropriate hydraulic conductivity properties and applied boundary conditions, the finite element method is then used to simulate steady seepage across the mesh. The total hydraulic head is computed at each nodal location, from which pore water pressures and seepage gradients can be calculated.

5.1.2 Seepage Model Calibration

The modeled permeability parameters for the materials in the embankments and foundations are summarized in Section 6.0. Typically, a seepage model for an existing dam is calibrated to in-situ conditions as recorded by onsite instrumentation and field observations. The boundary conditions, geometry, and assigned material parameters are varied until the model produces results consistent with piezometer readings and/or observations. For this preliminary design phase, instrumentation pertinent to seepage calibration of the proposed dams is not available. Instead, the models were focused on producing piezometric surfaces that were consistent with the existing conditions observed during site visits, during drilling, and from topographic mapping prior to dam construction.

5.1.3 Seepage Model Boundary Conditions

5.1.3.1 Available Boundary Conditions for Seepage Modeling

There are two fundamental boundary conditions for seepage analyses: specified hydraulic head or specified flux (flow rate across the boundary). Boundary conditions may be applied along the edges of the model and to internal nodes within the model (useful for representing sources and sinks, including drains). SEEP/W includes a number of special features to model the boundary conditions of a particular problem (GEO-SLOPE 2015a). These include the ability to specify pressures on a defined surface (the code internally converts the nodal pressures to total head), to simulate infiltration and evaporation at the ground surface (when used with a companion software module), and to vary the boundary conditions over time for transient analyses.

Where the line of seepage may exit to the ground surface, a potential seepage face boundary condition is specified. This special boundary condition is applied to the sloping surfaces of a dam when the exit point of the top flow line is unknown. In each iterative step of the analysis, the code checks the nodes along the seepage face. Points below the top flow line are assigned fixed heads equal to the node elevation, allowing seepage of water out to the ground surface. Points above the top flow line are assigned zero pressure head (no flow). A seepage face boundary condition is typically specified along the downstream face and toe of the dam, where the top flow line may exit the embankment.

5.1.3.2 Applied Boundary Conditions

The seepage models for the Eagle Creek, Blanchard River, and Potato Run Dams use specified hydraulic head boundary conditions applied in two locations: the upstream ground surface and vertical edge of the model, and downstream vertical edge of the model. The values of the specified head boundary conditions are described for the evaluated cross sections in Sections 6.1.2.1 and 6.2.2.1. No seepage (zero flux) is allowed across the horizontal boundary at the base of the model.

A potential seepage face boundary condition was applied to the ground surface downstream of the dam.

5.2 SLOPE STABILITY ANALYSES

5.2.1 Software Employed in Slope Stability Analyses

Slope stability was evaluated using conventional, limit equilibrium methods as implemented in the GeoStudio SLOPE/W 2016 software. Available from GEO-SLOPE International, Ltd., of Calgary, Alberta, Canada (www.geo-slope.com), SLOPE/W is a special-purpose computer code designed to compute the stability of earth slopes using two-dimensional, limit equilibrium, method of slices analyses (GEO-SLOPE 2015b). SLOPE/W 2016, version 8.16, is used for the analyses described herein. With SLOPE/W, the distribution of pore water pressures within the earth mass may be mapped directly from the results of a SEEP/W analysis.

5.2.2 Assumed System(s) of Slice Forces

Limit equilibrium methods for evaluating slope stability consider the static equilibrium of a soil mass above a potential failure surface. In conventional, two-dimensional methods of analysis, the slide mass above an assumed failure surface is split into vertical slices. Stresses are evaluated along the sides and base of each slice. The factor of safety against a slope failure (FS_{slope}) is defined as:

$$FS_{slope}=\frac{\text{shear strength of soil}}{\text{shear stress required for equilibrium}}$$

where the strengths and stresses are computed along a defined failure surface, on the base of the vertical slices. The shearing resistance at locations along the potential slip surface is computed, with appropriate Mohr-Coulomb strength parameters, as a function of the total or effective normal stress.

Spencer’s solution procedure (Spencer 1967), which satisfies all of the conditions of equilibrium for each slice, was used in this study. Key assumptions and features of Spencer’s method include (USACE 2003; Duncan and Wright 2005):

- All interslice forces are assumed to have the same inclination angle with respect to the horizontal. The inclination is computed as part of the solution.
- The normal force on the base of each slice is assumed to act at the center of the base.
- A trial and error solution is required, to solve for equilibrium.
- Force and moment equilibrium are satisfied for each slice, and the overall slide mass.
- Circular and noncircular potential failure surfaces can be evaluated.
- The procedure computes FS_{slope} for an assumed failure surface. A search must be made to find the critical slip surface corresponding to the lowest FS_{slope}.

5.2.3 Slip Surfaces Considered

SLOPE/W includes several options and trial routines to facilitate the search for the critical failure surface (GEO-SLOPE 2015b). In the “grid and radius” search method, a region (divided into a grid) for the circle centers and a range of possible radii are specified for the trial slip circles. The code then automatically evaluates a large number of trial circles within those parameters, searching for one circle having the lowest FS_{slope}. In the “entry and exit” method, the search considers potential slip circles that intersect the ground surface within specified ranges. Where a potential failure circle intersects a much stronger, “impenetrable” layer (such as rock), SLOPE/W automatically evaluates composite slip surface (circles with straight-line portions along the interface). Non-circular slip surfaces are considered using the “block method”.

Within the slope stability model geometry, “impenetrable” strength parameters can be assigned to materials such as concrete structures or bedrock. With that strength condition applied, a slip surface will not pass through the material. For these analyses, bedrock was modeled as “impenetrable.”

Once a critical slip surface is identified by the automated search routine, the “optimization” feature in SLOPE/W is used to consider the possible effects of localized changes in the slip surface. The code divides the critical slip circle into linear segments, then moves the end points while searching for a surface that yields a lower FS_{slope}. The optimization routine will sometimes produce a slip surface with reverse curves, or one that is not otherwise kinematically logical. If the inferred, failure mechanism is not a realistic representation of slope movements, the “optimized” result is discarded.

A variety of these methods is used in searching for the critical slip surface. The details of the employed strategy are relatively unimportant; however, as different approaches usually lead to similar answers.

The final failure surface, representing the critical slip surface associated with FS_{slope}, is selected by the engineer based on the analytical results, the automated search outcomes, and knowledge of the geotechnical conditions.

5.2.4 Pore Pressure Distribution for Stability Analyses

For the drained stability analyses, pore pressures are computed for steady state seepage at the normal pool (natural stream surface elevation) or flood pool levels. The distribution of pore pressures predicted in the SEEP/W analysis is mapped directly to the stability analysis. SLOPE/W uses an interpolation scheme to compute the pore pressures at the base of each slice along a failure surface, based on the pressure heads computed at adjacent nodal points in the SEEP/W solution mesh.

For the undrained stability analyses, pore water pressures are computed for steady state seepage at the normal pool (natural stream surface elevation) level. The dams considered in this preliminary analysis are assumed to be homogeneous embankments. In a homogeneous embankment, or any dam where all of the materials are treated as undrained, the pore pressures are mapped from a SEEP/W analysis. This provides a more accurate solution, as the use of an interpolated piezometric line only approximates the pore pressures computed with SEEP/W.

In the case of these proposed dams, use of either mapped pore pressures or a piezometric line are approximations, as instrumentation data is not available for conditions following construction. The mapped pore pressures are therefore dependent on acceptable definition of material parameters and boundary conditions as opposed to instrumentation validation.

5.2.5 Surcharge Pressures for Flood Cases

During a flood inflow event, the rising reservoir exerts an increasing hydraulic pressure on the submerged face of the dam and foundation. In a surficial soil unit where the modeled pore pressures correspond to the lower normal pool, a surcharge pressure must be separately computed and specified in the SLOPE/W analysis. This procedure, as described here, is necessary to correctly represent the flood pool cases using SLOPE/W.

By default, SLOPE/W evaluates the pore water pressures in the soil along the ground line. Where the pore pressure is positive at the ground surface, SLOPE/W automatically assumes water is ponded at an elevation equal to the total hydraulic head at that location. That is, the code assumes the water pressures are equal above and below the ground surface line. This results in a correct representation for those load cases where the pool levels are unchanged between the steady-state seepage condition and the slope stability analysis.

When modeling some flood load cases, the soil pore pressures are computed for a lower (normal) pool, and then used to quantify effective consolidation stresses and soil shear strengths. In this case, SLOPE/W will assume water pressures acting on the ground surface that correspond to the lower normal pool, not the elevated pool being analyzed for stability. A surcharge pressure, representing the added load from the rising pool, must be applied to the submerged ground line.

The additional surcharge pressure is computed and applied as follows:

- The surcharge pressure is equal to the difference in pool elevations (flood pool minus the normal pool), multiplied by the unit weight of water.
- The surcharge pressure is applied normal to the surface and uniformly at all points along the ground line that is submerged under the lower (normal) pool. The resulting surcharge line on the SLOPE/W graphical output is a line that follows and remains at a constant distance above the submerged ground surface.
- Along the ground surface that becomes submerged by the rising flood pool, the added pressure is normal to the ground line and increases linearly with depth. The applied pressure varies from zero at the flood pool elevation to the full surcharge pressure at the normal pool elevation. The resulting surcharge appears as a triangular pressure distribution on the SLOPE/W graphical output.

On the graphical output from SLOPE/W for the analysis of a flood case, a water surface appears above undrained materials at the level of the normal pool. This corresponds to the pool level for which the pore water pressures are computed, for steady-state seepage at the normal pool. In the case of a dry dam, the normal pool elevation is below the ground surface on the upstream side, therefore no water surface shows above the ground surface on the SLOPE/W output. The added pressure of the flood pool is depicted as a surcharge pressure along the ground line, but is applied only to undrained soil regions.

Surcharge pressures are not needed for a drained analysis with pore pressures that correspond to the flood pool.

5.2.6 Pore Pressure Conditions for Sudden Drawdown Conditions

Embankment dams become saturated by seepage during prolonged periods of high pool. When the reservoir is subsequently lowered, the external stabilizing pressure of the water on the submerged slope is reduced. This subjects the embankment soils to increasing shear stresses, resulting in excess pore pressures in contractive soils. If the pool is drawn down faster than the excess pore water pressures can dissipate, a potentially critical undrained loading condition may develop. Sudden drawdown conditions may develop within the upstream slope for headwater fluctuations, and/or the downstream slope for tailwater fluctuations. A three-stage analysis procedure is used to evaluate slope stability during a sudden drawdown event.

For the three-stage sudden drawdown analysis, SLOPE/W does not have the capability to directly map the pore pressures predicted by SEEP/W. For these load cases, two piezometric lines must be specified, representing steady state seepage for the higher and lower pool elevations. The phreatic lines predicted with SEEP/W are manually digitized for input to SLOPE/W, which then computes pore pressures at any point based on the depth below this line. The “phreatic correction” option in SLOPE/W is applied in both cases.

5.3 LOADING CONDITIONS AND ACCEPTANCE CRITERIA

The U.S. Army Corps of Engineers (USACE) provides guidance for analyzing the stability of slopes of new earth dams in Engineer Manual (EM) 1110-2-1902. This guidance was followed for this analysis. Table 5 provides the load cases to consider and the required minimum factors of safety for new earth dams.

Table 5. Minimum Required Factors of Safety: New Earth Dams

Case No.	Analysis Condition	Required Minimum Factor of Safety	Analyzed Pool Condition and Shear Strength Parameters	Slope
1	End of Construction	1.3	Normal headwater, total stress shear strengths	Upstream and Downstream[(1)]
2	Long-term (Steady seepage, maximum storage pool, spillway crest or top of gates)	1.5	Normal headwater, effective stress shear strengths	Downstream
3	Maximum Surcharge Pool	1.4	Normal headwater pore pressures, flood surcharge to flood headwater elevation, total stress shear strengths	Downstream
4			Normal headwater pore pressures, flood surcharge to flood headwater elevation, effective stress shear strengths	
5			Flood headwater pore pressures, effective stress shear strengths	
6	Sudden Drawdown	1.1 to 1.3(2)	Flood headwater to normal headwater pore pressures, sudden drawdown strengths	Upstream

(1) For this analysis, Case No. 1 was performed evaluating incipient motion in the downstream direction only because of the symmetry of the cross section.
(2) For this analysis, the required minimum FS = 1.1 since drawdown is from the flood (maximum surcharge) pool.

Drained, effective stress analyses were used to evaluate incipient motions in the downstream direction for Case Nos. 2, 4, and 5. The drained cohesion (c’) and drained friction angle (ϕ’) were applied to each material for these cases.

Undrained, total stress analyses were completed to evaluate incipient motion in the downstream direction for Case Nos. 1 and 3. In these analyses, the contribution of suction pressures to shearing resistance is effectively neglected by specifying composite drained-undrained strength envelopes. The shearing resistance at a given normal stress is then the lesser value of strength computed with the drained or undrained strength parameters. A composite drained-undrained envelope was applied to each material for these cases.

Sudden drawdown analysis (Case No. 6) evaluates incipient motion in the upstream direction using an interpolation scheme, which accounts for the effects of anisotropic consolidation to compute the undrained shear strength of the soil along the potential slip surface. This method uses a strength envelope that relates undrained shear strength to the static shear stress and effective consolidation stress acting on the failure plane. The slope and intercept of this failure surface, designated as ψ and d, are computed (within SLOPE/W) from the Mohr-Coulomb strength parameters. Mohr-Coulomb parameters must be specified for two limiting cases, for drained failure (c’ and ϕ’) and isotropically consolidated, undrained failure (c and ϕ).

6.0 ANALYSIS RESULTS

6.1 EAGLE CREEK DAM

6.1.1 Typical Cross Sectional Geometry

The preliminary Eagle Creek Dam alignment is approximately four miles long. To minimize the footprint of the dam while providing the necessary flood protection, the following geometry was assumed:

- Crest elevation = 812 feet
- Embankment side slopes = 2.5H:1V
- Bench elevation = 796 feet
- Crest and bench width = 16 feet to allow for vehicle access for maintenance and monitoring
- Bench sloping = 2 percent to provide surface drainage
- Excavation of 1 foot to remove vegetation and topsoil under the dam footprint
- Cutoff trench = 5 feet deep x 20 feet bottom width with 1H:1V side slopes
    - USBR (1987) suggests the use of a cutoff trench. The depth and bottom width were assumed to provide sufficient equipment access during construction.

To conduct preliminary seepage and slope stability analyses, two cross sections were considered. One cross section considered the maximum height of the proposed structure, where the dam would cross or run adjacent to Eagle

Creek. This cross section is shown in Figure 3. The preliminary alignment suggests the toe in these areas would be at approximate elevation 785 feet.

The second cross section considered the reaches of the dam that would be shorter. This cross section was modeled as 16 feet tall, the maximum height before requiring a mid-slope bench. This cross section is shown in Figure 4.

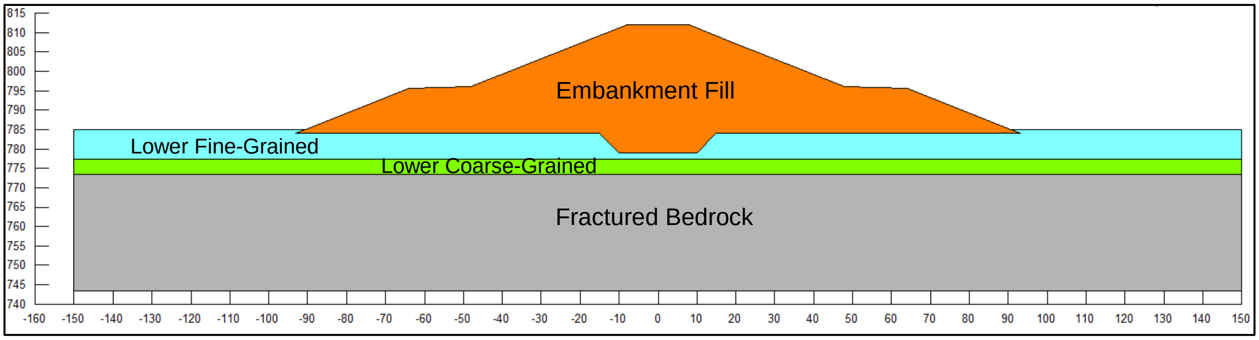

Figure 3. Eagle Creek Dam Section – Maximum Height

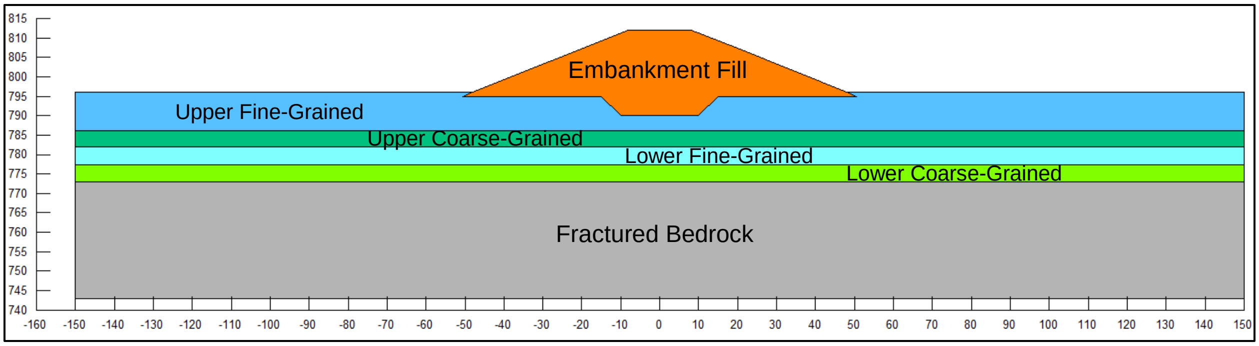

Figure 4. Eagle Creek Dam Section – 16-Foot Height

As part of this exploration, two borings (B-101 and B-102) were advanced in the vicinity of the preliminary alignment of Eagle Creek Dam. The soil types and material interface elevations encountered in the borings were used to determine representative, generalized subsurface geometry for the two analysis cross sections. The material thicknesses and locations within the soil profile (relative to the top of bedrock) were similar within the two borings. See Section 4.1 for further discussion on material types and locations where they were encountered.

The generalized subsurface profile used in the modeled cross sections is based on elevations encountered in Boring B-102. The material layers (and associated soil/rock classifications) used in the analyses are as follows: Embankment Fill (CL, SC), Upper Fine-Grained (CL), Upper Coarse-Grained (SP), Lower Fine-Grained (CL, CL-ML), Lower Coarse-Grained (GP-GC), and Fractured Bedrock (dolomite). The Embankment Fill was assumed to consist of compacted lean clay, sandy lean clay, lean clay with sand, or clayey sand. These soil types were encountered in the upper zones of the nearby borings. It was assumed that these materials would be excavated from within the proposed impoundment area to construct the embankment.

As shown in Figure 3, the existing ground surface for the maximum height cross section is at approximate elevation 785 feet. For the purposes of analysis, it was assumed that the dam would be founded on the Lower Fine-Grained material. This assumption resulted in a higher top elevation of the Lower Fine-Grained material modeled in the maximum height cross section than what was encountered in Boring B-102. This is appropriate for the generalized section during preliminary analysis, but should be re-visited during final dam design and analysis of specific critical cross sections associated with the final dam alignment.

6.1.2 Seepage Analysis

6.1.2.1 Assumed Headwater and Tailwater Conditions

The seepage analyses considered two cases, normal and flood pool conditions. Table 6 summarizes the headwater and tailwater conditions assumed for the Eagle Creek Dam analyses.

Table 6. Eagle Creek Dam Headwater and Tailwater Conditions

Condition	Headwater Elevation (ft)	Tailwater Elevation (ft)
Normal (Maximum Storage Pool)	785.0	783.0
Flood (Maximum Surcharge Pool)	810.5	783.0

The normal water level in Eagle Creek based on survey data from November 2016 is 784.0 feet within the channel near the proposed dam site. This elevation is consistent with the groundwater table elevation of 784.1 feet encountered in B-102, which was the closest boring to Eagle Creek. Headwater and tailwater boundary conditions were assigned one foot higher and lower hydraulic head, respectively, to model flow from upstream to downstream. The assigned headwater and tailwater elevations are tabulated in Table 6.

The flood elevation of 810.5 was provided by the project hydraulics and hydrology team. The flood tailwater elevation was assigned the same hydraulic head as the normal tailwater, assuming that a sudden rise in upstream water level due to a flood event would not likely impact the water level downstream of the dam.

6.1.2.2 Material Parameters

In typical geotechnical engineering practice, saturated permeability (k) is reported in units of cm/sec, measurements are made with vertical seepage (k_v), and saturated anisotropic permeability is characterized as the ratio of saturated horizontal to vertical permeability (k_h/k_v). Unsaturated permeability parameters were modeled using the functions developed by GEO-SLOPE for a given soil texture, which are based on functions taken from published literature (GEO-SLOPE 2015a). Additional inputs of saturated volumetric water content (θ_s) are needed for the unsaturated permeability functions.

The permeability parameters were used in SEEP/W analyses (Section 5.1.1), which requires inputs of saturated horizontal permeability (k_x) in feet/sec, a saturated anisotropy ratio of k_y/k_x, and a saturated volumetric water content used for the unsaturated permeability. These parameters are provided in Table 7.

Table 7. Eagle Creek Dam Seepage Parameters

	Saturated Permeability Parameters					Unsaturated Permeability Parameters(1)
				SEEP/W Input		
Material	**k_v (cm/sec)**	**k_h (cm/sec)**	**k_h/k_v**	**k_x (ft/sec)**	**k_y/k_x (unitless)**	**θ_s (unitless)**
Embankment Fill	6.1×10^{-8}	3.0×10^{-7}	5	1.0×10^{-8}	0.2	0.42
Upper Fine-Grained	1.0×10^{-8}	1.0×10^{-7}	10	3.3×10^{-9}	0.1	0.36
Upper Coarse-Grained	5.0×10^{-2}	5.0×10^{-2}	1	1.6×10^{-3}	1	0.32
Lower Fine-Grained	1.7×10^{-8}	1.7×10^{-7}	10	5.6×10^{-9}	0.1	0.31
Lower Coarse-Grained	5.0×10^{-2}	5.0×10^{-2}	1	1.6×10^{-3}	1	0.32
Fractured Bedrock	2.5×10^{-5}	2.5×10^{-5}	1	8.2×10^{-7}	1	0.25

(1) Bedrock was modeled as saturated only for SEEP/W computations

The saturated permeability of the Embankment Fill was based on typical values for compacted embankment core materials provided by NAVFAC (1986) and USBR (2011) for CL and SC classifications (assumed embankment material). An anisotropy ratio of 5 was selected for the Embankment Fill based on USBR (2011) recommendations for standard placement of embankment core material. The unsaturated permeability for the Embankment Fill was modeled using the built-in “clay” function within SEEP/W.

One falling head permeability test was performed on a sample of Upper Fine-Grained material, resulting in a vertical permeability value of 1.0×10^{-8} cm/sec. Two falling head permeability tests were performed on the Lower Fine-Grained material, resulting in vertical permeability values of 1.1×10^{-8} cm/sec and 2.4×10^{-8} cm/sec. An average (geometric) value of 1.7×10^{-8} was used to model the Lower Fine-Grained material. Lenses of sand with varying thicknesses were encountered within the deposits of fine-grained soils. Anisotropy ratios of 10 were selected for the fine-grained materials based on USBR (2011) recommendations for stratified deposits of natural soil. For the fine-grained soils, the built-in “silty clay” function in SEEP/W was used to model unsaturated permeability.

The permeability values of the Upper Coarse-Grained and Lower Coarse-Grained materials were estimated from typical values provided by NAVFAC (1986) and USBR (2011) for SP, GP, and GC classifications (similar to the coarse-grained materials encountered in this exploration). The coarse-grained soils were assumed to be free draining materials with an anisotropy ratio of one. The unsaturated permeability for the coarse-grained materials was modeled with the built-in “sand” function within SEEP/W.

USBR (2011) estimates the horizontal permeability of intact dolomite bedrock to be approximately 0 to 5×10^{-6} cm/sec. Borings indicated that the bedrock in the area was slightly fractured to moderately fractured, therefore a value of 2.5×10^{-5} cm/sec was selected for analysis. USBR (2011) guidance suggests that anisotropy of massive soil or rock ranges from 1 to 3, and fractured rock ranges from 0.1 to 10. An anisotropy ratio of one was selected for bedrock based on the suggested ranges from USBR (2011). Because groundwater in the applicable borings was encountered above the top of rock, and it is likely that groundwater is continuously perched above the top of rock, the bedrock materials were modeled with only saturated permeability parameters in the seepage model.

Saturated volumetric water contents (θ_S) of the soils were determined based on porosity calculated from the void ratios presented in Table 8. A value of 0.25 was assumed for the saturated volumetric water content of the bedrock, based on experience with similar models.

6.1.3 Slope Stability Analysis

6.1.3.1 Material Parameters

Table 8 presents a summary of the parameters used for the slope stability analyses of the proposed Eagle Creek Dam.

Table 8. Eagle Creek Dam Slope Stability Parameters

	Density Parameters			Drained Shear Strength		Undrained Shear Strength	
Material	Moist Unit Weight γ_m (pcf)	Saturated Unit Weight γ_{sat} (pcf)	Void Ratio e (unitless)	ϕ' (deg)	c' (psf)	ϕ (deg)	c (psf)
Embankment Fill	119	125	0.72	29	0	15	500
Upper Fine-Grained	130	131	0.56	34	0	32	400
Upper Coarse-Grained	132	132	0.47	32	0	32	0
Lower Fine-Grained	138	138	0.45	34	0	32	400
Lower Coarse-Grained	132	132	0.47	32	0	32	0
Fractured Bedrock	Impenetrable						

The Embankment Fill density parameters are based on typical values for compacted soil provided by NAVFAC (1986) for CL and SC classifications (assumed embankment material). Density parameters of the Upper and Lower Fine-Grained materials are based on results of laboratory testing. Specific gravity, moist unit weight, and moisture content were measured during laboratory triaxial and permeability tests. From those measured parameters, saturated unit weight and void ratio were calculated as reported in Table 8. Density parameters of the coarse-grained materials were calculated using typical vales of porosity of dense sand (Terzaghi et. al 1996), typical values of specific gravity for sands (G_s = 2.65), and moisture content results from laboratory testing.

Shear strength parameters for the Embankment Fill were estimated based on typical values for compacted (soil type/class) soil provided by NAVFAC (1986). Shear strengths for the coarse-grained materials were estimated based on published correlations to corrected SPT N-values per the guidance documented in Virginia Tech CGPR #12 (1998). It was assumed that this material would be free-draining; therefore, the drained and undrained shear strengths are equal.

Three CU triaxial tests were performed on samples of the Upper Fine-Grained soil and three CU triaxial tests were performed on samples of the Lower Fine-Grained soil. As described in Section 6.2.3.1, four additional CU triaxial tests were conducted on soil samples obtained for borings representative of the foundation soils of the Blanchard River Dam. The results of the 10 CU triaxial tests were plotted together in p'-q and p-q space to fit the drained and undrained failure envelopes representative of the Upper and Lower Fine-Grained materials. In fitting strength parameters to multiple test results, the practice of the U.S. Army Corps of Engineers is to select design values of c' and ϕ' (or c and ϕ) so that data from about two-thirds of the tests are above the failure envelope (USACE 2003). Figure 5 and Figure 6 present the resulting drained and undrained failure envelopes based on the combined CU triaxial testing results.

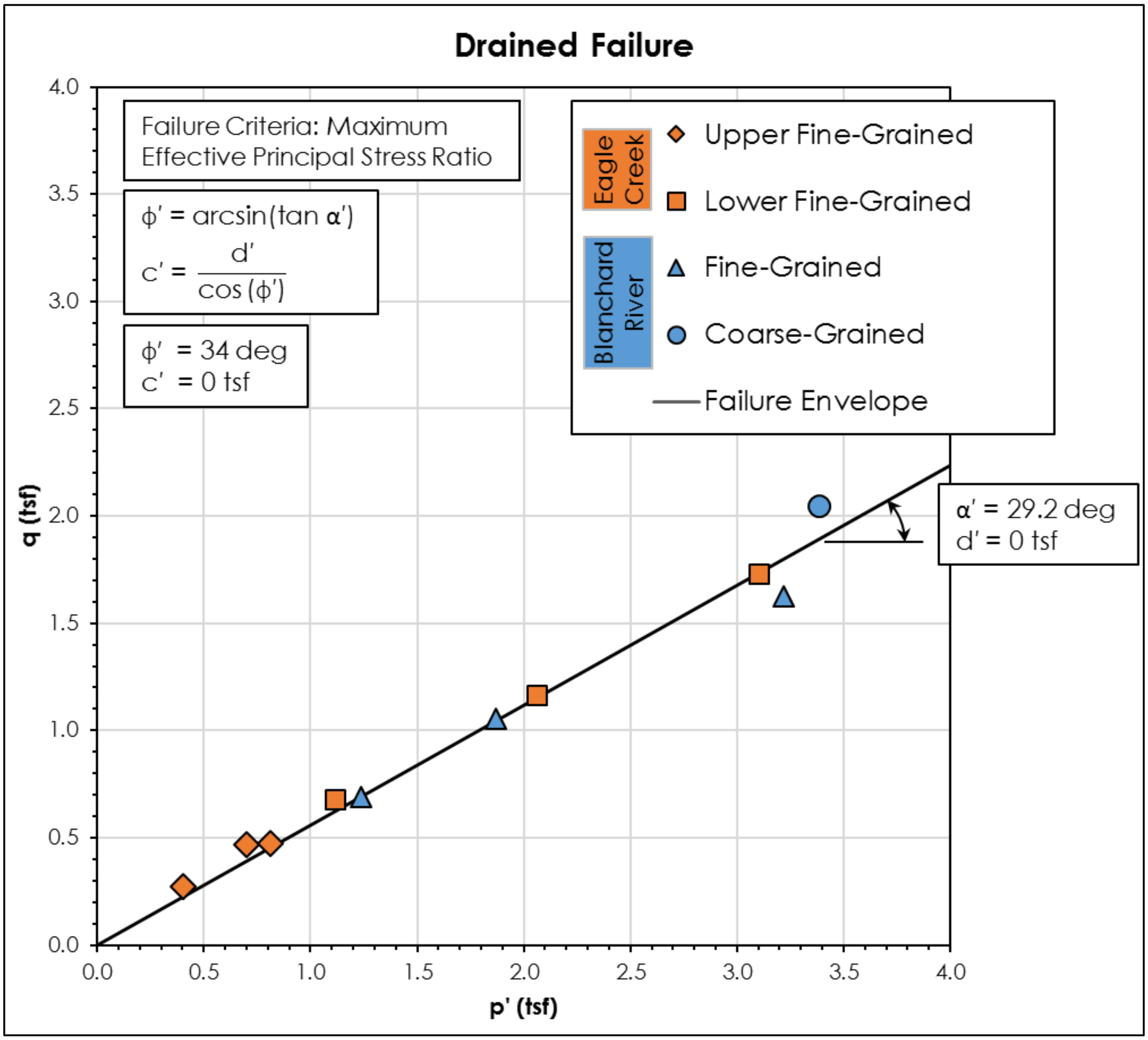

Figure 5. Drained Failure Envelope from CU Triaxial Testing Results

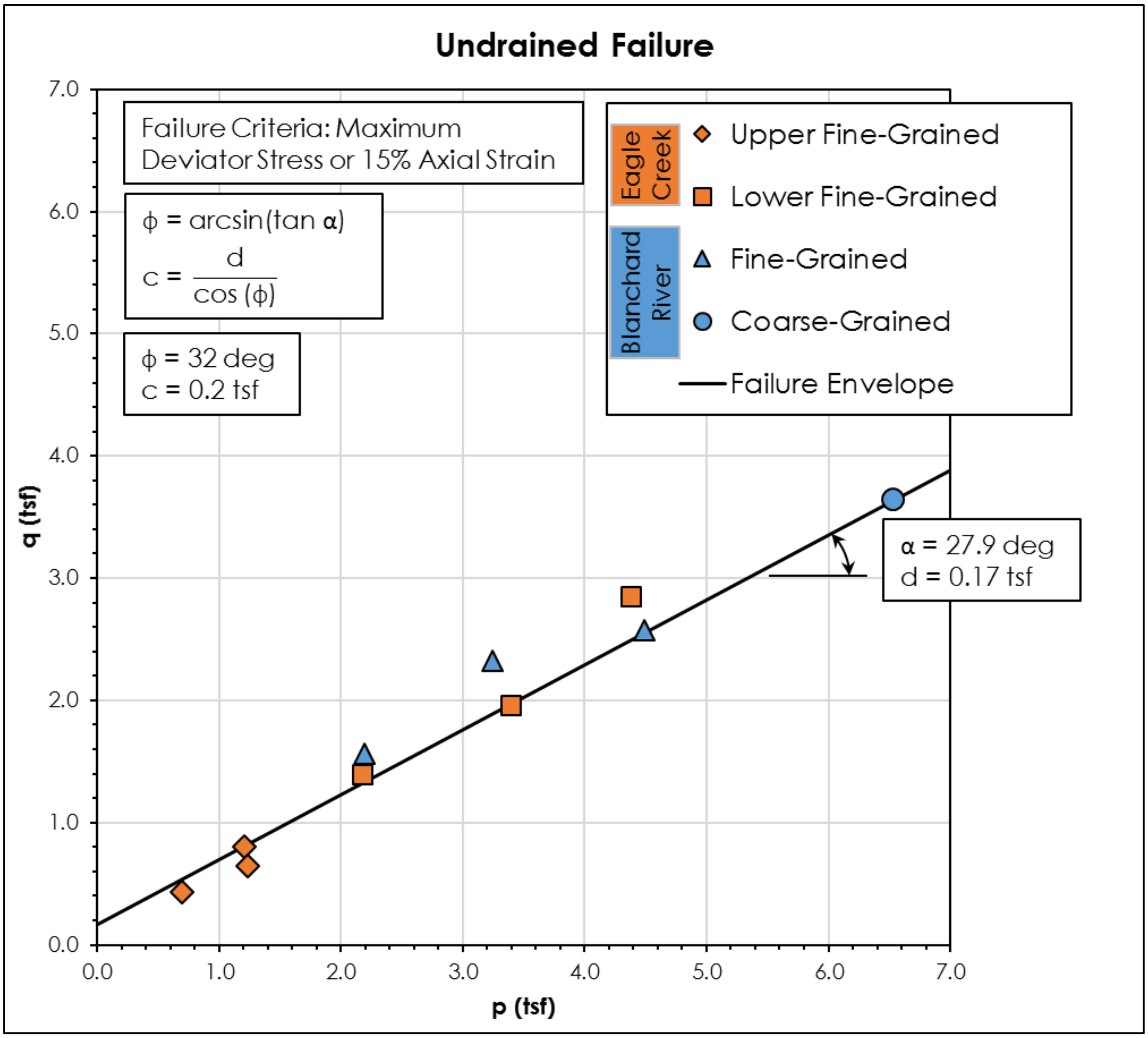

Figure 6. Undrained Failure Envelope from CU Triaxial Testing Results

6.1.3.2 Results

Table 9 summarizes the results of the preliminary slope stability analyses for the Eagle Creek Dam. Outputs of the slope stability analyses are provided in Appendix C.

Table 9. Eagle Creek Dam Slope Stability Analysis Results

Case No.	Analysis Condition	Required Minimum Factor of Safety	Calculated Factor of Safety		Analyzed Pool Condition and Shear Strength Parameters
			Shorter Section	Taller Section	
1	End of Construction	1.3	1.5	1.5	Normal headwater (El. 785), total stress shear strengths, downstream direction
2	Long-term (Steady seepage, maximum storage pool, spillway crest or top of gates)	1.5	1.5	1.5	Normal headwater, effective stress shear strengths, downstream direction
3	Maximum Surcharge Pool	1.4	1.5	1.5	Normal headwater pore pressures, flood surcharge to El. 807.5, total stress shear strengths, downstream direction
4			1.5	1.5	Normal headwater pore pressures, flood surcharge to El. 807.5, effective stress shear strengths, downstream direction
5			1.1	1.0	Flood headwater pore pressures (El. 807.5), effective stress shear strengths, downstream direction
6	Sudden Drawdown	1.1	1.5	1.5	Flood headwater to normal headwater pore pressures, sudden drawdown strengths, upstream direction

The preliminary stability analyses for Eagle Creek Dam met the minimum factor of safety requirements according to USACE (Section 5.3) except for one case. The case (Case No. 5) that did not meet the minimum factor of safety requirement considered steady-state seepage at the elevated flood pool. It is unlikely that steady-state seepage would develop at the flood level because the dam is for detention only; a permanent pool will not be stored. Case No. 4 (normal pool porewater pressures with a flood surcharge) is likely a better representation of field conditions during a flood event. The Federal Energy Regulatory Commission (FERC) provides engineering guidelines for evaluating embankment dams. Section 4-6.6.3 of FERC (2006) suggests using normal pool porewater pressures with a flood surcharge to evaluate flood conditions.

If the dam will be designed for steady-state seepage at flood levels, then an internal drainage system (chimney/blanket drain, finger drains, outlet pipes, etc.) should be considered for final design.

6.2 BLANCHARD RIVER AND POTATO RUN DAMS

6.2.1 Typical Cross Sectional Geometry

For the purpose of this evaluation, the surface and subsurface geometry of the Blanchard River and Potato Run dams were assumed to be similar. The preliminary alignments for the Blanchard River and Potato Run dams are 1.4

and 0.7 miles long, respectively. To minimize the footprint of the dams while providing the necessary flood protection, the following geometry was assumed:

- Crest elevation = 858 feet
- Embankment side slopes = 2.5H:1V
- Bench elevation = 842 feet
- Crest and bench width = 16 feet to allow for vehicle access for maintenance and monitoring
- Bench sloping = 2 percent to provide surface drainage
- Excavation of 1 foot to remove vegetation and topsoil under the dam footprint
- Cutoff trench = 5 feet deep x 20 feet bottom width with 1H:1V side slopes
  - USBR (2017) suggests the use of a cutoff trench. The depth and bottom width were assumed to provide sufficient equipment access during construction.

To conduct preliminary seepage and slope stability analyses, two cross sections were considered. One cross section considered the maximum height of the proposed structures, where the dam would cross the Blanchard River. This cross section is shown in Figure 7. The preliminary alignment suggests the toe in these areas would be at approximate elevation 830 feet.

The second cross section considered the reaches of the dam that would be shorter. This cross section was modeled as 16 feet tall, the maximum height before requiring a mid-slope bench. This cross section is shown in Figure 8.

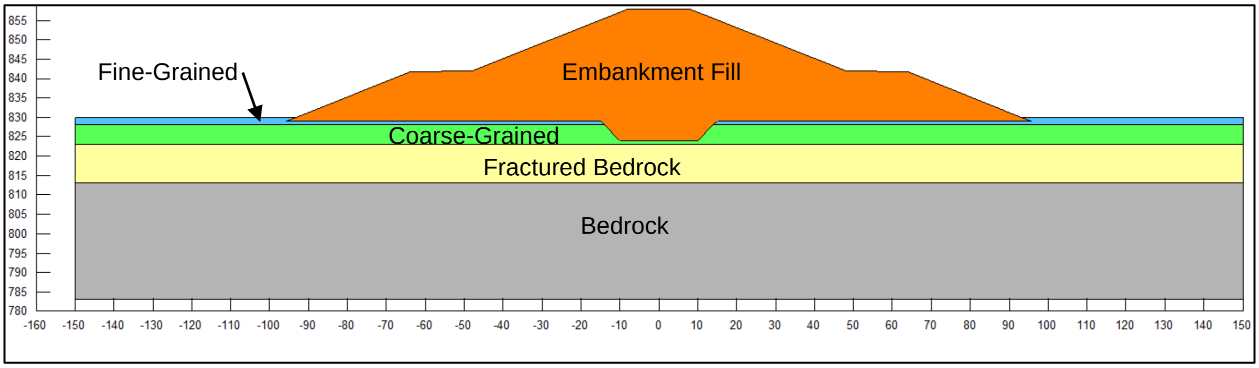

Figure 7. Blanchard River and Potato Run Dams Section – Maximum Height

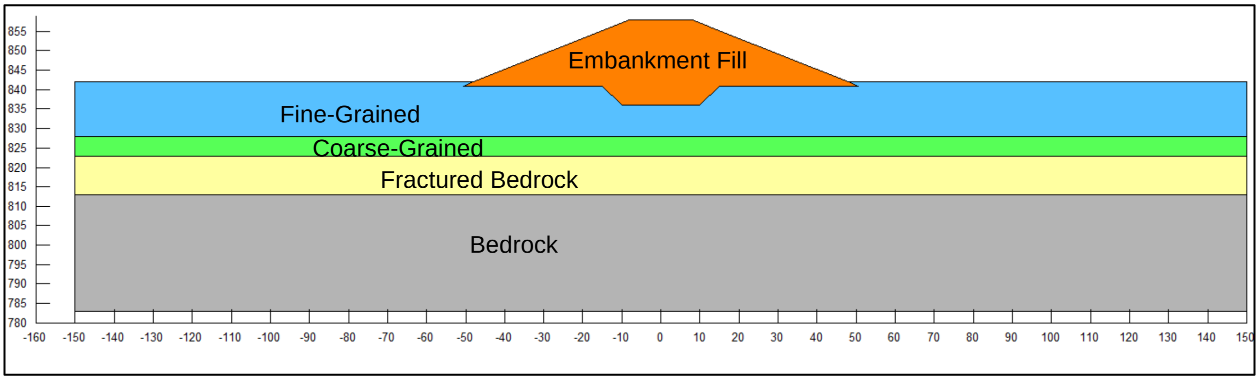

Figure 8. Blanchard River and Potato Run Dams Section – 16-Foot Height

As part of this exploration, two borings (B-103 and B-104) were advanced in the vicinity of the preliminary alignment of the Blanchard River Dam. Access to the proposed Potato Run Dam site was not available during the exploration phase of this study. The soil types and material interface elevations encountered in the borings were used to determine representative, generalized subsurface geometry for the two analysis cross sections. The material thicknesses and locations within the soil profile (relative to the top of bedrock) were similar within the two borings. See Section 4.2 for further discussion on material types and locations where they were encountered.

The generalized subsurface profile used in the modeled cross sections is based on elevations encountered in Boring B-104. Boring B-104 was advanced closest to the current alignment of the Blanchard River and was considered more representative of the subsurface geometry near the maximum height cross section. However, rather than model the fill that was encountered in Boring B-104, the material was assumed to be similar to that encountered in Boring B-103 above approximate elevation 828 feet. The material layers (and associated soil/rock classifications) used in the analyses are as follows: Embankment Fill (CL, SC), Fine-Grained material (CL, SC), Coarse-Grained material (SM), Fractured Bedrock (dolomite), and Bedrock (dolomite). The Embankment Fill was assumed to consist of compacted lean clay with sand or clayey sand which was encountered in the upper zones of the nearby borings. It was assumed that these materials would be excavated from within the proposed impoundment area to construct the embankment.

6.2.2 Seepage Analysis

6.2.2.1 Assumed Headwater and Tailwater Conditions

The seepage analyses considered two cases, normal and flood pool conditions. Table 10 summarizes the headwater and tailwater conditions assumed for the Blanchard River and Potato Run Dam analyses.

Table 10. Blanchard River and Potato Run Dam Headwater and Tailwater Conditions

Condition	Headwater Elevation (ft)	Tailwater Elevation (ft)
Normal (Maximum Storage Pool)	825.5	823.5
Flood (Maximum Surcharge Pool)	856.0	823.5

The normal water level in the Blanchard River based on survey data from November 2016 is 824.5 feet within the channel near the proposed dam site. Headwater and tailwater boundary conditions were assigned one foot higher and lower hydraulic head, respectively, to model flow from upstream to downstream. The assigned headwater and tailwater elevations are tabulated in Table 10. The assigned elevations are consistent with the groundwater table elevation of 825.5 feet encountered in B-104, which was the closest boring to the Blanchard River.

The flood elevation of 856.0 was provided by the project hydraulics and hydrology team. The flood tailwater elevation was assigned the same hydraulic head as the normal tailwater, assuming that a sudden rise in upstream water level due to a flood event would not likely impact the water level downstream of the dam.

Note that these boundary conditions are based on observations and survey data near the Blanchard River, and are assumed to be representative of Potato Run. Additional explorations are needed to estimate boundary conditions for detailed analyses of Potato Run in a later phase of the project.

6.2.2.2 Material Parameters

General information regarding the use of permeability parameters in typical geotechnical engineering practice and within SEEP/W is provided in Section 6.1.2.2. Parameters used to model the Blanchard River and Potato Run Dams are provided in Table 11.

Table 11. Blanchard River and Potato Run Dams Seepage Parameters

	Saturated Permeability Parameters					Unsaturated Permeability Parameters(1)
				SEEP/W Input		
Material	**k_v (cm/sec)**	**k_h (cm/sec)**	**k_h/k_v**	**k_x (ft/sec)**	**k_y/k_x (unitless)**	**θ_s (unitless)**
Embankment Fill	6.1×10^{-8}	3.0×10^{-7}	5	1.0×10^{-8}	0.2	0.42
Fine-Grained	1.8×10^{-8}	1.8×10^{-7}	10	5.9×10^{-9}	0.1	0.29
Coarse-Grained	1.5×10^{-6}	1.5×10^{-6}	1	4.9×10^{-8}	1	0.39
Fractured Bedrock	2.5×10^{-5}	2.5×10^{-5}	1	8.2×10^{-7}	1	0.25
Bedrock	2.5×10^{-6}	2.5×10^{-6}	1	8.2×10^{-8}	1	0.25

(1) Bedrock was modeled as saturated only for SEEP/W computations

The saturated permeability of the Embankment Fill is based on typical values for compacted embankment core materials provided by NAVFAC (1986) and USBR (2011) for CL and SC classifications (assumed embankment material). An anisotropy ratio of 5 was selected for the Embankment Fill based on USBR (2011) recommendations for standard placement of embankment core material. The unsaturated permeability for the Embankment Fill was modeled using the built-in “clay” function within SEEP/W.

One falling head permeability test was performed on a sample of the Fine-Grained material, resulting in a vertical permeability value of 1.8×10^{-8} cm/sec. Lenses of sand with varying thicknesses were encountered within the greater deposit of generally fine-grained soil. An anisotropy ratio of 10 was selected for the Fine-Grained material based on USBR (2011) recommendations for stratified deposits of natural soil. For the Fine-Grained material, the built-in “silty clay” function within SEEP/W was used to model unsaturated permeability.

One falling head permeability test was performed on a sample of the Coarse-Grained material, resulting in a vertical permeability value of 1.5 x 10^{-6} cm/sec. The Coarse-Grained material was assumed to be free draining with an anisotropy ratio of one. The unsaturated permeability for the Coarse-Grained material was modeled with the built-in “sand” function within SEEP/W.

USBR (2011) estimates the horizontal permeability of dolomite to be approximately 0 to 5 x 10^{-6} cm/sec. Therefore, a permeability of 2.5 x 10^{-6} was selected for the Bedrock. The permeability of Fractured Bedrock was estimated to be an order of magnitude greater to account for the increased fracturing encountered in the top 10 feet. USBR (2011) guidance suggests that anisotropy of massive soil or rock ranges from 1 to 3, and fractured rock ranges from 0.1 to 10. An anisotropy ratio of one was selected for bedrock based on the suggested ranges from USBR (2011). Because groundwater in the applicable borings was encountered above the top of rock, and it is likely that groundwater is continuously perched above the top of rock, the bedrock materials were modeled with only saturated permeability parameters in the seepage model.

Saturated volumetric water contents (θ_s) of the soils were determined based on porosity calculated from the void ratios presented in Table 12. A value of 0.25 was assumed for the saturated volumetric water content of the bedrock, based on experience with similar models.

6.2.3 Slope Stability Analysis

6.2.3.1 Material Parameters

Table 12 presents a summary of the parameters used for the slope stability analyses of the proposed Blanchard River and Potato Run Dams.

Table 12. Blanchard River and Potato Run Dams Slope Stability Parameters

	Index Properties			Effective Shear Strengths		Total Shear Strengths	
Material	**Moist Unit Weight γ_m (pcf)**	**Saturated Unit Weight γ_{sat} (pcf)**	**Void Ratio e (unitless)**	**ϕ' (deg)**	**c' (psf)**	**ϕ (deg)**	**c (psf)**
Embankment Fill	119	125	0.72	29	0	15	500
Fine-Grained	137	138	0.41	34	0	32	400
Coarse-Grained	127	127	0.64	34	0	32	400
Fractured Bedrock	Impenetrable						
Bedrock	Impenetrable						

Determination of the density and shear strength parameters of the Embankment Fill is discussed in Section 6.1.3.1.

Density parameters of the Fine-Grained and Coarse-Grained materials are based on results of laboratory testing. Specific gravity, moist unit weight, and moisture content were measured during laboratory triaxial and permeability tests. From those measured parameters, saturated unit weight and void ratio were calculated as reported in Table 12.

Three CU triaxial tests were performed on samples of the Fine-Grained soil, and one CU triaxial test was performed on a sample of the Coarse-Grained soil. Six additional CU triaxial tests were conducted on soil samples obtained from the borings representative of the foundation soils of the Eagle Creek Dam. The results of the 10 CU triaxial tests were plotted together in p'-q and p-q space to fit the drained and undrained failure envelopes representative of the Fine-Grained and Coarse-Grained materials. The drained and undrained failure envelopes were fit as described in Section 6.1.3.1 and are presented in Figure 5 and Figure 6.

6.2.3.2 Results

Table 13 summarizes the results of the preliminary slope stability analyses for the Blanchard River and Potato Run Dams. Outputs of the slope stability analyses are provided in Appendix C.

Table 13. Blanchard River and Potato Run Dams Slope Stability Analysis Results

Case No.	Analysis Condition	Required Minimum Factor of Safety	Calculated Factor of Safety		Analyzed Pool Condition and Shear Strength Parameters
			Shorter Section	Taller Section	
1	End of Construction	1.3	1.5	1.5	Normal headwater (El. 825.5), total stress shear strengths, downstream direction
2	Long-term (Steady seepage, maximum storage pool, spillway crest or top of gates)	1.5	1.5	1.5	Normal headwater, effective stress shear strengths, downstream direction
3	Maximum Surcharge Pool	1.4	1.5	1.5	Normal headwater pore pressures, flood surcharge to El. 855, total stress shear strengths, downstream direction
4			1.5	1.5	Normal headwater pore pressures, flood surcharge to El. 855, effective stress shear strengths, downstream direction
5			1.3	1.3	Flood headwater pore pressures (El. 855), effective stress shear strengths, downstream direction
6	Sudden Drawdown	1.1	1.5	1.5	Flood headwater to normal headwater pore pressures, sudden drawdown strengths, upstream direction

The preliminary stability analyses for Blanchard River and Potato Run Dams met the minimum factor of safety requirements according to USACE (Section 5.3) for the analyzed cases except for one case. The case (Case No. 5) that did not meet the minimum factor of safety requirement considered steady-state seepage at the elevated flood pool. It is unlikely that steady-state seepage would develop at the flood level because the dam is for detention only; a permanent pool will not be stored. Case No. 4 (normal pool porewater pressures with a flood surcharge) is likely a better representation of field conditions during a flood event. The Federal Energy Regulatory Commission (FERC) provides engineering guidelines for evaluating embankment dams. Section 4-6.6.3 of FERC (2006) suggests using normal pool porewater pressures with a flood surcharge to evaluate flood conditions.

If the dam will be designed for steady-state seepage at flood levels, then an internal drainage system (chimney/blanket drain, finger drains, outlet pipes, etc.) should be considered for final design.

7.0 RECOMMENDATIONS

7.1 GENERAL

The recommendations that follow are based on the information discussed in this report and the interpretation of the subsurface conditions encountered at the site during fieldwork. If future design changes are made, Stantec should be notified so that such changes can be reviewed and the recommendations amended as necessary.

These conclusions and recommendations are based on data and subsurface conditions from the borings advanced during this exploration using the degree of care and skill ordinarily exercised under similar circumstances by competent members of the engineering profession. No warranties can be made regarding the continuity of conditions.

7.2 PRELIMINARY DAM DESIGN

1. Additional exploration, including but not limited to, drilling, sampling, instrumentation, in-situ testing, and laboratory testing should be performed to further define the borrow sources and foundation soil and rock near the proposed dam locations. Future phases of work should separately explore and characterize the conditions for the Eagle Creek, Blanchard River, and Potato Run dam locations.
    a. The preliminary findings as discussed in Section 4.0 indicate that approximately 10 to 15 feet of suitable borrow soil would be available below the topsoil layer in the locations of the borings. A borrow source study should be performed to determine the available quantity of site specific fill materials. The study should include laboratory testing to determine design parameters of potential borrow soil, including optimal compaction, shear strength, potential dispersivity, and saturated and unsaturated permeability.
    b. Conduct additional geotechnical borings, test pits, and/or other exploration methods at regularly spaced intervals to adequately characterize subsurface conditions. Explorations should include locations along the dam alignments and at select cross sections, and should obtain information to support the design of foundation treatment and/or necessary seepage control measures for the sites.
        i. Explorations should include methods to better define characteristics of the dolomite bedrock, including faults, fractures, discontinuities, voids, etc. that could influence the seepage below the proposed dams.
        ii. Further identify the vertical and lateral extents of coarse-grained materials that may influence foundation treatment and seepage design. Specifically, the “Upper Coarse-Grained” material encountered below the proposed Eagle Creek dam and the “Coarse-Grained” material encountered below the proposed Blanchard River Dam should be targeted.

   c. Install temporary piezometers and/or groundwater wells to establish groundwater levels and boundary conditions appropriate for detailed seepage design models.

   d. Perform in-situ hydraulic conductivity testing of foundation soils and bedrock to develop site specific parameters for seepage design models. Testing should include packer testing of targeted soil and bedrock layers and slug testing of installed piezometers/groundwater wells.

   e. Perform soil water characteristic curve (SWCC) laboratory testing on applicable foundation and potential borrow materials to refine unsaturated permeability parameters for use in design.

   f. Perform dispersive clay laboratory testing to determine the dispersivity of foundation and potential borrow soils.

2. If the dams will be designed for steady-state seepage at flood levels, an internal drainage system (chimney/blanket drain, finger drains, outlet pipes, etc.) should be considered for final design. Without an internal drainage system, the preliminary stability analyses resulted in low factors of safety for steady-state flood conditions.

3. Design of the principal outlet conduits through the dams should include design of a filter diaphragm to intercept and filter preferential seepage paths along the conduits. Design filter diaphragms according to USACE filter criteria (USACE 2003) and other applicable design guidance (FEMA 2005).

4. The proposed structures will likely be classified as high hazard dams. According to the NRCS Technical Release Number 60 (TR-60), the project sites are in Seismic Zone 2, and will therefore require special investigations to determine liquefaction potential and the presence of nearby faults. These seismic analysis requirements should be considered when developing the detailed explorations prior to final design.

8.0 REFERENCES

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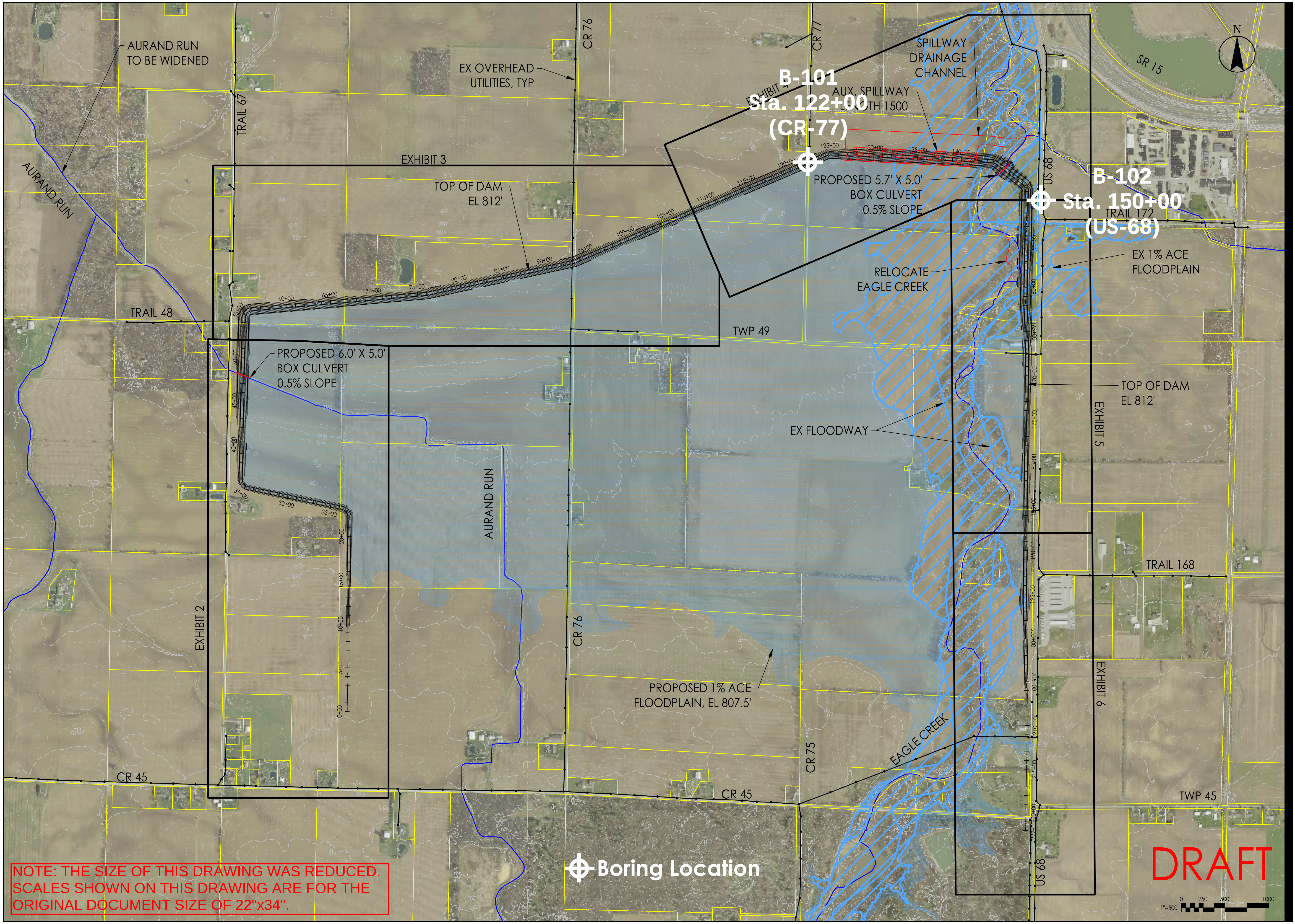
APPENDIX A
BORING LAYOUT AND BORING LOGS

BORING LAYOUT



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Revision	By	Appd.	YY.MM.DD

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Permit-Seal

Client/Project
MAUMEE WATERSHED CONSERVANCY DISTRICT

HANCOCK COUNTY FLOOD RISK REDUCTION PROJECT

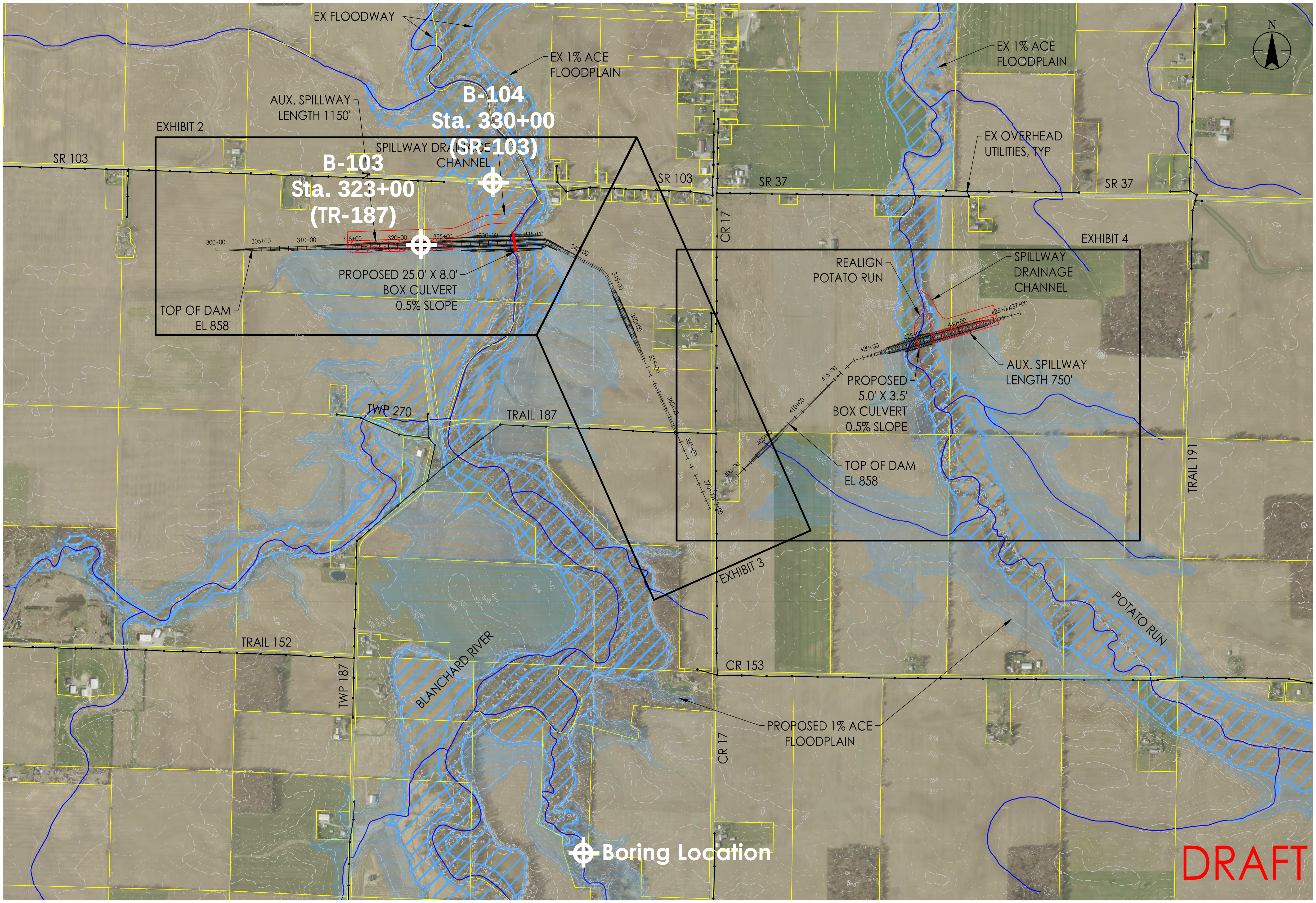
Hancock County, Ohio

Title
EAGLE CREEK DRY STORAGE BASIN
EXHIBIT 1 - PLAN OVERVIEW

Project Number: 174316204
File Name: 174316204_EC_storage_plan_prof.dwg

Dwn.	Chkd.	Dsgn.	YY.MM.DD

Drawing No. #
Revision 0
Sheet 6 of 15



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1"=500'
0 250' 500' 1000'

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Client/Project
MAUMEE WATERSHED CONSERVANCY DISTRICT

HANCOCK COUNTY FLOOD RISK REDUCTION PROJECT

Hancock County, Ohio

Title
MT. BLANCHARD DRY STORAGE BASIN
EXHIBIT 1 - PLAN OVERVIEW

Project Number: 174316204

File Name: 174316204_MB_storage_plan_prof.dwg

Dwn.	Chkd.	Dsgn.	YY.MM.DD

Drawing No. #

Revision 0

Sheet 12 of 15

BORING LOGS

Strata Graphics

Symbol	Soil
⊠	Fill
▦	Topsoil
▩	Gravel
▥	ML Soil
▨	CL Soil
▥	MH Soil
▨	CH Soil
▨	CLML Soil
⁙	SW Soil
⁙	SP Soil
▥	SM Soil
▨	SC Soil
▨	SCSM Soil
⁙	GW Soil
⁙	GP Soil
▥	GM Soil
▨	GC Soil
▥	GPGM Soil
▧	Fly Ash
▤	Bottom Ash
▧	Gypsum
≋	Non-Durable Shale
≋	Durable Shale
■	Coal
▦	Limestone
░	Sandstone

Water Level Graphics

Symbol	Description
▼	Measured in standpipe, piezometer, or well
▽	Inferred

Sampler Graphics

Symbol	Sampler	
░	SPT	Split Spoon (2" dia.)
▭	S3	Split Spoon (3" dia.)
▨	ST	Shelby Tube
▤	U	Undisturbed Piston
▬	RC	Rock Core

Consistency of Fine-Grained Soils

Condition	N-Value (blows/ft)
Very Soft	<2
Soft	2 – 4
Medium Stiff	4 – 8
Stiff	8 – 15
Very Stiff	>15

Density of Coarse-Grained Soils

Condition	N-Value (blows/ft)
Very Loose	<4
Loose	4 – 10
Medium Dense	10 – 30
Dense	30 – 50
Very Dense	>50

Common Abbreviations

WH	Weight of Hammer
WR	Weight of Rod
HSA	Hollow Stem Auger
RQD	Rock Quality Designation

Additional Notes

Lab. Classification	Classification performed per ASTM D2487
Lab. Description	Visual description noted by laboratory technician

SUBSURFACE LOG

Page: 1 of 3

Stantec Boring No. **B-101**

Client	MWCD	Boring Location	482,428.1 N; 1,648,212.6 E
Project Number	174316204	Surface Elevation	799.5 ft
		Elevation Datum	NAVD83
Project Name	HCFRR Program - Dams Preliminary	Date Started	11/6/17
		Completed	11/6/17
Project Location	Hancock County, Ohio	Depth to Water	11.5 ft
		Date/Time	11/6/17
Inspector	Stantec - R. Lopina	Depth to Water	N/A
		Date/Time	N/A
Drilling Contractor	TTL - T. Brister	Drill Rig Type and ID	CME 550X

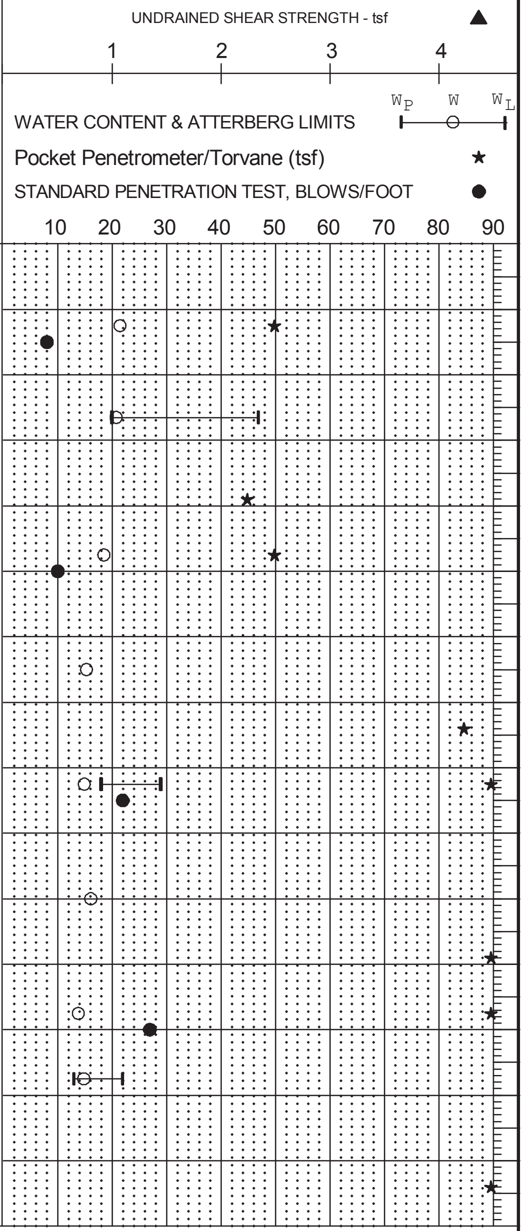
Overburden Drilling and Sampling Tools (Type and Size) 3.25" ID HSA, 2" SPT, 3" ST

Rock Drilling and Sampling Tools (Type and Size) NQ

Sampler Hammer Type Automatic Weight 140 lb Drop 30 in Efficiency 80.3

Borehole Azimuth N/A (Vertical) Borehole Inclination (from Vertical) Vertical

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	SAMPLES TYPE	NUMBER	RECOVERY ft	BLOWS / PRESS.(psi) / RQD (%)
0	799.5	Topsoil				
	798.8	Lean Clay with Sand (CL), brown, moist, medium stiff to stiff	SPT	1	1.2	2-3-5
			ST	1	1.2	350
		some fine gravel in SPT-2	SPT	2	1.5	3-4-6
			ST	2	1.3	450
	792.0	Lean Clay with Sand (CL), brown, moist, very stiff	SPT	3	1.5	5-7-15
			ST	3	1.2	900
	789.0	Sandy Lean Clay (CL), gray, moist, very stiff *1" sand seam at 11.3'* *2" sand seam at 12.0'*	SPT	4	1.2	4-19-8
			ST	4	1.7	800
15						



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Stantec Boring No. **B-101**

Client MWCD

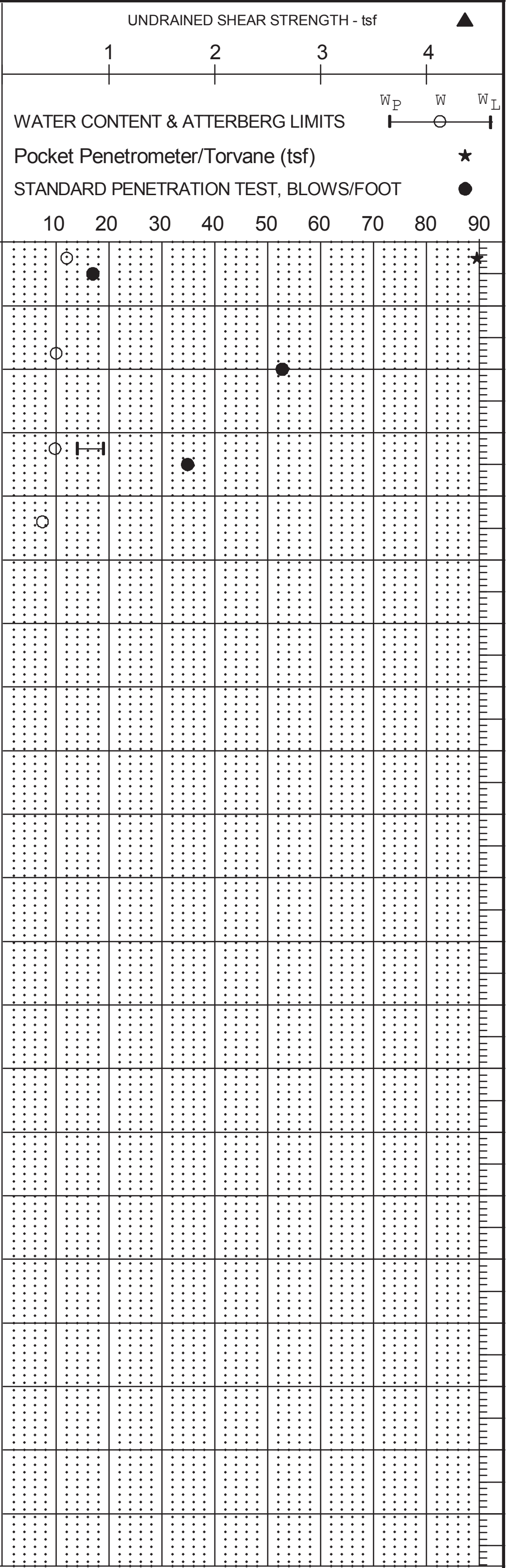
Boring Location 482,428.1 N; 1,648,212.6 E

Project Number 174316204

Surface Elevation 799.5 ft

Elevation Datum NAVD83

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY ft	SAMPLES BLOWS / PRESS.(psi) / RQD (%)	MONITOR WELL / PIEZOMETER
15	783.5	Sandy Lean Clay (CL), gray, moist, very stiff - (Continued) *increased gravel in SPT-5*		SPT	5	1.0	5-8-9	
16		Poorly Graded Gravel with Clay and Sand (GP-GC), gray and black, moist, dense to very dense		SPT	6	1.1	29-25-28	
18				SPT	7	0.8	19-19-16	
19	779.7			SPT	8	0.3	10-50/0.3'	
20		Dolomite, gray, slightly weathered, moderately fractured, slightly rough, thin to medium bedded		RC	1	5.0	48	
25		*darker thin seams from 28.9'-29.3'*		RC	2	5.0	60	
30		*larger blocks and increased weathering/discoloration in RC-3*		RC	3	5.0	68	



Stantec

SUBSURFACE LOG

Page: 3 of 3

Stantec Boring No. **B-101**

Client MWCD

Boring Location 482,428.1 N; 1,648,212.6 E

Project Number 174316204

Surface Elevation 799.5 ft

Elevation Datum NAVD83

UNDRAINED SHEAR STRENGTH - tsf ▲
1 2 3 4

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

Pocket Penetrometer/Torvane (tsf) ★

STANDARD PENETRATION TEST, BLOWS/FOOT ●

10 20 30 40 50 60 70 80 90

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY ft	SAMPLES BLOWS / PRESS.(psi) / RQD (%)	MONITOR WELL / PIEZOMETER
36		Dolomite, gray, slightly weathered, moderately fractured, slightly rough, thin to medium bedded - (Continued)						
37				RC	4	4.8	87	
38								
39		*small vugs from 39.1'-40.0'* *2" void at 39.5'*						
40								
41		*water loss at 41.5'*						
42				RC	5	4.5	57	
43		*increased fracturing from 43.0'-45.0'*						
44	754.5							
45		*Boring terminated and grouted (40 gal water, 188 lb portland cement, 35 lb bentonite)*						
46								
47								
48								
49								
50								
51								
52								
53								
54								
55								
56								

Printed on 1/3/18

SUBSURFACE LOG

Stantec Boring No. **B-102**

Client MWCD

Project Number 174316204

Project Name HCFRR Program - Dams Preliminary

Project Location Hancock County, Ohio

Inspector Stantec - R. Lopina

Drilling Contractor TTL - T. Brister

Boring Location 481,965.9 N; 1,650,844.8 E

Surface Elevation 795.5 ft Elevation Datum NAVD83

Date Started 11/9/17 Completed 11/9/17

Depth to Water 11.4 ft Date/Time 11/9/17

Depth to Water N/A Date/Time N/A

Drill Rig Type and ID CME 75

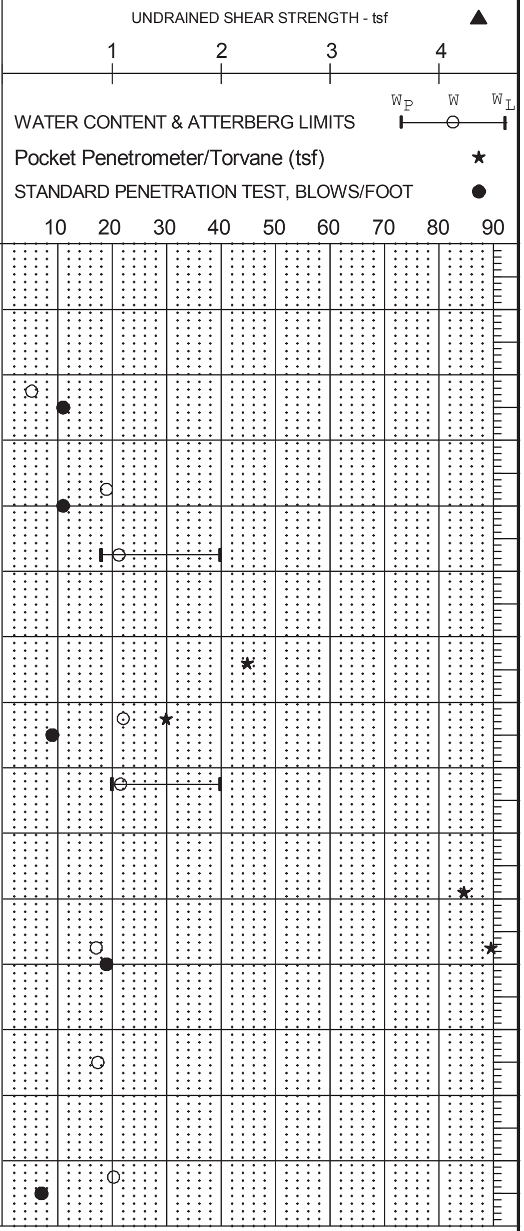
Overburden Drilling and Sampling Tools (Type and Size) 3.25" ID HSA, 2" SPT, 3" ST

Rock Drilling and Sampling Tools (Type and Size) NQ

Sampler Hammer Type Automatic Weight 140 lb Drop 30 in Efficiency 74.5

Borehole Azimuth N/A (Vertical) Borehole Inclination (from Vertical) Vertical

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	NUMBER	RECOVERY ft	BLOWS / PRESS.(psi) / RQD (%)	MONITOR WELL / PIEZOMETER
0	795.5	Roadway Pavement						
1	794.4	Fill - Lean Clay with Sand (visual), brown and gray, dry, stiff		SPT	1	0.6	10-7-4	
3	792.6	Lean Clay with Sand (CL), olive gray to dark brown, moist, stiff		SPT	2	0.8	3-4-7	
				ST	1	1.2	625	
				SPT	3	1.2	3-3-6	
				ST	2	1.4	550	
		increased sand content in SPT-4	▽	SPT	4	1.0	5-7-12	
11	784.1	Poorly Graded Sand (visual), gray to dark gray, moist, dense, increased gravel from 12.0'-13.3'		ST	3	2.0	575	
13	782.2	Silty Clay with Sand (CL-ML), gray, moist, medium stiff		SPT	5	1.1	1-2-5	
15								



Stantec Boring No. **B-102**

Client MWCD

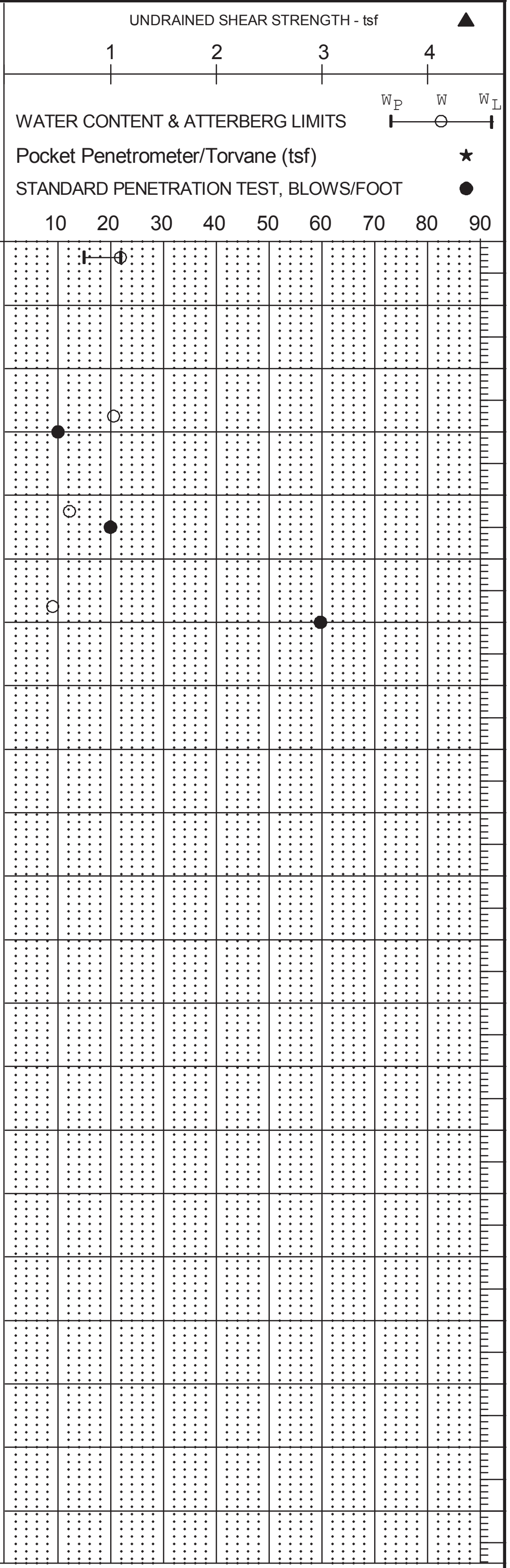
Boring Location 481,965.9 N; 1,650,844.8 E

Project Number 174316204

Surface Elevation 795.5 ft

Elevation Datum NAVD83

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	NUMBER	RECOVERY ft	BLOWS / PRESS.(psi) / RQD (%)	MONITOR WELL / PIEZOMETER
15 16		Silty Clay with Sand (CL-ML), gray, moist, medium stiff - (Continued)		ST	4	1.9	475	
17 18	777.3			SPT	6	1.3	2-1-9	
19		Poorly Graded Gravel with Clay and Sand (visual), gray and black, moist, medium dense to very dense		SPT	7	1.0	7-8-12	
20 21		*hydro-carbon odor in SPT-8*		SPT	8	0.9	9-21-39	
22	773.4			SPT	9	0.3	25-50/0.1'	
		Dolomite, gray, slightly weathered, fractured to moderately fractured, slightly rough, thin to medium bedded						
23 24				RC	1	2.2	46	
25 26 27 28 29		*fractured from 25.6'-26.1'* *fractured from 26.6'-27.0'* *black laminations at 27.3', 27.7', 27.9', 29.1'*		RC	2	4.8	45	
30 31 32 33 34		*intact from 32.6'-36.8'*		RC	3	4.9	50	
35								



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SUBSURFACE LOG

Stantec Boring No. **B-102**

Client MWCD

Boring Location 481,965.9 N; 1,650,844.8 E

Project Number 174316204

Surface Elevation 795.5 ft

Elevation Datum NAVD83

UNDRAINED SHEAR STRENGTH - tsf ▲ 1 2 3 4

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

Pocket Penetrometer/Torvane (tsf) ★

STANDARD PENETRATION TEST, BLOWS/FOOT ● 10 20 30 40 50 60 70 80 90

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	NUMBER	RECOVERY ft	BLOWS / PRESS.(psi) / RQD (%)	MONITOR WELL / PIEZOMETER
36		Dolomite, gray, slightly weathered, fractured to moderately fractured, slightly rough, thin to medium bedded - (Continued)						
37				RC	4	4.9	57	
38		*laminated from 36.8'-39.8'*						
39								
40								
41		*fractured at 40.7', 41.8'*						
42				RC	5	4.8	33	
43								
44		*black laminations at 44.1', 44.9', 45.5', 45.8', 46.6', 46.7', 46.8', 47.1'*						
45								
46				RC	6	2.8	53	
47	747.7							
48		*Boring terminated and grouted (30 gal water, 94 lb portland cement, 35 lb bentonite)* *Surface finished with cold-patch asphalt*						
49								
50								
51								
52								
53								
54								
55								
56								

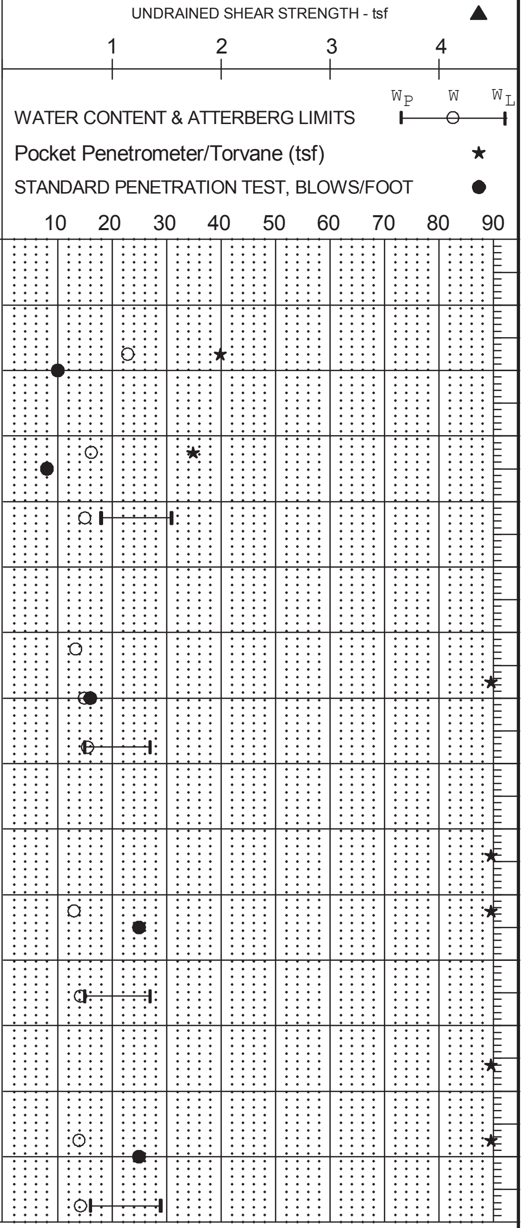
Stantec

SUBSURFACE LOG

Stantec Boring No. **B-103**

Client: MWCD
Project Number: 174316204
Project Name: HCFRR Program - Dams Preliminary
Project Location: Hancock County, Ohio
Inspector: Stantec - R. Lopina
Drilling Contractor: TTL - T. Brister
Boring Location: 447,211.1 N; 1,673,094.4 E
Surface Elevation: 843.1 ft Elevation Datum: NAVD83
Date Started: 11/7/17 Completed: 11/7/17
Depth to Water: 6.0 ft Date/Time: 11/7/17
Depth to Water: N/A Date/Time: N/A
Drill Rig Type and ID: CME 75
Overburden Drilling and Sampling Tools (Type and Size): 3.25" ID HSA, 2" SPT, 3" ST
Rock Drilling and Sampling Tools (Type and Size): NQ
Sampler Hammer Type: Automatic Weight: 140 lb Drop: 30 in Efficiency: 74.5
Borehole Azimuth: N/A (Vertical) Borehole Inclination (from Vertical): Vertical

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	SAMPLES TYPE	NUMBER	RECOVERY ft	BLOWS / PRESS.(psi) / RQD (%)
0	843.1					
	842.7	Roadway Pavement				
	842.3	Granular Base				
1		Fill - Lean Clay with Sand (visual), brown and black, moist, medium stiff, trace organics	SPT	1	0.8	3-4-6
3	839.4		SPT	2	0.7	2-4-4
4		Clayey Sand (SC), brown and gray, moist, medium dense	ST	1	1.8	650
6	836.6	*increased gravel content from 5.8'-6.5'*				
7		Lean Clay with Sand (CL), gray, moist, very stiff	SPT	3	1.5	8-7-9
8			ST	2	1.6	1400
10			SPT	4	1.5	8-11-14
12			ST	3	1.4	1400
14			SPT	5	1.3	8-10-15
15						



MONITOR WELL / PIEZOMETER

SUBSURFACE LOG

Stantec Boring No. **B-103**

Client MWCD

Boring Location 447,211.1 N; 1,673,094.4 E

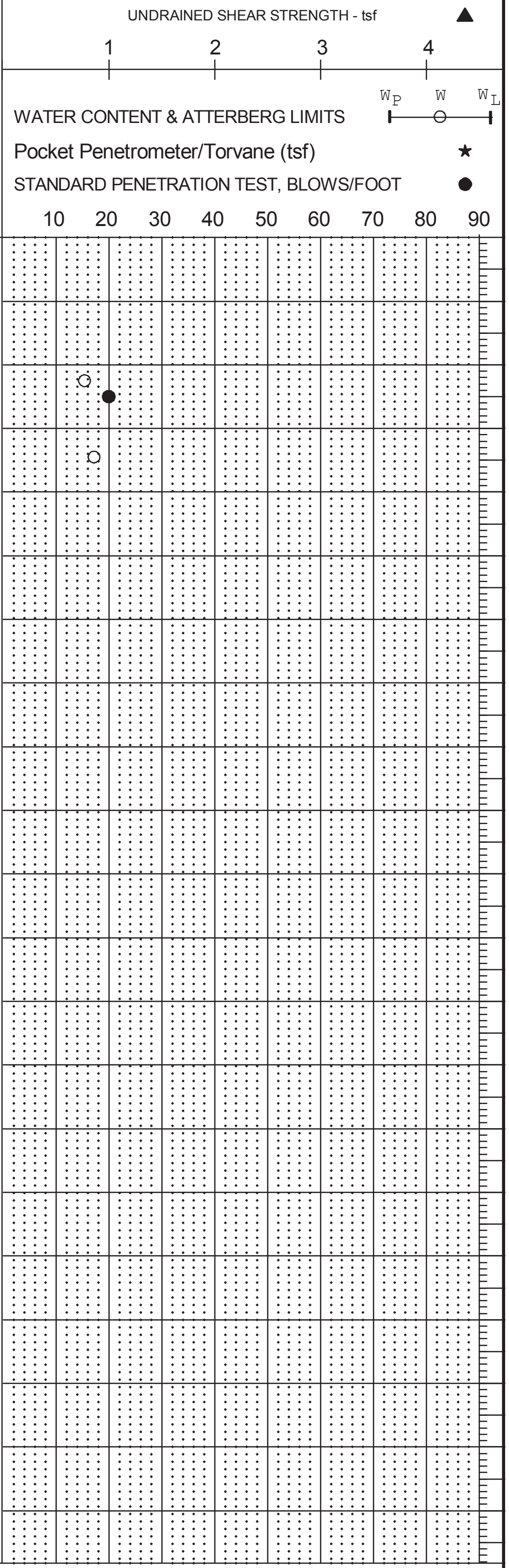
Project Number 174316204

Surface Elevation 843.1 ft

Elevation Datum NAVD83

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	SAMPLES TYPE	NUMBER	RECOVERY ft	BLOWS / PRESS.(psi) / RQD (%)
15		Lean Clay with Sand (CL), gray, moist, very stiff -	ST	4	1.2	1400
16	826.6	(Continued)				
17		Silty Sand (visual), gray, moist, medium dense	SPT	6	1.3	6-8-12
18	824.2		SPT	7	0.5	28-50/0.4'
19		Dolomite, gray, slightly weathered, fractured to moderately fractured, slightly rough, thin to medium bedded				
20						
21						
22		*vuggy from 21.7'-26.5'*	RC	1	4.9	13
23						
24						
25						
26						
27		*dark gray laminations from 26.5'-29.5'*	RC	2	4.9	20
28						
29						
30						
31			RC	3	4.0	54
32						
33						
34		*black laminations from 34.1'-34.5'*	RC	4	1.8	48
35		*dark gray laminations from 35.2'-36.2'*				

MONITOR WELL / PIEZOMETER



Stantec Boring No. **B-103**

Client MWCD

Project Number 174316204

Boring Location 447,211.1 N; 1,673,094.4 E

Surface Elevation 843.1 ft

Elevation Datum NAVD83

UNDRAINED SHEAR STRENGTH - tsf ▲
1 2 3 4

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

Pocket Penetrometer/Torvane (tsf) ★

STANDARD PENETRATION TEST, BLOWS/FOOT ●
10 20 30 40 50 60 70 80 90

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES				MONITOR WELL / PIEZOMETER
				TYPE	NUMBER	RECOVERY	BLOWS / PRESS.(psi) / RQD (%)	
						ft		
36 37 38 39	803.6	Dolomite, gray, slightly weathered, fractured to moderately fractured, slightly rough, thin to medium bedded - (Continued)		RC	5	3.7	81	

Boring terminated and grouted (30 gal water, 94 lb portland cement, 35 lb bentonite)
Surface finished with cold-patch asphalt

40
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54
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56

SUBSURFACE LOG

Stantec Boring No. **B-104**

Client	MWCD	Boring Location	447,911.3 N; 1,673,911.7 E
Project Number	174316204	Surface Elevation	836.0 ft
Elevation Datum	NAVD83		
Project Name	HCFRR Program - Dams Preliminary	Date Started	11/8/17
Completed	11/8/17		
Project Location	Hancock County, Ohio	Depth to Water	10.5 ft
Date/Time	11/8/17		
Inspector	Stantec - R. Lopina	Depth to Water	N/A
Date/Time	N/A		
Drilling Contractor	TTL - T. Brister	Drill Rig Type and ID	CME 75

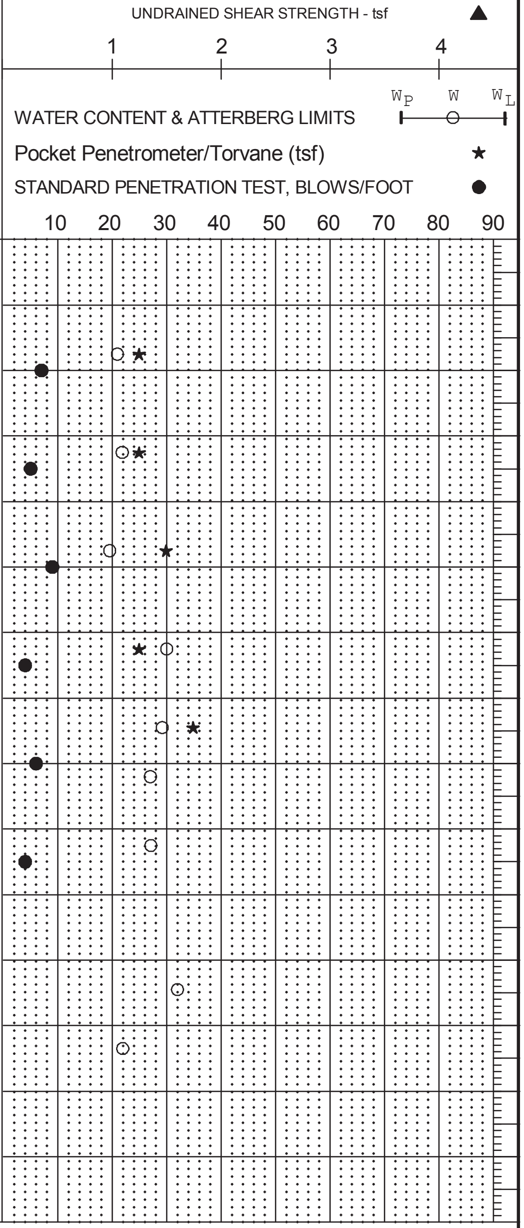
Overburden Drilling and Sampling Tools (Type and Size) 3.25" ID HSA, 2" SPT, 3" ST

Rock Drilling and Sampling Tools (Type and Size) NQ

Sampler Hammer Type Automatic Weight 140 lb Drop 30 in Efficiency 74.5

Borehole Azimuth N/A (Vertical) Borehole Inclination (from Vertical) Vertical

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	SAMPLES TYPE	NUMBER	RECOVERY ft	BLOWS / PRESS.(psi) / RQD (%)
0	836.0	Roadway Pavement				
	835.1	Granular Base				
1	834.7	Fill - Lean Clay with Sand (visual), dark brown, moist, medium stiff to stiff	SPT	1	0.7	3-4-3
3			SPT	2	0.9	1-2-3
4.5			SPT	3	1.0	3-4-5
6			SPT	4	0.6	1-2-2
7.5			SPT	5	1.4	3-3-3
8	828.1	Silty Sand (SM), brown, moist to wet, loose				
9			SPT	6	1.5	1-2-2
10.5		*Atterberg limits = NP*	ST	1	1.9	450
12.5	823.3	*hydro-carbon odor in SPT-7*	SPT	7	0.7	7-50/0.2'
12.7		Dolomite, gray, slightly weathered, fractured to moderately fractured, slightly rough, thin to medium bedded				
15						



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SUBSURFACE LOG

Stantec Boring No. **B-104**

Client MWCD

Boring Location 447,911.3 N; 1,673,911.7 E

Project Number 174316204

Surface Elevation 836.0 ft

Elevation Datum NAVD83

UNDRAINED SHEAR STRENGTH - tsf ▲ (1, 2, 3, 4)

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

Pocket Penetrometer/Torvane (tsf) ★

STANDARD PENETRATION TEST, BLOWS/FOOT ● (10, 20, 30, 40, 50, 60, 70, 80, 90)

DEPTH(ft)	ELEVATION(ft)	SOIL/ROCK DESCRIPTION	STRATA PLOT	SAMPLES TYPE	NUMBER	RECOVERY ft	BLOWS / PRESS.(psi) / RQD (%)	MONITOR WELL / PIEZOMETER
15 16 17 18 19		*fractured from 14.8'-16.1'* Dolomite, gray, slightly weathered, fractured to moderately fractured, slightly rough, thin to medium bedded - (Continued) *black laminations at 18.3', 18.6'* *1/8" quartz seam at 19.2'*		RC	1	4.8	20	
20 21 22 23 24		*thin quartz layers from 19.8'-20.2'* *vuggy from 20.3'-20.6'* *black laminations at 22.1', 22.2', 22.4'*		RC	2	5.0	20	
25 26 27 28 29		*vugs partially filled with quartz crystals at 29.3', 30.1', 30.8', 31.4'*		RC	3	5.0	80	
30 31 32 33 34	801.2			RC	4	5.0	100	

35

Boring terminated and grouted (30 gal water, 94 lb portland cement, 35 lb bentonite)
Surface finished with cold-patch asphalt

APPENDIX B
LABORATORY TEST RESULTS

NATURAL MOISTURE CONTENT TESTING

Stantec

Moisture Content of Soil

ASTM D 2216

Project Name HCFRR - Dams Preliminary

Project Number 174316204

Tested By RJ

Test Method ASTM

Maximum Particle Size in Sample	No. 10	No. 4	3/8"	3/4"	1 1/2"	3"
Recommended Minimum Mass (g)	20	100	500	2,500	10,000	50,000

Material Type: Stratified, Laminated, Lensed, Homogeneous, Disturbed

Source	Lab ID	Date Tested	Material Type	Maximum Particle Size	Material Excluded		Pass Min. Mass? (Y/N)	Can Weight (g)	Wet Soil & Can Weight (g)	Dry Soil & CanWeight (g)	Moisture Content (%)
					Amount	Size					
B-101, 0.5'-2.0'	40	11/28/17	Hom	No. 4			No	31.57	118.11	102.78	21.5
B-101, 4.0'-5.5'	41	11/28/17	Hom	3/8"			No	31.62	127.40	112.48	18.5
B-101, 7.5'-9.0'	42	11/28/17	Hom	3/8"			No	29.85	102.01	92.66	14.9
B-101, 11.0'-12.5'	43	11/28/17	Hom	3/4"	2	3/4"	No	31.75	167.54	151.11	13.8
B-101, 14.5'-16.0'	44	11/28/17	Hom	1 1/2"	1	1 1/2"	No	31.59	151.15	138.36	12.0
B-101, 16.0'-17.5'	45	11/28/17	Dist	1 1/2"			No	31.68	74.94	71.01	10.0
B-101, 17.5'-19.0'	46	11/28/17	Dist	1 1/2"			No	30.38	81.85	77.26	9.8
B-101, 19.0'-19.8'	47	11/28/17	Dist	1 1/2"			No	30.31	88.92	84.88	7.4
B-102, 1.5'-3.0'	48	11/28/17	Dist	3/8"			No	31.84	109.43	105.60	5.2
B-102, 3.0'-4.5'	49	11/28/17	Hom	3/8"			No	31.55	133.69	117.40	19.0
B-102, 6.5'-8.0'	50	11/28/17	Hom	No. 10			Yes	30.03	144.21	123.55	22.1
B-102, 10.0'-11.5'	51	11/28/17	Hom	No. 10			Yes	30.13	124.88	111.03	17.1
B-102, 13.5'-15.0'	52	11/28/17	Hom	No. 10			Yes	30.62	167.19	144.16	20.3
B-102, 17.0'-18.5'	53	11/28/17	Dist	3/4"			No	31.51	136.67	118.69	20.6
B-102, 18.5'-20.0'	54	11/28/17	Dist	1 1/2"			No	31.50	180.52	164.28	12.2
B-102, 20.0'-21.5' Hydro-carbon odor	55	11/28/17	Dist	1 1/2"			No	30.76	167.30	156.02	9.0
B-103, 1.0'-2.5'	56	11/28/17	Dist	3/4"			No	30.74	99.05	86.30	22.9
B-103, 2.5'-4.0'	57	11/28/17	Dist	3/4"			No	31.85	122.44	109.84	16.2
B-103, 6.0'-6.5'	58A	11/28/17	Dist	1 1/2"			No	31.73	130.40	118.83	13.3
B-103, 6.5'-7.5'	58B	11/28/17	Dist	No. 4			Yes	30.52	156.56	140.21	14.9
B-103, 9.5'-11.0'	59	11/28/17	Hom	No. 4			Yes	30.75	154.95	140.69	13.0
B-103, 13.0'-14.5'	60	11/28/17	Hom	No. 4			Yes	30.97	156.40	141.12	13.9
B-103, 16.5'-18.0'	61	11/28/17	Hom	3/8"			No	31.68	112.66	101.87	15.4
B-103, 18.0'-18.9'	62	11/28/17	Hom	3/4"			No	31.05	142.45	126.13	17.2
B-104, 1.0'-2.5'	63	11/28/17	Hom	1 1/2"			No	30.24	123.00	106.92	21.0
B-104, 2.5'-4.0'	64	11/28/17	Hom	No. 10			Yes	31.32	128.81	111.32	21.9
B-104, 4.0'-5.5'	65	11/28/17	Hom	No. 4			No	32.17	116.16	102.39	19.6
B-104, 5.5'-7.0'	66	11/28/17	Hom	No. 10			Yes	31.43	116.98	97.18	30.1

Stantec

Moisture Content of Soil

ASTM D 2216

Project Name HCFRR - Dams Preliminary

Project Number 174316204

Tested By RJ

Maximum Particle Size in Sample	No. 10	No. 4	3/8"	3/4"	1 1/2"	3"
Recommended Minimum Mass (g)	20	100	500	2,500	10,000	50,000

Test Method ASTM

Material Type: Stratified, Laminated, Lensed, Homogeneous, Disturbed

Source	Lab ID	Date Tested	Material Type	Maximum Particle Size	Material Excluded Amount	Material Excluded Size	Pass Min. Mass? (Y/N)	Can Weight (g)	Wet Soil & Can Weight (g)	Dry Soil & CanWeight (g)	Moisture Content (%)
B-104, 7.0'-7.9'	67A	11/28/17	Hom	No. 10			Yes	30.67	117.97	98.18	29.3
B-104, 7.9'-8.5'	67B	11/28/17	Hom	3/8"			No	32.20	98.75	84.57	27.1
B-104, 8.5'-10.0'	68	11/28/17	Dist	No. 10			Yes	30.13	152.87	126.60	27.2
B-104, 12.0'-12.7'	69	11/28/17	Dist	3/8"			No	31.43	152.32	130.52	22.0

Comments

Reviewed By RJ

SUMMARIES OF SOIL TESTS

Stantec

Summary of Soil Tests

Project Name HCFRR - Dams Preliminary

Project Number 174316204

Source B-101, 2.4'-2.9'

Lab ID 27

Sample Type ST

Date Received 11-15-17

Date Reported 12-21-17

Test Results

Natural Moisture Content

Test Method: ASTM D 2216

Moisture Content (%): 20.8

Particle Size Analysis

Preparation Method: ASTM D 421

Gradation Method: ASTM D 422

Hydrometer Method: ASTM D 422

Particle Size		%
Sieve Size	(mm)	Passing
	N/A	
	N/A	
	N/A	
	N/A	
	N/A	
3/8"	9.5	100.0
No. 4	4.75	99.8
No. 10	2	99.2
No. 40	0.425	95.8
No. 200	0.075	82.4
	0.02	67.0
	0.005	48.2
	0.002	37.7
estimated	0.001	30.4

Plus 3 in. material, not included: 0 (%)

	ASTM	AASHTO
Range	(%)	(%)
Gravel	0.2	0.8
Coarse Sand	0.6	3.4
Medium Sand	3.4	---
Fine Sand	13.4	13.4
Silt	34.2	44.7
Clay	48.2	37.7

Atterberg Limits

Test Method: ASTM D 4318 Method A

Prepared: Dry

Liquid Limit: 47

Plastic Limit: 20

Plasticity Index: 27

Activity Index: 0.7

Moisture-Density Relationship

Test Not Performed

Maximum Dry Density (lb/ft^3): N/A

Maximum Dry Density (kg/m^3): N/A

Optimum Moisture Content (%): N/A

Over Size Correction %: N/A

California Bearing Ratio

Test Not Performed

Bearing Ratio (%): N/A

Compacted Dry Density (lb/ft^3): N/A

Compacted Moisture Content (%): N/A

Specific Gravity

Estimated

Particle Size: No. 10

Specific Gravity at 20° Celsius: 2.70

Classification

Unified Group Symbol: CL

Group Name: Lean clay with sand

AASHTO Classification: A-7-6 (22)

Comments:

Reviewed By RJ

Stantec

Particle-Size Analysis of Soils

ASTM D 422

Project Name HCFRR - Dams Preliminary
Source B-101, 2.4'-2.9'
Project Number 174316204
Lab ID 27

Sieve analysis for the Portion Coarser than the No. 10 Sieve

Test Method ASTM D 422
Prepared using ASTM D 421

Particle Shape Angular
Particle Hardness: Hard and Durable

Tested By GW
Test Date 12-12-2017
Date Received 11-15-2017

Maximum Particle size: 3/8" Sieve

Sieve Size	% Passing
3/8"	100.0
No. 4	99.8
No. 10	99.2

Analysis for the portion Finer than the No. 10 Sieve

Analysis Based on -3 inch fraction only

Specific Gravity 2.7

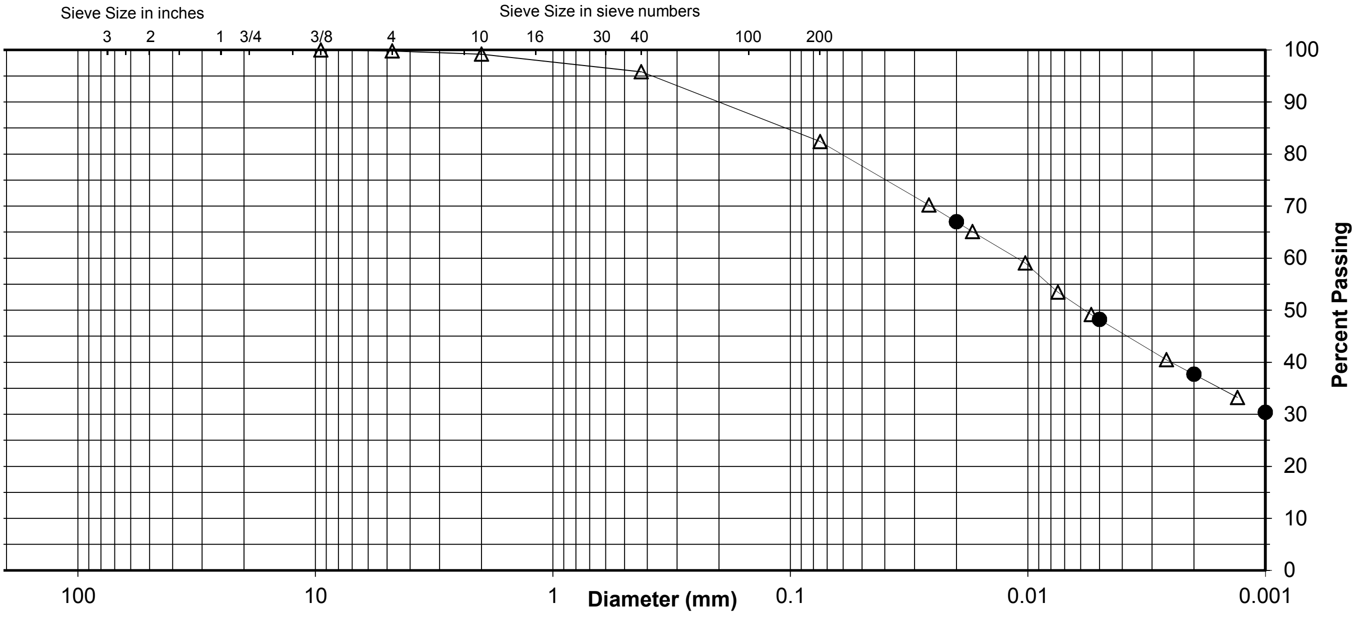
Dispersed using Apparatus A - Mechanical, for 1 minute

No. 40	95.8
No. 200	82.4
0.02 mm	67.0
0.005 mm	48.2
0.002 mm	37.7
0.001 mm	30.4

Particle Size Distribution

ASTM	Coarse Gravel	Fine Gravel	C. Sand	Medium Sand	Fine Sand	Silt	Clay
	0.0	0.2	0.6	3.4	13.4	34.2	48.2

AASHTO	Gravel	Coarse Sand	Fine Sand	Silt	Clay
	0.8	3.4	13.4	44.7	37.7



Comments

Reviewed By RJ

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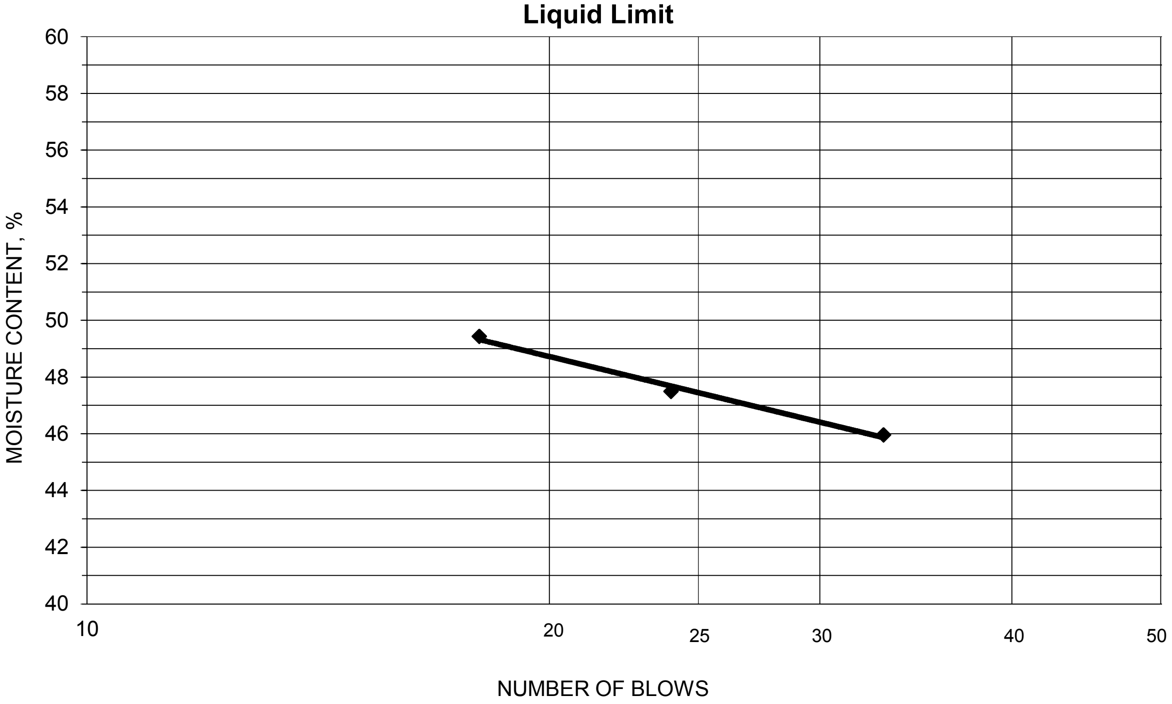
ATTERBERG LIMITS

Project HCFRR - Dams Preliminary
Project No. 174316204
Source B-101, 2.4'-2.9'
Lab ID 27
% + No. 40 4
Tested By CM
Test Method ASTM D 4318 Method A
Date Received 11-15-2017
Test Date 12-14-2017
Prepared Dry

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Number of Blows	Water Content (%)	Liquid Limit
22.18	18.71	11.16	33	46.0	47
21.39	17.99	10.83	24	47.5	
21.83	18.38	11.40	18	49.4	



PLASTIC LIMIT AND PLASTICITY INDEX

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Water Content (%)	Plastic Limit	Plasticity Index
19.26	17.96	11.45	20.0	20	27
18.58	17.36	11.10	19.5		

Remarks:

Reviewed By RJ

Stantec

Summary of Soil Tests

Project Name HCFRR - Dams Preliminary
Project Number 174316204
Source B-101, 7.5'-9.0'
Lab ID 42

Sample Type SPT
Date Received 11-15-17
Date Reported 12-19-17

Test Results

Natural Moisture Content

Test Method: ASTM D 2216
Moisture Content (%): 14.9

Particle Size Analysis

Preparation Method: ASTM D 421
Gradation Method: ASTM D 422
Hydrometer Method: ASTM D 422

Particle Size		%
Sieve Size	(mm)	Passing
	N/A	
	N/A	
	N/A	
	N/A	
	N/A	
3/8"	9.5	100.0
No. 4	4.75	98.3
No. 10	2	94.0
No. 40	0.425	87.2
No. 200	0.075	74.0
	0.02	57.5
	0.005	37.8
	0.002	25.8
estimated	0.001	17.4

Plus 3 in. material, not included: 0 (%)

	ASTM	AASHTO
Range	(%)	(%)
Gravel	1.7	6.0
Coarse Sand	4.3	6.8
Medium Sand	6.8	---
Fine Sand	13.2	13.2
Silt	36.2	48.2
Clay	37.8	25.8

Atterberg Limits

Test Method: ASTM D 4318 Method A
Prepared: Dry
Liquid Limit: 29
Plastic Limit: 18
Plasticity Index: 11
Activity Index: 0.4

Moisture-Density Relationship

Test Not Performed
Maximum Dry Density (lb/ft^3): N/A
Maximum Dry Density (kg/m^3): N/A
Optimum Moisture Content (%): N/A
Over Size Correction %: N/A

California Bearing Ratio

Test Not Performed
Bearing Ratio (%): N/A
Compacted Dry Density (lb/ft^3): N/A
Compacted Moisture Content (%): N/A

Specific Gravity

Estimated

Particle Size: No. 10
Specific Gravity at 20° Celsius: 2.70

Classification

Unified Group Symbol: CL
Group Name: Lean clay with sand

AASHTO Classification: A-6 (6)

Comments:

Reviewed By RJ

Stantec

Particle-Size Analysis of Soils
ASTM D 422

Project Name HCFRR - Dams Preliminary
Source B-101, 7.5'-9.0'
Project Number 174316204
Lab ID 42

Sieve analysis for the Portion Coarser than the No. 10 Sieve

Test Method ASTM D 422
Prepared using ASTM D 421

Particle Shape Angular
Particle Hardness: Hard and Durable

Tested By GW/RJ
Test Date 11-29-2017
Date Received 11-15-2017

Maximum Particle size: 3/8" Sieve

Sieve Size	% Passing
3/8"	100.0
No. 4	98.3
No. 10	94.0

Analysis for the portion Finer than the No. 10 Sieve

Analysis Based on -3 inch fraction only

Specific Gravity 2.7

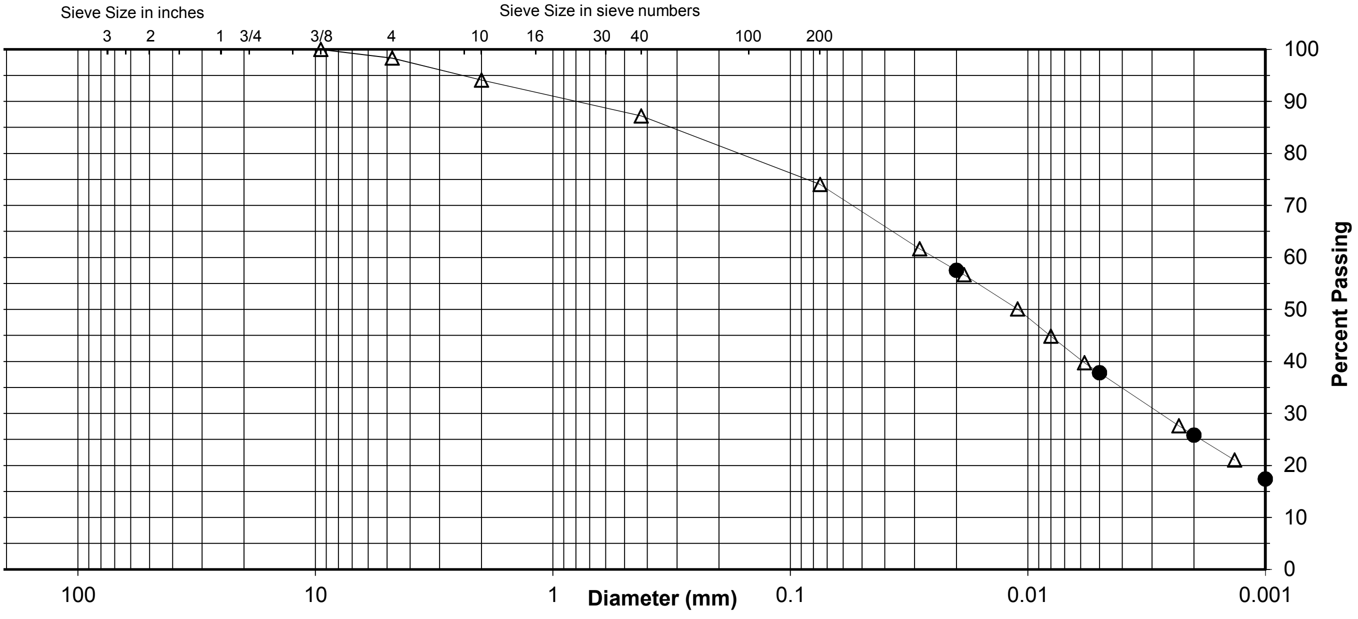
Dispersed using Apparatus A - Mechanical, for 1 minute

No. 40	87.2
No. 200	74.0
0.02 mm	57.5
0.005 mm	37.8
0.002 mm	25.8
0.001 mm	17.4

Particle Size Distribution

ASTM	Coarse Gravel	Fine Gravel	C. Sand	Medium Sand	Fine Sand	Silt	Clay
	0.0	1.7	4.3	6.8	13.2	36.2	37.8

AASHTO	Gravel	Coarse Sand	Fine Sand	Silt	Clay
	6.0	6.8	13.2	48.2	25.8



Comments

Reviewed By RJ

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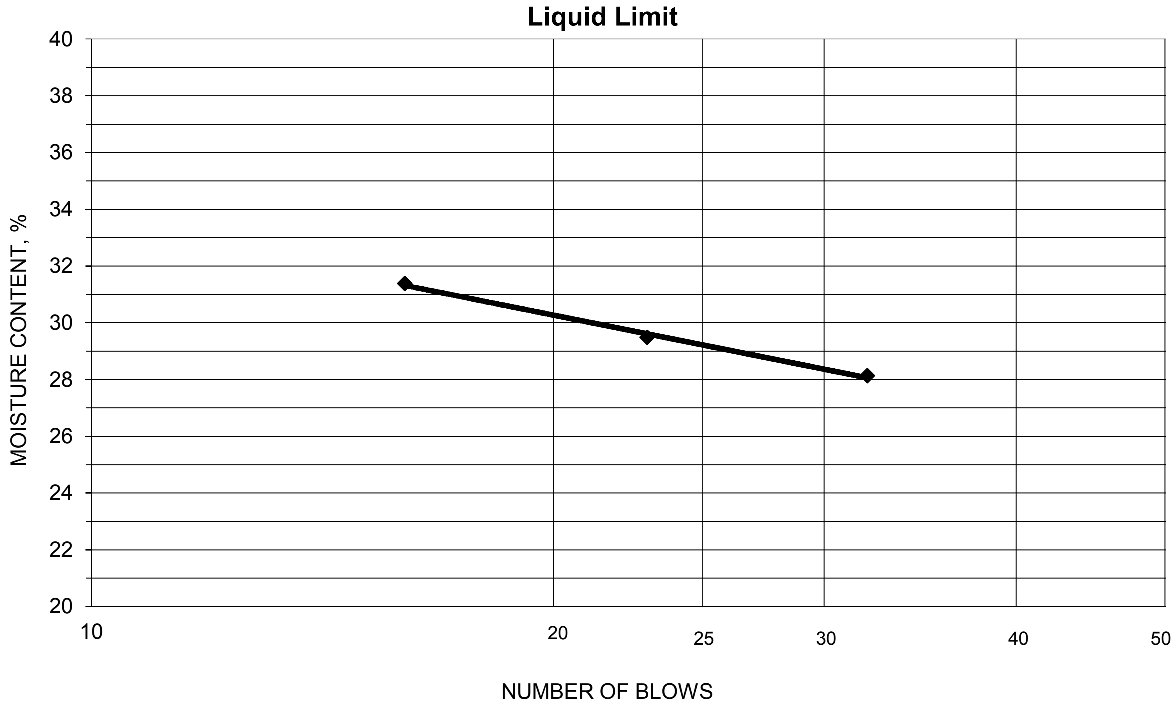
ATTERBERG LIMITS

Project	HCFRR - Dams Preliminary	Project No.	174316204
Source	B-101, 7.5'-9.0'	Lab ID	42
		% + No. 40	13
Tested By	CM	Test Method	ASTM D 4318 Method A
Date Received	11-15-2017		
Test Date	12-05-2017	Prepared	Dry

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Number of Blows	Water Content (%)	Liquid Limit
23.01	20.38	11.03	32	28.1	29
22.11	19.58	11.00	23	29.5	
22.00	19.38	11.03	16	31.4	



PLASTIC LIMIT AND PLASTICITY INDEX

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Water Content (%)	Plastic Limit	Plasticity Index
18.58	17.43	11.12	18.2	18	11
20.04	18.70	11.34	18.2		

Remarks:

Reviewed By RJ

Stantec

Summary of Soil Tests

Project Name HCFRR - Dams Preliminary
Project Number 174316204
Source B-101, 12.5'-13.0'
Lab ID 30

Sample Type ST
Date Received 11-15-17
Date Reported 12-21-17

Test Results

Natural Moisture Content

Test Method: ASTM D 2216
Moisture Content (%): 14.8

Particle Size Analysis

Preparation Method: ASTM D 421
Gradation Method: ASTM D 422
Hydrometer Method: ASTM D 422

Particle Size		%
Sieve Size	(mm)	Passing
	N/A	
	N/A	
	N/A	
	N/A	
3/4"	19	100.0
3/8"	9.5	99.0
No. 4	4.75	95.8
No. 10	2	90.8
No. 40	0.425	79.7
No. 200	0.075	60.7
	0.02	43.6
	0.005	24.9
	0.002	16.2
estimated	0.001	10.4

Plus 3 in. material, not included: 0 (%)

	ASTM	AASHTO
Range	(%)	(%)
Gravel	4.2	9.2
Coarse Sand	5.0	11.1
Medium Sand	11.1	---
Fine Sand	19.0	19.0
Silt	35.8	44.5
Clay	24.9	16.2

Atterberg Limits

Test Method: ASTM D 4318 Method A
Prepared: Dry
Liquid Limit: 22
Plastic Limit: 13
Plasticity Index: 9
Activity Index: 0.6

Moisture-Density Relationship

Test Not Performed
Maximum Dry Density (lb/ft^3): N/A
Maximum Dry Density (kg/m^3): N/A
Optimum Moisture Content (%): N/A
Over Size Correction %: N/A

California Bearing Ratio

Test Not Performed
Bearing Ratio (%): N/A
Compacted Dry Density (lb/ft^3): N/A
Compacted Moisture Content (%): N/A

Specific Gravity

Estimated
Particle Size: No. 10
Specific Gravity at 20° Celsius: 2.70

Classification

Unified Group Symbol: CL
Group Name: Sandy lean clay
AASHTO Classification: A-4 (2)

Comments:

Reviewed By RJ

Stantec

Particle-Size Analysis of Soils
ASTM D 422

Project Name HCFRR - Dams Preliminary
Source B-101, 12.5'-13.0'
Project Number 174316204
Lab ID 30

Sieve analysis for the Portion Coarser than the No. 10 Sieve

Test Method ASTM D 422
Prepared using ASTM D 421

Particle Shape Angular
Particle Hardness: Hard and Durable

Tested By GW
Test Date 12-11-2017
Date Received 11-15-2017

Maximum Particle size: 3/4" Sieve

Sieve Size	% Passing
3/4"	100.0
3/8"	99.0
No. 4	95.8
No. 10	90.8

Analysis for the portion Finer than the No. 10 Sieve

Analysis Based on -3 inch fraction only

Specific Gravity 2.7

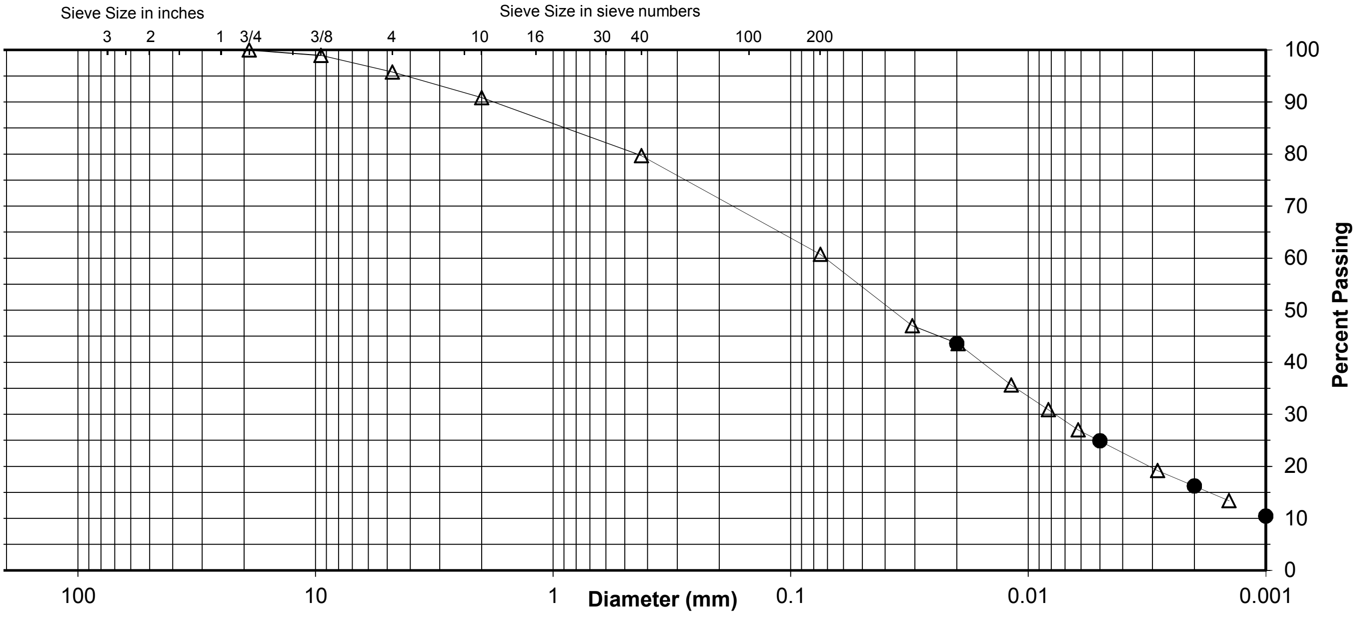
Dispersed using Apparatus A - Mechanical, for 1 minute

No. 40	79.7
No. 200	60.7
0.02 mm	43.6
0.005 mm	24.9
0.002 mm	16.2
0.001 mm	10.4

Particle Size Distribution

ASTM	Coarse Gravel	Fine Gravel	C. Sand	Medium Sand	Fine Sand	Silt	Clay
	0.0	4.2	5.0	11.1	19.0	35.8	24.9

AASHTO	Gravel	Coarse Sand	Fine Sand	Silt	Clay
	9.2	11.1	19.0	44.5	16.2



Comments

Reviewed By RJ

Stantec

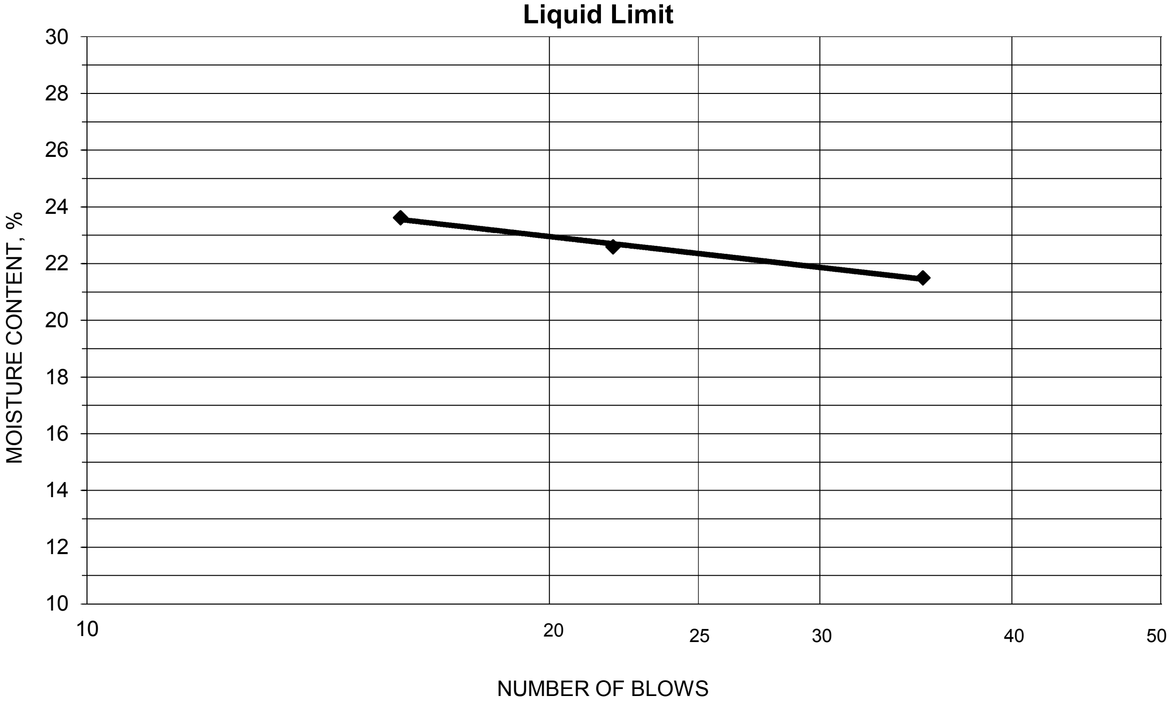
ATTERBERG LIMITS

Project	HCFRR - Dams Preliminary	Project No.	174316204
Source	B-101, 12.5'-13.0'	Lab ID	30
		% + No. 40	20

Tested By RJ Test Method ASTM D 4318 Method A Date Received 11-15-2017

Test Date 12-20-2017 Prepared Dry

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Number of Blows	Water Content (%)	Liquid Limit
25.36	22.71	11.49	16	23.6	22
25.29	22.71	11.29	22	22.6	
25.66	23.19	11.70	35	21.5	



PLASTIC LIMIT AND PLASTICITY INDEX

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Water Content (%)	Plastic Limit	Plasticity Index
20.45	19.39	11.39	13.3	13	9
20.66	19.57	11.46	13.4		

Remarks:

Reviewed By RJ

Stantec

Summary of Soil Tests

Project Name HCFRR - Dams Preliminary
Project Number 174316204
Source B-101, 16.0'-17.5', 17.5'-19.0', & 19.0'-19.8'
Lab ID 45

Sample Type SPT Composite
Date Received 11-15-17
Date Reported 12-19-17

Test Results

Natural Moisture Content

Test Not Performed
Moisture Content (%): N/A

Particle Size Analysis

Preparation Method: ASTM D 421
Gradation Method: ASTM D 422
Hydrometer Method: ASTM D 422

Particle Size		%
Sieve Size	(mm)	Passing
	N/A	
	N/A	
	N/A	
1 1/2"	37.5	100.0
3/4"	19	82.8
3/8"	9.5	60.0
No. 4	4.75	47.0
No. 10	2	32.5
No. 40	0.425	18.7
No. 200	0.075	11.6
	0.02	7.1
	0.005	3.5
	0.002	2.3
estimated	0.001	1.6

Plus 3 in. material, not included: 0 (%)

	ASTM	AASHTO
Range	(%)	(%)
Gravel	53.0	67.5
Coarse Sand	14.5	13.8
Medium Sand	13.8	---
Fine Sand	7.1	7.1
Silt	8.1	9.3
Clay	3.5	2.3

Atterberg Limits

Test Method: ASTM D 4318 Method A
Prepared: Dry
Liquid Limit: 19
Plastic Limit: 14
Plasticity Index: 5
Activity Index: 2.2

Moisture-Density Relationship

Test Not Performed
Maximum Dry Density (lb/ft^3): N/A
Maximum Dry Density (kg/m^3): N/A
Optimum Moisture Content (%): N/A
Over Size Correction %: N/A

California Bearing Ratio

Test Not Performed
Bearing Ratio (%): N/A
Compacted Dry Density (lb/ft^3): N/A
Compacted Moisture Content (%): N/A

Specific Gravity

Test Method: ASTM D 854
Prepared: Dry
Particle Size: No. 10
Specific Gravity at 20° Celsius: 2.70

Classification

Unified Group Symbol: GP-GC
Group Name: Poorly graded gravel with clay and sand (or silty clay and sand)

AASHTO Classification: A-1-a (0)

Comments:

Reviewed By RJ

Stantec

Particle-Size Analysis of Soils
ASTM D 422

Project Name HCFRR - Dams Preliminary
Source B-101, 16.0'-17.5', 17.5'-19.0', & 19.0'-19.8'

Project Number 174316204
Lab ID 45

Sieve analysis for the Portion Coarser than the No. 10 Sieve

Test Method ASTM D 422
Prepared using ASTM D 421

Particle Shape Rounded
Particle Hardness: Hard and Durable

Tested By GW/RJ
Test Date 11-29-2017
Date Received 11-15-2017

Maximum Particle size: 1 1/2" Sieve

Sieve Size	% Passing
1 1/2"	100.0
3/4"	82.8
3/8"	60.0
No. 4	47.0
No. 10	32.5

Analysis for the portion Finer than the No. 10 Sieve

Analysis Based on -3 inch fraction only

Specific Gravity 2.7

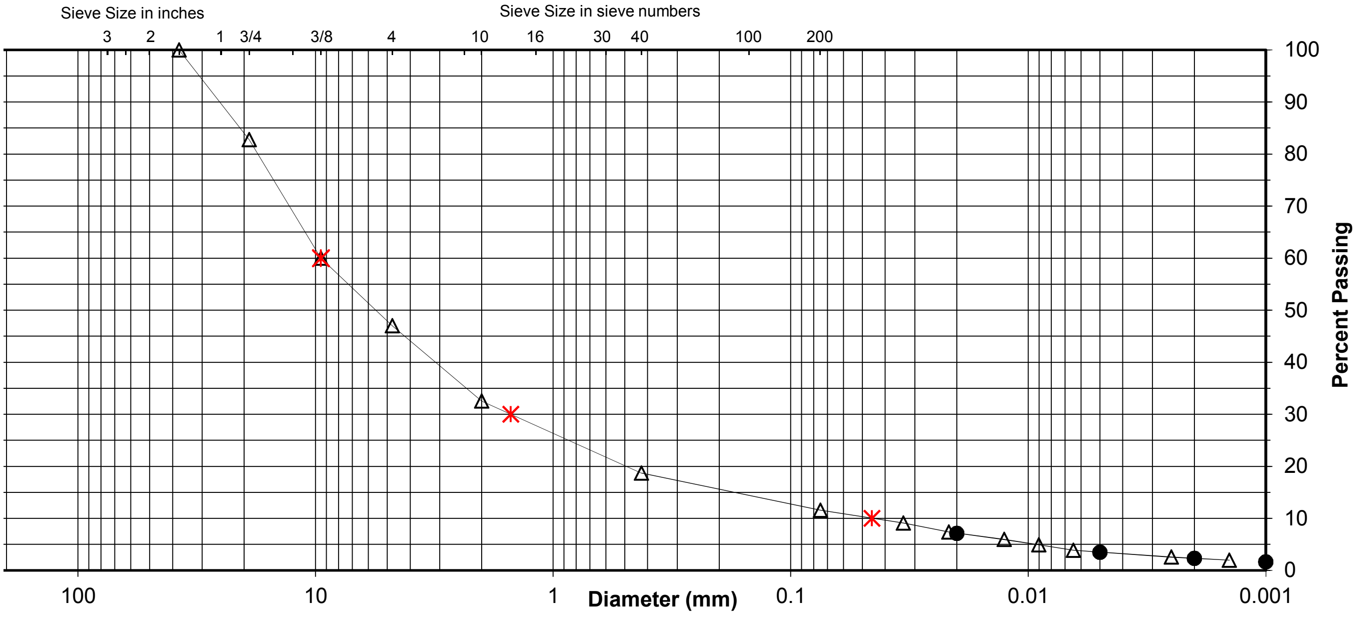
Dispersed using Apparatus A - Mechanical, for 1 minute

No. 40	18.7
No. 200	11.6
0.02 mm	7.1
0.005 mm	3.5
0.002 mm	2.3
0.001 mm	1.6

Particle Size Distribution

ASTM	Coarse Gravel	Fine Gravel	C. Sand	Medium Sand	Fine Sand	Silt	Clay
	17.2	35.8	14.5	13.8	7.1	8.1	3.5

AASHTO	Gravel	Coarse Sand	Fine Sand	Silt	Clay
	67.5	13.8	7.1	9.3	2.3



Comments

Reviewed By RJ

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Stantec Consulting Services Inc.
Lexington, Kentucky

Reported By: RJ
Report Date: 12/19/2017

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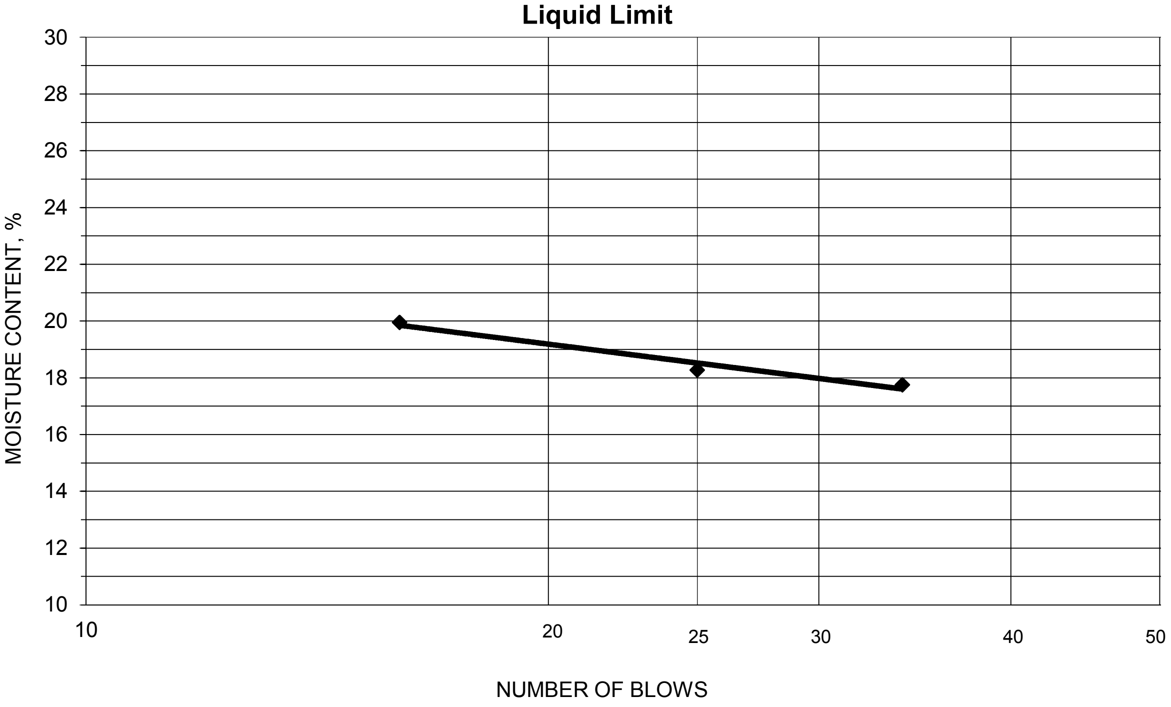
ATTERBERG LIMITS

Project	HCFRR - Dams Preliminary	Project No.	174316204
Source	B-101, 16.0'-17.5', 17.5'-19.0', & 19.0'-19.8'	Lab ID	45
		% + No. 40	81

Tested By	CM	Test Method	ASTM D 4318 Method A	Date Received	11-15-2017
Test Date	12-05-2017	Prepared	Dry		

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Number of Blows	Water Content (%)	Liquid Limit
23.15	21.30	10.88	34	17.8	19
24.53	22.46	11.13	25	18.3	
21.57	19.83	11.11	16	20.0	



PLASTIC LIMIT AND PLASTICITY INDEX

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Water Content (%)	Plastic Limit	Plasticity Index
18.07	17.20	11.09	14.2	14	5
19.08	18.11	11.27	14.2		

Remarks: ______

Reviewed By RJ

Stantec

Summary of Soil Tests

Project Name HCFRR - Dams Preliminary
Project Number 174316204
Source B-102, 4.5'-5.0'
Lab ID 31
Sample Type ST
Date Received 11-15-17
Date Reported 12-21-17

Test Results

Natural Moisture Content

Test Method: ASTM D 2216
Moisture Content (%): 21.3

Particle Size Analysis

Preparation Method: ASTM D 421
Gradation Method: ASTM D 422
Hydrometer Method: ASTM D 422

Particle Size		%
Sieve Size	(mm)	Passing
	N/A	
	N/A	
	N/A	
	N/A	
	N/A	
3/8"	9.5	100.0
No. 4	4.75	99.9
No. 10	2	99.0
No. 40	0.425	94.9
No. 200	0.075	78.8
	0.02	60.6
	0.005	40.2
	0.002	30.2
estimated	0.001	24.4

Plus 3 in. material, not included: 0 (%)

	ASTM	AASHTO
Range	(%)	(%)
Gravel	0.1	1.0
Coarse Sand	0.9	4.1
Medium Sand	4.1	---
Fine Sand	16.1	16.1
Silt	38.6	48.6
Clay	40.2	30.2

Atterberg Limits

Test Method: ASTM D 4318 Method A
Prepared: Dry
Liquid Limit: 40
Plastic Limit: 18
Plasticity Index: 22
Activity Index: 0.7

Moisture-Density Relationship

Test Not Performed
Maximum Dry Density (lb/ft^3): N/A
Maximum Dry Density (kg/m^3): N/A
Optimum Moisture Content (%): N/A
Over Size Correction %: N/A

California Bearing Ratio

Test Not Performed
Bearing Ratio (%): N/A
Compacted Dry Density (lb/ft^3): N/A
Compacted Moisture Content (%): N/A

Specific Gravity

Estimated
Particle Size: No. 10
Specific Gravity at 20° Celsius: 2.70

Classification

Unified Group Symbol: CL
Group Name: Lean clay with sand
AASHTO Classification: A-6 (16)

Comments:

Reviewed By RJ

Stantec

Particle-Size Analysis of Soils

ASTM D 422

Project Name HCFRR - Dams Preliminary
Project Number 174316204
Source B-102, 4.5'-5.0'
Lab ID 31

Sieve analysis for the Portion Coarser than the No. 10 Sieve

Test Method ASTM D 422
Prepared using ASTM D 421

Particle Shape Angular
Particle Hardness: Hard and Durable

Tested By GW
Test Date 12-12-2017
Date Received 11-15-2017

Maximum Particle size: 3/8" Sieve

Sieve Size	% Passing
3/8"	100.0
No. 4	99.9
No. 10	99.0

Analysis for the portion Finer than the No. 10 Sieve

Analysis Based on -3 inch fraction only

Specific Gravity 2.7

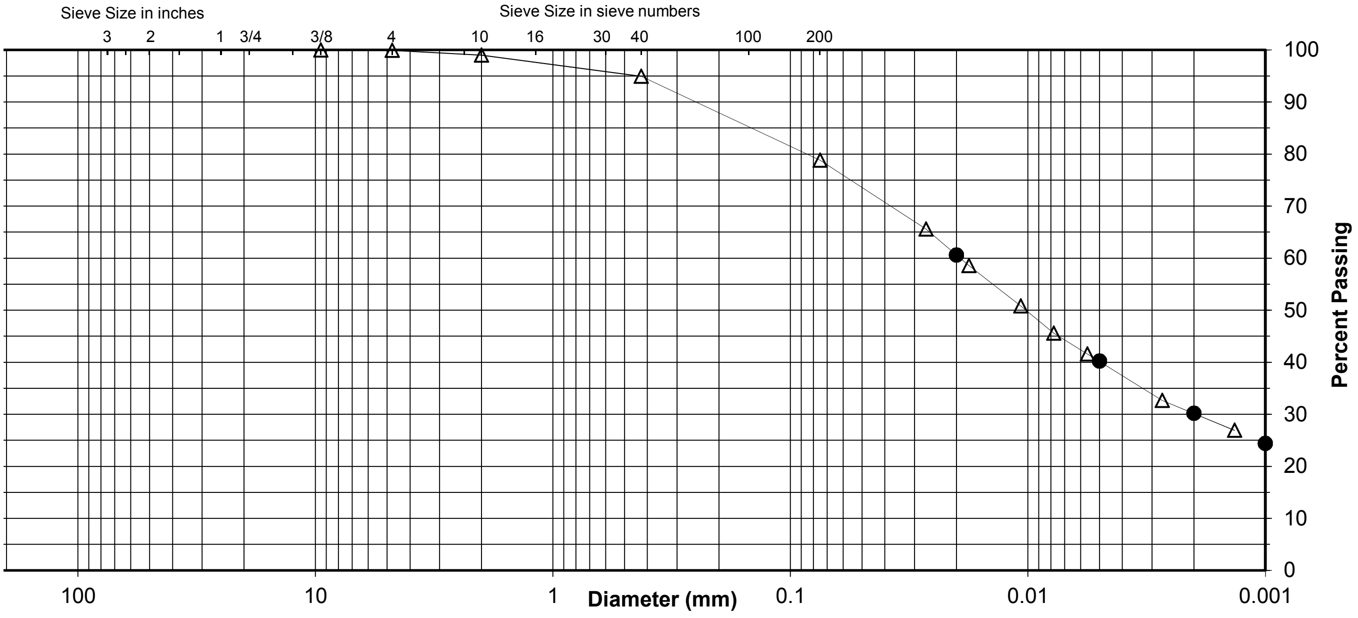
Dispersed using Apparatus A - Mechanical, for 1 minute

No. 40	94.9
No. 200	78.8
0.02 mm	60.6
0.005 mm	40.2
0.002 mm	30.2
0.001 mm	24.4

Particle Size Distribution

ASTM	Coarse Gravel	Fine Gravel	C. Sand	Medium Sand	Fine Sand	Silt	Clay
	0.0	0.1	0.9	4.1	16.1	38.6	40.2

AASHTO	Gravel	Coarse Sand	Fine Sand	Silt	Clay
	1.0	4.1	16.1	48.6	30.2



Comments

Reviewed By RJ

Stantec

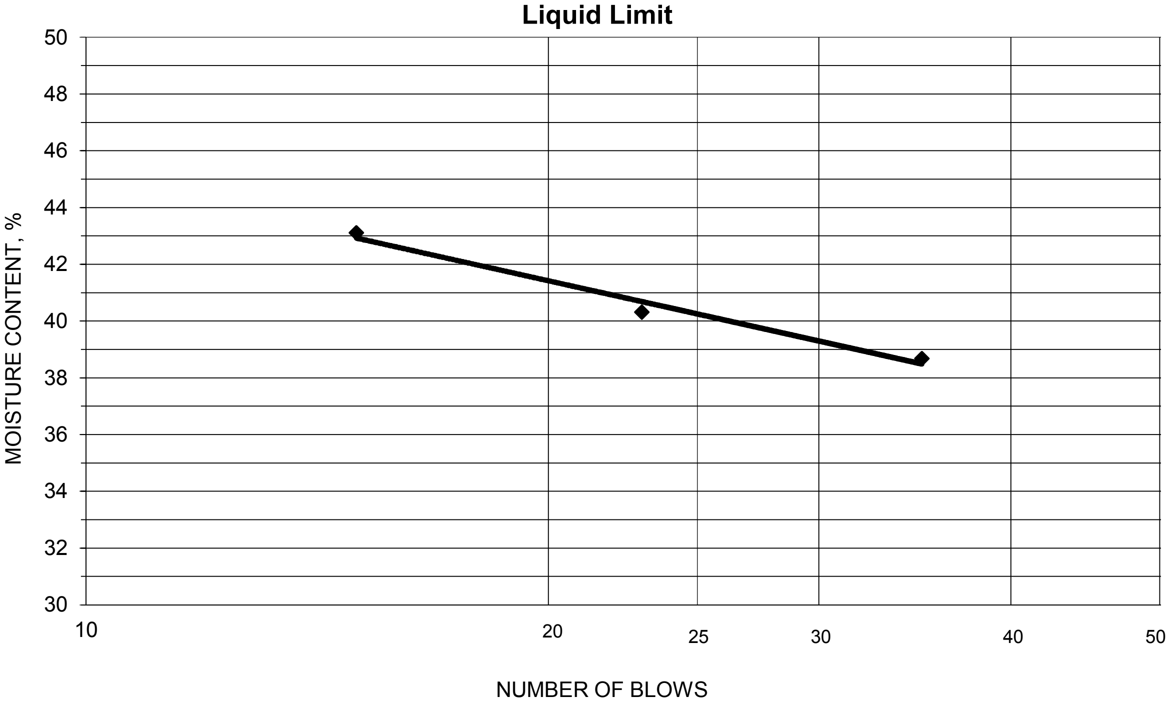
ATTERBERG LIMITS

Project	HCFRR - Dams Preliminary	Project No.	174316204
Source	B-102, 4.5'-5.0'	Lab ID	31
		% + No. 40	5

Tested By RJ　Test Method ASTM D 4318 Method A　Date Received 11-15-2017

Test Date 12-20-2017　Prepared Dry

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Number of Blows	Water Content (%)	Liquid Limit
24.82	20.96	10.98	35	38.7	40
25.31	21.21	11.04	23	40.3	
25.58	21.20	11.04	15	43.1	



PLASTIC LIMIT AND PLASTICITY INDEX

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Water Content (%)	Plastic Limit	Plasticity Index
20.39	18.97	10.90	17.6	18	22
20.87	19.43	11.48	18.1		

Remarks:

Reviewed By RJ

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Version: 20170217
Approved By: RJ

Reported By: RJ
Report Date: 12/21/2017

Stantec

Summary of Soil Tests

Project Name HCFRR - Dams Preliminary
Project Number 174316204
Source B-102, 8.0'-8.5'
Lab ID 32

Sample Type ST
Date Received 11-15-17
Date Reported 12-21-17

Test Results

Natural Moisture Content

Test Method: ASTM D 2216
Moisture Content (%): 21.6

Particle Size Analysis

Preparation Method: ASTM D 421
Gradation Method: ASTM D 422
Hydrometer Method: ASTM D 422

Particle Size		%
Sieve Size	(mm)	Passing
	N/A	
	N/A	
	N/A	
	N/A	
3/4"	19	100.0
3/8"	9.5	99.7
No. 4	4.75	98.8
No. 10	2	97.4
No. 40	0.425	92.6
No. 200	0.075	82.3
	0.02	68.0
	0.005	49.4
	0.002	34.6
estimated	0.001	25.3

Plus 3 in. material, not included: 0 (%)

	ASTM	AASHTO
Range	(%)	(%)
Gravel	1.2	2.6
Coarse Sand	1.4	4.8
Medium Sand	4.8	---
Fine Sand	10.3	10.3
Silt	32.9	47.7
Clay	49.4	34.6

Atterberg Limits

Test Method: ASTM D 4318 Method A
Prepared: Dry
Liquid Limit: 40
Plastic Limit: 20
Plasticity Index: 20
Activity Index: 0.6

Moisture-Density Relationship

Test Not Performed
Maximum Dry Density (lb/ft^3): N/A
Maximum Dry Density (kg/m^3): N/A
Optimum Moisture Content (%): N/A
Over Size Correction %: N/A

California Bearing Ratio

Test Not Performed
Bearing Ratio (%): N/A
Compacted Dry Density (lb/ft^3): N/A
Compacted Moisture Content (%): N/A

Specific Gravity

Estimated
Particle Size: No. 10
Specific Gravity at 20° Celsius: 2.70

Classification

Unified Group Symbol: CL
Group Name: Lean clay with sand
AASHTO Classification: A-6 (16)

Comments:

Reviewed By RJ

Stantec

Particle-Size Analysis of Soils

ASTM D 422

Project Name HCFRR - Dams Preliminary
Source B-102, 8.0'-8.5'
Project Number 174316204
Lab ID 32

Sieve analysis for the Portion Coarser than the No. 10 Sieve

Test Method ASTM D 422
Prepared using ASTM D 421

Particle Shape Angular
Particle Hardness: Hard and Durable

Tested By GW
Test Date 12-12-2017
Date Received 11-15-2017

Maximum Particle size: 3/4" Sieve

Sieve Size	% Passing
3/4"	100.0
3/8"	99.7
No. 4	98.8
No. 10	97.4

Analysis for the portion Finer than the No. 10 Sieve

Analysis Based on -3 inch fraction only

Specific Gravity 2.7

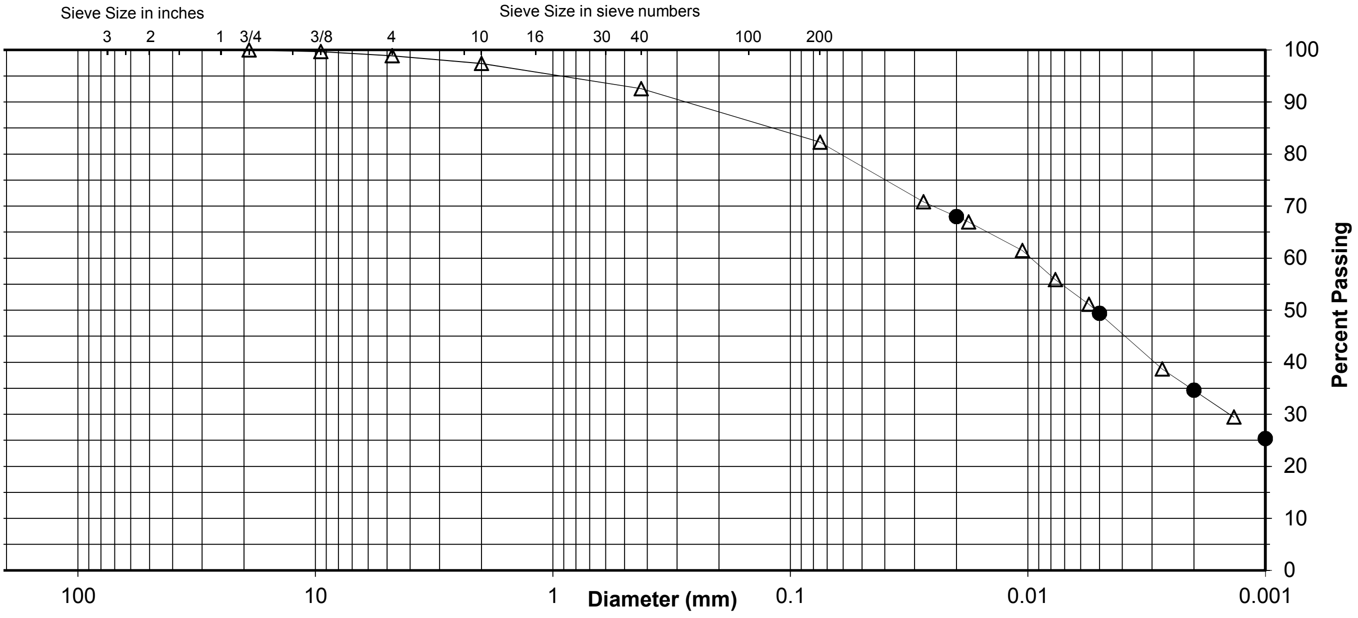
Dispersed using Apparatus A - Mechanical, for 1 minute

No. 40	92.6
No. 200	82.3
0.02 mm	68.0
0.005 mm	49.4
0.002 mm	34.6
0.001 mm	25.3

Particle Size Distribution

ASTM	Coarse Gravel	Fine Gravel	C. Sand	Medium Sand	Fine Sand	Silt	Clay
	0.0	1.2	1.4	4.8	10.3	32.9	49.4

AASHTO	Gravel	Coarse Sand	Fine Sand	Silt	Clay
	2.6	4.8	10.3	47.7	34.6



Comments

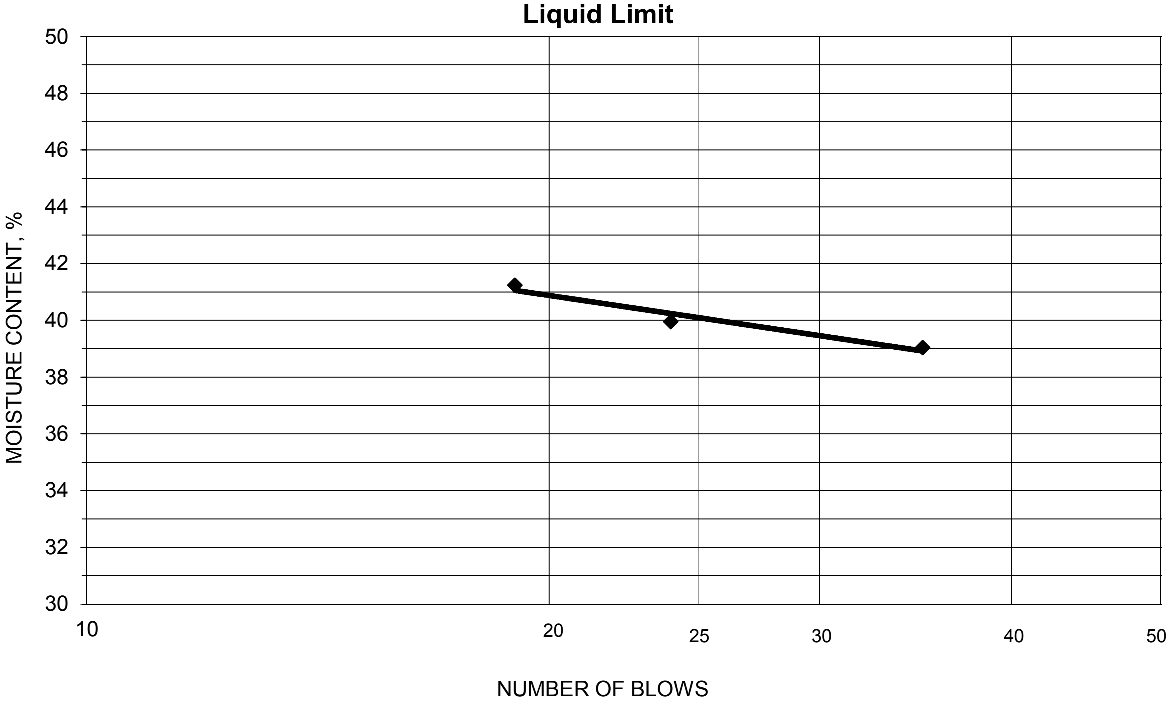
Reviewed By RJ

Stantec

ATTERBERG LIMITS

Project	HCFRR - Dams Preliminary	Project No.	174316204
Source	B-102, 8.0'-8.5'	Lab ID	32
		% + No. 40	7
Tested By	RJ	Test Method	ASTM D 4318 Method A
Date Received	11-15-2017		
Test Date	12-20-2017	Prepared	Dry

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Number of Blows	Water Content (%)	Liquid Limit
22.71	19.30	11.03	19	41.2	40
22.54	19.28	11.12	24	40.0	
22.48	19.26	11.01	35	39.0	



PLASTIC LIMIT AND PLASTICITY INDEX

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Water Content (%)	Plastic Limit	Plasticity Index
20.84	19.14	10.80	20.4	20	20
20.54	18.91	10.82	20.1		

Remarks:

Reviewed By RJ

Stantec

Summary of Soil Tests

Project Name HCFRR - Dams Preliminary
Project Number 174316204
Source B-102, 15.0'-15.5'
Lab ID 34A

Sample Type ST
Date Received 11-15-17
Date Reported 12-21-17

Test Results

Natural Moisture Content

Test Method: ASTM D 2216
Moisture Content (%): 21.9

Particle Size Analysis

Preparation Method: ASTM D 421
Gradation Method: ASTM D 422
Hydrometer Method: ASTM D 422

Particle Size		%
Sieve Size	(mm)	Passing
	N/A	
	N/A	
	N/A	
1 1/2"	37.5	100.0
3/4"	19	96.5
3/8"	9.5	92.1
No. 4	4.75	91.6
No. 10	2	90.9
No. 40	0.425	89.0
No. 200	0.075	82.8
	0.02	51.6
	0.005	26.2
	0.002	16.9
estimated	0.001	11.2

Plus 3 in. material, not included: 0 (%)

	ASTM	AASHTO
Range	(%)	(%)
Gravel	8.4	9.1
Coarse Sand	0.7	1.9
Medium Sand	1.9	---
Fine Sand	6.2	6.2
Silt	56.6	65.9
Clay	26.2	16.9

Atterberg Limits

Test Method: ASTM D 4318 Method A
Prepared: Dry
Liquid Limit: 22
Plastic Limit: 15
Plasticity Index: 7
Activity Index: 0.4

Moisture-Density Relationship

Test Not Performed
Maximum Dry Density (lb/ft^3): N/A
Maximum Dry Density (kg/m^3): N/A
Optimum Moisture Content (%): N/A
Over Size Correction %: N/A

California Bearing Ratio

Test Not Performed
Bearing Ratio (%): N/A
Compacted Dry Density (lb/ft^3): N/A
Compacted Moisture Content (%): N/A

Specific Gravity

Estimated

Particle Size: No. 10
Specific Gravity at 20° Celsius: 2.70

Classification

Unified Group Symbol: CL-ML
Group Name: Silty clay with sand

AASHTO Classification: A-4 (3)

Comments:

Reviewed By RJ

Particle-Size Analysis of Soils

ASTM D 422

Project Name HCFRR - Dams Preliminary
Source B-102, 15.0'-15.5'

Project Number 174316204
Lab ID 34A

Sieve analysis for the Portion Coarser than the No. 10 Sieve

Test Method ASTM D 422
Prepared using ASTM D 421

Particle Shape Angular
Particle Hardness: Hard and Durable

Tested By GW
Test Date 12-11-2017
Date Received 11-15-2017

Maximum Particle size: 1 1/2" Sieve

Sieve Size	% Passing
1 1/2"	100.0
3/4"	96.5
3/8"	92.1
No. 4	91.6
No. 10	90.9

Analysis for the portion Finer than the No. 10 Sieve

Analysis Based on -3 inch fraction only

Specific Gravity 2.7

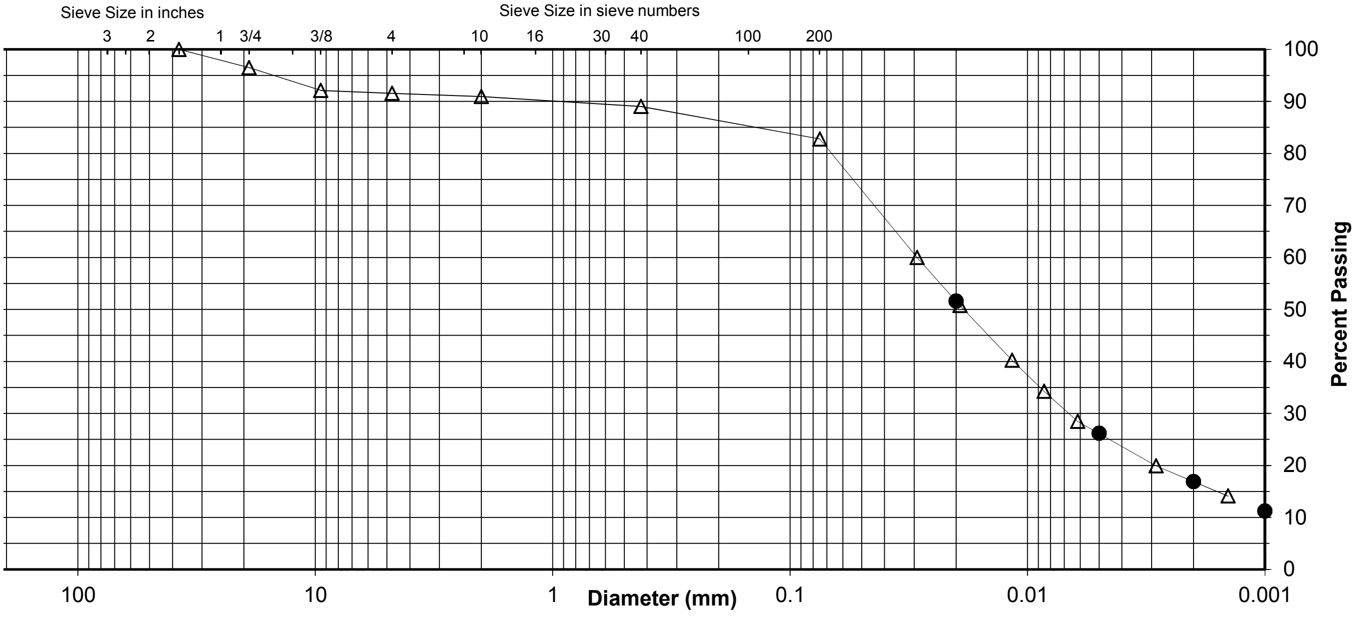
Dispersed using Apparatus A - Mechanical, for 1 minute

No. 40	89.0
No. 200	82.8
0.02 mm	51.6
0.005 mm	26.2
0.002 mm	16.9
0.001 mm	11.2

Particle Size Distribution

ASTM	Coarse Gravel	Fine Gravel	C. Sand	Medium Sand	Fine Sand	Silt	Clay
	3.5	4.9	0.7	1.9	6.2	56.6	26.2

AASHTO	Gravel	Coarse Sand	Fine Sand	Silt	Clay
	9.1	1.9	6.2	65.9	16.9



Comments

Reviewed By RJ

Stantec

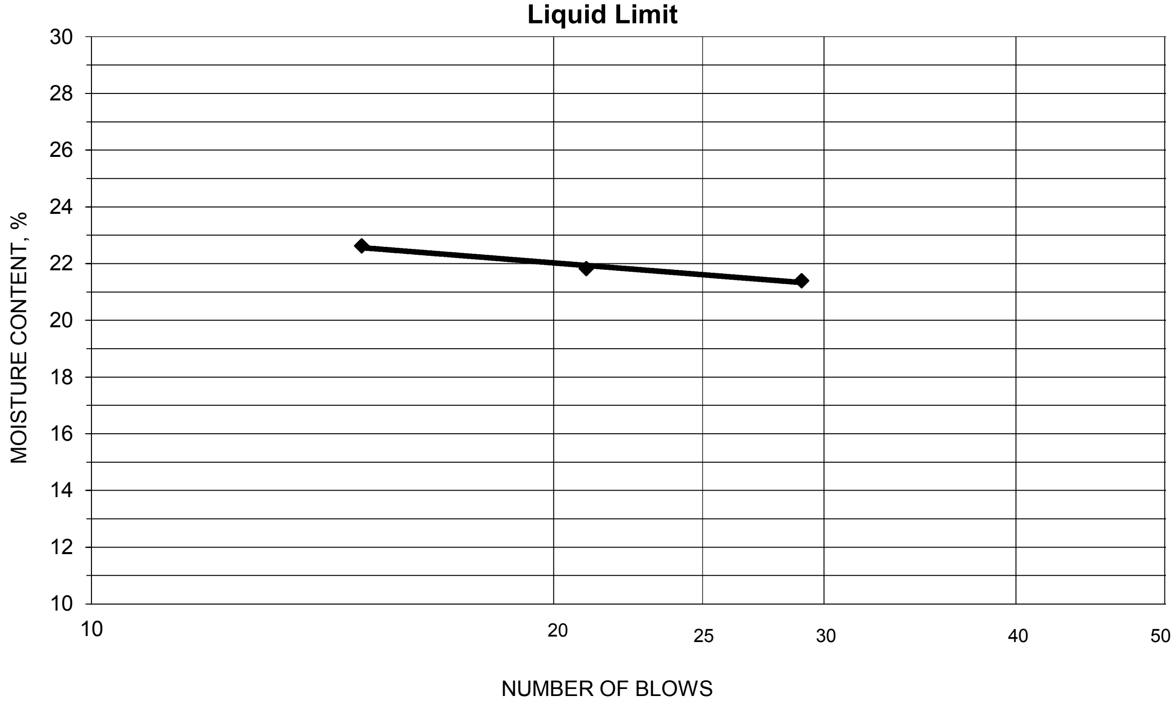
ATTERBERG LIMITS

Project	HCFRR - Dams Preliminary	Project No.	174316204
Source	B-102, 15.0'-15.5'	Lab ID	34A
		% + No. 40	11

Tested By RJ Test Method ASTM D 4318 Method A Date Received 11-15-2017

Test Date 12-20-2017 Prepared Dry

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Number of Blows	Water Content (%)	Liquid Limit
23.03	20.91	11.00	29	21.4	22
23.56	21.33	11.11	21	21.8	
23.68	21.33	10.94	15	22.6	



PLASTIC LIMIT AND PLASTICITY INDEX

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Water Content (%)	Plastic Limit	Plasticity Index
20.41	19.18	11.07	15.2	15	7
20.22	18.99	10.94	15.3		

Remarks:

Reviewed By RJ

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Version: 20170217
Approved By: RJ

Reported By: RJ
Report Date: 12/21/2017

Stantec

Summary of Soil Tests

Project Name: HCFRR - Dams Preliminary
Project Number: 174316204
Source: B-103, 4.0'-4.5'
Lab ID: 35

Sample Type: ST
Date Received: 11-15-17
Date Reported: 12-22-17

Test Results

Natural Moisture Content

Test Method: ASTM D 2216
Moisture Content (%): 15.0

Atterberg Limits

Test Method: ASTM D 4318 Method A
Prepared: Dry
Liquid Limit: 31
Plastic Limit: 18
Plasticity Index: 13
Activity Index: 1.3

Particle Size Analysis

Preparation Method: ASTM D 421
Gradation Method: ASTM D 422
Hydrometer Method: ASTM D 422

Particle Size		%
Sieve Size	(mm)	Passing
	N/A	
	N/A	
	N/A	
	N/A	
3/4"	19	100.0
3/8"	9.5	96.0
No. 4	4.75	88.7
No. 10	2	68.9
No. 40	0.425	48.5
No. 200	0.075	35.5
	0.02	23.8
	0.005	13.8
	0.002	9.8
estimated	0.001	7.2

Plus 3 in. material, not included: 0 (%)

	ASTM	AASHTO
Range	(%)	(%)
Gravel	11.3	31.1
Coarse Sand	19.8	20.4
Medium Sand	20.4	---
Fine Sand	13.0	13.0
Silt	21.7	25.7
Clay	13.8	9.8

Moisture-Density Relationship

Test Not Performed
Maximum Dry Density (lb/ft^3): N/A
Maximum Dry Density (kg/m^3): N/A
Optimum Moisture Content (%): N/A
Over Size Correction %: N/A

California Bearing Ratio

Test Not Performed
Bearing Ratio (%): N/A
Compacted Dry Density (lb/ft^3): N/A
Compacted Moisture Content (%): N/A

Specific Gravity

Estimated

Particle Size: No. 10
Specific Gravity at 20° Celsius: 2.70

Classification

Unified Group Symbol: SC
Group Name: Clayey sand

AASHTO Classification: A-6 (1)

Comments:

Reviewed By KG

Particle-Size Analysis of Soils
ASTM D 422

Project Name HCFRR - Dams Preliminary
Project Number 174316204
Source B-103, 4.0'-4.5'
Lab ID 35

Sieve analysis for the Portion Coarser than the No. 10 Sieve

Test Method ASTM D 422
Prepared using ASTM D 421

Particle Shape Angular
Particle Hardness: Hard and Durable

Tested By RC
Test Date 12-19-2017
Date Received 11-15-2017

Maximum Particle size: 3/4" Sieve

Sieve Size	% Passing
3/4"	100.0
3/8"	96.0
No. 4	88.7
No. 10	68.9

Analysis for the portion Finer than the No. 10 Sieve

Analysis Based on -3 inch fraction only

Specific Gravity 2.7

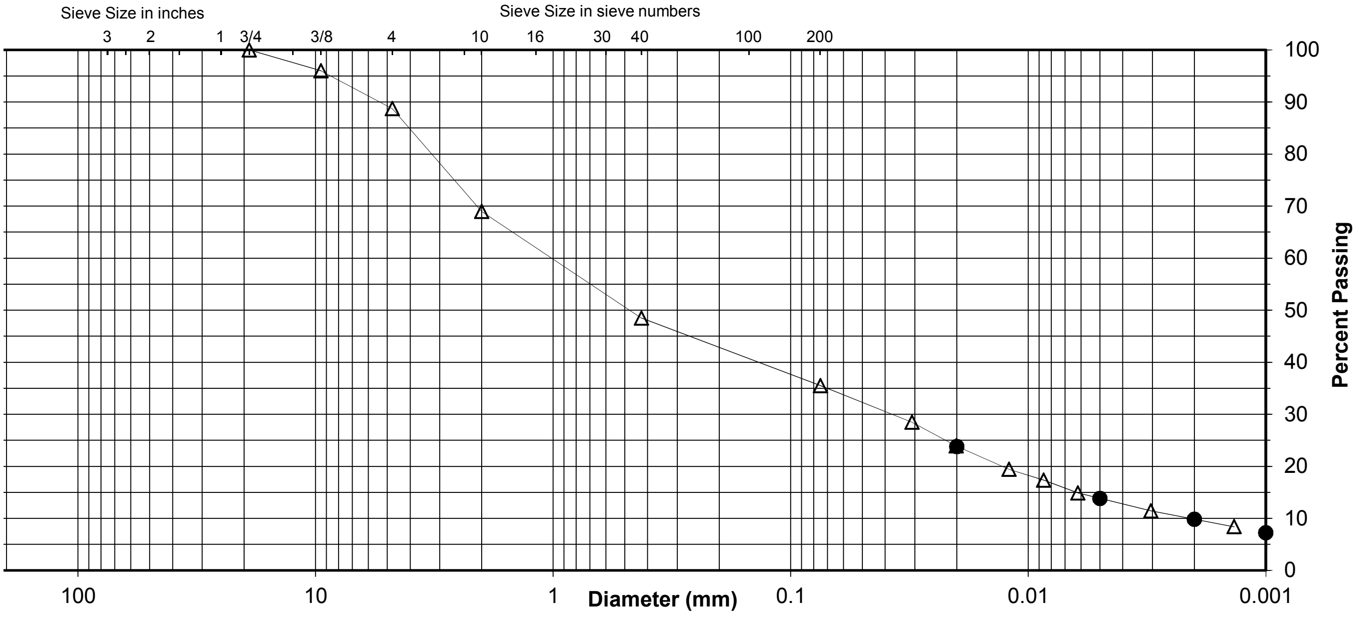
Dispersed using Apparatus A - Mechanical, for 1 minute

No. 40	48.5
No. 200	35.5
0.02 mm	23.8
0.005 mm	13.8
0.002 mm	9.8
0.001 mm	7.2

Particle Size Distribution

ASTM	Coarse Gravel	Fine Gravel	C. Sand	Medium Sand	Fine Sand	Silt	Clay
	0.0	11.3	19.8	20.4	13.0	21.7	13.8

AASHTO	Gravel	Coarse Sand	Fine Sand	Silt	Clay
	31.1	20.4	13.0	25.7	9.8



Comments

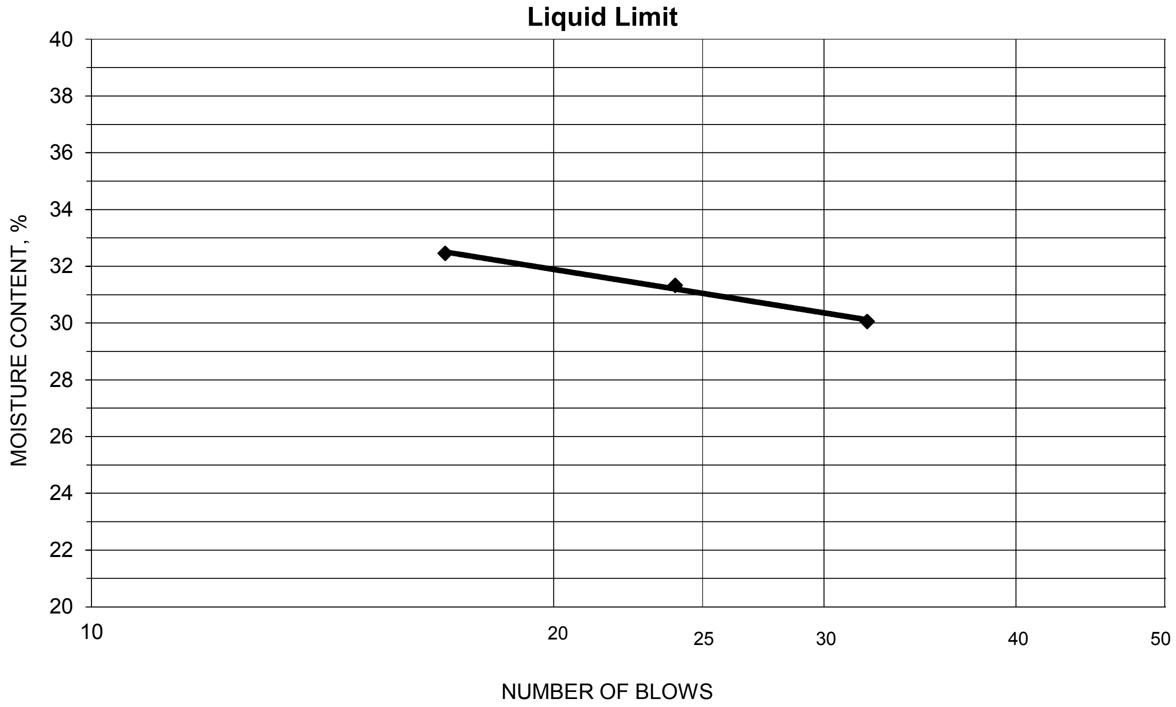
Reviewed By KG

Stantec

ATTERBERG LIMITS

Project: HCFRR - Dams Preliminary
Source: B-103, 4.0'-4.5'
Project No.: 174316204
Lab ID: 35
% + No. 40: 52
Tested By: RJ
Test Method: ASTM D 4318 Method A
Date Received: 11-15-2017
Test Date: 12-20-2017
Prepared: Dry

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Number of Blows	Water Content (%)	Liquid Limit
25.00	21.77	11.02	32	30.0	31
25.54	22.05	10.91	24	31.3	
26.13	22.47	11.19	17	32.4	



PLASTIC LIMIT AND PLASTICITY INDEX

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Water Content (%)	Plastic Limit	Plasticity Index
24.00	21.98	10.83	18.1	18	13
23.46	21.54	10.83	17.9		

Remarks:

Reviewed By KG

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Approved By: RJ

Reported By: KG
Report Date: 12/22/2017

Stantec

Summary of Soil Tests

Project Name: HCFRR - Dams Preliminary
Project Number: 174316204
Source: B-103, 7.5'-8.0'
Lab ID: 36A
Sample Type: ST
Date Received: 11-15-17
Date Reported: 12-21-17

Test Results

Natural Moisture Content

Test Method: ASTM D 2216
Moisture Content (%): 15.5

Particle Size Analysis

Preparation Method: ASTM D 421
Gradation Method: ASTM D 422
Hydrometer Method: ASTM D 422

Particle Size		%
Sieve Size	(mm)	Passing
	N/A	
	N/A	
	N/A	
	N/A	
3/4"	19	100.0
3/8"	9.5	99.3
No. 4	4.75	97.7
No. 10	2	94.7
No. 40	0.425	88.6
No. 200	0.075	77.0
	0.02	61.2
	0.005	39.5
	0.002	26.6
estimated	0.001	19.4

Plus 3 in. material, not included: 0 (%)

	ASTM	AASHTO
Range	(%)	(%)
Gravel	2.3	5.3
Coarse Sand	3.0	6.1
Medium Sand	6.1	---
Fine Sand	11.6	11.6
Silt	37.5	50.4
Clay	39.5	26.6

Atterberg Limits

Test Method: ASTM D 4318 Method A
Prepared: Dry
Liquid Limit: 27
Plastic Limit: 15
Plasticity Index: 12
Activity Index: 0.5

Moisture-Density Relationship

Test Not Performed
Maximum Dry Density (lb/ft^3): N/A
Maximum Dry Density (kg/m^3): N/A
Optimum Moisture Content (%): N/A
Over Size Correction %: N/A

California Bearing Ratio

Test Not Performed
Bearing Ratio (%): N/A
Compacted Dry Density (lb/ft^3): N/A
Compacted Moisture Content (%): N/A

Specific Gravity

Estimated
Particle Size: No. 10
Specific Gravity at 20° Celsius: 2.70

Classification

Unified Group Symbol: CL
Group Name: Lean clay with sand
AASHTO Classification: A-6 (7)

Comments:

Reviewed By RJ

Stantec

Particle-Size Analysis of Soils
ASTM D 422

Project Name HCFRR - Dams Preliminary

Project Number 174316204

Source B-103, 7.5'-8.0'

Lab ID 36A

Sieve analysis for the Portion Coarser than the No. 10 Sieve

Test Method ASTM D 422

Prepared using ASTM D 421

Particle Shape Angular

Particle Hardness: Hard and Durable

Tested By GW

Test Date 12-15-2017

Date Received 11-15-2017

Maximum Particle size: 3/4" Sieve

Sieve Size	% Passing
3/4"	100.0
3/8"	99.3
No. 4	97.7
No. 10	94.7

Analysis for the portion Finer than the No. 10 Sieve

Analysis Based on -3 inch fraction only

Specific Gravity 2.7

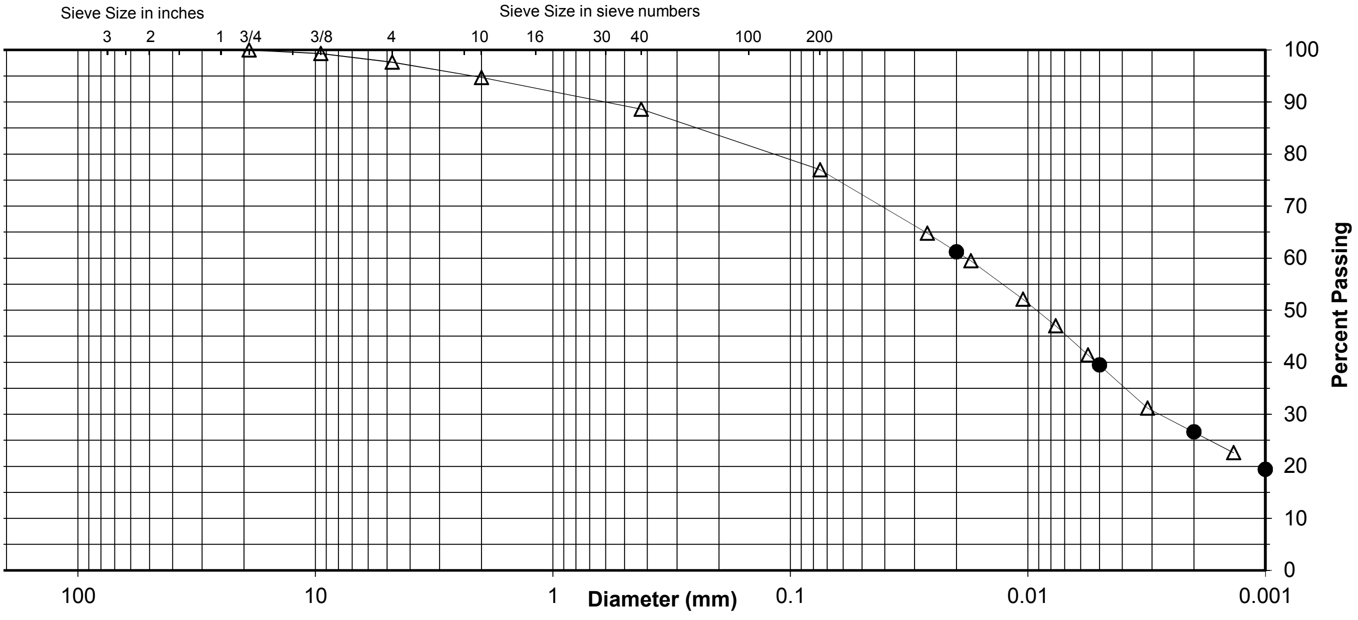
Dispersed using Apparatus A - Mechanical, for 1 minute

No. 40	88.6
No. 200	77.0
0.02 mm	61.2
0.005 mm	39.5
0.002 mm	26.6
0.001 mm	19.4

Particle Size Distribution

ASTM	Coarse Gravel	Fine Gravel	C. Sand	Medium Sand	Fine Sand	Silt	Clay
	0.0	2.3	3.0	6.1	11.6	37.5	39.5

AASHTO	Gravel	Coarse Sand	Fine Sand	Silt	Clay
	5.3	6.1	11.6	50.4	26.6



Comments

Reviewed By RJ

Template: tmp_sum_input.xlsm
Version: 20170217
Approved By: RJ

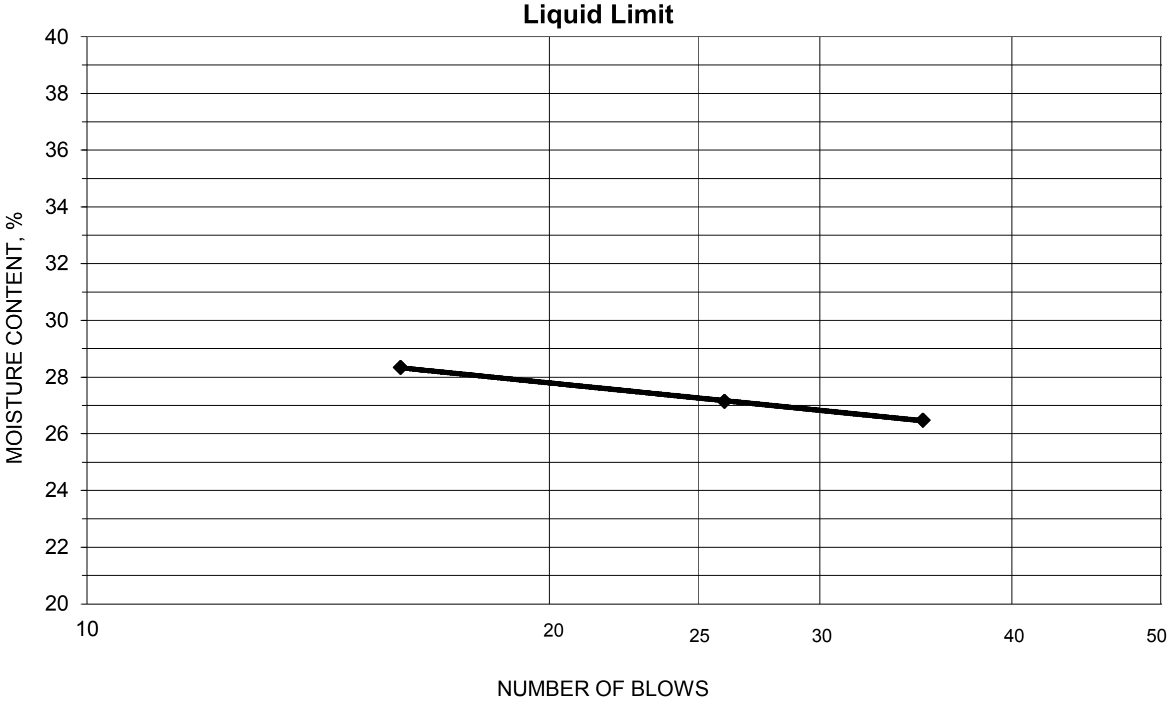
Stantec Consulting Services Inc.
Lexington, Kentucky

Reported By: RJ
Report Date: 12/21/2017

ATTERBERG LIMITS

Project	HCFRR - Dams Preliminary	Project No.	174316204
Source	B-103, 7.5'-8.0'	Lab ID	36A
		% + No. 40	11
Tested By	RJ	Test Method	ASTM D 4318 Method A
Date Received	11-15-2017		
Test Date	12-20-2017	Prepared	Dry

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Number of Blows	Water Content (%)	Liquid Limit
23.26	20.57	10.66	26	27.1	27
24.08	21.43	11.42	35	26.5	
24.25	21.34	11.07	16	28.3	



PLASTIC LIMIT AND PLASTICITY INDEX

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Water Content (%)	Plastic Limit	Plasticity Index
20.37	19.13	11.14	15.5	15	12
20.65	19.34	10.82	15.4		

Remarks:

Reviewed By RJ

Stantec

Summary of Soil Tests

Project Name HCFRR - Dams Preliminary
Project Number 174316204
Source B-103, 11.3'-11.8'
Lab ID 37

Sample Type ST
Date Received 11-15-17
Date Reported 12-21-17

Test Results

Natural Moisture Content

Test Method: ASTM D 2216
Moisture Content (%): 14.2

Particle Size Analysis

Preparation Method: ASTM D 421
Gradation Method: ASTM D 422
Hydrometer Method: ASTM D 422

Particle Size		%
Sieve Size	(mm)	Passing
	N/A	
	N/A	
	N/A	
	N/A	
3/4"	19	100.0
3/8"	9.5	99.2
No. 4	4.75	97.7
No. 10	2	94.9
No. 40	0.425	88.8
No. 200	0.075	78.3
	0.02	62.3
	0.005	41.1
	0.002	28.1
estimated	0.001	20.1

Plus 3 in. material, not included: 0 (%)

	ASTM	AASHTO
Range	(%)	(%)
Gravel	2.3	5.1
Coarse Sand	2.8	6.1
Medium Sand	6.1	---
Fine Sand	10.5	10.5
Silt	37.2	50.2
Clay	41.1	28.1

Atterberg Limits

Test Method: ASTM D 4318 Method A
Prepared: Dry
Liquid Limit: 27
Plastic Limit: 15
Plasticity Index: 12
Activity Index: 0.4

Moisture-Density Relationship

Test Not Performed
Maximum Dry Density (lb/ft^3): N/A
Maximum Dry Density (kg/m^3): N/A
Optimum Moisture Content (%): N/A
Over Size Correction %: N/A

California Bearing Ratio

Test Not Performed
Bearing Ratio (%): N/A
Compacted Dry Density (lb/ft^3): N/A
Compacted Moisture Content (%): N/A

Specific Gravity

Estimated

Particle Size: No. 10
Specific Gravity at 20° Celsius: 2.70

Classification

Unified Group Symbol: CL
Group Name: Lean clay with sand

AASHTO Classification: A-6 (7)

Comments:

Reviewed By RJ

Particle-Size Analysis of Soils

ASTM D 422

Project Name HCFRR - Dams Preliminary
Project Number 174316204
Source B-103, 11.3'-11.8'
Lab ID 37

Sieve analysis for the Portion Coarser than the No. 10 Sieve

Test Method ASTM D 422
Prepared using ASTM D 421

Particle Shape Angular
Particle Hardness: Hard and Durable

Tested By GW
Test Date 12-15-2017
Date Received 11-15-2017

Maximum Particle size: 3/4" Sieve

Sieve Size	% Passing
3/4"	100.0
3/8"	99.2
No. 4	97.7
No. 10	94.9

Analysis for the portion Finer than the No. 10 Sieve

Analysis Based on -3 inch fraction only

Specific Gravity 2.7

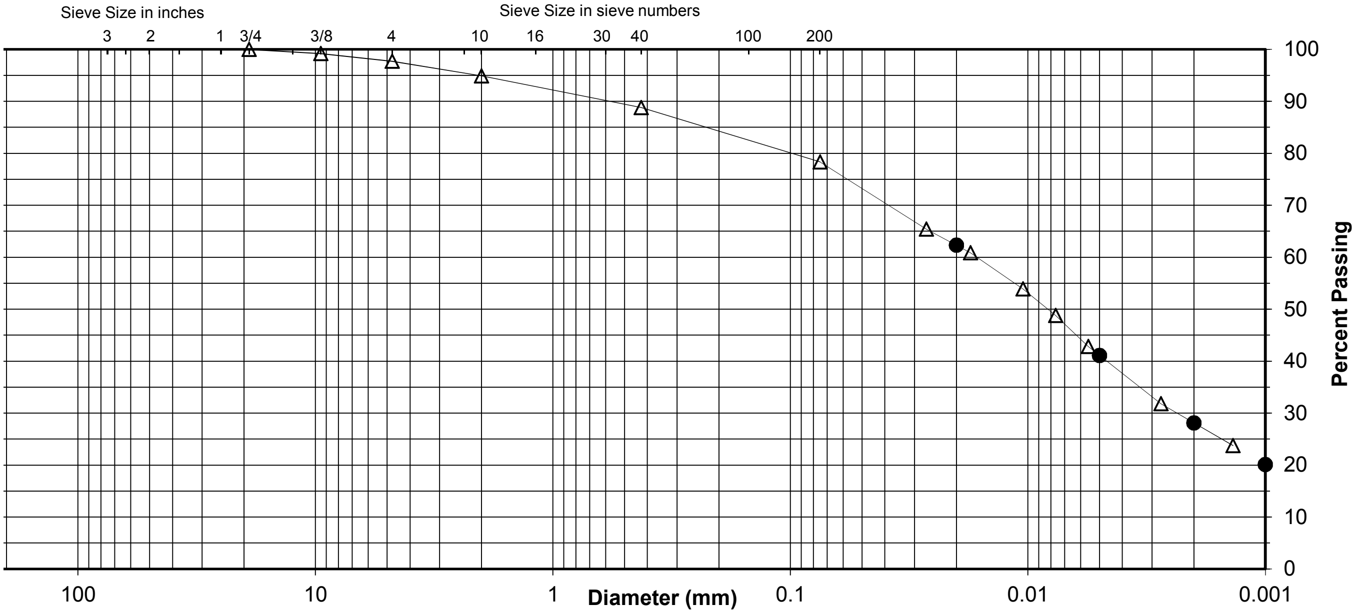
Dispersed using Apparatus A - Mechanical, for 1 minute

No. 40	88.8
No. 200	78.3
0.02 mm	62.3
0.005 mm	41.1
0.002 mm	28.1
0.001 mm	20.1

Particle Size Distribution

ASTM	Coarse Gravel	Fine Gravel	C. Sand	Medium Sand	Fine Sand	Silt	Clay
	0.0	2.3	2.8	6.1	10.5	37.2	41.1

AASHTO	Gravel	Coarse Sand	Fine Sand	Silt	Clay
	5.1	6.1	10.5	50.2	28.1



Comments

Reviewed By RJ

Template: tmp_sum_input.xlsm
Version: 20170217
Approved By: RJ

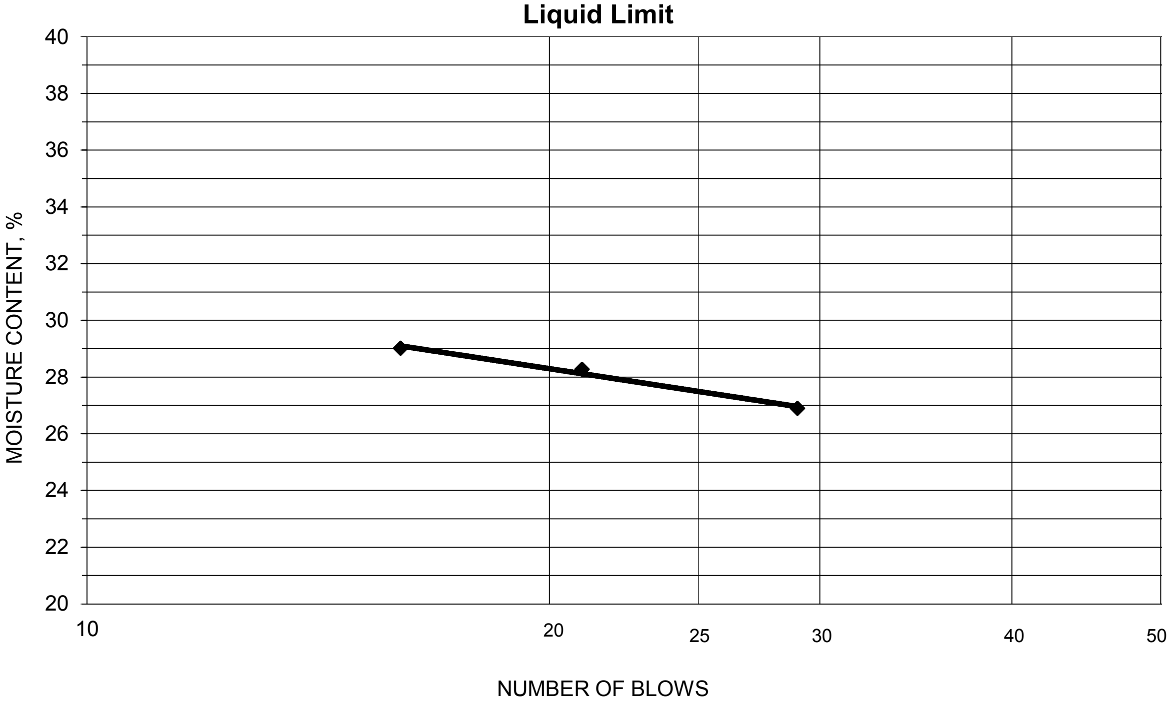
Reported By: RJ
Report Date: 12/21/2017

Stantec

ATTERBERG LIMITS

Project: HCFRR - Dams Preliminary
Project No.: 174316204
Source: B-103, 11.3'-11.8'
Lab ID: 37
% + No. 40: 11
Tested By: KG
Test Method: ASTM D 4318 Method A
Date Received: 11-15-2017
Test Date: 12-20-2017
Prepared: Dry

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Number of Blows	Water Content (%)	Liquid Limit
21.19	19.02	10.95	29	26.9	27
21.51	19.22	11.12	21	28.3	
20.93	18.69	10.97	16	29.0	



PLASTIC LIMIT AND PLASTICITY INDEX

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Water Content (%)	Plastic Limit	Plasticity Index
18.96	17.95	11.08	14.7	15	12
18.11	17.23	11.20	14.6		

Remarks:

Reviewed By RJ

Stantec

Summary of Soil Tests

Project Name HCFRR - Dams Preliminary
Project Number 174316204
Source B-103, 14.5'-15.0'
Lab ID 38
Sample Type ST
Date Received 11-15-17
Date Reported 12-21-17

Test Results

Natural Moisture Content

Test Method: ASTM D 2216
Moisture Content (%): 14.2

Particle Size Analysis

Preparation Method: ASTM D 421
Gradation Method: ASTM D 422
Hydrometer Method: ASTM D 422

Particle Size		%
Sieve Size	(mm)	Passing
	N/A	
	N/A	
	N/A	
1 1/2"	37.5	100.0
3/4"	19	97.9
3/8"	9.5	97.9
No. 4	4.75	97.2
No. 10	2	95.1
No. 40	0.425	89.8
No. 200	0.075	80.3
	0.02	64.0
	0.005	41.6
	0.002	28.7
estimated	0.001	20.4

Plus 3 in. material, not included: 0 (%)

	ASTM	AASHTO
Range	(%)	(%)
Gravel	2.8	4.9
Coarse Sand	2.1	5.3
Medium Sand	5.3	---
Fine Sand	9.5	9.5
Silt	38.7	51.6
Clay	41.6	28.7

Atterberg Limits

Test Method: ASTM D 4318 Method A
Prepared: Dry
Liquid Limit: 29
Plastic Limit: 16
Plasticity Index: 13
Activity Index: 0.5

Moisture-Density Relationship

Test Not Performed
Maximum Dry Density (lb/ft^3): N/A
Maximum Dry Density (kg/m^3): N/A
Optimum Moisture Content (%): N/A
Over Size Correction %: N/A

California Bearing Ratio

Test Not Performed
Bearing Ratio (%): N/A
Compacted Dry Density (lb/ft^3): N/A
Compacted Moisture Content (%): N/A

Specific Gravity

Estimated
Particle Size: No. 10
Specific Gravity at 20° Celsius: 2.70

Classification

Unified Group Symbol: CL
Group Name: Lean clay with sand
AASHTO Classification: A-6 (8)

Comments:

Reviewed By RJ

Stantec

Particle-Size Analysis of Soils

ASTM D 422

Project Name HCFRR - Dams Preliminary
Project Number 174316204
Source B-103, 14.5'-15.0'
Lab ID 38

Sieve analysis for the Portion Coarser than the No. 10 Sieve

Test Method ASTM D 422
Prepared using ASTM D 421

Particle Shape Rounded and Angular
Particle Hardness: Hard and Durable

Tested By BM
Test Date 12-15-2017
Date Received 11-15-2017

Maximum Particle size: 1 1/2" Sieve

Sieve Size	% Passing
1 1/2"	100.0
3/4"	97.9
3/8"	97.9
No. 4	97.2
No. 10	95.1

Analysis for the portion Finer than the No. 10 Sieve

Analysis Based on -3 inch fraction only

Specific Gravity 2.7

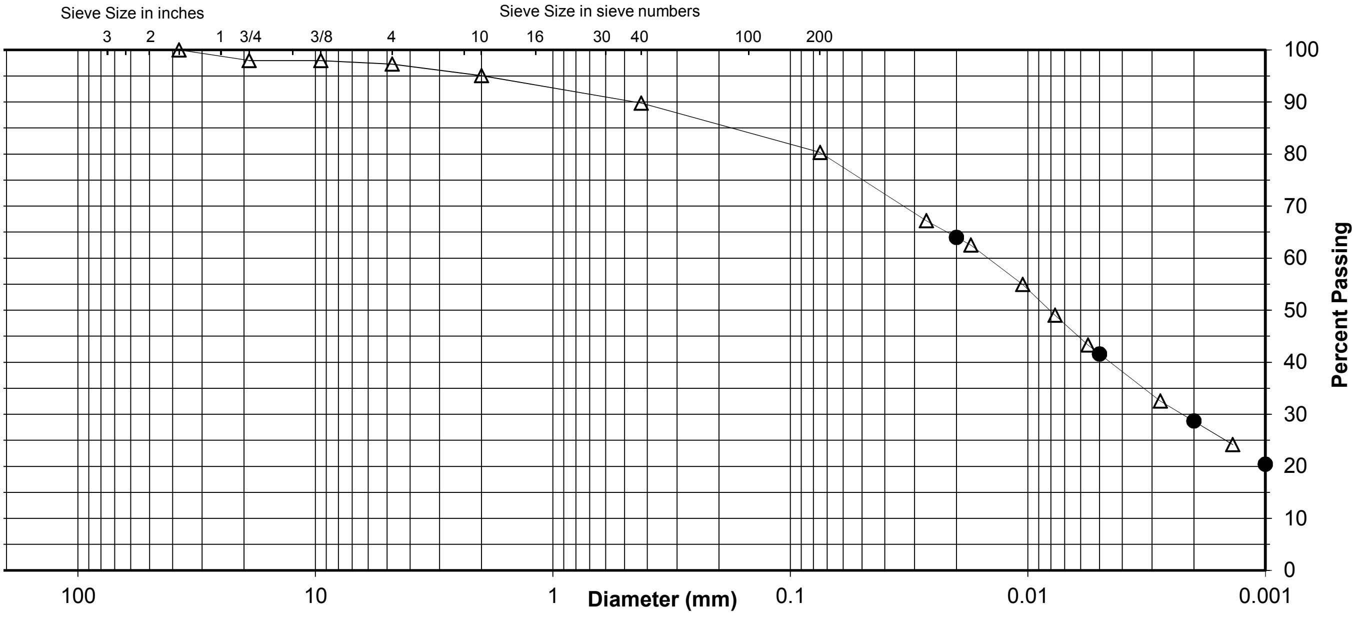
Dispersed using Apparatus A - Mechanical, for 1 minute

No. 40	89.8
No. 200	80.3
0.02 mm	64.0
0.005 mm	41.6
0.002 mm	28.7
0.001 mm	20.4

Particle Size Distribution

ASTM	Coarse Gravel	Fine Gravel	C. Sand	Medium Sand	Fine Sand	Silt	Clay
	2.1	0.7	2.1	5.3	9.5	38.7	41.6

AASHTO	Gravel	Coarse Sand	Fine Sand	Silt	Clay
	4.9	5.3	9.5	51.6	28.7



Comments

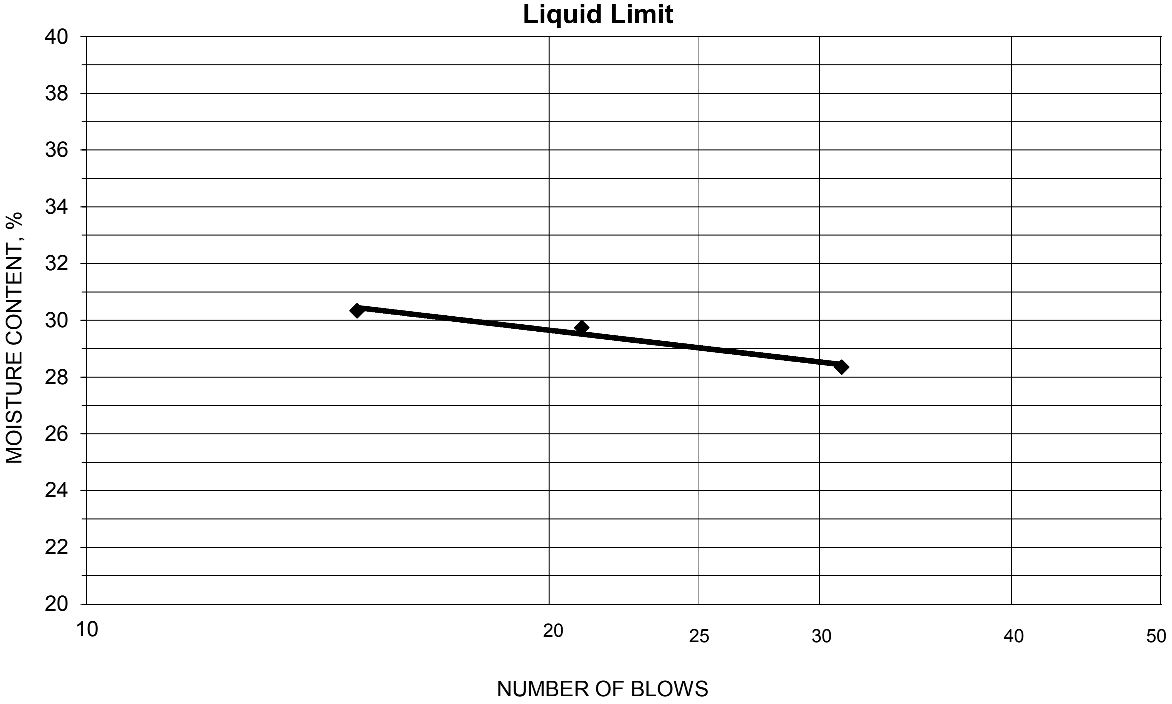
Reviewed By RJ

Stantec

ATTERBERG LIMITS

Project	HCFRR - Dams Preliminary	Project No.	174316204
Source	B-103, 14.5'-15.0'	Lab ID	38
		% + No. 40	10
Tested By	KG	Test Method ASTM D 4318 Method A	Date Received 11-15-2017
Test Date	12-20-2017	Prepared Dry	

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Number of Blows	Water Content (%)	Liquid Limit
21.91	19.62	11.54	31	28.3	29
22.26	19.81	11.57	21	29.7	
22.07	19.58	11.37	15	30.3	



PLASTIC LIMIT AND PLASTICITY INDEX

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Water Content (%)	Plastic Limit	Plasticity Index
17.08	16.33	11.48	15.5	16	13
17.27	16.44	11.36	16.3		

Remarks:

Reviewed By RJ

Stantec

Summary of Soil Tests

Project Name: HCFRR - Dams Preliminary
Project Number: 174316204
Source: B-104, 11.2'-11.7'
Lab ID: 39

Sample Type: ST
Date Received: 11-15-17
Date Reported: 12-21-17

Test Results

Natural Moisture Content

Test Method: ASTM D 2216
Moisture Content (%): 32.1

Particle Size Analysis

Preparation Method: ASTM D 421
Gradation Method: ASTM D 422
Hydrometer Method: ASTM D 422

Particle Size		% Passing
Sieve Size	(mm)	
	N/A	
	N/A	
	N/A	
	N/A	
3/4"	19	100.0
3/8"	9.5	99.9
No. 4	4.75	99.0
No. 10	2	96.9
No. 40	0.425	79.5
No. 200	0.075	16.8
	0.02	10.5
	0.005	6.1
	0.002	4.4
estimated	0.001	3.0

Plus 3 in. material, not included: 0 (%)

Range	ASTM (%)	AASHTO (%)
Gravel	1.0	3.1
Coarse Sand	2.1	17.4
Medium Sand	17.4	---
Fine Sand	62.7	62.7
Silt	10.7	12.4
Clay	6.1	4.4

Atterberg Limits

Test Method: ASTM D 4318 Method A
Prepared: Dry
Liquid Limit: NP
Plastic Limit: NP
Plasticity Index: NP
Activity Index: N/A

Moisture-Density Relationship

Test Not Performed
Maximum Dry Density (lb/ft^3): N/A
Maximum Dry Density (kg/m^3): N/A
Optimum Moisture Content (%): N/A
Over Size Correction %: N/A

California Bearing Ratio

Test Not Performed
Bearing Ratio (%): N/A
Compacted Dry Density (lb/ft^3): N/A
Compacted Moisture Content (%): N/A

Specific Gravity

Estimated
Particle Size: No. 10
Specific Gravity at 20° Celsius: 2.70

Classification

Unified Group Symbol: SM
Group Name: Silty sand
AASHTO Classification: A-2-4 (0)

Comments:

Reviewed By: RJ

Particle-Size Analysis of Soils
ASTM D 422

Project Name HCFRR - Dams Preliminary
Project Number 174316204
Source B-104, 11.2'-11.7'
Lab ID 39

Sieve analysis for the Portion Coarser than the No. 10 Sieve

Test Method ASTM D 422
Prepared using ASTM D 421

Particle Shape Rounded
Particle Hardness: Hard and Durable

Tested By GW
Test Date 12-14-2017
Date Received 11-15-2017

Maximum Particle size: 3/4" Sieve

Sieve Size	% Passing
3/4"	100.0
3/8"	99.9
No. 4	99.0
No. 10	96.9

Analysis for the portion Finer than the No. 10 Sieve

Analysis Based on -3 inch fraction only

Specific Gravity 2.7

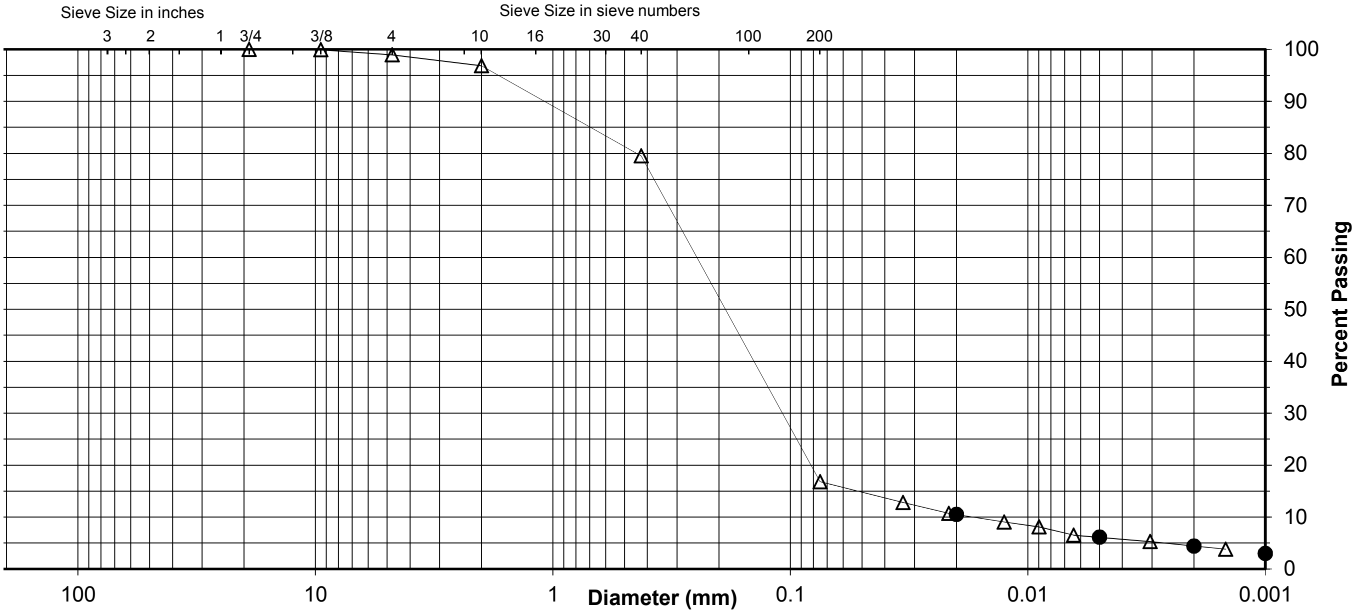
Dispersed using Apparatus A - Mechanical, for 1 minute

No. 40	79.5
No. 200	16.8
0.02 mm	10.5
0.005 mm	6.1
0.002 mm	4.4
0.001 mm	3.0

Particle Size Distribution

ASTM	Coarse Gravel	Fine Gravel	C. Sand	Medium Sand	Fine Sand	Silt	Clay
	0.0	1.0	2.1	17.4	62.7	10.7	6.1

AASHTO	Gravel	Coarse Sand	Fine Sand	Silt	Clay
	3.1	17.4	62.7	12.4	4.4



Comments

Reviewed By RJ

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Approved By: RJ

Stantec Consulting Services Inc.
Lexington, Kentucky

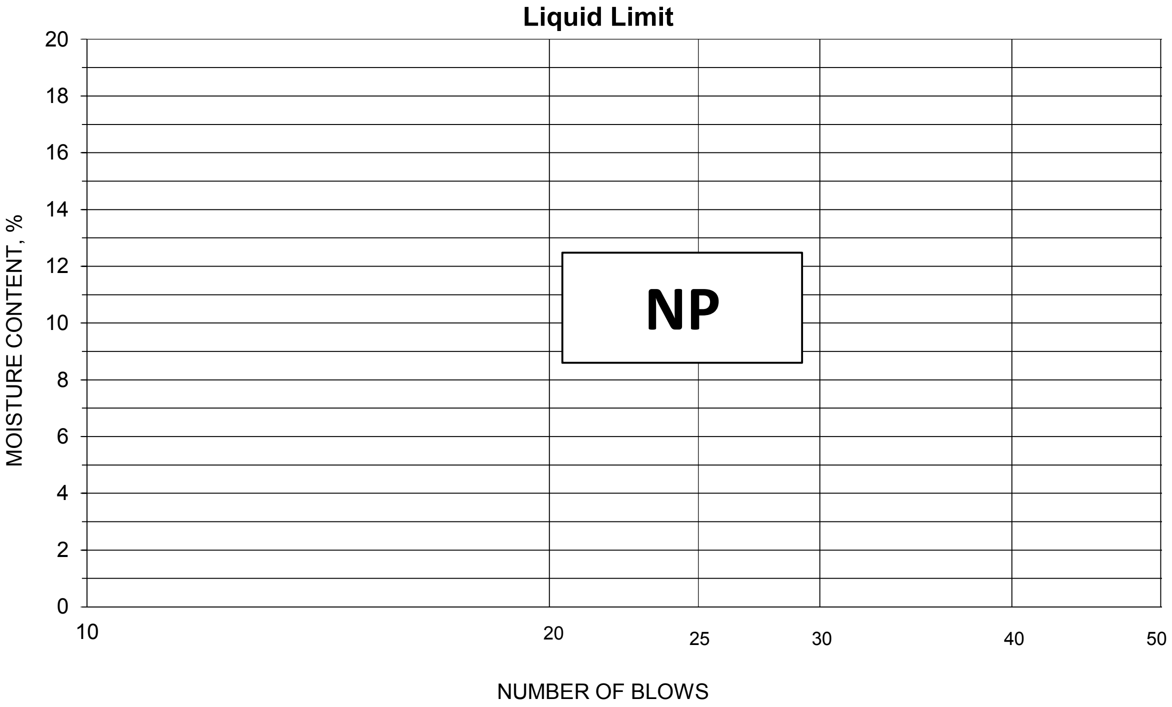
Reported By: RJ
Report Date: 12/21/2017

Stantec

ATTERBERG LIMITS

Project	HCFRR - Dams Preliminary	Project No.	174316204
Source	B-104, 11.2'-11.7'	Lab ID	39
		% + No. 40	20
Tested By	CM	Date Received	11-15-2017
Test Method	ASTM D 4318 Method A		
Test Date	12-14-2017		
Prepared	Dry		

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Number of Blows	Water Content (%)	Liquid Limit



PLASTIC LIMIT AND PLASTICITY INDEX

Wet Soil and Tare Mass (g)	Dry Soil and Tare Mass (g)	Tare Mass (g)	Water Content (%)	Plastic Limit	Plasticity Index

Remarks:

Reviewed By RJ

HYDRAULIC CONDUCTIVITY TESTING

Stantec

Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

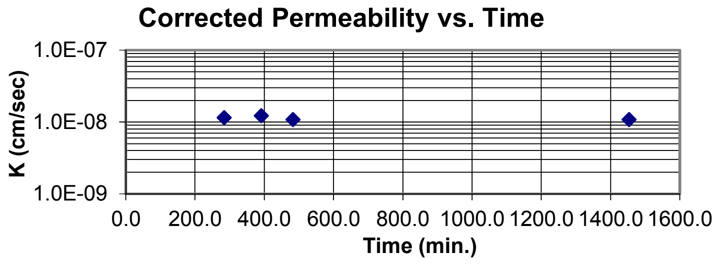
ASTM D 5084, Method C

Project Name HCFRR - Dams Preliminary
Project No. 174316204
Source B-101, 13.2'-13.9'
Test ID 30B
Description Sandy Lean Clay (CL), brown, moist, firm
Prepared By KG
Specific Gravity 2.73 ASTM D854, Dry
Date 12-7-17
Specimen Undisturbed
LL 22
Preparation
PL 13
Maximum Dry Density (pcf)
Permeant De-aired Tap Water
PI 9
Percent of Maximum

Specimens (if compacted) were compacted in a Proctor Mold as follows: The Maximum Dry Density was converted to Wet Density, this mass was divided by 4 (layers) and 3 of the 4 layers were compacted into the mold using a Proctor Hammer using 25 blows per layer. The density was varied by reducing the height of the drop by the amount listed beside "Compacted". The specimen was trimmed from the bottom two layers.

	Initial Specimen Data	After Consolidation Data	After Test Data	Final Pressures (psi)			
Height (in.)	2.4433	2.4312	2.4286	Chamber	42		
Diameter (in.)	2.8013		2.8051	Influent	32		
Moisture Content (%)	12.0		12.2	Effluent	30	Applied Head Difference (psi)	2
Dry Unit Weight (pcf)	125.8		126.3			Back Pressure Saturated to (psi)	30
Void Ratio	0.354		0.350			Maximum Effective Consolidation Stress (psi)	12
Degree of Saturation (%)	92.7		95.4			Minimum Effective Consolidation Stress (psi)	10

						Hydraulic Conductivity			
Date	Clock (24H:M)	Temp. (°F)	Bottom Head (in)	Top Head (in)	Test Time (sec)	k (m/s)	k (cm/s)	k @ 20° C (m/s)	k @ 20° C (cm/s)
12-19-17	8:28	71.0	21.81	3.86	0	---	---	---	---
12-19-17	13:13	71.0	21.50	4.15	1.71E+04	1.2E-10	1.2E-08	1.1E-10	1.1E-08
12-19-17	15:00	71.0	21.39	4.28	6.42E+03	1.3E-10	1.3E-08	1.2E-10	1.2E-08
12-19-17	16:31	71.0	21.30	4.37	5.46E+03	1.1E-10	1.1E-08	1.1E-10	1.1E-08
12-20-17	8:42	71.0	20.29	5.24	5.83E+04	1.1E-10	1.1E-08	1.1E-10	1.1E-08



A gradient of approximately 22.7 was used for this test.

Average Hydraulic Conductivity @ 20° C (last 4 determinations)	m/s	1.13E-10	cm/s	1.13E-08
Average Hydraulic Conductivity @ 20° C (last run)	m/s	1.13E-10	cm/s	1.13E-08

Comments

Reviewed By KG

Stantec

Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

ASTM D 5084, Method C

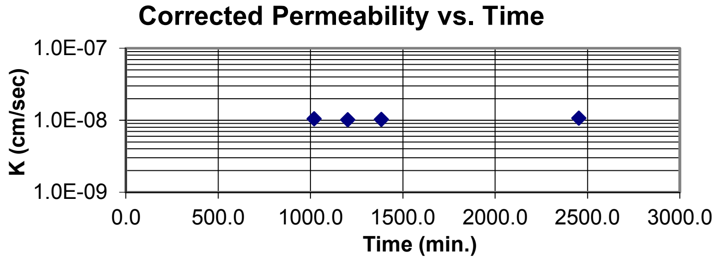
Project Name HCFRR - Dams Preliminary
Project No. 174316204
Source B-102, 8.6'-9.2'
Test ID 32B
Description Lean Clay with Sand (CL), brown, moist, firm
Prepared By KG
Specific Gravity 2.72 ASTM D854, Dry
Date 12-7-17
Specimen Undisturbed
LL 40
Preparation
PL 20
Maximum Dry Density (pcf)
Permeant De-aired Tap Water
PI 20
Percent of Maximum

Specimens (if compacted) were compacted in a Proctor Mold as follows: The Maximum Dry Density was converted to Wet Density, this mass was divided by 4 (layers) and 3 of the 4 layers were compacted into the mold using a Proctor Hammer using 25 blows per layer. The density was varied by reducing the height of the drop by the amount listed beside "Compacted". The specimen was trimmed from the bottom two layers.

	Initial Specimen Data	After Consolidation Data	After Test Data	Final Pressures (psi)	
Height (in.)	2.4453	2.4299	2.4271	Chamber	49
Diameter (in.)	2.7983		2.7873	Influent	42
Moisture Content (%)	22.2		23.3	Effluent	40
Dry Unit Weight (pcf)	103.1		104.7		
Void Ratio	0.647		0.622		
Degree of Saturation (%)	93.2		101.8		

Applied Head Difference (psi) 2
Back Pressure Saturated to (psi) 40
Maximum Effective Consolidation Stress (psi) 9
Minimum Effective Consolidation Stress (psi) 7

						Hydraulic Conductivity			
Date	Clock (24H:M)	Temp. (°F)	Bottom Head (in)	Top Head (in)	Test Time (sec)	k (m/s)	k (cm/s)	k @ 20° C (m/s)	k @ 20° C (cm/s)
12-19-17	15:17	72.0	15.91	12.03	0	---	---	---	---
12-20-17	8:17	72.0	15.21	12.92	6.12E+04	1.1E-10	1.1E-08	1.0E-10	1.0E-08
12-20-17	11:19	72.0	15.09	13.07	1.09E+04	1.1E-10	1.1E-08	1.0E-10	1.0E-08
12-20-17	14:21	72.0	14.97	13.22	1.09E+04	1.1E-10	1.1E-08	1.0E-10	1.0E-08
12-21-17	8:11	72.0	14.23	14.11	6.42E+04	1.1E-10	1.1E-08	1.1E-10	1.1E-08



A gradient of approximately 22.6 was used for this test.

Average Hydraulic Conductivity @ 20° C (last 4 determinations) m/s 1.03E-10 cm/s 1.03E-08
Average Hydraulic Conductivity @ 20° C (last run) m/s 1.03E-10 cm/s 1.03E-08

Comments

Reviewed By KG

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Version: 20170216
Approved By: RJ

Stantec Consulting Services Inc.
Lexington, Kentucky

Reported By: KG
Report Date: 01/03/2018

Stantec

Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

ASTM D 5084, Method C

Project Name HCFRR - Dams Preliminary
Project No. 174316204
Source B-102, 15.5'-16.1'
Test ID 34B
Description Silty Clay with Sand (CL-ML), gray, wet, very soft
Prepared By KG
Specific Gravity 2.7 ASTM D854, Dry
Date 12-13-17
Specimen Undisturbed
LL 22
Preparation
PL 15
Maximum Dry Density (pcf)
Permeant De-aired Tap Water
PI 7
Percent of Maximum

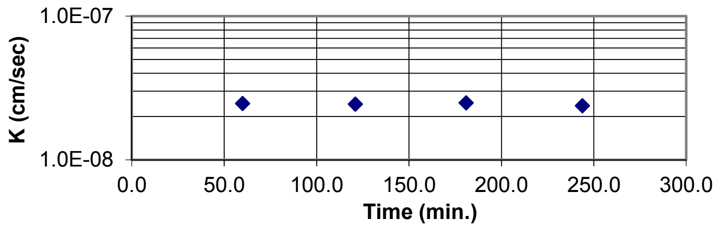
Specimens (if compacted) were compacted in a Proctor Mold as follows: The Maximum Dry Density was converted to Wet Density, this mass was divided by 4 (layers) and 3 of the 4 layers were compacted into the mold using a Proctor Hammer using 25 blows per layer. The density was varied by reducing the height of the drop by the amount listed beside "Compacted". The specimen was trimmed from the bottom two layers.

	Initial Specimen Data	After Consolidation Data	After Test Data	Final Pressures (psi)	
Height (in.)	2.2425	2.2406	2.1867	Chamber	34
Diameter (in.)	2.9120		2.8884	Influent	21
Moisture Content (%)	17.2		14.2	Effluent	20
Dry Unit Weight (pcf)	116.0		121.0		
Void Ratio	0.453		0.394		
Degree of Saturation (%)	102.6		97.4		

Applied Head Difference (psi) 1
Back Pressure Saturated to (psi) 20
Maximum Effective Consolidation Stress (psi) 14
Minimum Effective Consolidation Stress (psi) 13

						Hydraulic Conductivity			
Date	Clock (24H:M)	Temp. (°F)	Bottom Head (in)	Top Head (in)	Test Time (sec)	k (m/s)	k (cm/s)	k @ 20° C (m/s)	k @ 20° C (cm/s)
12-19-17	8:27	71.0	22.00	3.50	0	---	---	---	---
12-19-17	9:27	71.0	21.90	3.60	3.60E+03	2.6E-10	2.6E-08	2.5E-10	2.5E-08
12-19-17	10:28	71.0	21.80	3.70	3.66E+03	2.5E-10	2.5E-08	2.4E-10	2.4E-08
12-19-17	11:28	71.0	21.70	3.80	3.60E+03	2.6E-10	2.6E-08	2.5E-10	2.5E-08
12-19-17	12:31	71.0	21.60	3.90	3.78E+03	2.5E-10	2.5E-08	2.4E-10	2.4E-08

Corrected Permeability vs. Time



A gradient of approximately 12.3 was used for this test.

Average Hydraulic Conductivity @ 20° C (last 4 determinations) m/s 2.44E-10 cm/s 2.44E-08
Average Hydraulic Conductivity @ 20° C (last run) m/s 2.44E-10 cm/s 2.44E-08

Comments

Reviewed By KG

Template: tmp_fhp_input.xlsm
Version: 20170216
Approved By: RJ

Stantec Consulting Services Inc.
Lexington, Kentucky

Reported By: KG
Report Date: 12/21/2017

Stantec

Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

ASTM D 5084, Method C

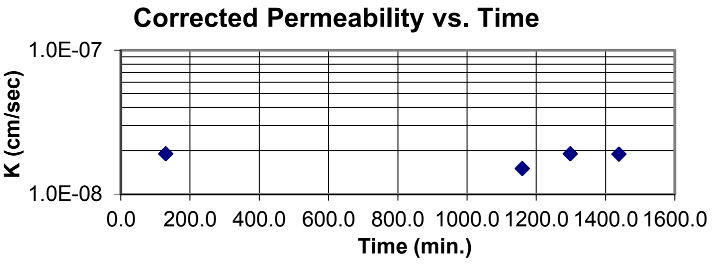
Project Name HCFRR - Dams Preliminary
Project No. 174316204
Source B-103, 8.0'-9.1'
Test ID 36B
Description Lean Clay with Sand (CL), dark brown, moist, firm
Prepared By GW
Specific Gravity 2.72 ASTM D854, Dry
Date 12-14-17
Specimen Preparation Undisturbed
LL 27
PL 15
Maximum Dry Density (pcf)
Permeant De-aired Tap Water
PI 12
Percent of Maximum

Specimens (if compacted) were compacted in a Proctor Mold as follows: The Maximum Dry Density was converted to Wet Density, this mass was divided by 4 (layers) and 3 of the 4 layers were compacted into the mold using a Proctor Hammer using 19 blows per layer. The density was varied by reducing the height of the drop by the amount listed beside "Compacted". The specimen was trimmed from the bottom two layers.

	Initial Specimen Data	After Consolidation Data	After Test Data	Final Pressures (psi)	
Height (in.)	1.4724	1.4602	1.4609	Chamber	48
Diameter (in.)	2.8050		2.8091	Influent	42
Moisture Content (%)	13.6		14.6	Effluent	40
Dry Unit Weight (pcf)	121.5		122.1		
Void Ratio	0.397		0.390		
Degree of Saturation (%)	92.8		101.6		

Applied Head Difference (psi) 2
Back Pressure Saturated to (psi) 40
Maximum Effective Consolidation Stress (psi) 8
Minimum Effective Consolidation Stress (psi) 6

						Hydraulic Conductivity			
Date	Clock (24H:M)	Temp. (°F)	Bottom Head (in)	Top Head (in)	Test Time (sec)	k (m/s)	k (cm/s)	k @ 20° C (m/s)	k @ 20° C (cm/s)
12-19-17	13:21	71.0	21.54	3.73	0	---	---	---	---
12-19-17	15:31	71.0	21.44	3.82	7.80E+03	2.0E-10	2.0E-08	1.9E-10	1.9E-08
12-20-17	8:41	71.0	20.84	4.40	6.18E+04	1.6E-10	1.6E-08	1.5E-10	1.5E-08
12-20-17	11:00	71.0	20.74	4.50	8.34E+03	2.0E-10	2.0E-08	1.9E-10	1.9E-08
12-20-17	13:20	71.0	20.64	4.60	8.40E+03	2.0E-10	2.0E-08	1.9E-10	1.9E-08



A gradient of approximately 37.6 was used for this test.

Average Hydraulic Conductivity @ 20° C (last 4 determinations) m/s 1.80E-10 cm/s 1.80E-08
Average Hydraulic Conductivity @ 20° C (last run) m/s 1.80E-10 cm/s 1.80E-08

Comments

Reviewed By KG

Template: tmp_fhp_input.xlsm
Version: 20170216
Approved By: RJ

Stantec Consulting Services Inc.
Lexington, Kentucky

Reported By: KG
Report Date: 12/21/2017

Stantec

Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

ASTM D 5084, Method C

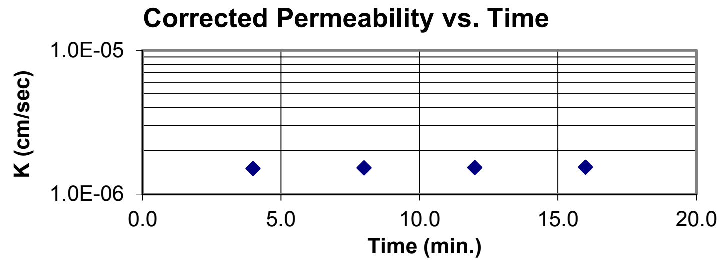
Project Name HCFRR - Dams Preliminary
Project No. 174316204
Source B-104, 10.0'-10.6'
Test ID 39A
Description Silty Sand (SM), brown, wet, very soft
Prepared By GW
Specific Gravity 2.72 ASTM D854, Dry
Date 12-14-17
Specimen Preparation Undisturbed
LL NP
PL NP
PI NP
Maximum Dry Density (pcf)
Percent of Maximum
Permeant De-aired Tap Water

Specimens (if compacted) were compacted in a Proctor Mold as follows: The Maximum Dry Density was converted to Wet Density, this mass was divided by 4 (layers) and 3 of the 4 layers were compacted into the mold using a Proctor Hammer using 25 blows per layer. The density was varied by reducing the height of the drop by the amount listed beside "Compacted". The specimen was trimmed from the bottom two layers.

	Initial Specimen Data	After Consolidation Data	After Test Data	Final Pressures (psi)	
Height (in.)	1.4484	1.4469	1.4396	Chamber	31
Diameter (in.)	2.7900		2.7804	Influent	20.5
Moisture Content (%)	20.6		19.3	Effluent	20
Dry Unit Weight (pcf)	109.2		110.6		
Void Ratio	0.555		0.535		
Degree of Saturation (%)	101.1		98.2		

Applied Head Difference (psi) 0.5
Back Pressure Saturated to (psi) 20
Maximum Effective Consolidation Stress (psi) 11
Minimum Effective Consolidation Stress (psi) 10.5

						Hydraulic Conductivity			
Date	Clock (24H:M)	Temp. (°F)	Bottom Head (in)	Top Head (in)	Test Time (sec)	k (m/s)	k (cm/s)	k @ 20° C (m/s)	k @ 20° C (cm/s)
12-18-17	16:03	71.0	21.60	3.89	0	---	---	---	---
12-18-17	16:07	71.0	21.50	3.99	2.40E+02	1.6E-08	1.6E-06	1.5E-08	1.5E-06
12-18-17	16:11	71.0	21.40	4.09	2.40E+02	1.6E-08	1.6E-06	1.5E-08	1.5E-06
12-18-17	16:15	71.0	21.30	4.19	2.40E+02	1.6E-08	1.6E-06	1.5E-08	1.5E-06
12-18-17	16:19	71.0	21.20	4.29	2.40E+02	1.6E-08	1.6E-06	1.5E-08	1.5E-06



A gradient of approximately 9.6 was used for this test.

Average Hydraulic Conductivity @ 20° C (last 4 determinations) m/s 1.52E-08 cm/s 1.52E-06
Average Hydraulic Conductivity @ 20° C (last run) m/s 1.52E-08 cm/s 1.52E-06

Comments

Reviewed By KG

Template: tmp_fhp_input.xlsm
Version: 20170216
Approved By: RJ

Stantec Consulting Services Inc.
Lexington, Kentucky

Reported By: KG
Report Date: 12/21/2017

TRIAXIAL COMPRESSION TESTING

Stantec

Consolidated Undrained Triaxial Compression

ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-101, 2.4'-2.9'
Description Lean Clay with Sand (CL), brown, moist, firm
Specimen Type Intact
Preparation Wet Mounting

Project No. 174316204
Lab ID 27
Test ID 27-A

Date Received 11/15/2017
Date Tested 12/08/2017

Specific Gravity 2.73
ASTM D 854, Dry

Liquid Limit 47
Plastic Limit 20
Plasticity Index 27
ASTM D 4318

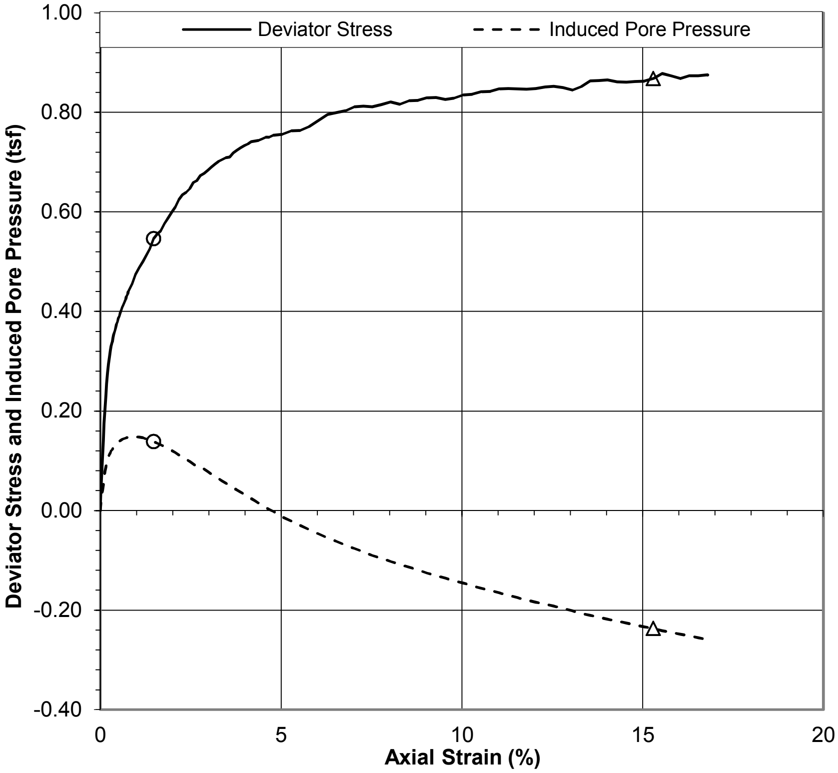
Target Test Parameters
Nominal Chamber Pressure (psi) 90
Nominal Back Pressure (psi) 86.5
Nominal Consolidation Pressure (psi) 3.5

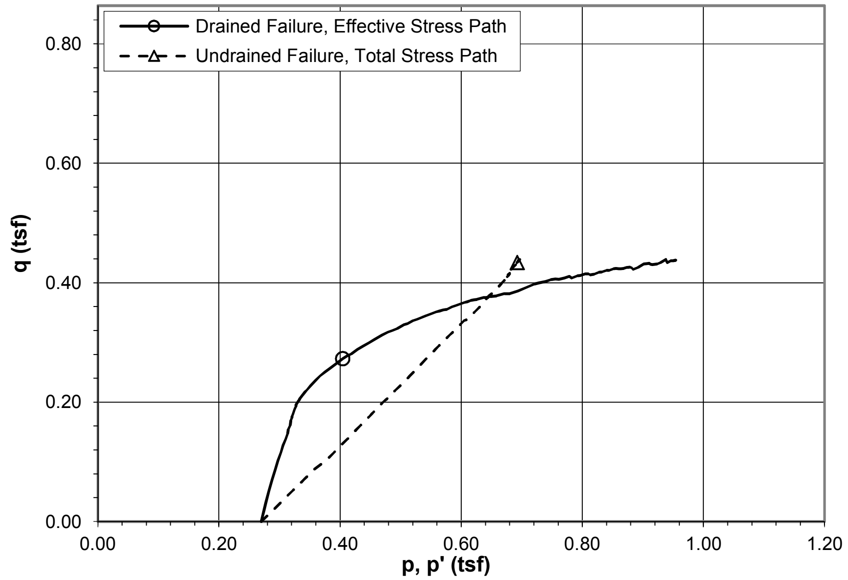
Saturation / Consolidation Results
Pore Pressure Parameter B 0.98
Measured Effective Consol. Stress (tsf) 0.268
Time to 50% Consolidation (min) 26.00
Actual Axial Strain Rate of Test (%/min) 0.011

Consolidated Specimen Conditions
Moist Unit Weight (pcf) 129.1
Moisture Content (%) 22.5
Dry Unit Weight (pcf) 105.3
Void Ratio 0.615
Degree of Saturation (%) 100.0

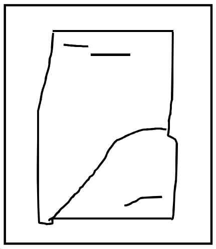
At Drained Failure
Failure Criterion: Max. Eff. Prin. Stress Ratio
Axial Strain (%) 1.472
Deviator Stress (tsf) 0.546
Induced Pore Pressure (tsf) 0.138
Minor Effective Stress, σ_3' (tsf) 0.131
Major Effective Stress, σ_1' (tsf) 0.677
Eff. Principal Stress Ratio, σ_1'/σ_3' 5.157
p' (tsf) 0.404
q (tsf) 0.273

At Consolidated Undrained Failure
Failure Criterion: 15% Axial Strain
Axial Strain (%) 15.291
Deviator Stress (tsf) 0.868
Minor Principal Stress, σ_3 (tsf) 0.259
Major Principal Stress, σ_1 (tsf) 1.126
p (tsf) 0.692
q (tsf) 0.434





Failure Sketch



Comments

Reviewed KG

Template: tmp_cu_input.xlsm
Version: 20170216
Approved By: RJ

Stantec Consulting Services Inc.
Lexington, Kentucky

Reported By: KG
Report Date: 12/21/2017

Stantec

Consolidated Undrained Triaxial Compression

ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-101, 2.4'-2.9'
Description Lean Clay with Sand (CL), brown, moist, firm

Project No. 174316204
Lab ID 27
Test ID 27-A

Initial Specimen Conditions		Consolidated Specimen Conditions	
Average Height (in)	6.043	Calculated Height (in)	6.067
Average Diameter (in)	2.858	Calculated Diameter (in)	2.877
Calculated Area (in^2)	6.417	Calculated Area (in^2)	6.501
Moist Weight (lb)	2.895	Moist Weight (lb)	2.945
Moist Unit Weight (pcf)	129.0	Moist Unit Weight (pcf)	129.1
Moisture Content (%)	20.4	Moisture Content (%)	22.5
Dry Weight (lb)	2.404	Dry Weight (lb)	2.404
Dry Unit Weight (pcf)	107.1	Dry Unit Weight (pcf)	105.3
Void Ratio	0.588	Void Ratio	0.615
Degree of Saturation (%)	94.8	Degree of Saturation (%)	100.0

Specific Gravity 2.73
ASTM D 854, Dry

Liquid Limit 47
Plastic Limit 20
Plasticity Index 27
ASTM D 4318

Confining Stress
σ_3 (tsf) 0.270

Effective Consolidation Stress
σ_3' (tsf) 0.270

Moisture contents obtained using partial specimen.
Specimen consolidated cross-sectional area determined using method B.
Membrane corrections have been applied,where Em = 200 lbf/in and t = 0.012 in.
All other tests performed in association with this specimen are reported separately.

Project: 174316204			Source: B-101, 2.4'-2.9'								Lab ID: 27		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
0.0	0.0	0.000	0.00	6.501	0.000	0.000	6.210	0.000	0.270	0.270	0.270	0.270	0.270	0.000	1.000
2.2	3.3	0.001	0.02	6.502	0.036	0.036	6.224	0.014	0.306	0.293	0.256	0.288	0.274	0.018	1.141
4.4	5.7	0.002	0.03	6.503	0.063	0.063	6.234	0.024	0.333	0.309	0.246	0.302	0.278	0.031	1.256
6.5	9.3	0.003	0.05	6.504	0.103	0.103	6.249	0.039	0.373	0.334	0.231	0.321	0.283	0.052	1.446
8.7	12.7	0.005	0.08	6.506	0.141	0.141	6.262	0.052	0.411	0.359	0.218	0.340	0.288	0.070	1.646
10.9	15.8	0.006	0.10	6.507	0.175	0.175	6.274	0.064	0.445	0.381	0.206	0.357	0.293	0.088	1.851
13.1	18.4	0.008	0.12	6.509	0.204	0.204	6.289	0.079	0.478	0.400	0.196	0.376	0.298	0.102	2.040
15.2	21.0	0.009	0.15	6.510	0.232	0.232	6.298	0.088	0.506	0.418	0.187	0.390	0.303	0.116	2.240
17.4	23.1	0.010	0.17	6.512	0.256	0.255	6.305	0.095	0.529	0.434	0.179	0.401	0.306	0.128	2.429
19.6	25.1	0.012	0.19	6.513	0.277	0.277	6.312	0.102	0.550	0.449	0.172	0.412	0.310	0.138	2.607
21.7	26.7	0.013	0.22	6.515	0.296	0.295	6.318	0.108	0.568	0.461	0.166	0.421	0.313	0.148	2.778
23.9	27.9	0.015	0.25	6.517	0.309	0.308	6.323	0.113	0.581	0.468	0.160	0.427	0.314	0.154	2.923
26.1	29.2	0.017	0.27	6.518	0.323	0.322	6.327	0.116	0.595	0.479	0.156	0.434	0.317	0.161	3.062
28.3	30.0	0.018	0.29	6.520	0.331	0.330	6.330	0.120	0.603	0.483	0.153	0.438	0.318	0.165	3.160
30.4	30.7	0.020	0.33	6.522	0.339	0.338	6.333	0.122	0.611	0.488	0.150	0.441	0.319	0.169	3.259
32.6	31.5	0.021	0.35	6.523	0.348	0.347	6.336	0.126	0.620	0.494	0.147	0.446	0.320	0.174	3.367
34.8	32.1	0.022	0.37	6.525	0.354	0.353	6.339	0.128	0.625	0.497	0.144	0.449	0.321	0.177	3.451
37.0	32.8	0.024	0.40	6.527	0.362	0.361	6.340	0.130	0.633	0.503	0.142	0.453	0.322	0.180	3.545
39.1	33.4	0.026	0.43	6.528	0.368	0.367	6.343	0.132	0.639	0.507	0.140	0.456	0.323	0.184	3.632
41.3	34.0	0.027	0.44	6.529	0.375	0.374	6.344	0.134	0.646	0.512	0.137	0.459	0.324	0.187	3.727
43.5	34.5	0.028	0.47	6.531	0.380	0.379	6.346	0.136	0.651	0.515	0.136	0.461	0.325	0.190	3.791
45.7	35.1	0.030	0.50	6.533	0.387	0.386	6.348	0.138	0.658	0.520	0.134	0.465	0.327	0.193	3.885
47.8	35.6	0.032	0.52	6.535	0.392	0.391	6.349	0.139	0.662	0.523	0.132	0.467	0.327	0.195	3.962
50.0	36.2	0.033	0.55	6.537	0.398	0.397	6.351	0.140	0.668	0.528	0.131	0.470	0.329	0.199	4.036
52.2	36.7	0.035	0.57	6.538	0.404	0.403	6.352	0.142	0.674	0.533	0.130	0.473	0.331	0.201	4.108
54.4	37.3	0.036	0.60	6.540	0.410	0.409	6.353	0.143	0.680	0.537	0.129	0.476	0.333	0.204	4.177
56.5	37.5	0.038	0.62	6.542	0.412	0.411	6.354	0.144	0.683	0.539	0.128	0.477	0.333	0.205	4.217
58.7	37.9	0.040	0.65	6.543	0.417	0.416	6.355	0.144	0.687	0.543	0.127	0.479	0.335	0.208	4.268
60.9	38.4	0.041	0.67	6.545	0.422	0.420	6.355	0.145	0.692	0.547	0.126	0.482	0.337	0.210	4.326
63.1	38.8	0.043	0.70	6.547	0.427	0.425	6.356	0.146	0.697	0.551	0.126	0.484	0.338	0.212	4.376
65.3	39.3	0.044	0.72	6.548	0.432	0.430	6.357	0.147	0.702	0.556	0.125	0.487	0.341	0.215	4.428
67.4	39.7	0.046	0.75	6.550	0.437	0.435	6.357	0.147	0.707	0.560	0.125	0.489	0.342	0.217	4.484
69.6	40.2	0.047	0.78	6.552	0.442	0.440	6.357	0.147	0.712	0.565	0.125	0.492	0.345	0.220	4.527
78.3	41.7	0.053	0.87	6.558	0.458	0.455	6.358	0.148	0.727	0.579	0.124	0.499	0.351	0.228	4.684
87.0	43.4	0.059	0.97	6.564	0.476	0.474	6.359	0.148	0.745	0.597	0.123	0.508	0.360	0.237	4.845
95.7	44.8	0.065	1.07	6.571	0.491	0.488	6.358	0.148	0.759	0.611	0.123	0.515	0.367	0.244	4.970
104.4	46.0	0.071	1.18	6.578	0.503	0.500	6.356	0.146	0.771	0.625	0.125	0.521	0.375	0.250	5.008
113.1	47.1	0.077	1.27	6.584	0.515	0.512	6.354	0.144	0.782	0.639	0.127	0.527	0.383	0.256	5.039
121.8	48.4	0.083	1.36	6.591	0.529	0.526	6.352	0.141	0.796	0.654	0.129	0.533	0.391	0.263	5.085

Project: 174316204			Source: B-101, 2.4'-2.9'								Lab ID: 27		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
130.5	50.4	0.089	1.47	6.598	0.549	0.546	6.349	0.138	0.816	0.677	0.131	0.543	0.404	0.273	5.157
139.2	51.3	0.095	1.57	6.604	0.559	0.555	6.346	0.136	0.825	0.689	0.134	0.548	0.412	0.278	5.133
147.9	51.9	0.101	1.66	6.611	0.566	0.562	6.342	0.132	0.831	0.699	0.138	0.551	0.419	0.281	5.076
156.6	53.3	0.107	1.77	6.618	0.580	0.576	6.339	0.128	0.845	0.717	0.141	0.557	0.429	0.288	5.094
165.3	54.4	0.113	1.87	6.624	0.592	0.587	6.335	0.125	0.856	0.731	0.144	0.563	0.438	0.294	5.071
174.0	55.7	0.120	1.97	6.632	0.604	0.600	6.331	0.121	0.869	0.748	0.148	0.569	0.448	0.300	5.046
182.7	56.7	0.126	2.07	6.638	0.615	0.610	6.327	0.117	0.879	0.762	0.152	0.574	0.457	0.305	5.015
191.4	58.1	0.131	2.17	6.645	0.630	0.624	6.322	0.112	0.893	0.781	0.157	0.581	0.469	0.312	4.975
200.1	59.1	0.138	2.27	6.652	0.640	0.634	6.318	0.108	0.903	0.796	0.162	0.586	0.479	0.317	4.920
208.8	59.7	0.144	2.37	6.659	0.645	0.640	6.313	0.103	0.909	0.806	0.167	0.589	0.486	0.320	4.840
217.5	60.4	0.150	2.47	6.666	0.652	0.646	6.309	0.099	0.916	0.817	0.171	0.593	0.494	0.323	4.782
226.2	61.6	0.156	2.57	6.672	0.665	0.659	6.304	0.093	0.927	0.834	0.175	0.598	0.505	0.329	4.757
234.9	62.0	0.162	2.66	6.679	0.669	0.662	6.298	0.088	0.931	0.843	0.180	0.600	0.511	0.331	4.678
243.6	63.1	0.168	2.77	6.686	0.680	0.673	6.294	0.084	0.941	0.857	0.184	0.605	0.521	0.337	4.658
252.2	63.6	0.174	2.87	6.693	0.685	0.678	6.294	0.084	0.950	0.866	0.188	0.611	0.527	0.339	4.601
261.0	64.3	0.180	2.97	6.700	0.691	0.684	6.288	0.078	0.955	0.877	0.193	0.613	0.535	0.342	4.542
269.7	65.0	0.187	3.07	6.707	0.697	0.690	6.283	0.073	0.961	0.888	0.198	0.616	0.543	0.345	4.481
278.3	65.6	0.192	3.17	6.714	0.704	0.696	6.279	0.069	0.968	0.899	0.203	0.620	0.551	0.348	4.429
287.0	66.2	0.199	3.27	6.721	0.710	0.702	6.274	0.064	0.973	0.909	0.207	0.622	0.558	0.351	4.387
295.7	66.6	0.204	3.37	6.727	0.713	0.705	6.270	0.059	0.976	0.917	0.212	0.624	0.564	0.353	4.328
304.4	67.1	0.211	3.47	6.735	0.717	0.709	6.265	0.055	0.980	0.925	0.216	0.625	0.570	0.355	4.288
313.1	67.3	0.217	3.58	6.742	0.719	0.710	6.260	0.050	0.982	0.931	0.221	0.626	0.576	0.355	4.213
321.8	68.2	0.223	3.67	6.748	0.728	0.719	6.256	0.046	0.990	0.944	0.225	0.631	0.585	0.359	4.192
330.5	68.7	0.229	3.77	6.755	0.732	0.723	6.252	0.042	0.994	0.953	0.229	0.633	0.591	0.362	4.154
339.2	69.4	0.235	3.88	6.763	0.738	0.729	6.247	0.037	1.000	0.963	0.234	0.635	0.598	0.365	4.119
347.9	69.8	0.242	3.98	6.770	0.743	0.733	6.243	0.033	1.004	0.971	0.238	0.637	0.604	0.367	4.084
356.6	70.3	0.247	4.08	6.777	0.746	0.737	6.238	0.028	1.006	0.979	0.242	0.638	0.610	0.368	4.043
365.3	70.8	0.253	4.17	6.784	0.751	0.741	6.234	0.024	1.011	0.986	0.245	0.640	0.616	0.371	4.022
374.0	71.0	0.259	4.28	6.791	0.753	0.742	6.230	0.020	1.012	0.992	0.250	0.641	0.621	0.371	3.969
382.7	71.2	0.265	4.37	6.798	0.754	0.744	6.225	0.015	1.013	0.998	0.254	0.641	0.626	0.372	3.930
391.4	71.6	0.272	4.48	6.806	0.757	0.747	6.221	0.010	1.016	1.005	0.259	0.642	0.632	0.373	3.888
400.1	72.0	0.277	4.57	6.812	0.761	0.750	6.216	0.006	1.019	1.013	0.263	0.644	0.638	0.375	3.855
408.8	72.1	0.283	4.67	6.819	0.761	0.750	6.213	0.002	1.020	1.017	0.267	0.644	0.642	0.375	3.811
417.5	72.6	0.290	4.78	6.827	0.765	0.754	6.209	-0.001	1.023	1.024	0.270	0.646	0.647	0.377	3.788
439.3	73.0	0.305	5.03	6.845	0.768	0.756	6.198	-0.012	1.024	1.036	0.280	0.646	0.658	0.378	3.698
461.0	73.9	0.321	5.28	6.863	0.776	0.763	6.189	-0.021	1.032	1.053	0.290	0.650	0.671	0.381	3.631
482.7	74.2	0.335	5.52	6.881	0.777	0.763	6.180	-0.030	1.032	1.062	0.299	0.651	0.681	0.382	3.554
504.5	75.2	0.350	5.77	6.899	0.785	0.771	6.172	-0.038	1.041	1.079	0.308	0.655	0.694	0.386	3.506
526.2	76.7	0.366	6.03	6.918	0.798	0.783	6.164	-0.047	1.052	1.099	0.315	0.661	0.707	0.392	3.484
547.9	78.1	0.381	6.29	6.937	0.811	0.796	6.156	-0.055	1.064	1.118	0.322	0.666	0.720	0.398	3.468
569.7	78.7	0.396	6.53	6.955	0.815	0.800	6.148	-0.062	1.067	1.129	0.329	0.667	0.729	0.400	3.427
591.4	79.4	0.412	6.79	6.974	0.820	0.803	6.141	-0.070	1.071	1.141	0.337	0.669	0.739	0.402	3.383
613.2	80.4	0.426	7.03	6.992	0.828	0.811	6.134	-0.076	1.078	1.154	0.343	0.672	0.748	0.405	3.365
634.9	80.8	0.441	7.28	7.011	0.830	0.812	6.127	-0.083	1.079	1.162	0.349	0.672	0.756	0.406	3.325
656.6	81.0	0.457	7.53	7.030	0.829	0.811	6.120	-0.090	1.077	1.167	0.356	0.671	0.761	0.406	3.280
678.4	81.7	0.472	7.78	7.049	0.834	0.815	6.114	-0.096	1.082	1.178	0.363	0.674	0.770	0.408	3.249
700.1	82.5	0.488	8.04	7.069	0.840	0.821	6.108	-0.102	1.087	1.189	0.369	0.677	0.779	0.410	3.226
721.9	82.3	0.503	8.28	7.088	0.836	0.816	6.102	-0.108	1.082	1.191	0.374	0.674	0.782	0.408	3.180
743.6	83.3	0.518	8.54	7.108	0.844	0.823	6.096	-0.114	1.089	1.204	0.380	0.678	0.792	0.412	3.166
765.4	83.7	0.533	8.79	7.127	0.845	0.824	6.091	-0.120	1.090	1.209	0.385	0.678	0.797	0.412	3.140
787.1	84.5	0.548	9.03	7.146	0.851	0.829	6.085	-0.125	1.095	1.220	0.391	0.680	0.806	0.415	3.122
808.8	84.8	0.563	9.28	7.166	0.852	0.830	6.080	-0.131	1.094	1.225	0.395	0.679	0.810	0.415	3.099
830.6	84.7	0.579	9.54	7.186	0.849	0.826	6.074	-0.136	1.090	1.226	0.400	0.677	0.813	0.413	3.063
852.3	85.3	0.593	9.78	7.206	0.852	0.828	6.069	-0.141	1.093	1.234	0.405	0.679	0.819	0.414	3.044
874.1	86.2	0.609	10.04	7.226	0.859	0.835	6.064	-0.146	1.099	1.245	0.410	0.681	0.827	0.418	3.039
895.8	86.7	0.624	10.28	7.246	0.861	0.837	6.060	-0.151	1.100	1.251	0.414	0.682	0.832	0.418	3.020
917.5	87.5	0.639	10.54	7.266	0.867	0.841	6.054	-0.156	1.104	1.261	0.419	0.684	0.840	0.421	3.006
939.3	87.8	0.654	10.78	7.287	0.868	0.842	6.050	-0.160	1.105	1.265	0.423	0.684	0.844	0.421	2.988
961.0	88.7	0.670	11.04	7.307	0.874	0.847	6.045	-0.166	1.110	1.275	0.428	0.686	0.852	0.424	2.978
982.8	89.1	0.685	11.28	7.328	0.875	0.848	6.041	-0.170	1.110	1.279	0.432	0.686	0.856	0.424	2.965
1004.5	89.3	0.700	11.54	7.349	0.875	0.847	6.035	-0.175	1.109	1.284	0.437	0.685	0.860	0.424	2.940
1026.3	89.5	0.715	11.79	7.370	0.875	0.846	6.031	-0.180	1.108	1.287	0.441	0.684	0.864	0.423	2.920
1048.0	90.0	0.731	12.05	7.391	0.877	0.848	6.026	-0.184	1.109	1.293	0.445	0.685	0.869	0.424	2.906
1069.7	90.7	0.746	12.30	7.412	0.881	0.851	6.022	-0.188	1.112	1.299	0.448	0.686	0.874	0.426	2.899
1091.5	91.1	0.761	12.54	7.433	0.883	0.852	6.018	-0.192	1.113	1.305	0.452	0.686	0.879	0.426	2.885
1113.2	91.2	0.776	12.79	7.454	0.881	0.850	6.014	-0.197	1.110	1.306	0.457	0.685	0.882	0.425	2.861
1135.0	91.0	0.792	13.05	7.476	0.876	0.845	6.009	-0.202	1.105	1.307	0.462	0.683	0.884	0.422	2.829
1156.7	92.0	0.807	13.30	7.498	0.884	0.852	6.004	-0.206	1.111	1.318	0.466	0.685	0.892	0.426	2.827
1178.4	93.5	0.822	13.55	7.519	0.896	0.863	6.000	-0.210	1.123	1.333	0.470	0.691	0.902	0.432	2.836

Project: 174316204 | **Source: B-101, 2.4'-2.9'** | **Lab ID: 27** | **Test ID**

Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
1200.2	94.0	0.837	13.79	7.541	0.897	0.864	5.996	-0.214	1.124	1.339	0.474	0.692	0.906	0.432	2.821
1221.9	94.4	0.851	14.03	7.562	0.899	0.865	5.992	-0.218	1.125	1.343	0.478	0.692	0.910	0.433	2.810
1243.7	94.4	0.867	14.29	7.585	0.896	0.861	5.988	-0.222	1.121	1.343	0.482	0.690	0.912	0.431	2.788
1265.4	94.6	0.883	14.55	7.607	0.896	0.861	5.984	-0.226	1.120	1.346	0.486	0.690	0.916	0.430	2.772
1287.1	95.1	0.897	14.79	7.629	0.897	0.862	5.981	-0.230	1.121	1.351	0.489	0.690	0.920	0.431	2.763
1308.9	95.5	0.913	15.04	7.652	0.899	0.862	5.977	-0.233	1.122	1.355	0.493	0.690	0.924	0.431	2.751
1330.6	96.4	0.928	15.29	7.674	0.904	0.868	5.974	-0.237	1.126	1.363	0.495	0.692	0.929	0.434	2.751
1352.4	97.8	0.943	15.54	7.697	0.915	0.878	5.969	-0.241	1.136	1.377	0.499	0.697	0.938	0.439	2.759
1374.1	97.7	0.959	15.80	7.721	0.911	0.873	5.966	-0.245	1.131	1.376	0.503	0.695	0.939	0.437	2.737
1395.8	97.5	0.974	16.05	7.743	0.906	0.868	5.962	-0.249	1.126	1.375	0.507	0.692	0.941	0.434	2.711
1417.6	98.5	0.989	16.30	7.767	0.913	0.873	5.959	-0.252	1.132	1.383	0.510	0.695	0.947	0.437	2.713
1439.3	98.8	1.004	16.55	7.789	0.913	0.873	5.955	-0.255	1.131	1.386	0.513	0.694	0.950	0.437	2.701
1461.1	99.4	1.019	16.80	7.813	0.916	0.876	5.951	-0.259	1.133	1.392	0.516	0.695	0.954	0.438	2.696
1461.3	99.3	1.019	16.80	7.814	0.915	0.875	5.951	-0.259	1.132	1.391	0.516	0.695	0.954	0.437	2.694

Consolidated Undrained Triaxial Compression

ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-101, 12.5'-13.0'
Description Sandy Lean Clay (CL), brown, moist, firm
Specimen Type Intact
Preparation Wet Mounting

Project No. 174316204
Lab ID 30
Test ID 30-A

Date Received 11/15/2017
Date Tested 12/07/2017

Specific Gravity 2.72
ASTM D 854, Dry

Liquid Limit 22
Plastic Limit 13
Plasticity Index 9
ASTM D 4318

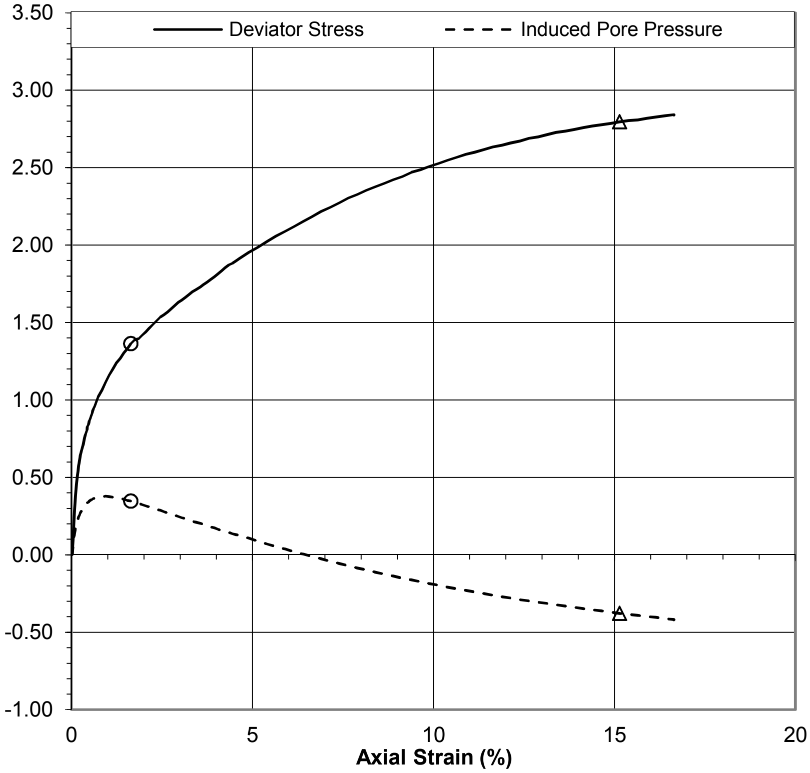
Target Test Parameters
Nominal Chamber Pressure (psi) 90
Nominal Back Pressure (psi) 78
Nominal Consolidation Pressure (psi) 12

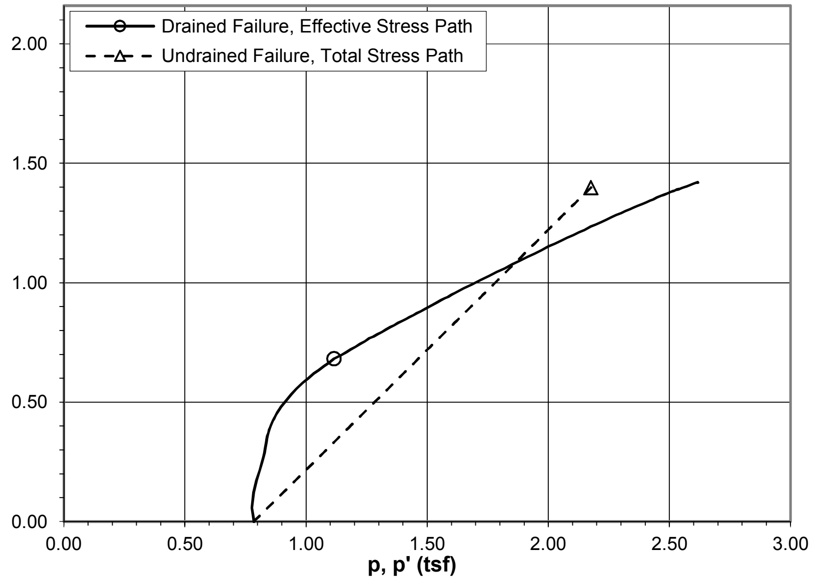
Saturation / Consolidation Results
Pore Pressure Parameter B 0.98
Measured Effective Consol. Stress (tsf) 0.781
Time to 50% Consolidation (min) 6.40
Actual Axial Strain Rate of Test (%/min) 0.047

Consolidated Specimen Conditions
Moist Unit Weight (pcf) 141.0
Moisture Content (%) 13.3
Dry Unit Weight (pcf) 124.5
Void Ratio 0.362
Degree of Saturation (%) 100.0

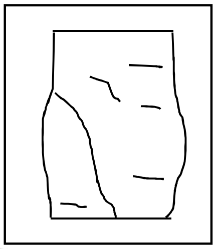
At Drained Failure
Failure Criterion: Max. Eff. Prin. Stress Ratio
Axial Strain (%) 1.643
Deviator Stress (tsf) 1.363
Induced Pore Pressure (tsf) 0.347
Minor Effective Stress, σ_3' (tsf) 0.434
Major Effective Stress, σ_1' (tsf) 1.798
Eff. Principal Stress Ratio, σ_1'/σ_3' 4.138
p' (tsf) 1.116
q (tsf) 0.682

At Consolidated Undrained Failure
Failure Criterion: 15% Axial Strain
Axial Strain (%) 15.143
Deviator Stress (tsf) 2.795
Minor Principal Stress, σ_3 (tsf) 0.778
Major Principal Stress, σ_1 (tsf) 3.573
p (tsf) 2.175
q (tsf) 1.397





Failure Sketch



Comments

Reviewed KG

Stantec

Consolidated Undrained Triaxial Compression

ASTM D 4767

Project Name	HCFRR - Dams Preliminary	Project No.	174316204
Source	B-101, 12.5'-13.0'	Lab ID	30
Description	Sandy Lean Clay (CL), brown, moist, firm	Test ID	30-A

Initial Specimen Conditions		Consolidated Specimen Conditions		Specific Gravity	2.72
Average Height (in)	6.072	Calculated Height (in)	6.061	ASTM D 854, Dry	
Average Diameter (in)	2.834	Calculated Diameter (in)	2.834		
Calculated Area (in^2)	6.308	Calculated Area (in^2)	6.308	Liquid Limit	22
Moist Weight (lb)	3.139	Moist Weight (lb)	3.120	Plastic Limit	13
Moist Unit Weight (pcf)	141.6	Moist Unit Weight (pcf)	141.0	Plasticity Index	9
Moisture Content (%)	14.0	Moisture Content (%)	13.3	ASTM D 4318	
Dry Weight (lb)	2.754	Dry Weight (lb)	2.754		
Dry Unit Weight (pcf)	124.3	Dry Unit Weight (pcf)	124.5	Confining Stress	
Void Ratio	0.364	Void Ratio	0.362	σ_3 (tsf)	0.785
Degree of Saturation (%)	104.4	Degree of Saturation (%)	100.0		
				Effective Consolidation Stress	
				σ_3' (tsf)	0.785

Moisture contents obtained using partial specimen.
Specimen consolidated cross-sectional area determined using method B.
Membrane corrections have been applied,where Em = 200 lbf/in and t = 0.012 in.
All other tests performed in association with this specimen are reported separately.

Project: 174316204			Source:	B-101, 12.5'-13.0'							Lab ID: 30		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
0.0	0.0	0.000	0.00	6.308	0.000	0.000	5.699	0.000	0.785	0.785	0.785	0.785	0.785	0.000	1.000
0.6	0.4	0.001	0.02	6.309	0.005	0.005	5.701	0.002	0.789	0.787	0.782	0.787	0.785	0.002	1.006
1.1	10.0	0.003	0.05	6.311	0.114	0.114	5.764	0.065	0.899	0.834	0.719	0.841	0.776	0.057	1.159
1.6	21.5	0.004	0.07	6.312	0.245	0.245	5.822	0.123	1.029	0.906	0.661	0.906	0.783	0.122	1.370
2.1	30.4	0.006	0.10	6.314	0.346	0.346	5.860	0.161	1.130	0.969	0.623	0.957	0.796	0.173	1.555
2.7	37.6	0.007	0.12	6.316	0.429	0.429	5.889	0.190	1.213	1.023	0.594	0.998	0.809	0.214	1.721
3.2	43.1	0.009	0.15	6.317	0.491	0.491	5.911	0.212	1.275	1.063	0.572	1.029	0.817	0.245	1.857
3.8	47.3	0.011	0.17	6.319	0.539	0.538	5.928	0.229	1.322	1.093	0.555	1.053	0.824	0.269	1.970
4.3	50.7	0.012	0.20	6.320	0.577	0.577	5.943	0.244	1.361	1.116	0.540	1.072	0.828	0.288	2.068
4.9	53.7	0.013	0.22	6.322	0.612	0.611	5.956	0.258	1.395	1.137	0.526	1.089	0.832	0.306	2.161
5.4	56.3	0.015	0.24	6.323	0.641	0.640	5.969	0.270	1.424	1.154	0.514	1.104	0.834	0.320	2.246
5.9	58.8	0.017	0.28	6.326	0.669	0.669	5.981	0.282	1.452	1.170	0.502	1.118	0.836	0.334	2.333
6.4	60.9	0.018	0.30	6.327	0.693	0.692	5.991	0.292	1.475	1.183	0.491	1.129	0.837	0.346	2.409
7.0	63.1	0.020	0.33	6.329	0.718	0.718	6.000	0.301	1.501	1.200	0.482	1.142	0.841	0.359	2.488
7.5	65.3	0.021	0.34	6.330	0.743	0.742	6.008	0.309	1.525	1.216	0.474	1.154	0.845	0.371	2.567
8.1	67.6	0.022	0.37	6.331	0.769	0.768	6.018	0.319	1.551	1.233	0.464	1.167	0.849	0.384	2.654
8.6	69.2	0.024	0.40	6.333	0.787	0.786	6.024	0.325	1.569	1.245	0.458	1.176	0.852	0.393	2.715
9.2	71.0	0.026	0.42	6.335	0.807	0.806	6.030	0.331	1.589	1.258	0.452	1.186	0.855	0.403	2.782
9.7	72.8	0.027	0.44	6.336	0.827	0.826	6.036	0.337	1.609	1.273	0.446	1.196	0.860	0.413	2.850
10.2	74.4	0.029	0.47	6.338	0.845	0.844	6.041	0.342	1.627	1.285	0.441	1.205	0.863	0.422	2.911
10.7	76.2	0.030	0.49	6.339	0.865	0.864	6.045	0.346	1.647	1.300	0.436	1.215	0.868	0.432	2.980
11.3	77.5	0.031	0.52	6.341	0.880	0.879	6.049	0.350	1.662	1.311	0.433	1.222	0.872	0.439	3.031
11.8	79.0	0.033	0.54	6.342	0.897	0.896	6.053	0.354	1.679	1.325	0.429	1.231	0.877	0.448	3.091
12.4	80.5	0.034	0.57	6.344	0.914	0.913	6.056	0.357	1.695	1.338	0.426	1.239	0.882	0.456	3.144
12.9	82.1	0.036	0.59	6.345	0.931	0.930	6.060	0.361	1.713	1.352	0.422	1.248	0.887	0.465	3.203
13.5	83.6	0.037	0.62	6.347	0.948	0.947	6.062	0.363	1.729	1.365	0.419	1.256	0.892	0.473	3.260
14.0	84.7	0.039	0.64	6.348	0.961	0.959	6.065	0.366	1.742	1.376	0.417	1.263	0.897	0.480	3.301
16.1	90.3	0.045	0.74	6.355	1.023	1.021	6.072	0.373	1.804	1.431	0.410	1.293	0.921	0.511	3.490
18.3	94.2	0.051	0.85	6.362	1.067	1.065	6.075	0.376	1.847	1.471	0.406	1.315	0.939	0.532	3.620
20.4	98.7	0.057	0.94	6.368	1.115	1.113	6.077	0.378	1.896	1.518	0.404	1.339	0.961	0.557	3.753
22.5	102.9	0.063	1.04	6.374	1.162	1.160	6.075	0.376	1.942	1.566	0.406	1.362	0.986	0.580	3.854
24.7	106.7	0.069	1.14	6.381	1.204	1.201	6.072	0.373	1.983	1.610	0.409	1.382	1.010	0.600	3.934
26.8	110.3	0.075	1.24	6.387	1.243	1.240	6.068	0.370	2.022	1.653	0.412	1.402	1.033	0.620	4.007
28.9	112.9	0.082	1.35	6.394	1.271	1.268	6.063	0.364	2.049	1.685	0.418	1.415	1.051	0.634	4.036
31.1	116.1	0.088	1.45	6.400	1.306	1.303	6.058	0.359	2.085	1.726	0.423	1.434	1.075	0.651	4.079
33.2	118.7	0.094	1.54	6.407	1.334	1.330	6.051	0.352	2.112	1.760	0.430	1.447	1.095	0.665	4.094
35.3	121.8	0.100	1.64	6.413	1.367	1.363	6.046	0.347	2.145	1.798	0.434	1.463	1.116	0.682	4.138
37.5	123.9	0.105	1.74	6.420	1.390	1.386	6.038	0.339	2.168	1.829	0.443	1.475	1.136	0.693	4.128
39.6	125.0	0.112	1.85	6.427	1.400	1.396	6.031	0.332	2.177	1.845	0.450	1.479	1.148	0.698	4.103

Project: 174316204 | **Source:** B-101, 12.5'-13.0' | **Lab ID:** 30 | **Test ID**

Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
41.8	127.0	0.118	1.95	6.434	1.421	1.417	6.023	0.324	2.198	1.874	0.457	1.490	1.165	0.708	4.099
43.9	129.3	0.125	2.06	6.440	1.445	1.440	6.016	0.317	2.222	1.905	0.465	1.502	1.185	0.720	4.101
46.0	131.5	0.130	2.14	6.446	1.469	1.464	6.008	0.309	2.245	1.936	0.472	1.513	1.204	0.732	4.102
48.2	133.6	0.136	2.24	6.452	1.491	1.486	6.001	0.302	2.267	1.965	0.479	1.524	1.222	0.743	4.100
50.3	135.9	0.142	2.34	6.459	1.515	1.509	5.993	0.294	2.291	1.996	0.487	1.536	1.242	0.755	4.098
52.5	138.5	0.149	2.45	6.466	1.542	1.536	5.987	0.288	2.317	2.029	0.493	1.549	1.261	0.768	4.115
54.6	139.8	0.155	2.55	6.473	1.555	1.549	5.977	0.278	2.330	2.052	0.503	1.556	1.277	0.775	4.081
56.7	141.7	0.161	2.65	6.480	1.574	1.568	5.970	0.271	2.349	2.078	0.511	1.565	1.294	0.784	4.070
58.9	143.6	0.167	2.75	6.486	1.594	1.587	5.961	0.262	2.368	2.106	0.519	1.575	1.312	0.794	4.061
61.0	145.6	0.172	2.84	6.492	1.614	1.607	5.954	0.255	2.389	2.133	0.526	1.585	1.330	0.804	4.057
63.1	147.7	0.179	2.95	6.500	1.636	1.629	5.947	0.248	2.411	2.163	0.534	1.596	1.348	0.815	4.053
65.3	149.2	0.185	3.05	6.506	1.651	1.644	5.939	0.240	2.425	2.185	0.541	1.603	1.363	0.822	4.038
67.4	151.2	0.191	3.15	6.513	1.671	1.663	5.931	0.232	2.444	2.212	0.549	1.613	1.380	0.832	4.031
69.6	152.8	0.197	3.24	6.519	1.688	1.680	5.924	0.225	2.461	2.236	0.557	1.621	1.397	0.840	4.017
71.7	154.6	0.203	3.34	6.526	1.706	1.698	5.916	0.217	2.478	2.261	0.563	1.630	1.412	0.849	4.013
73.8	156.1	0.209	3.44	6.533	1.720	1.712	5.909	0.210	2.494	2.283	0.571	1.638	1.427	0.856	3.996
76.0	157.9	0.216	3.56	6.540	1.738	1.730	5.902	0.203	2.511	2.308	0.579	1.646	1.443	0.865	3.989
78.1	159.4	0.221	3.64	6.546	1.754	1.745	5.896	0.197	2.526	2.328	0.584	1.653	1.456	0.872	3.989
80.2	161.1	0.227	3.75	6.554	1.770	1.761	5.887	0.188	2.542	2.355	0.594	1.662	1.474	0.881	3.967
82.4	163.0	0.233	3.85	6.560	1.789	1.779	5.879	0.180	2.561	2.380	0.601	1.671	1.491	0.890	3.960
84.5	164.7	0.239	3.95	6.567	1.805	1.796	5.871	0.172	2.576	2.404	0.608	1.678	1.506	0.898	3.953
86.7	166.5	0.245	4.05	6.574	1.824	1.814	5.865	0.166	2.595	2.429	0.616	1.688	1.523	0.907	3.946
88.8	168.6	0.252	4.15	6.581	1.844	1.834	5.857	0.158	2.616	2.458	0.624	1.699	1.541	0.917	3.941
91.0	170.5	0.257	4.24	6.588	1.863	1.853	5.849	0.150	2.634	2.483	0.630	1.707	1.557	0.927	3.940
93.1	172.4	0.263	4.34	6.594	1.882	1.872	5.842	0.143	2.653	2.509	0.638	1.717	1.573	0.936	3.936
95.2	173.6	0.269	4.44	6.601	1.893	1.882	5.835	0.136	2.663	2.527	0.645	1.722	1.586	0.941	3.920
97.3	175.3	0.276	4.55	6.608	1.910	1.899	5.829	0.130	2.680	2.550	0.651	1.731	1.600	0.949	3.916
99.5	176.8	0.281	4.64	6.615	1.925	1.913	5.824	0.125	2.695	2.570	0.657	1.738	1.613	0.957	3.913
104.8	181.0	0.297	4.90	6.633	1.964	1.953	5.806	0.107	2.734	2.627	0.675	1.758	1.651	0.976	3.893
110.2	184.7	0.312	5.15	6.651	1.999	1.987	5.788	0.089	2.767	2.678	0.691	1.774	1.685	0.993	3.873
115.5	188.5	0.327	5.40	6.668	2.035	2.022	5.769	0.070	2.803	2.733	0.710	1.792	1.721	1.011	3.846
120.9	192.4	0.342	5.65	6.686	2.072	2.058	5.753	0.054	2.839	2.785	0.727	1.810	1.756	1.029	3.830
126.2	195.9	0.358	5.90	6.704	2.104	2.089	5.737	0.038	2.870	2.832	0.743	1.825	1.787	1.045	3.812
131.5	199.3	0.373	6.15	6.721	2.135	2.120	5.719	0.020	2.900	2.880	0.760	1.840	1.820	1.060	3.791
136.9	203.1	0.388	6.41	6.740	2.169	2.154	5.703	0.004	2.933	2.929	0.775	1.856	1.852	1.077	3.778
142.2	206.4	0.403	6.64	6.757	2.199	2.183	5.688	-0.011	2.963	2.974	0.791	1.871	1.882	1.091	3.759
147.6	210.1	0.418	6.90	6.775	2.233	2.216	5.673	-0.026	2.996	3.022	0.806	1.888	1.914	1.108	3.750
152.9	213.3	0.433	7.15	6.794	2.261	2.243	5.658	-0.041	3.023	3.064	0.821	1.901	1.942	1.122	3.733
158.2	216.7	0.448	7.40	6.812	2.291	2.273	5.643	-0.056	3.052	3.108	0.835	1.916	1.972	1.136	3.721
163.6	220.3	0.463	7.65	6.830	2.322	2.303	5.628	-0.070	3.082	3.153	0.849	1.930	2.001	1.152	3.712
168.9	223.2	0.479	7.90	6.849	2.346	2.327	5.615	-0.084	3.106	3.190	0.863	1.942	2.026	1.163	3.696
174.2	226.4	0.493	8.14	6.867	2.373	2.354	5.601	-0.098	3.133	3.231	0.877	1.956	2.054	1.177	3.683
179.6	229.2	0.509	8.39	6.886	2.396	2.376	5.587	-0.111	3.155	3.266	0.890	1.967	2.078	1.188	3.669
184.9	232.1	0.524	8.65	6.905	2.420	2.399	5.575	-0.124	3.178	3.302	0.903	1.978	2.102	1.200	3.658
190.3	235.0	0.539	8.89	6.923	2.444	2.422	5.561	-0.138	3.201	3.338	0.916	1.990	2.127	1.211	3.644
195.6	237.6	0.554	9.14	6.943	2.464	2.442	5.549	-0.150	3.220	3.370	0.928	1.999	2.149	1.221	3.631
200.9	241.0	0.569	9.39	6.961	2.493	2.470	5.537	-0.162	3.248	3.411	0.941	2.013	2.176	1.235	3.626
206.3	243.4	0.585	9.65	6.981	2.510	2.486	5.525	-0.174	3.265	3.439	0.953	2.022	2.196	1.243	3.610
211.6	246.3	0.600	9.89	7.000	2.533	2.509	5.513	-0.186	3.288	3.473	0.964	2.033	2.219	1.255	3.603
216.9	248.9	0.615	10.14	7.020	2.552	2.528	5.502	-0.197	3.306	3.503	0.975	2.042	2.239	1.264	3.592
222.3	251.6	0.630	10.39	7.040	2.574	2.548	5.491	-0.208	3.326	3.534	0.986	2.052	2.260	1.274	3.585
227.6	254.2	0.645	10.64	7.059	2.592	2.566	5.480	-0.219	3.344	3.563	0.997	2.061	2.280	1.283	3.574
233.0	256.7	0.660	10.90	7.079	2.611	2.584	5.469	-0.230	3.363	3.593	1.008	2.070	2.301	1.292	3.563
238.3	258.9	0.675	11.14	7.099	2.626	2.598	5.458	-0.241	3.376	3.617	1.018	2.077	2.318	1.299	3.552
243.7	261.4	0.691	11.40	7.119	2.644	2.616	5.449	-0.250	3.394	3.644	1.028	2.086	2.336	1.308	3.544
249.0	263.8	0.706	11.64	7.139	2.660	2.632	5.438	-0.261	3.409	3.671	1.039	2.093	2.355	1.316	3.534
254.3	265.8	0.721	11.89	7.159	2.673	2.644	5.428	-0.271	3.422	3.692	1.048	2.099	2.370	1.322	3.523
259.7	268.1	0.736	12.14	7.179	2.689	2.659	5.419	-0.280	3.437	3.717	1.058	2.107	2.387	1.330	3.514
265.0	270.2	0.751	12.39	7.200	2.702	2.672	5.410	-0.289	3.450	3.739	1.067	2.114	2.403	1.336	3.504
270.3	272.6	0.766	12.64	7.221	2.718	2.687	5.400	-0.298	3.465	3.764	1.076	2.122	2.420	1.344	3.497
275.7	274.7	0.782	12.90	7.242	2.731	2.699	5.392	-0.307	3.477	3.784	1.085	2.128	2.434	1.350	3.488
281.0	276.9	0.797	13.14	7.263	2.745	2.713	5.384	-0.315	3.491	3.806	1.093	2.134	2.449	1.357	3.483
286.4	279.2	0.812	13.39	7.283	2.760	2.728	5.376	-0.323	3.506	3.829	1.102	2.142	2.465	1.364	3.476
291.7	280.9	0.827	13.65	7.305	2.769	2.736	5.367	-0.332	3.514	3.846	1.110	2.146	2.478	1.368	3.465
297.0	282.8	0.842	13.89	7.325	2.780	2.746	5.359	-0.340	3.524	3.864	1.118	2.151	2.491	1.373	3.456
302.4	285.1	0.857	14.15	7.347	2.794	2.759	5.351	-0.348	3.537	3.885	1.125	2.157	2.505	1.380	3.452
307.7	286.9	0.872	14.39	7.368	2.803	2.768	5.343	-0.356	3.546	3.902	1.134	2.162	2.518	1.384	3.442
313.1	288.8	0.888	14.65	7.390	2.813	2.778	5.337	-0.362	3.556	3.918	1.140	2.167	2.529	1.389	3.436
318.4	290.4	0.903	14.89	7.412	2.821	2.784	5.328	-0.371	3.562	3.933	1.148	2.170	2.541	1.392	3.425

Project: 174316204			**Source: B-101, 12.5'-13.0'**								**Lab ID: 30**		**Test ID**		
Test Time (min)	**Corr. Axial Load (lbf)**	**Axial Deform. (in)**	**Axial Strain (%)**	**Corr. Area (in^2)**	**Deviator Stress (tsf)**	**Corr. Deviator Stress (tsf)**	**Pore Pressure (tsf)**	**Induced Pore Pressure (tsf)**	**σ_1 (tsf)**	**σ_1' (tsf)**	**σ_3' (tsf)**	**p (tsf)**	**p' (tsf)**	**q (tsf)**	**Eff. Princ. Stress Ratio σ_1'/σ_3'**
323.8	292.4	0.918	15.14	7.434	2.832	2.795	5.321	-0.378	3.573	3.950	1.156	2.175	2.553	1.397	3.419
329.1	294.2	0.933	15.39	7.456	2.841	2.804	5.314	-0.385	3.582	3.967	1.163	2.180	2.565	1.402	3.411
334.4	295.7	0.949	15.65	7.478	2.847	2.809	5.308	-0.391	3.587	3.978	1.169	2.183	2.573	1.405	3.403
339.8	297.7	0.963	15.89	7.500	2.858	2.819	5.300	-0.399	3.597	3.996	1.177	2.188	2.586	1.410	3.396
345.1	299.5	0.979	16.14	7.522	2.867	2.827	5.295	-0.404	3.606	4.010	1.182	2.192	2.596	1.414	3.391
350.4	301.4	0.994	16.40	7.545	2.876	2.836	5.288	-0.411	3.613	4.025	1.189	2.195	2.607	1.418	3.385
355.8	303.0	1.009	16.64	7.567	2.883	2.842	5.281	-0.418	3.620	4.038	1.196	2.199	2.617	1.421	3.377
355.8	302.6	1.009	16.65	7.568	2.879	2.839	5.279	-0.420	3.617	4.037	1.198	2.197	2.618	1.419	3.369

Stantec

Consolidated Undrained Triaxial Compression

ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-102, 4.5'-5.0'
Description Lean Clay with Sand (CL), dark brown, moist, firm
Specimen Type Intact
Preparation Wet Mounting

Project No. 174316204
Lab ID 31
Test ID 31-A

Date Received 11/15/2017
Date Tested 12/08/2017

Specific Gravity 2.70
ASTM D 854, Dry

Liquid Limit 40
Plastic Limit 18
Plasticity Index 22
ASTM D 4318

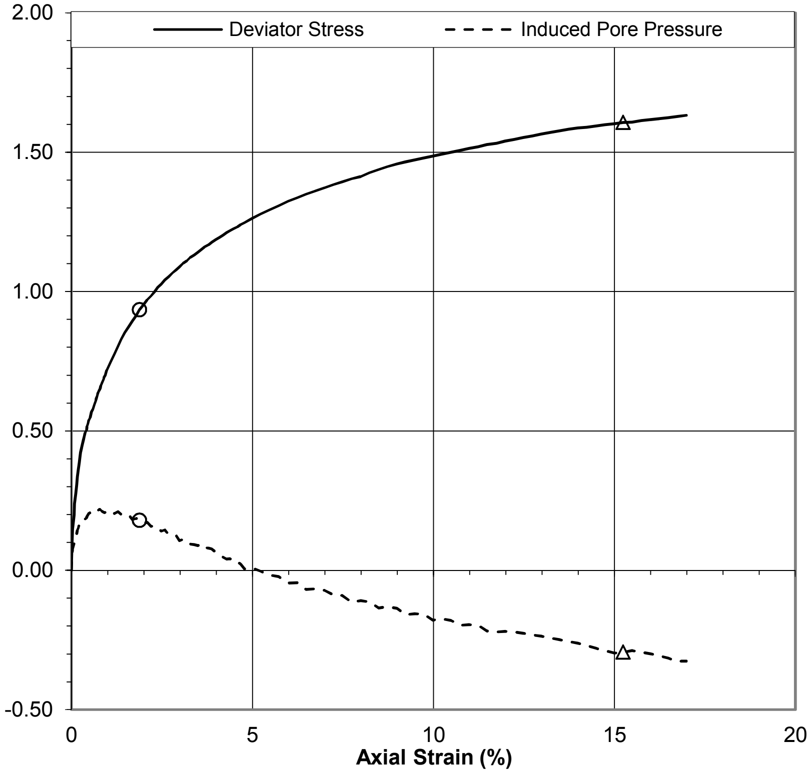
Target Test Parameters
Nominal Chamber Pressure (psi) 90
Nominal Back Pressure (psi) 84
Nominal Consolidation Pressure (psi) 6

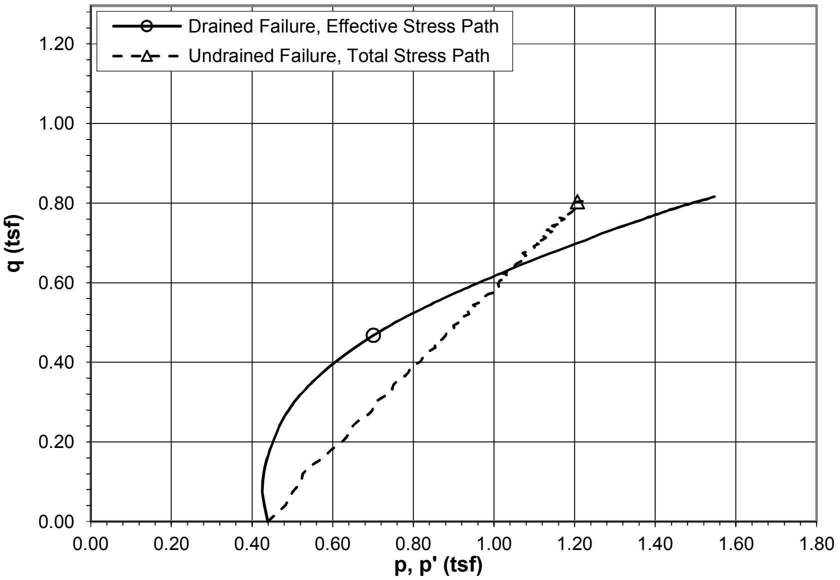
Saturation / Consolidation Results
Pore Pressure Parameter B 0.99
Measured Effective Consol. Stress (tsf) 0.412
Time to 50% Consolidation (min) 21.60
Actual Axial Strain Rate of Test (%/min) 0.014

Consolidated Specimen Conditions
Moist Unit Weight (pcf) 128.5
Moisture Content (%) 22.2
Dry Unit Weight (pcf) 105.2
Void Ratio 0.600
Degree of Saturation (%) 100.0

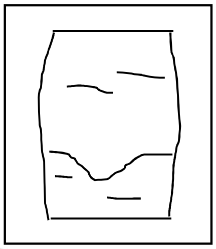
At Drained Failure
Failure Criterion: Max. Eff. Prin. Stress Ratio
Axial Strain (%) 1.878
Deviator Stress (tsf) 0.935
Induced Pore Pressure (tsf) 0.179
Minor Effective Stress, σ_3' (tsf) 0.233
Major Effective Stress, σ_1' (tsf) 1.168
Eff. Principal Stress Ratio, σ_1'/σ_3' 5.014
p' (tsf) 0.701
q (tsf) 0.468

At Consolidated Undrained Failure
Failure Criterion: 15% Axial Strain
Axial Strain (%) 15.238
Deviator Stress (tsf) 1.606
Minor Principal Stress, σ_3 (tsf) 0.404
Major Principal Stress, σ_1 (tsf) 2.010
p (tsf) 1.207
q (tsf) 0.803





Failure Sketch



Comments

Reviewed KG

Consolidated Undrained Triaxial Compression
ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-102, 4.5'-5.0'
Description Lean Clay with Sand (CL), dark brown, moist, firm

Project No. 174316204
Lab ID 31
Test ID 31-A

Initial Specimen Conditions
Average Height (in) 6.056
Average Diameter (in) 2.844
Calculated Area (in^2) 6.351
Moist Weight (lb) 2.903
Moist Unit Weight (pcf) 130.4
Moisture Content (%) 21.5
Dry Weight (lb) 2.390
Dry Unit Weight (pcf) 107.4
Void Ratio 0.567
Degree of Saturation (%) 102.3

Consolidated Specimen Conditions
Calculated Height (in) 6.060
Calculated Diameter (in) 2.872
Calculated Area (in^2) 6.480
Moist Weight (lb) 2.921
Moist Unit Weight (pcf) 128.5
Moisture Content (%) 22.2
Dry Weight (lb) 2.390
Dry Unit Weight (pcf) 105.2
Void Ratio 0.600
Degree of Saturation (%) 100.0

Specific Gravity 2.70
ASTM D 854, Dry

Liquid Limit 40
Plastic Limit 18
Plasticity Index 22
ASTM D 4318

Confining Stress
σ_3 (tsf) 0.440

Effective Consolidation Stress
σ_3' (tsf) 0.440

Moisture contents obtained using partial specimen.
Specimen consolidated cross-sectional area determined using method B.
Membrane corrections have been applied,where Em = 200 lbf/in and t = 0.012 in.
All other tests performed in association with this specimen are reported separately.

Project: 174316204			Source:	B-102, 4.5'-5.0'							Lab ID: 31		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
0.0	0.0	0.000	0.00	6.480	0.000	0.000	6.068	0.000	0.440	0.440	0.440	0.440	0.440	0.000	1.000
1.8	7.6	0.001	0.02	6.481	0.084	0.084	6.121	0.053	0.526	0.473	0.388	0.483	0.430	0.042	1.217
3.6	13.3	0.002	0.03	6.482	0.148	0.148	6.143	0.075	0.575	0.500	0.351	0.501	0.425	0.074	1.421
5.4	18.0	0.004	0.07	6.484	0.199	0.199	6.164	0.096	0.622	0.526	0.327	0.523	0.426	0.100	1.610
7.2	21.6	0.005	0.09	6.485	0.240	0.240	6.165	0.097	0.646	0.548	0.309	0.526	0.429	0.120	1.776
9.0	24.8	0.007	0.11	6.487	0.275	0.275	6.178	0.110	0.679	0.569	0.294	0.542	0.432	0.137	1.933
10.9	27.7	0.008	0.14	6.489	0.307	0.307	6.199	0.131	0.720	0.590	0.283	0.567	0.436	0.153	2.084
12.7	30.3	0.010	0.16	6.490	0.336	0.336	6.212	0.144	0.752	0.608	0.273	0.584	0.441	0.168	2.231
14.5	32.7	0.011	0.19	6.492	0.362	0.362	6.220	0.152	0.778	0.626	0.264	0.597	0.445	0.181	2.372
16.3	34.9	0.013	0.21	6.493	0.387	0.386	6.232	0.164	0.807	0.643	0.257	0.614	0.450	0.193	2.505
18.1	36.6	0.014	0.23	6.495	0.406	0.405	6.241	0.173	0.828	0.655	0.250	0.626	0.453	0.202	2.617
19.9	38.3	0.015	0.25	6.496	0.424	0.424	6.245	0.177	0.846	0.669	0.245	0.634	0.457	0.212	2.730
21.7	39.7	0.017	0.28	6.498	0.440	0.439	6.248	0.180	0.859	0.680	0.240	0.639	0.460	0.220	2.828
23.5	41.1	0.018	0.30	6.499	0.455	0.454	6.249	0.181	0.871	0.690	0.236	0.644	0.463	0.227	2.927
25.3	42.3	0.020	0.33	6.501	0.468	0.468	6.249	0.181	0.880	0.699	0.232	0.646	0.465	0.234	3.019
27.1	43.5	0.021	0.35	6.503	0.481	0.481	6.250	0.182	0.890	0.708	0.228	0.650	0.468	0.240	3.108
28.9	44.6	0.023	0.38	6.504	0.493	0.492	6.252	0.184	0.902	0.717	0.225	0.655	0.471	0.246	3.190
30.8	45.6	0.025	0.42	6.507	0.505	0.504	6.257	0.189	0.915	0.726	0.222	0.663	0.474	0.252	3.270
32.6	46.7	0.026	0.43	6.508	0.517	0.516	6.262	0.194	0.929	0.735	0.219	0.671	0.477	0.258	3.352
34.4	47.7	0.028	0.46	6.509	0.528	0.526	6.267	0.199	0.942	0.743	0.217	0.679	0.480	0.263	3.428
36.2	48.8	0.029	0.48	6.511	0.539	0.538	6.273	0.205	0.957	0.753	0.215	0.688	0.484	0.269	3.509
38.0	49.7	0.031	0.52	6.513	0.550	0.548	6.275	0.207	0.968	0.761	0.213	0.694	0.487	0.274	3.578
39.8	50.6	0.032	0.53	6.514	0.560	0.558	6.275	0.207	0.977	0.770	0.211	0.698	0.490	0.279	3.644
41.6	51.6	0.033	0.55	6.515	0.570	0.568	6.274	0.207	0.984	0.778	0.209	0.700	0.494	0.284	3.714
43.4	52.4	0.036	0.59	6.518	0.579	0.577	6.272	0.204	0.989	0.785	0.208	0.701	0.497	0.289	3.775
45.2	53.3	0.037	0.61	6.519	0.589	0.587	6.270	0.202	0.996	0.794	0.206	0.702	0.500	0.294	3.847
47.0	54.3	0.039	0.64	6.521	0.599	0.598	6.270	0.202	1.005	0.802	0.205	0.706	0.504	0.299	3.918
48.8	55.1	0.040	0.66	6.523	0.608	0.607	6.272	0.204	1.014	0.810	0.204	0.710	0.507	0.303	3.980
50.6	56.0	0.041	0.68	6.524	0.618	0.616	6.274	0.206	1.025	0.819	0.203	0.717	0.511	0.308	4.040
52.5	56.9	0.043	0.71	6.526	0.628	0.626	6.278	0.210	1.038	0.828	0.202	0.725	0.515	0.313	4.101
54.3	57.7	0.044	0.73	6.527	0.636	0.634	6.282	0.214	1.050	0.836	0.202	0.733	0.519	0.317	4.148
56.1	58.5	0.046	0.75	6.529	0.645	0.644	6.285	0.217	1.061	0.844	0.201	0.739	0.522	0.322	4.209
57.9	59.2	0.048	0.79	6.531	0.653	0.651	6.286	0.218	1.070	0.852	0.201	0.745	0.526	0.326	4.245
59.7	60.2	0.049	0.81	6.532	0.663	0.661	6.285	0.217	1.078	0.862	0.200	0.748	0.531	0.331	4.301
61.5	61.0	0.050	0.83	6.534	0.672	0.670	6.281	0.213	1.082	0.870	0.200	0.748	0.535	0.335	4.348
63.3	61.7	0.052	0.86	6.536	0.680	0.678	6.278	0.210	1.088	0.878	0.200	0.749	0.539	0.339	4.397
65.1	62.5	0.054	0.88	6.537	0.688	0.686	6.276	0.208	1.094	0.885	0.199	0.751	0.542	0.343	4.439
66.9	63.2	0.055	0.91	6.539	0.696	0.694	6.275	0.207	1.100	0.893	0.200	0.753	0.546	0.347	4.476
68.7	64.0	0.057	0.94	6.541	0.704	0.702	6.276	0.208	1.109	0.901	0.199	0.758	0.550	0.351	4.525

Project: 174316204			**Source: B-102, 4.5'-5.0'**								**Lab ID: 31**		**Test ID**		
Test Time (min)	**Corr. Axial Load (lbf)**	**Axial Deform. (in)**	**Axial Strain (%)**	**Corr. Area (in^2)**	**Deviator Stress (tsf)**	**Corr. Deviator Stress (tsf)**	**Pore Pressure (tsf)**	**Induced Pore Pressure (tsf)**	**σ_1 (tsf)**	**σ_1' (tsf)**	**σ_3' (tsf)**	**p (tsf)**	**p' (tsf)**	**q (tsf)**	**Eff. Princ. Stress Ratio σ_1'/σ_3'**
70.6	64.7	0.058	0.96	6.542	0.712	0.709	6.278	0.211	1.119	0.909	0.199	0.764	0.554	0.355	4.562
72.4	65.4	0.059	0.98	6.544	0.720	0.718	6.281	0.213	1.130	0.917	0.200	0.772	0.558	0.359	4.594
79.6	68.3	0.066	1.09	6.551	0.750	0.748	6.281	0.213	1.161	0.948	0.201	0.787	0.575	0.374	4.723
86.8	70.9	0.072	1.19	6.558	0.779	0.776	6.271	0.203	1.182	0.979	0.203	0.794	0.591	0.388	4.830
94.1	73.5	0.078	1.28	6.564	0.807	0.804	6.279	0.211	1.221	1.010	0.206	0.819	0.608	0.402	4.896
101.3	75.9	0.083	1.38	6.570	0.832	0.829	6.268	0.200	1.239	1.039	0.210	0.824	0.624	0.414	4.947
108.5	78.1	0.089	1.47	6.576	0.855	0.852	6.264	0.196	1.263	1.066	0.214	0.837	0.640	0.426	4.975
115.7	80.4	0.096	1.58	6.584	0.879	0.875	6.267	0.199	1.292	1.094	0.219	0.855	0.656	0.438	5.005
123.0	82.3	0.102	1.69	6.591	0.899	0.895	6.249	0.182	1.299	1.118	0.223	0.852	0.670	0.447	5.011
130.2	84.2	0.108	1.79	6.598	0.919	0.914	6.254	0.186	1.328	1.142	0.228	0.871	0.685	0.457	5.010
137.4	86.2	0.114	1.88	6.604	0.940	0.935	6.247	0.179	1.348	1.168	0.233	0.880	0.701	0.468	5.014
144.7	87.9	0.120	1.98	6.611	0.957	0.952	6.237	0.169	1.360	1.191	0.239	0.884	0.715	0.476	4.988
151.9	89.6	0.126	2.09	6.618	0.975	0.970	6.241	0.173	1.387	1.214	0.244	0.902	0.729	0.485	4.976
159.1	91.1	0.133	2.19	6.625	0.990	0.985	6.226	0.158	1.392	1.234	0.250	0.900	0.742	0.492	4.944
166.4	92.6	0.139	2.29	6.632	1.005	1.000	6.226	0.158	1.412	1.254	0.254	0.912	0.754	0.500	4.936
173.6	94.1	0.145	2.39	6.638	1.021	1.015	6.223	0.155	1.430	1.276	0.261	0.923	0.768	0.507	4.890
180.8	95.3	0.150	2.48	6.644	1.033	1.027	6.208	0.140	1.434	1.294	0.267	0.921	0.780	0.514	4.850
188.1	96.8	0.156	2.57	6.651	1.048	1.042	6.213	0.145	1.459	1.315	0.273	0.938	0.794	0.521	4.816
195.3	98.0	0.162	2.68	6.658	1.060	1.053	6.197	0.129	1.462	1.333	0.279	0.935	0.806	0.527	4.768
202.5	99.3	0.169	2.79	6.665	1.073	1.066	6.194	0.126	1.478	1.352	0.286	0.945	0.819	0.533	4.734
209.8	100.6	0.175	2.89	6.673	1.085	1.078	6.192	0.125	1.495	1.370	0.292	0.955	0.831	0.539	4.697
217.0	101.7	0.181	2.98	6.679	1.096	1.089	6.174	0.106	1.493	1.387	0.298	0.948	0.842	0.545	4.660
224.2	102.9	0.187	3.08	6.686	1.108	1.101	6.180	0.112	1.515	1.403	0.302	0.965	0.853	0.551	4.643
231.4	103.9	0.193	3.18	6.693	1.118	1.111	6.168	0.100	1.519	1.419	0.309	0.964	0.864	0.555	4.594
238.7	105.2	0.199	3.28	6.699	1.130	1.122	6.163	0.095	1.531	1.436	0.314	0.970	0.875	0.561	4.576
245.9	106.2	0.205	3.39	6.707	1.140	1.131	6.160	0.092	1.543	1.451	0.320	0.978	0.886	0.566	4.535
253.1	107.3	0.212	3.50	6.714	1.150	1.142	6.157	0.089	1.556	1.467	0.325	0.985	0.896	0.571	4.511
260.4	108.2	0.217	3.58	6.720	1.159	1.151	6.163	0.095	1.576	1.482	0.331	1.001	0.906	0.575	4.479
267.6	109.1	0.223	3.67	6.727	1.168	1.159	6.150	0.082	1.579	1.497	0.337	0.999	0.917	0.580	4.439
274.8	110.1	0.230	3.79	6.735	1.178	1.168	6.147	0.079	1.590	1.511	0.342	1.005	0.926	0.584	4.413
282.1	111.1	0.235	3.88	6.741	1.187	1.177	6.143	0.076	1.601	1.526	0.348	1.013	0.937	0.589	4.381
289.3	112.1	0.241	3.98	6.748	1.196	1.186	6.133	0.065	1.604	1.540	0.353	1.011	0.946	0.593	4.360
296.5	113.0	0.248	4.09	6.756	1.204	1.195	6.122	0.054	1.608	1.554	0.359	1.011	0.956	0.597	4.328
303.8	113.9	0.254	4.19	6.763	1.213	1.203	6.116	0.048	1.614	1.567	0.364	1.013	0.965	0.601	4.304
311.0	114.8	0.260	4.29	6.770	1.221	1.211	6.108	0.040	1.620	1.580	0.369	1.014	0.974	0.606	4.286
318.2	115.7	0.266	4.38	6.777	1.229	1.219	6.109	0.041	1.635	1.593	0.375	1.025	0.984	0.609	4.254
325.5	116.4	0.271	4.48	6.783	1.236	1.225	6.097	0.029	1.634	1.605	0.380	1.021	0.992	0.613	4.225
332.7	117.3	0.278	4.59	6.791	1.244	1.233	6.098	0.030	1.647	1.617	0.384	1.031	1.001	0.616	4.207
339.9	118.2	0.283	4.68	6.798	1.252	1.240	6.090	0.022	1.651	1.630	0.389	1.031	1.009	0.620	4.188
347.2	118.9	0.290	4.78	6.805	1.258	1.247	6.073	0.005	1.645	1.640	0.394	1.022	1.017	0.623	4.167
354.4	119.7	0.295	4.87	6.812	1.265	1.254	6.077	0.009	1.661	1.652	0.398	1.034	1.025	0.627	4.146
361.6	120.7	0.302	4.99	6.820	1.274	1.262	6.077	0.009	1.673	1.665	0.403	1.042	1.034	0.631	4.132
379.7	122.5	0.317	5.23	6.837	1.290	1.278	6.064	-0.004	1.688	1.691	0.414	1.049	1.053	0.639	4.088
397.8	124.4	0.331	5.47	6.854	1.307	1.294	6.051	-0.017	1.702	1.718	0.425	1.055	1.072	0.647	4.045
415.8	126.2	0.347	5.73	6.874	1.322	1.309	6.046	-0.022	1.722	1.745	0.436	1.068	1.090	0.654	4.000
433.9	128.1	0.363	5.99	6.892	1.338	1.324	6.022	-0.046	1.723	1.770	0.446	1.062	1.108	0.662	3.967
452.0	129.7	0.378	6.24	6.911	1.352	1.337	6.023	-0.045	1.747	1.792	0.456	1.079	1.124	0.668	3.933
470.1	131.3	0.393	6.48	6.929	1.365	1.349	5.999	-0.069	1.746	1.815	0.466	1.072	1.140	0.675	3.897
488.1	132.9	0.408	6.74	6.948	1.377	1.361	6.002	-0.066	1.771	1.837	0.476	1.091	1.157	0.680	3.856
506.2	134.5	0.424	6.99	6.967	1.390	1.373	5.996	-0.072	1.787	1.859	0.486	1.101	1.173	0.686	3.823
524.3	136.0	0.439	7.24	6.986	1.401	1.384	5.979	-0.089	1.791	1.880	0.496	1.099	1.188	0.692	3.792
542.4	137.3	0.453	7.48	7.004	1.411	1.393	5.978	-0.090	1.807	1.897	0.504	1.110	1.200	0.697	3.767
560.4	138.8	0.469	7.74	7.023	1.423	1.404	5.954	-0.114	1.801	1.916	0.511	1.099	1.213	0.702	3.746
578.5	140.1	0.484	7.99	7.042	1.432	1.413	5.959	-0.109	1.824	1.934	0.521	1.118	1.227	0.706	3.712
596.6	141.8	0.499	8.23	7.061	1.446	1.426	5.954	-0.113	1.842	1.955	0.529	1.129	1.242	0.713	3.697
614.7	143.4	0.514	8.48	7.080	1.458	1.437	5.933	-0.135	1.839	1.974	0.536	1.120	1.255	0.719	3.680
632.7	144.9	0.529	8.72	7.099	1.470	1.449	5.937	-0.131	1.861	1.992	0.543	1.137	1.268	0.724	3.665
650.8	146.2	0.545	8.99	7.120	1.479	1.457	5.932	-0.136	1.872	2.008	0.551	1.144	1.280	0.728	3.643
668.9	147.5	0.559	9.23	7.138	1.488	1.465	5.909	-0.159	1.864	2.023	0.558	1.132	1.291	0.733	3.626
687.0	148.6	0.575	9.48	7.158	1.495	1.472	5.913	-0.155	1.883	2.038	0.566	1.147	1.302	0.736	3.600
705.0	149.8	0.589	9.72	7.177	1.503	1.480	5.911	-0.157	1.895	2.052	0.573	1.155	1.313	0.740	3.583
723.1	151.0	0.605	9.99	7.198	1.510	1.486	5.889	-0.179	1.887	2.065	0.580	1.144	1.323	0.743	3.563
741.2	152.2	0.620	10.23	7.218	1.518	1.493	5.893	-0.175	1.905	2.080	0.587	1.158	1.333	0.747	3.546
759.3	153.3	0.636	10.49	7.239	1.525	1.500	5.888	-0.180	1.913	2.093	0.593	1.163	1.343	0.750	3.528
777.3	154.5	0.651	10.74	7.260	1.533	1.507	5.871	-0.197	1.909	2.106	0.599	1.156	1.353	0.753	3.515
795.4	155.7	0.666	10.99	7.279	1.540	1.513	5.873	-0.195	1.925	2.119	0.606	1.168	1.363	0.757	3.498
813.5	156.7	0.681	11.23	7.300	1.546	1.519	5.871	-0.197	1.934	2.131	0.612	1.175	1.371	0.760	3.483
831.6	158.1	0.696	11.48	7.320	1.555	1.527	5.850	-0.218	1.925	2.143	0.616	1.161	1.380	0.764	3.478
849.6	159.1	0.712	11.75	7.342	1.560	1.532	5.847	-0.221	1.934	2.155	0.624	1.169	1.389	0.766	3.457

Project: 174316204			**Source: B-102, 4.5'-5.0'**								**Lab ID: 31**		**Test ID**		
Test Time (min)	**Corr. Axial Load (lbf)**	**Axial Deform. (in)**	**Axial Strain (%)**	**Corr. Area (in^2)**	**Deviator Stress (tsf)**	**Corr. Deviator Stress (tsf)**	**Pore Pressure (tsf)**	**Induced Pore Pressure (tsf)**	**σ_1 (tsf)**	**σ_1' (tsf)**	**σ_3' (tsf)**	**p (tsf)**	**p' (tsf)**	**q (tsf)**	**Eff. Princ. Stress Ratio σ_1'/σ_3'**
867.7	160.4	0.726	11.98	7.362	1.569	1.540	5.849	-0.219	1.949	2.168	0.628	1.179	1.398	0.770	3.451
885.8	161.5	0.741	12.23	7.383	1.575	1.545	5.846	-0.222	1.958	2.180	0.635	1.186	1.407	0.773	3.435
903.8	162.8	0.756	12.48	7.404	1.583	1.553	5.842	-0.226	1.967	2.193	0.640	1.191	1.417	0.776	3.425
921.9	163.9	0.772	12.73	7.425	1.589	1.559	5.836	-0.232	1.974	2.206	0.647	1.195	1.426	0.779	3.409
940.0	165.1	0.787	12.98	7.446	1.597	1.566	5.831	-0.237	1.981	2.218	0.652	1.198	1.435	0.783	3.400
958.1	166.3	0.802	13.23	7.468	1.603	1.571	5.825	-0.243	1.988	2.231	0.659	1.202	1.445	0.786	3.383
976.1	167.4	0.817	13.48	7.489	1.609	1.576	5.819	-0.249	1.992	2.242	0.665	1.204	1.453	0.788	3.370
994.2	168.5	0.832	13.73	7.511	1.616	1.583	5.812	-0.256	1.997	2.253	0.670	1.206	1.461	0.791	3.362
1012.3	169.6	0.848	13.99	7.533	1.621	1.587	5.806	-0.262	2.000	2.262	0.675	1.207	1.469	0.794	3.352
1030.4	170.4	0.863	14.23	7.555	1.624	1.590	5.798	-0.270	2.000	2.269	0.680	1.205	1.475	0.795	3.338
1048.5	171.4	0.878	14.48	7.577	1.629	1.594	5.789	-0.279	2.000	2.279	0.685	1.203	1.482	0.797	3.328
1066.5	172.4	0.893	14.74	7.599	1.633	1.598	5.780	-0.288	1.999	2.287	0.689	1.200	1.488	0.799	3.318
1084.6	173.4	0.908	14.99	7.622	1.638	1.602	5.771	-0.297	1.998	2.295	0.693	1.197	1.494	0.801	3.311
1102.7	174.4	0.923	15.24	7.644	1.643	1.606	5.774	-0.293	2.010	2.303	0.697	1.207	1.500	0.803	3.303
1120.8	175.1	0.938	15.49	7.667	1.645	1.608	5.780	-0.288	2.022	2.311	0.703	1.219	1.507	0.804	3.286
1138.8	176.3	0.954	15.74	7.690	1.651	1.613	5.775	-0.293	2.028	2.321	0.708	1.221	1.515	0.806	3.277
1156.9	177.3	0.969	15.99	7.713	1.655	1.616	5.769	-0.299	2.030	2.329	0.713	1.222	1.521	0.808	3.268
1175.0	178.3	0.984	16.24	7.736	1.659	1.620	5.762	-0.306	2.031	2.337	0.717	1.221	1.527	0.810	3.258
1193.0	179.2	0.999	16.48	7.758	1.663	1.624	5.753	-0.315	2.031	2.346	0.722	1.219	1.534	0.812	3.249
1211.1	180.4	1.015	16.75	7.783	1.669	1.628	5.742	-0.326	2.028	2.354	0.726	1.214	1.540	0.814	3.243
1228.9	181.4	1.030	16.99	7.806	1.673	1.632	5.742	-0.326	2.037	2.363	0.730	1.221	1.547	0.816	3.235

Stantec

Consolidated Undrained Triaxial Compression
ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-102, 8.0'-8.5'
Description Lean Clay (CL), brown, moist, firm
Specimen Type Intact
Preparation Wet Mounting

Project No. 174316204
Lab ID 32
Test ID 32-A

Date Received 11/15/2017
Date Tested 12/08/2017

Specific Gravity 2.75
ASTM D 854, Dry

Liquid Limit ______
Plastic Limit ______
Plasticity Index ______

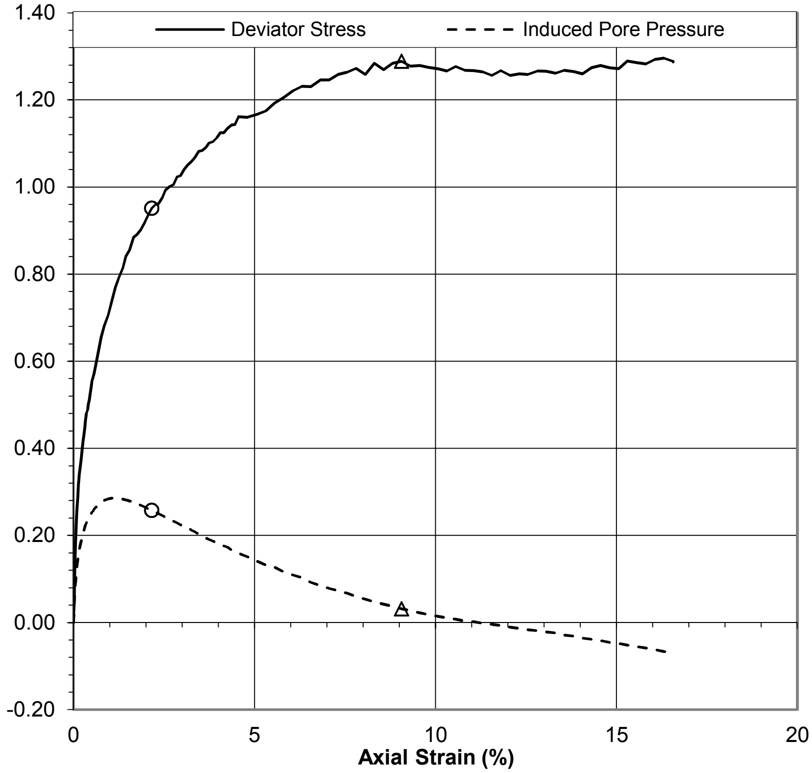
Target Test Parameters
Nominal Chamber Pressure (psi) 90
Nominal Back Pressure (psi) 81
Nominal Consolidation Pressure (psi) 9

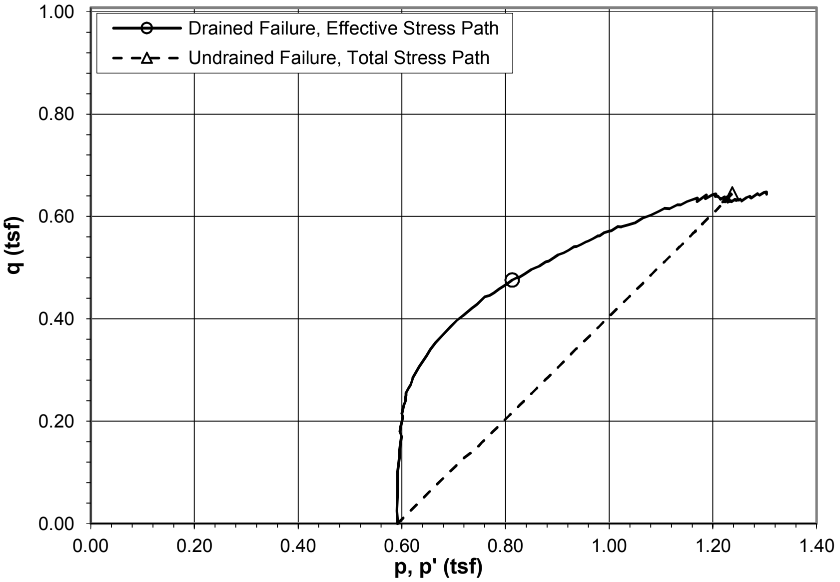
Saturation / Consolidation Results
Pore Pressure Parameter B 0.96
Measured Effective Consol. Stress (tsf) 0.594
Time to 50% Consolidation (min) 11.80
Actual Axial Strain Rate of Test (%/min) 0.025

Consolidated Specimen Conditions
Moist Unit Weight (pcf) 126.6
Moisture Content (%) 25.3
Dry Unit Weight (pcf) 101.1
Void Ratio 0.696
Degree of Saturation (%) 100.0

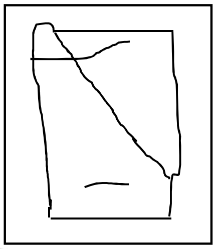
At Drained Failure
Failure Criterion: Max. Eff. Prin. Stress Ratio
Axial Strain (%) 2.159
Deviator Stress (tsf) 0.952
Induced Pore Pressure (tsf) 0.258
Minor Effective Stress, σ_3' (tsf) 0.337
Major Effective Stress, σ_1' (tsf) 1.289
Eff. Principal Stress Ratio, σ_1'/σ_3' 3.821
p' (tsf) 0.813
q (tsf) 0.476

At Consolidated Undrained Failure
Failure Criterion: Peak Deviator Stress
Axial Strain (%) 9.067
Deviator Stress (tsf) 1.288
Minor Principal Stress, σ_3 (tsf) 0.593
Major Principal Stress, σ_1 (tsf) 1.881
p (tsf) 1.237
q (tsf) 0.644





Failure Sketch



Comments ______

Reviewed KG

Stantec

Consolidated Undrained Triaxial Compression

ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-102, 8.0'-8.5'
Description Lean Clay (CL), brown, moist, firm

Project No. 174316204
Lab ID 32
Test ID 32-A

Initial Specimen Conditions		**Consolidated Specimen Conditions**		Specific Gravity	2.75
Average Height (in)	6.061	Calculated Height (in)	6.062	ASTM D 854, Dry	
Average Diameter (in)	2.857	Calculated Diameter (in)	2.854		
Calculated Area (in^2)	6.411	Calculated Area (in^2)	6.398	Liquid Limit	
Moist Weight (lb)	2.828	Moist Weight (lb)	2.842	Plastic Limit	
Moist Unit Weight (pcf)	125.8	Moist Unit Weight (pcf)	126.6	Plasticity Index	
Moisture Content (%)	24.7	Moisture Content (%)	25.3		
Dry Weight (lb)	2.269	Dry Weight (lb)	2.269		
Dry Unit Weight (pcf)	100.9	Dry Unit Weight (pcf)	101.1	Confining Stress	
Void Ratio	0.699	Void Ratio	0.696	σ_3 (tsf)	0.592
Degree of Saturation (%)	97.1	Degree of Saturation (%)	100.0		
				Effective Consolidation Stress	
				σ_3' (tsf)	0.592

Moisture contents obtained using partial specimen.
Specimen consolidated cross-sectional area determined using method B.
Membrane corrections have been applied,where Em = 200 lbf/in and t = 0.012 in.
All other tests performed in association with this specimen are reported separately.

Project: 174316204			Source: B-102, 8.0'-8.5'								Lab ID: 32		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
0.0	0.0	0.000	0.00	6.398	0.000	0.000	5.888	0.000	0.592	0.592	0.592	0.592	0.592	0.000	1.000
1.0	4.5	0.001	0.02	6.400	0.050	0.050	5.914	0.026	0.642	0.616	0.566	0.617	0.591	0.025	1.089
2.0	12.2	0.003	0.04	6.401	0.137	0.137	5.956	0.068	0.729	0.661	0.524	0.660	0.592	0.069	1.262
2.9	18.1	0.004	0.07	6.403	0.204	0.203	5.989	0.101	0.795	0.694	0.490	0.693	0.592	0.102	1.415
3.9	22.7	0.006	0.09	6.405	0.255	0.255	6.012	0.124	0.847	0.723	0.468	0.719	0.595	0.127	1.545
4.9	25.5	0.007	0.11	6.406	0.287	0.286	6.032	0.144	0.883	0.739	0.453	0.740	0.596	0.143	1.633
5.9	28.2	0.008	0.14	6.407	0.317	0.317	6.045	0.157	0.913	0.756	0.440	0.755	0.598	0.158	1.720
6.9	30.5	0.010	0.16	6.409	0.342	0.342	6.056	0.168	0.938	0.770	0.428	0.768	0.599	0.171	1.798
7.9	32.0	0.011	0.18	6.410	0.359	0.359	6.067	0.179	0.955	0.776	0.417	0.776	0.596	0.179	1.860
8.9	33.6	0.013	0.21	6.412	0.378	0.377	6.076	0.188	0.974	0.786	0.409	0.785	0.597	0.189	1.922
9.8	35.7	0.014	0.24	6.414	0.401	0.400	6.084	0.196	0.996	0.801	0.400	0.796	0.600	0.200	2.000
10.8	37.4	0.016	0.26	6.415	0.420	0.419	6.092	0.204	1.015	0.811	0.392	0.806	0.602	0.210	2.068
11.8	38.3	0.017	0.29	6.417	0.430	0.429	6.098	0.210	1.025	0.815	0.385	0.810	0.600	0.215	2.114
12.8	39.9	0.019	0.31	6.418	0.448	0.447	6.106	0.218	1.044	0.825	0.378	0.820	0.602	0.224	2.181
13.8	41.4	0.020	0.33	6.420	0.465	0.464	6.111	0.223	1.060	0.837	0.373	0.828	0.605	0.232	2.246
14.8	42.9	0.021	0.35	6.421	0.481	0.480	6.117	0.229	1.076	0.848	0.368	0.836	0.608	0.240	2.306
15.7	43.7	0.024	0.39	6.423	0.490	0.489	6.121	0.233	1.085	0.852	0.363	0.840	0.607	0.245	2.349
16.7	44.9	0.025	0.41	6.424	0.503	0.502	6.127	0.239	1.098	0.859	0.357	0.847	0.608	0.251	2.405
17.7	45.7	0.026	0.44	6.426	0.512	0.511	6.131	0.243	1.106	0.863	0.353	0.851	0.608	0.255	2.446
18.7	47.1	0.028	0.46	6.428	0.527	0.526	6.135	0.247	1.122	0.876	0.349	0.859	0.613	0.263	2.506
19.7	48.5	0.030	0.49	6.430	0.543	0.541	6.137	0.250	1.137	0.887	0.346	0.866	0.617	0.271	2.565
20.6	49.4	0.031	0.51	6.431	0.553	0.552	6.141	0.253	1.148	0.894	0.342	0.872	0.618	0.276	2.611
21.6	50.3	0.033	0.54	6.433	0.564	0.562	6.144	0.256	1.158	0.902	0.339	0.877	0.620	0.281	2.657
22.6	51.2	0.034	0.57	6.435	0.573	0.572	6.148	0.260	1.168	0.908	0.336	0.882	0.622	0.286	2.703
26.5	55.0	0.041	0.67	6.441	0.615	0.613	6.157	0.269	1.209	0.940	0.327	0.902	0.633	0.307	2.875
30.5	58.8	0.046	0.76	6.448	0.657	0.655	6.164	0.276	1.251	0.975	0.320	0.923	0.647	0.328	3.048
34.4	61.2	0.052	0.86	6.454	0.683	0.681	6.168	0.280	1.276	0.995	0.315	0.935	0.655	0.340	3.161
38.3	63.5	0.058	0.96	6.460	0.708	0.706	6.172	0.284	1.302	1.018	0.312	0.949	0.665	0.353	3.263
42.2	66.3	0.064	1.06	6.467	0.738	0.736	6.173	0.286	1.332	1.046	0.310	0.964	0.678	0.368	3.372
46.1	69.5	0.070	1.16	6.474	0.773	0.770	6.174	0.286	1.365	1.079	0.310	0.981	0.694	0.385	3.487
50.1	71.7	0.076	1.26	6.480	0.797	0.794	6.174	0.286	1.389	1.103	0.310	0.992	0.706	0.397	3.564
54.0	73.7	0.083	1.36	6.487	0.818	0.815	6.171	0.283	1.410	1.127	0.312	1.003	0.720	0.407	3.611
57.9	76.3	0.088	1.45	6.493	0.846	0.842	6.169	0.281	1.437	1.156	0.314	1.016	0.735	0.421	3.679
61.8	77.7	0.094	1.56	6.500	0.861	0.857	6.167	0.279	1.453	1.174	0.317	1.024	0.745	0.429	3.707
65.7	80.4	0.101	1.66	6.507	0.889	0.885	6.166	0.278	1.480	1.203	0.318	1.038	0.760	0.443	3.787
69.7	81.0	0.107	1.76	6.513	0.895	0.891	6.160	0.272	1.486	1.214	0.323	1.041	0.769	0.445	3.757
73.6	82.1	0.113	1.86	6.520	0.907	0.902	6.157	0.269	1.498	1.229	0.327	1.047	0.778	0.451	3.761
77.5	83.5	0.119	1.96	6.526	0.921	0.917	6.153	0.266	1.512	1.246	0.329	1.053	0.788	0.458	3.782
81.5	85.2	0.124	2.05	6.533	0.939	0.934	6.149	0.261	1.530	1.268	0.334	1.063	0.801	0.467	3.794

Project: 174316204			Source:	B-102, 8.0'-8.5'							Lab ID: 32		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
85.4	86.9	0.131	2.16	6.540	0.957	0.952	6.146	0.258	1.546	1.289	0.337	1.071	0.813	0.476	3.821
89.3	87.8	0.137	2.26	6.547	0.965	0.960	6.142	0.254	1.555	1.301	0.341	1.075	0.821	0.480	3.813
93.2	88.0	0.142	2.35	6.552	0.967	0.962	6.138	0.250	1.557	1.307	0.345	1.076	0.826	0.481	3.787
97.1	89.4	0.149	2.45	6.559	0.981	0.975	6.134	0.246	1.570	1.325	0.349	1.083	0.837	0.488	3.790
101.0	91.1	0.154	2.55	6.566	0.999	0.993	6.129	0.242	1.588	1.346	0.353	1.091	0.850	0.496	3.810
105.0	92.0	0.161	2.66	6.573	1.007	1.001	6.125	0.237	1.596	1.359	0.358	1.096	0.858	0.501	3.798
108.9	92.5	0.167	2.76	6.580	1.012	1.006	6.120	0.233	1.600	1.368	0.362	1.097	0.865	0.503	3.778
112.8	94.2	0.173	2.86	6.587	1.030	1.023	6.117	0.229	1.618	1.390	0.366	1.107	0.878	0.512	3.793
116.7	94.6	0.179	2.96	6.594	1.033	1.026	6.112	0.224	1.621	1.397	0.371	1.108	0.884	0.513	3.769
120.7	96.0	0.185	3.05	6.600	1.048	1.040	6.109	0.221	1.636	1.415	0.375	1.115	0.895	0.520	3.777
124.6	97.1	0.191	3.15	6.607	1.058	1.050	6.107	0.219	1.646	1.427	0.377	1.121	0.902	0.525	3.789
128.5	97.9	0.198	3.26	6.614	1.066	1.058	6.100	0.212	1.653	1.441	0.383	1.124	0.912	0.529	3.763
132.4	98.9	0.203	3.35	6.620	1.076	1.068	6.096	0.208	1.663	1.455	0.387	1.129	0.921	0.534	3.757
136.4	100.3	0.209	3.45	6.627	1.090	1.081	6.091	0.203	1.676	1.473	0.391	1.135	0.932	0.541	3.763
140.3	100.6	0.215	3.55	6.634	1.092	1.084	6.087	0.199	1.679	1.479	0.396	1.137	0.937	0.542	3.739
144.2	101.4	0.222	3.65	6.641	1.100	1.091	6.082	0.195	1.686	1.491	0.400	1.140	0.946	0.545	3.726
148.1	102.5	0.227	3.75	6.647	1.110	1.101	6.079	0.191	1.696	1.505	0.404	1.146	0.955	0.550	3.723
152.0	102.9	0.234	3.85	6.655	1.114	1.104	6.075	0.187	1.699	1.512	0.408	1.147	0.960	0.552	3.710
156.0	103.9	0.240	3.96	6.662	1.123	1.113	6.071	0.183	1.708	1.525	0.412	1.152	0.969	0.557	3.701
159.9	105.1	0.246	4.05	6.669	1.134	1.125	6.067	0.179	1.719	1.540	0.416	1.157	0.978	0.562	3.705
163.8	105.2	0.252	4.15	6.676	1.135	1.125	6.064	0.176	1.719	1.543	0.419	1.157	0.981	0.562	3.685
167.7	106.3	0.258	4.26	6.683	1.145	1.135	6.061	0.173	1.730	1.557	0.422	1.162	0.989	0.568	3.691
171.6	107.1	0.264	4.36	6.690	1.153	1.142	6.055	0.167	1.737	1.570	0.428	1.166	0.999	0.571	3.665
175.6	107.4	0.271	4.46	6.697	1.155	1.144	6.050	0.162	1.738	1.576	0.432	1.166	1.004	0.572	3.647
179.5	109.1	0.276	4.56	6.704	1.172	1.161	6.047	0.159	1.756	1.597	0.436	1.175	1.016	0.581	3.664
189.3	109.3	0.291	4.81	6.721	1.171	1.160	6.039	0.151	1.754	1.603	0.444	1.175	1.023	0.580	3.615
199.1	110.3	0.308	5.07	6.740	1.179	1.166	6.029	0.141	1.761	1.620	0.454	1.178	1.037	0.583	3.572
208.9	111.4	0.322	5.32	6.758	1.187	1.174	6.020	0.132	1.769	1.637	0.462	1.181	1.049	0.587	3.540
218.7	113.5	0.337	5.56	6.775	1.206	1.193	6.015	0.127	1.787	1.660	0.467	1.191	1.064	0.596	3.552
228.5	115.1	0.352	5.81	6.793	1.220	1.205	6.004	0.116	1.800	1.684	0.478	1.197	1.081	0.603	3.521
238.3	116.9	0.368	6.07	6.812	1.235	1.221	5.997	0.109	1.815	1.706	0.485	1.205	1.096	0.610	3.515
248.1	118.2	0.383	6.31	6.829	1.247	1.231	5.991	0.103	1.826	1.722	0.491	1.210	1.107	0.616	3.508
257.9	118.6	0.398	6.56	6.848	1.246	1.231	5.980	0.093	1.824	1.732	0.501	1.209	1.116	0.615	3.456
267.7	120.4	0.413	6.82	6.867	1.262	1.246	5.973	0.085	1.839	1.754	0.508	1.216	1.131	0.623	3.451
277.5	120.8	0.428	7.06	6.885	1.263	1.246	5.966	0.079	1.839	1.761	0.515	1.217	1.138	0.623	3.418
287.4	122.3	0.443	7.31	6.903	1.276	1.258	5.961	0.073	1.852	1.779	0.521	1.223	1.150	0.629	3.415
297.1	123.2	0.458	7.56	6.922	1.282	1.264	5.955	0.067	1.857	1.790	0.526	1.226	1.158	0.632	3.400
307.0	124.5	0.473	7.81	6.940	1.291	1.272	5.948	0.060	1.866	1.806	0.534	1.230	1.170	0.636	3.384
316.8	123.5	0.489	8.06	6.959	1.278	1.258	5.941	0.053	1.851	1.798	0.540	1.222	1.169	0.629	3.329
326.6	126.4	0.504	8.32	6.979	1.304	1.284	5.935	0.047	1.877	1.829	0.545	1.235	1.187	0.642	3.354
336.4	125.4	0.520	8.57	6.998	1.290	1.270	5.930	0.043	1.863	1.820	0.551	1.228	1.186	0.635	3.305
346.2	127.2	0.534	8.81	7.017	1.305	1.284	5.925	0.037	1.877	1.840	0.556	1.235	1.198	0.642	3.308
356.0	128.0	0.550	9.07	7.036	1.310	1.288	5.920	0.032	1.881	1.850	0.562	1.237	1.206	0.644	3.294
365.8	127.4	0.564	9.31	7.055	1.300	1.278	5.915	0.027	1.870	1.843	0.566	1.232	1.204	0.639	3.259
375.6	128.0	0.580	9.57	7.075	1.302	1.279	5.910	0.022	1.871	1.849	0.570	1.232	1.209	0.639	3.244
385.4	128.0	0.595	9.82	7.095	1.299	1.275	5.906	0.018	1.867	1.849	0.574	1.230	1.212	0.637	3.220
395.2	128.0	0.610	10.07	7.115	1.296	1.271	5.902	0.014	1.864	1.849	0.578	1.228	1.214	0.636	3.200
405.0	127.9	0.625	10.32	7.134	1.291	1.266	5.898	0.011	1.858	1.848	0.582	1.225	1.215	0.633	3.177
414.8	129.4	0.640	10.56	7.154	1.302	1.277	5.895	0.007	1.868	1.861	0.584	1.230	1.222	0.638	3.186
424.6	129.0	0.655	10.81	7.174	1.294	1.268	5.892	0.004	1.859	1.856	0.588	1.225	1.222	0.634	3.158
434.4	129.3	0.670	11.06	7.194	1.294	1.267	5.890	0.002	1.858	1.857	0.590	1.225	1.223	0.633	3.148
444.2	129.4	0.686	11.31	7.214	1.292	1.264	5.886	-0.002	1.856	1.857	0.593	1.223	1.225	0.632	3.132
454.0	129.1	0.701	11.56	7.234	1.284	1.256	5.884	-0.004	1.847	1.852	0.595	1.219	1.223	0.628	3.111
463.8	130.6	0.716	11.81	7.255	1.296	1.267	5.881	-0.007	1.858	1.866	0.598	1.225	1.232	0.634	3.119
473.6	129.9	0.731	12.06	7.276	1.285	1.256	5.877	-0.011	1.846	1.857	0.601	1.218	1.229	0.628	3.091
483.5	130.7	0.747	12.32	7.297	1.290	1.260	5.874	-0.014	1.850	1.864	0.604	1.220	1.234	0.630	3.086
493.2	131.0	0.761	12.55	7.317	1.289	1.258	5.872	-0.016	1.849	1.865	0.607	1.220	1.236	0.629	3.073
503.0	132.2	0.777	12.82	7.339	1.297	1.266	5.869	-0.019	1.857	1.876	0.609	1.223	1.242	0.633	3.079
512.9	132.6	0.792	13.06	7.360	1.298	1.266	5.866	-0.022	1.856	1.878	0.612	1.223	1.245	0.633	3.068
522.7	132.6	0.808	13.32	7.382	1.294	1.261	5.864	-0.024	1.851	1.875	0.614	1.221	1.245	0.631	3.054
532.5	133.7	0.822	13.56	7.402	1.301	1.268	5.859	-0.029	1.857	1.886	0.619	1.223	1.253	0.634	3.050
542.3	133.9	0.838	13.82	7.425	1.299	1.265	5.857	-0.031	1.856	1.887	0.621	1.223	1.254	0.633	3.036
552.1	133.8	0.852	14.06	7.445	1.294	1.260	5.853	-0.035	1.850	1.885	0.625	1.220	1.255	0.630	3.016
561.9	135.7	0.868	14.31	7.467	1.309	1.274	5.850	-0.038	1.864	1.902	0.628	1.227	1.265	0.637	3.027
571.7	136.7	0.883	14.56	7.489	1.314	1.279	5.846	-0.042	1.869	1.911	0.631	1.229	1.271	0.640	3.026
581.5	136.6	0.898	14.81	7.511	1.310	1.274	5.842	-0.046	1.863	1.909	0.635	1.226	1.272	0.637	3.006
591.3	136.8	0.913	15.07	7.533	1.308	1.271	5.840	-0.048	1.861	1.909	0.638	1.226	1.274	0.636	2.993
601.1	139.1	0.928	15.30	7.555	1.326	1.289	5.836	-0.052	1.879	1.931	0.642	1.234	1.286	0.645	3.009
610.9	139.2	0.943	15.56	7.577	1.323	1.285	5.833	-0.055	1.875	1.930	0.645	1.232	1.287	0.643	2.993

Project: 174316204			Source: B-102, 8.0'-8.5'								Lab ID: 32		Test ID			
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
620.7	139.4	0.959	15.82	7.600	1.321	1.282	5.829	-0.059	1.872	1.931	0.648	1.231	1.290	0.641	2.978
630.5	141.0	0.974	16.06	7.623	1.332	1.293	5.826	-0.062	1.882	1.944	0.651	1.235	1.298	0.647	2.986
640.3	141.8	0.989	16.31	7.645	1.335	1.296	5.822	-0.066	1.885	1.951	0.655	1.237	1.303	0.648	2.977
650.1	141.5	1.004	16.57	7.669	1.328	1.288	5.819	-0.069	1.878	1.947	0.659	1.234	1.303	0.644	2.954
650.3	141.4	1.004	16.57	7.669	1.327	1.287	5.818	-0.070	1.877	1.947	0.660	1.233	1.303	0.644	2.950

Stantec

Consolidated Undrained Triaxial Compression

ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-102, 15.0'-15.5'
Description Silty Clay with Sand (CL-ML), dark brown, wet, soft
Specimen Type Intact
Preparation Wet Mounting

Project No. 174316204
Lab ID 34A
Test ID 34A-A

Date Received 11/15/2017
Date Tested 12/07/2017

Specific Gravity 2.75
ASTM D 854, Dry

Liquid Limit 22
Plastic Limit 15
Plasticity Index 7
ASTM D 4318

Target Test Parameters

Nominal Chamber Pressure (psi) 90
Nominal Back Pressure (psi) 70
Nominal Consolidation Pressure (psi) 20

Saturation / Consolidation Results

Pore Pressure Parameter B 0.95
Measured Effective Consol. Stress (tsf) 1.433
Time to 50% Consolidation (min) 5.10
Actual Axial Strain Rate of Test (%/min) 0.057

Consolidated Specimen Conditions

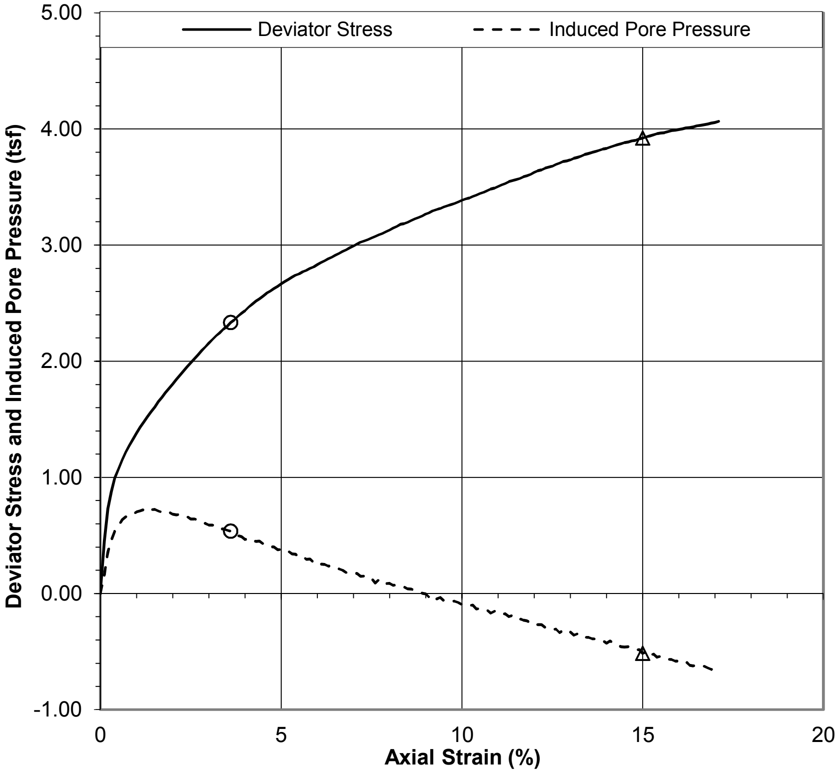
Moist Unit Weight (pcf) 134.3
Moisture Content (%) 18.7
Dry Unit Weight (pcf) 113.2
Void Ratio 0.514
Degree of Saturation (%) 100.0

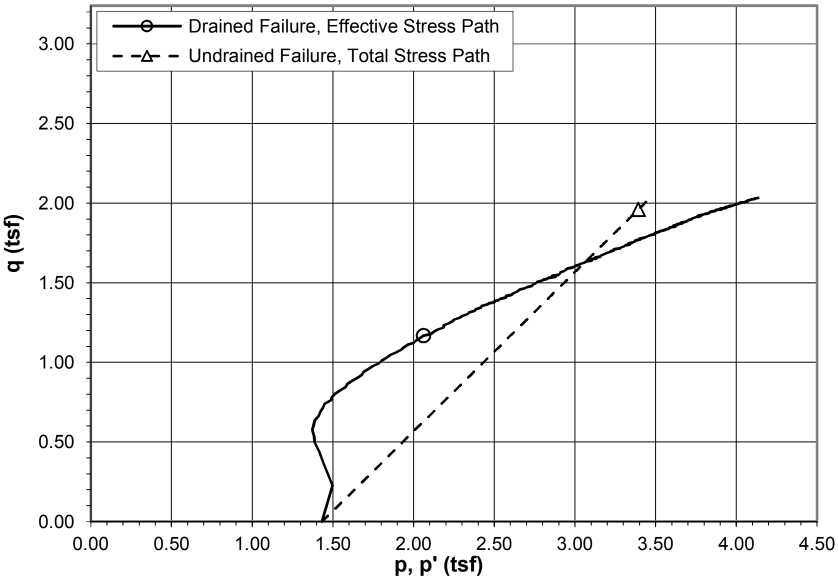
At Drained Failure

Failure Criterion: Max. Eff. Prin. Stress Ratio
Axial Strain (%) 3.603
Deviator Stress (tsf) 2.333
Induced Pore Pressure (tsf) 0.538
Minor Effective Stress, σ_3' (tsf) 0.896
Major Effective Stress, σ_1' (tsf) 3.229
Eff. Principal Stress Ratio, σ_1'/σ_3' 3.605
p' (tsf) 2.062
q (tsf) 1.167

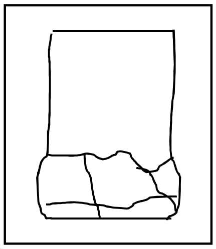
At Consolidated Undrained Failure

Failure Criterion: 15% Axial Strain
Axial Strain (%) 15.000
Deviator Stress (tsf) 3.920
Minor Principal Stress, σ_3 (tsf) 1.433
Major Principal Stress, σ_1 (tsf) 5.353
p (tsf) 3.393
q (tsf) 1.960





Failure Sketch



Comments

Reviewed KG

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Stantec Consulting Services Inc.
Lexington, Kentucky

Reported By: KG
Report Date: 12/22/2017

Stantec

Consolidated Undrained Triaxial Compression

ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-102, 15.0'-15.5'
Description Silty Clay with Sand (CL-ML), dark brown, wet, soft

Project No. 174316204
Lab ID 34A
Test ID 34A-A

Initial Specimen Conditions		Consolidated Specimen Conditions			
Average Height (in)	5.856	Calculated Height (in)	5.840	Specific Gravity	2.75
Average Diameter (in)	2.776	Calculated Diameter (in)	2.788	ASTM D 854, Dry	
Calculated Area (in^2)	6.051	Calculated Area (in^2)	6.103	Liquid Limit	22
Moist Weight (lb)	2.846	Moist Weight (lb)	2.771	Plastic Limit	15
Moist Unit Weight (pcf)	138.8	Moist Unit Weight (pcf)	134.3	Plasticity Index	7
Moisture Content (%)	21.9	Moisture Content (%)	18.7	ASTM D 4318	
Dry Weight (lb)	2.334	Dry Weight (lb)	2.334		
Dry Unit Weight (pcf)	113.8	Dry Unit Weight (pcf)	113.2	Confining Stress	
Void Ratio	0.506	Void Ratio	0.514	σ_3 (tsf)	1.433
Degree of Saturation (%)	119.2	Degree of Saturation (%)	100.0		
				Effective Consolidation Stress	
				σ_3' (tsf)	1.433

Moisture contents obtained using partial specimen.
Specimen consolidated cross-sectional area determined using method B.
Membrane corrections have been applied,where Em = 200 lbf/in and t = 0.012 in.
All other tests performed in association with this specimen are reported separately.

Project: 174316204 Source: B-102, 15.0'-15.5' Lab ID: 34A Test ID

Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
0.0	0.0	0.000	0.00	6.103	0.000	0.000	5.047	0.000	1.433	1.433	1.433	1.433	1.433	0.000	1.000
1.8	38.2	0.006	0.10	6.110	0.451	0.450	5.206	0.159	1.883	1.724	1.274	1.658	1.499	0.225	1.353
3.6	62.0	0.012	0.20	6.116	0.730	0.729	5.401	0.354	2.163	1.809	1.079	1.798	1.444	0.365	1.676
5.2	74.8	0.018	0.30	6.122	0.880	0.879	5.505	0.458	2.312	1.854	0.975	1.873	1.414	0.440	1.902
6.9	84.7	0.024	0.40	6.128	0.995	0.994	5.589	0.542	2.427	1.885	0.891	1.930	1.388	0.497	2.116
8.5	91.8	0.030	0.51	6.134	1.078	1.076	5.634	0.587	2.509	1.923	0.846	1.971	1.385	0.538	2.272
10.3	98.4	0.035	0.60	6.140	1.153	1.152	5.682	0.636	2.585	1.949	0.798	2.009	1.373	0.576	2.444
12.0	104.0	0.041	0.70	6.146	1.218	1.216	5.707	0.660	2.649	1.989	0.773	2.041	1.381	0.608	2.574
13.6	108.8	0.047	0.80	6.153	1.273	1.271	5.728	0.682	2.705	2.023	0.752	2.069	1.387	0.636	2.692
15.4	114.1	0.053	0.90	6.159	1.334	1.332	5.733	0.686	2.765	2.079	0.747	2.099	1.413	0.666	2.783
17.1	118.7	0.058	1.00	6.165	1.386	1.384	5.748	0.701	2.817	2.116	0.732	2.125	1.424	0.692	2.890
18.8	122.9	0.064	1.10	6.171	1.434	1.431	5.757	0.711	2.864	2.154	0.723	2.149	1.438	0.716	2.981
20.4	127.1	0.070	1.20	6.178	1.481	1.478	5.770	0.723	2.912	2.188	0.710	2.172	1.449	0.739	3.083
22.1	131.2	0.076	1.30	6.184	1.528	1.525	5.754	0.707	2.958	2.250	0.726	2.195	1.488	0.762	3.100
23.7	134.8	0.082	1.40	6.190	1.568	1.565	5.768	0.721	2.998	2.277	0.712	2.215	1.494	0.782	3.197
25.4	138.5	0.088	1.50	6.196	1.609	1.606	5.771	0.724	3.039	2.315	0.709	2.236	1.512	0.803	3.264
27.1	142.8	0.094	1.60	6.203	1.657	1.653	5.758	0.711	3.086	2.376	0.722	2.260	1.549	0.827	3.288
28.7	145.9	0.099	1.70	6.209	1.692	1.688	5.746	0.700	3.121	2.421	0.734	2.277	1.577	0.844	3.301
30.4	149.6	0.105	1.80	6.215	1.733	1.729	5.756	0.709	3.162	2.453	0.724	2.298	1.589	0.865	3.387
32.1	153.3	0.111	1.90	6.222	1.774	1.769	5.746	0.699	3.202	2.503	0.734	2.318	1.619	0.884	3.409
33.8	156.6	0.117	2.00	6.228	1.810	1.805	5.731	0.684	3.238	2.554	0.749	2.336	1.651	0.902	3.410
35.5	160.0	0.123	2.10	6.234	1.848	1.843	5.723	0.676	3.276	2.599	0.757	2.354	1.678	0.921	3.435
37.1	163.6	0.129	2.20	6.241	1.887	1.881	5.729	0.682	3.315	2.632	0.751	2.374	1.691	0.941	3.506
38.8	167.0	0.134	2.30	6.247	1.924	1.918	5.719	0.672	3.352	2.680	0.761	2.392	1.720	0.959	3.521
40.5	170.3	0.140	2.40	6.253	1.960	1.954	5.709	0.662	3.388	2.725	0.771	2.410	1.748	0.977	3.535
42.2	173.3	0.146	2.50	6.260	1.993	1.987	5.689	0.642	3.420	2.779	0.791	2.427	1.785	0.994	3.511
43.8	176.4	0.152	2.60	6.266	2.027	2.021	5.689	0.642	3.454	2.812	0.791	2.444	1.801	1.010	3.555
45.6	179.6	0.158	2.70	6.273	2.061	2.054	5.678	0.631	3.488	2.857	0.802	2.460	1.830	1.027	3.561
47.3	183.1	0.164	2.80	6.279	2.100	2.093	5.670	0.623	3.526	2.903	0.810	2.480	1.857	1.046	3.582
48.9	186.1	0.170	2.90	6.286	2.132	2.125	5.650	0.603	3.558	2.955	0.830	2.496	1.893	1.062	3.559
50.7	189.3	0.175	3.00	6.292	2.166	2.158	5.636	0.589	3.591	3.003	0.844	2.512	1.924	1.079	3.556
52.3	192.0	0.181	3.10	6.299	2.195	2.187	5.635	0.588	3.620	3.032	0.845	2.527	1.939	1.094	3.588
54.1	195.1	0.187	3.20	6.305	2.228	2.221	5.627	0.581	3.654	3.073	0.853	2.543	1.963	1.110	3.604
55.7	197.5	0.193	3.30	6.312	2.253	2.245	5.602	0.555	3.678	3.123	0.878	2.555	2.000	1.122	3.557
57.4	200.3	0.199	3.40	6.318	2.283	2.274	5.602	0.555	3.707	3.153	0.878	2.570	2.015	1.137	3.589
59.2	202.9	0.205	3.50	6.325	2.310	2.301	5.592	0.545	3.735	3.189	0.888	2.584	2.038	1.151	3.592
60.9	206.0	0.210	3.60	6.331	2.342	2.333	5.584	0.538	3.767	3.229	0.896	2.600	2.062	1.167	3.605
62.6	208.2	0.216	3.71	6.338	2.366	2.356	5.551	0.504	3.789	3.286	0.929	2.611	2.108	1.178	3.535
64.3	211.0	0.222	3.80	6.344	2.394	2.385	5.546	0.500	3.818	3.318	0.934	2.626	2.126	1.192	3.554

Project: 174316204			Source:	B-102, 15.0'-15.5'							Lab ID: 34A		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in²)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
66.0	213.7	0.228	3.90	6.351	2.423	2.413	5.538	0.491	3.846	3.355	0.942	2.640	2.149	1.207	3.562
67.7	215.9	0.234	4.00	6.358	2.445	2.435	5.512	0.466	3.869	3.403	0.968	2.651	2.185	1.218	3.517
69.4	219.0	0.239	4.10	6.364	2.477	2.467	5.524	0.477	3.900	3.423	0.956	2.667	2.189	1.233	3.581
71.2	221.2	0.245	4.20	6.371	2.500	2.489	5.509	0.462	3.922	3.460	0.971	2.678	2.216	1.245	3.563
72.9	224.1	0.251	4.30	6.378	2.530	2.519	5.494	0.448	3.952	3.505	0.986	2.693	2.245	1.260	3.556
74.6	225.9	0.257	4.40	6.384	2.547	2.537	5.497	0.450	3.970	3.519	0.983	2.701	2.251	1.268	3.581
76.4	228.3	0.263	4.50	6.391	2.572	2.561	5.475	0.428	3.994	3.566	1.005	2.714	2.286	1.280	3.547
78.1	230.8	0.269	4.60	6.398	2.597	2.586	5.469	0.422	4.019	3.597	1.011	2.726	2.304	1.293	3.558
79.8	232.6	0.275	4.70	6.404	2.615	2.604	5.448	0.401	4.037	3.635	1.032	2.735	2.334	1.302	3.523
81.5	234.8	0.280	4.80	6.411	2.637	2.625	5.448	0.402	4.058	3.657	1.032	2.746	2.344	1.313	3.545
83.2	236.9	0.286	4.90	6.418	2.658	2.646	5.425	0.378	4.079	3.701	1.055	2.756	2.378	1.323	3.508
85.0	239.0	0.292	5.00	6.425	2.679	2.666	5.427	0.380	4.099	3.719	1.053	2.766	2.386	1.333	3.533
86.7	241.0	0.298	5.10	6.431	2.698	2.686	5.407	0.360	4.119	3.759	1.073	2.776	2.416	1.343	3.503
88.4	243.0	0.304	5.20	6.438	2.718	2.705	5.411	0.364	4.138	3.774	1.069	2.786	2.421	1.353	3.531
90.2	245.0	0.310	5.30	6.445	2.738	2.724	5.387	0.340	4.158	3.818	1.093	2.795	2.455	1.362	3.492
91.9	246.8	0.315	5.40	6.452	2.754	2.741	5.385	0.338	4.174	3.836	1.095	2.804	2.466	1.371	3.503
93.6	248.1	0.321	5.50	6.459	2.765	2.752	5.356	0.310	4.185	3.875	1.124	2.809	2.499	1.376	3.449
95.4	250.1	0.327	5.60	6.466	2.785	2.771	5.364	0.317	4.204	3.888	1.116	2.819	2.502	1.386	3.482
97.1	251.4	0.333	5.70	6.472	2.796	2.782	5.343	0.296	4.215	3.920	1.137	2.824	2.529	1.391	3.446
98.8	253.2	0.339	5.80	6.479	2.814	2.799	5.344	0.297	4.232	3.935	1.136	2.833	2.536	1.400	3.464
100.5	254.7	0.345	5.90	6.486	2.827	2.813	5.314	0.267	4.246	3.978	1.166	2.839	2.572	1.406	3.413
102.3	256.8	0.351	6.00	6.493	2.848	2.833	5.323	0.276	4.266	3.990	1.157	2.850	2.573	1.416	3.448
104.0	258.4	0.356	6.10	6.500	2.863	2.847	5.299	0.253	4.281	4.028	1.181	2.857	2.604	1.424	3.412
105.7	260.3	0.362	6.20	6.507	2.880	2.865	5.296	0.249	4.298	4.049	1.184	2.866	2.616	1.432	3.420
107.4	262.0	0.368	6.30	6.514	2.896	2.881	5.285	0.238	4.314	4.076	1.195	2.873	2.636	1.440	3.410
109.2	263.6	0.374	6.40	6.521	2.911	2.895	5.283	0.236	4.328	4.092	1.197	2.881	2.645	1.448	3.418
110.9	265.4	0.380	6.50	6.528	2.927	2.911	5.281	0.234	4.344	4.110	1.199	2.889	2.654	1.455	3.428
112.6	267.2	0.385	6.60	6.535	2.944	2.927	5.258	0.211	4.360	4.149	1.222	2.897	2.685	1.464	3.396
114.4	269.0	0.391	6.70	6.542	2.961	2.945	5.248	0.202	4.378	4.176	1.232	2.905	2.704	1.472	3.391
116.1	270.6	0.397	6.80	6.549	2.975	2.958	5.228	0.181	4.392	4.210	1.252	2.912	2.731	1.479	3.363
117.8	272.7	0.403	6.90	6.556	2.995	2.978	5.230	0.183	4.411	4.228	1.250	2.922	2.739	1.489	3.383
119.6	274.3	0.409	7.00	6.563	3.009	2.991	5.220	0.173	4.425	4.252	1.260	2.929	2.756	1.496	3.374
121.3	276.1	0.415	7.10	6.570	3.026	3.008	5.221	0.174	4.441	4.267	1.259	2.937	2.763	1.504	3.390
123.1	278.0	0.421	7.20	6.577	3.043	3.025	5.195	0.148	4.459	4.311	1.285	2.946	2.798	1.513	3.354
124.8	279.3	0.426	7.30	6.584	3.054	3.036	5.197	0.150	4.469	4.319	1.283	2.951	2.801	1.518	3.367
126.5	280.7	0.432	7.40	6.591	3.066	3.047	5.178	0.131	4.481	4.349	1.302	2.957	2.825	1.524	3.341
128.2	282.2	0.438	7.50	6.598	3.079	3.060	5.177	0.130	4.493	4.363	1.303	2.963	2.833	1.530	3.349
130.0	283.7	0.444	7.60	6.605	3.092	3.074	5.137	0.090	4.507	4.417	1.343	2.970	2.880	1.537	3.288
131.7	285.4	0.450	7.70	6.613	3.107	3.088	5.164	0.117	4.521	4.404	1.316	2.977	2.860	1.544	3.347
133.5	286.8	0.456	7.80	6.620	3.119	3.100	5.132	0.085	4.533	4.448	1.348	2.983	2.898	1.550	3.299
135.2	288.6	0.461	7.90	6.627	3.136	3.116	5.131	0.084	4.549	4.465	1.349	2.991	2.907	1.558	3.309
137.0	290.3	0.467	8.00	6.634	3.150	3.130	5.135	0.088	4.564	4.476	1.345	2.998	2.911	1.565	3.327
138.7	292.0	0.473	8.10	6.641	3.166	3.146	5.119	0.072	4.579	4.507	1.361	3.006	2.934	1.573	3.312
140.5	293.8	0.479	8.20	6.649	3.181	3.161	5.120	0.073	4.594	4.521	1.360	3.014	2.941	1.580	3.324
142.2	295.7	0.485	8.30	6.656	3.199	3.178	5.115	0.068	4.612	4.543	1.365	3.022	2.954	1.589	3.329
144.0	296.7	0.491	8.40	6.663	3.206	3.185	5.105	0.059	4.618	4.560	1.375	3.026	2.967	1.592	3.317
145.8	298.1	0.496	8.50	6.670	3.218	3.197	5.088	0.041	4.630	4.589	1.392	3.032	2.991	1.599	3.296
147.5	299.9	0.502	8.60	6.678	3.234	3.213	5.085	0.038	4.646	4.608	1.395	3.039	3.002	1.606	3.303
149.3	301.5	0.508	8.70	6.685	3.247	3.225	5.068	0.021	4.659	4.638	1.412	3.046	3.025	1.613	3.284
151.1	302.9	0.514	8.80	6.692	3.259	3.237	5.066	0.019	4.670	4.651	1.414	3.052	3.033	1.619	3.289
152.9	304.6	0.520	8.90	6.700	3.274	3.252	5.049	0.003	4.685	4.682	1.431	3.059	3.056	1.626	3.273
154.7	306.3	0.526	9.00	6.707	3.289	3.266	5.043	-0.004	4.699	4.704	1.437	3.066	3.071	1.633	3.272
156.5	307.9	0.532	9.10	6.714	3.302	3.279	5.014	-0.032	4.712	4.745	1.466	3.073	3.105	1.639	3.237
158.2	309.7	0.537	9.20	6.722	3.317	3.294	5.033	-0.014	4.727	4.741	1.447	3.080	3.094	1.647	3.276
160.0	311.1	0.543	9.30	6.729	3.329	3.306	5.000	-0.047	4.739	4.786	1.480	3.086	3.133	1.653	3.234
161.8	312.4	0.549	9.40	6.737	3.338	3.315	5.013	-0.034	4.748	4.783	1.467	3.091	3.125	1.658	3.259
163.6	314.0	0.555	9.50	6.744	3.352	3.328	4.986	-0.060	4.761	4.822	1.494	3.097	3.158	1.664	3.228
165.3	315.3	0.561	9.60	6.751	3.363	3.339	4.989	-0.058	4.772	4.830	1.491	3.103	3.161	1.670	3.240
167.1	316.5	0.567	9.70	6.759	3.372	3.348	4.986	-0.061	4.781	4.842	1.494	3.107	3.168	1.674	3.241
168.9	317.9	0.572	9.80	6.767	3.383	3.358	4.981	-0.066	4.791	4.858	1.499	3.112	3.179	1.679	3.240
170.6	319.5	0.578	9.90	6.774	3.396	3.372	4.969	-0.078	4.805	4.883	1.511	3.119	3.197	1.686	3.232
172.4	321.3	0.584	10.00	6.782	3.411	3.386	4.953	-0.094	4.820	4.914	1.527	3.126	3.221	1.693	3.217
174.2	322.7	0.590	10.10	6.789	3.423	3.398	4.958	-0.089	4.831	4.920	1.522	3.132	3.221	1.699	3.232
175.9	323.9	0.596	10.20	6.797	3.431	3.406	4.944	-0.103	4.839	4.942	1.536	3.136	3.239	1.703	3.217
177.7	325.6	0.602	10.30	6.804	3.446	3.420	4.948	-0.099	4.853	4.952	1.532	3.143	3.242	1.710	3.233
179.5	327.1	0.607	10.40	6.812	3.457	3.431	4.915	-0.132	4.864	4.996	1.565	3.149	3.280	1.716	3.193
181.3	328.7	0.613	10.50	6.819	3.470	3.444	4.916	-0.131	4.878	5.008	1.564	3.155	3.286	1.722	3.202
183.1	330.2	0.619	10.60	6.827	3.482	3.456	4.903	-0.144	4.889	5.033	1.577	3.161	3.305	1.728	3.191
184.9	331.9	0.625	10.70	6.835	3.496	3.470	4.904	-0.143	4.903	5.045	1.576	3.168	3.311	1.735	3.202

Project: 174316204			Source: B-102, 15.0'-15.5'								Lab ID: 34A		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
186.7	333.5	0.631	10.80	6.842	3.509	3.482	4.879	-0.167	4.916	5.083	1.601	3.174	3.342	1.741	3.176
188.5	334.8	0.637	10.90	6.850	3.519	3.492	4.896	-0.151	4.925	5.076	1.584	3.179	3.330	1.746	3.204
190.3	336.5	0.642	11.00	6.858	3.533	3.505	4.876	-0.171	4.938	5.110	1.604	3.186	3.357	1.753	3.185
192.1	338.1	0.648	11.10	6.865	3.546	3.518	4.868	-0.179	4.951	5.130	1.612	3.192	3.371	1.759	3.182
193.9	339.7	0.654	11.20	6.873	3.558	3.530	4.872	-0.175	4.963	5.138	1.608	3.198	3.373	1.765	3.196
195.7	341.6	0.660	11.30	6.881	3.574	3.546	4.847	-0.200	4.979	5.179	1.633	3.206	3.406	1.773	3.172
197.5	342.8	0.666	11.40	6.889	3.583	3.555	4.859	-0.188	4.988	5.176	1.621	3.211	3.399	1.777	3.192
199.3	344.1	0.672	11.50	6.896	3.592	3.564	4.831	-0.216	4.997	5.212	1.649	3.215	3.431	1.782	3.161
201.1	345.4	0.677	11.60	6.904	3.602	3.573	4.829	-0.218	5.006	5.224	1.651	3.220	3.437	1.787	3.165
202.9	347.3	0.683	11.70	6.912	3.617	3.588	4.817	-0.230	5.021	5.252	1.663	3.227	3.458	1.794	3.157
204.7	348.4	0.689	11.80	6.920	3.625	3.596	4.812	-0.235	5.029	5.264	1.668	3.231	3.466	1.798	3.155
206.5	350.2	0.695	11.90	6.928	3.639	3.610	4.789	-0.258	5.043	5.301	1.691	3.238	3.496	1.805	3.135
208.3	352.1	0.701	12.00	6.936	3.655	3.625	4.796	-0.251	5.058	5.309	1.684	3.246	3.496	1.813	3.153
210.1	353.8	0.707	12.10	6.944	3.668	3.638	4.778	-0.269	5.071	5.340	1.702	3.252	3.521	1.819	3.138
212.0	355.1	0.713	12.20	6.952	3.678	3.647	4.780	-0.267	5.080	5.347	1.700	3.257	3.523	1.824	3.146
213.8	356.7	0.718	12.30	6.960	3.691	3.660	4.753	-0.294	5.093	5.387	1.727	3.263	3.557	1.830	3.119
215.6	358.1	0.724	12.40	6.967	3.701	3.670	4.752	-0.294	5.103	5.397	1.728	3.268	3.562	1.835	3.124
217.5	359.4	0.730	12.50	6.975	3.709	3.678	4.737	-0.310	5.112	5.421	1.743	3.272	3.582	1.839	3.111
219.3	361.3	0.736	12.60	6.983	3.725	3.694	4.741	-0.306	5.127	5.433	1.739	3.280	3.586	1.847	3.124
221.1	363.0	0.742	12.70	6.991	3.738	3.707	4.710	-0.336	5.140	5.476	1.770	3.286	3.623	1.853	3.095
222.9	364.6	0.748	12.80	6.999	3.750	3.718	4.729	-0.318	5.152	5.469	1.751	3.292	3.610	1.859	3.124
224.7	365.6	0.753	12.90	7.007	3.757	3.725	4.706	-0.341	5.158	5.499	1.774	3.296	3.636	1.862	3.100
226.6	367.0	0.759	13.00	7.015	3.766	3.734	4.716	-0.331	5.167	5.498	1.764	3.300	3.631	1.867	3.117
228.3	368.6	0.765	13.10	7.023	3.779	3.746	4.688	-0.359	5.179	5.538	1.792	3.306	3.665	1.873	3.090
230.2	369.9	0.771	13.20	7.032	3.788	3.755	4.701	-0.346	5.188	5.534	1.779	3.311	3.656	1.877	3.111
232.0	371.3	0.777	13.30	7.040	3.798	3.765	4.675	-0.372	5.198	5.570	1.805	3.316	3.687	1.882	3.086
233.8	373.2	0.783	13.40	7.048	3.813	3.779	4.672	-0.375	5.213	5.588	1.808	3.323	3.698	1.890	3.090
235.6	374.4	0.789	13.50	7.056	3.821	3.787	4.670	-0.377	5.220	5.597	1.810	3.327	3.703	1.894	3.093
237.4	375.8	0.794	13.60	7.064	3.830	3.796	4.658	-0.389	5.229	5.618	1.822	3.331	3.720	1.898	3.084
239.2	377.1	0.800	13.70	7.072	3.839	3.805	4.656	-0.391	5.238	5.629	1.824	3.336	3.727	1.902	3.086
241.0	378.5	0.806	13.80	7.080	3.849	3.815	4.650	-0.397	5.248	5.646	1.830	3.341	3.738	1.908	3.084
242.8	380.1	0.812	13.90	7.089	3.860	3.826	4.640	-0.407	5.259	5.666	1.840	3.346	3.753	1.913	3.079
244.6	381.2	0.818	14.00	7.097	3.868	3.833	4.620	-0.427	5.266	5.693	1.860	3.350	3.776	1.916	3.061
246.4	382.7	0.823	14.10	7.105	3.878	3.843	4.639	-0.408	5.277	5.684	1.841	3.355	3.763	1.922	3.088
248.2	384.2	0.829	14.20	7.114	3.888	3.853	4.615	-0.432	5.286	5.719	1.865	3.360	3.792	1.927	3.066
250.0	385.5	0.835	14.30	7.122	3.897	3.862	4.608	-0.439	5.295	5.734	1.872	3.364	3.803	1.931	3.063
251.7	386.8	0.841	14.40	7.130	3.906	3.870	4.588	-0.459	5.303	5.762	1.892	3.368	3.827	1.935	3.045
253.5	388.4	0.847	14.50	7.138	3.917	3.881	4.586	-0.461	5.314	5.775	1.894	3.374	3.835	1.941	3.049
255.3	389.6	0.853	14.60	7.147	3.924	3.888	4.589	-0.458	5.321	5.779	1.891	3.377	3.835	1.944	3.056
257.1	390.9	0.859	14.70	7.155	3.933	3.897	4.579	-0.468	5.330	5.798	1.901	3.382	3.849	1.948	3.050
258.8	391.9	0.864	14.80	7.164	3.939	3.902	4.560	-0.487	5.336	5.822	1.920	3.384	3.871	1.951	3.033
260.7	393.6	0.870	14.90	7.172	3.952	3.915	4.564	-0.483	5.348	5.831	1.916	3.391	3.874	1.957	3.043
262.4	394.6	0.876	15.00	7.180	3.957	3.920	4.532	-0.515	5.353	5.868	1.948	3.393	3.908	1.960	3.012
264.2	396.2	0.882	15.10	7.189	3.968	3.931	4.546	-0.501	5.364	5.865	1.934	3.398	3.900	1.965	3.032
266.0	397.6	0.888	15.20	7.197	3.977	3.940	4.512	-0.534	5.373	5.907	1.968	3.403	3.937	1.970	3.002
267.8	399.0	0.894	15.30	7.206	3.987	3.949	4.525	-0.522	5.382	5.904	1.955	3.408	3.929	1.974	3.020
269.6	400.4	0.899	15.40	7.214	3.996	3.958	4.498	-0.549	5.391	5.940	1.982	3.412	3.961	1.979	2.997
271.4	401.5	0.905	15.50	7.223	4.002	3.964	4.506	-0.541	5.397	5.938	1.974	3.415	3.956	1.982	3.008
273.2	402.5	0.911	15.60	7.232	4.007	3.969	4.489	-0.558	5.402	5.960	1.991	3.417	3.975	1.984	2.993
274.9	403.8	0.917	15.70	7.240	4.016	3.977	4.482	-0.565	5.410	5.975	1.998	3.421	3.986	1.988	2.990
276.7	405.1	0.923	15.80	7.249	4.023	3.984	4.478	-0.569	5.417	5.986	2.002	3.425	3.994	1.992	2.990
278.5	406.2	0.929	15.90	7.257	4.030	3.990	4.464	-0.583	5.423	6.007	2.016	3.428	4.011	1.995	2.979
280.3	407.2	0.934	16.00	7.266	4.035	3.995	4.464	-0.583	5.428	6.011	2.016	3.431	4.014	1.998	2.982
282.1	408.3	0.940	16.10	7.275	4.042	4.002	4.451	-0.596	5.435	6.031	2.029	3.434	4.030	2.001	2.972
283.9	409.5	0.946	16.20	7.283	4.048	4.008	4.459	-0.588	5.441	6.030	2.021	3.437	4.025	2.004	2.983
285.7	410.3	0.952	16.30	7.292	4.051	4.011	4.428	-0.619	5.444	6.063	2.052	3.439	4.058	2.006	2.955
287.5	411.5	0.958	16.40	7.301	4.058	4.017	4.423	-0.624	5.450	6.074	2.057	3.442	4.066	2.009	2.953
289.3	412.8	0.964	16.50	7.309	4.066	4.025	4.431	-0.616	5.458	6.074	2.049	3.446	4.061	2.012	2.964
291.1	413.8	0.969	16.60	7.318	4.071	4.030	4.426	-0.621	5.463	6.084	2.054	3.448	4.069	2.015	2.962
293.0	415.0	0.975	16.70	7.327	4.078	4.036	4.420	-0.627	5.469	6.097	2.060	3.451	4.078	2.018	2.959
294.8	416.2	0.981	16.80	7.336	4.084	4.043	4.408	-0.638	5.476	6.114	2.072	3.455	4.093	2.021	2.952
296.7	417.6	0.987	16.90	7.345	4.093	4.051	4.394	-0.653	5.484	6.138	2.086	3.459	4.112	2.026	2.942
298.5	418.4	0.993	17.00	7.354	4.097	4.055	4.395	-0.652	5.488	6.140	2.085	3.461	4.113	2.027	2.945
300.3	420.1	0.999	17.10	7.362	4.108	4.066	4.378	-0.669	5.499	6.168	2.102	3.466	4.135	2.033	2.934

Stantec

Consolidated Undrained Triaxial Compression
ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-102, 16.2'-16.7'
Description Silty Clay with Sand (CL-ML), dark brown, wet, soft
Specimen Type Intact
Preparation Wet Mounting

Project No. 174316204
Lab ID 34B
Test ID 34B-A

Date Received 11/15/2017
Date Tested 12/07/2017

Specific Gravity 2.70
ASTM D 854, Dry

Liquid Limit 22
Plastic Limit 15
Plasticity Index 7
ASTM D 4318

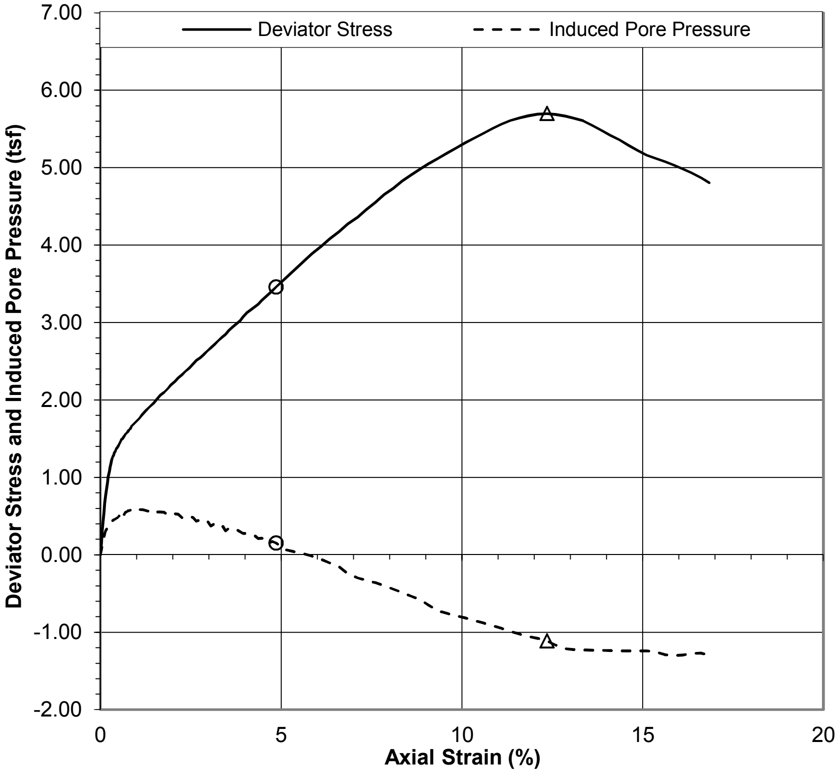
Target Test Parameters
Nominal Chamber Pressure (psi) 90
Nominal Back Pressure (psi) 65
Nominal Consolidation Pressure (psi) 25

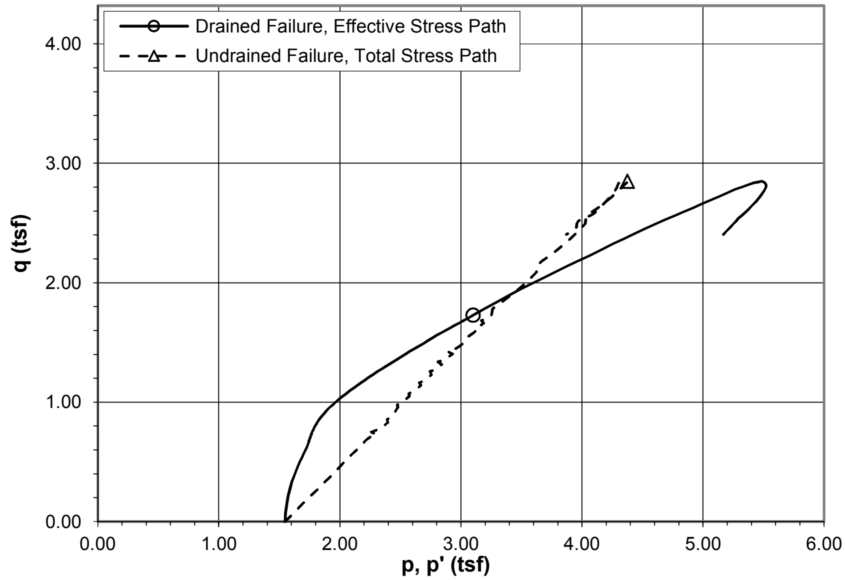
Saturation / Consolidation Results
Pore Pressure Parameter B 0.99
Measured Effective Consol. Stress (tsf) 1.522
Time to 50% Consolidation (min) 4.90
Actual Axial Strain Rate of Test (%/min) 0.061

Consolidated Specimen Conditions
Moist Unit Weight (pcf) 129.9
Moisture Content (%) 21.0
Dry Unit Weight (pcf) 107.3
Void Ratio 0.568
Degree of Saturation (%) 100.0

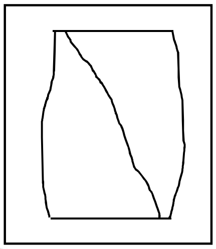
At Drained Failure
Failure Criterion: Max. Eff. Prin. Stress Ratio
Axial Strain (%) 4.864
Deviator Stress (tsf) 3.459
Induced Pore Pressure (tsf) 0.152
Minor Effective Stress, σ_3' (tsf) 1.370
Major Effective Stress, σ_1' (tsf) 4.829
Eff. Principal Stress Ratio, σ_1'/σ_3' 3.525
p' (tsf) 3.100
q (tsf) 1.730

At Consolidated Undrained Failure
Failure Criterion: Peak Deviator Stress
Axial Strain (%) 12.355
Deviator Stress (tsf) 5.698
Minor Principal Stress, σ_3 (tsf) 1.526
Major Principal Stress, σ_1 (tsf) 7.223
p (tsf) 4.374
q (tsf) 2.849





Failure Sketch



Comments

Reviewed KG

Stantec Consulting Services Inc.
Lexington, Kentucky

Reported By: KG
Report Date: 12/22/2017

Stantec

Consolidated Undrained Triaxial Compression

ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-102, 16.2'-16.7'
Description Silty Clay with Sand (CL-ML), dark brown, wet, soft

Project No. 174316204
Lab ID 34B
Test ID 34B-A

Initial Specimen Conditions		Consolidated Specimen Conditions	
Average Height (in)	5.996	Calculated Height (in)	5.994
Average Diameter (in)	2.797	Calculated Diameter (in)	2.798
Calculated Area (in^2)	6.143	Calculated Area (in^2)	6.148
Moist Weight (lb)	2.843	Moist Weight (lb)	2.770
Moist Unit Weight (pcf)	133.4	Moist Unit Weight (pcf)	129.9
Moisture Content (%)	24.2	Moisture Content (%)	21.0
Dry Weight (lb)	2.288	Dry Weight (lb)	2.288
Dry Unit Weight (pcf)	107.3	Dry Unit Weight (pcf)	107.3
Void Ratio	0.568	Void Ratio	0.568
Degree of Saturation (%)	115.3	Degree of Saturation (%)	100.0

Specific Gravity 2.70
ASTM D 854, Dry

Liquid Limit 22
Plastic Limit 15
Plasticity Index 7
ASTM D 4318

Confining Stress
σ_3 (tsf) 1.547

Effective Consolidation Stress
σ_3' (tsf) 1.547

Moisture contents obtained using whole specimen.
Specimen consolidated cross-sectional area determined using method B.
Membrane corrections have been applied,where Em = 200 lbf/in and t = 0.012 in.
All other tests performed in association with this specimen are reported separately.

Project: 174316204			Source: B-102, 16.2'-16.7'								Lab ID: 34B		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
0.0	0.0	0.000	0.00	6.148	0.000	0.000	4.964	0.000	1.547	1.547	1.547	1.547	1.547	0.000	1.000
0.4	12.8	0.002	0.03	6.150	0.150	0.150	5.035	0.071	1.696	1.625	1.476	1.622	1.551	0.075	1.101
0.8	25.2	0.003	0.05	6.151	0.295	0.295	5.095	0.130	1.839	1.708	1.413	1.691	1.561	0.147	1.209
1.2	36.6	0.004	0.07	6.152	0.429	0.429	5.150	0.186	1.973	1.787	1.358	1.759	1.573	0.214	1.316
1.7	47.1	0.006	0.10	6.154	0.551	0.551	5.200	0.236	2.099	1.863	1.312	1.823	1.587	0.276	1.420
2.1	56.8	0.007	0.12	6.155	0.664	0.664	5.238	0.274	2.209	1.935	1.272	1.877	1.604	0.332	1.522
2.5	65.4	0.009	0.14	6.157	0.765	0.765	5.273	0.308	2.313	2.004	1.240	1.930	1.622	0.382	1.617
2.9	72.9	0.010	0.17	6.159	0.852	0.852	5.294	0.329	2.394	2.064	1.213	1.968	1.638	0.426	1.702
3.3	79.7	0.012	0.20	6.160	0.932	0.931	5.315	0.350	2.471	2.121	1.190	2.006	1.655	0.466	1.783
3.7	86.4	0.013	0.22	6.161	1.010	1.009	5.334	0.369	2.546	2.176	1.167	2.041	1.672	0.505	1.865
4.1	92.3	0.015	0.25	6.163	1.079	1.078	5.349	0.385	2.613	2.228	1.150	2.074	1.689	0.539	1.938
4.5	97.1	0.016	0.27	6.164	1.134	1.133	5.364	0.400	2.667	2.267	1.134	2.100	1.700	0.566	1.999
4.9	101.5	0.018	0.29	6.166	1.185	1.184	5.381	0.416	2.721	2.305	1.121	2.129	1.713	0.592	2.056
5.3	105.2	0.019	0.31	6.167	1.228	1.227	5.395	0.431	2.768	2.337	1.110	2.154	1.724	0.614	2.105
5.8	108.3	0.020	0.34	6.169	1.264	1.263	5.408	0.443	2.806	2.362	1.099	2.174	1.731	0.632	2.150
6.2	111.0	0.022	0.37	6.171	1.295	1.294	5.417	0.452	2.836	2.384	1.090	2.189	1.737	0.647	2.188
6.6	113.5	0.024	0.40	6.172	1.324	1.323	5.422	0.458	2.861	2.404	1.081	2.200	1.742	0.661	2.224
7.0	115.3	0.025	0.42	6.174	1.345	1.344	5.428	0.464	2.880	2.416	1.072	2.208	1.744	0.672	2.253
7.4	117.3	0.026	0.44	6.175	1.367	1.366	5.435	0.470	2.902	2.431	1.065	2.218	1.748	0.683	2.283
7.8	119.2	0.028	0.47	6.177	1.390	1.389	5.445	0.480	2.926	2.446	1.058	2.232	1.752	0.694	2.313
8.2	121.0	0.030	0.50	6.179	1.410	1.409	5.456	0.491	2.951	2.459	1.051	2.246	1.755	0.704	2.340
8.6	122.6	0.031	0.52	6.180	1.428	1.427	5.464	0.500	2.971	2.471	1.045	2.257	1.758	0.713	2.366
9.0	124.4	0.033	0.54	6.182	1.449	1.448	5.496	0.532	3.019	2.488	1.040	2.295	1.764	0.724	2.393
9.4	126.2	0.034	0.56	6.183	1.469	1.468	5.503	0.538	3.039	2.500	1.032	2.305	1.766	0.734	2.422
9.9	127.7	0.035	0.58	6.184	1.487	1.486	5.470	0.506	3.016	2.510	1.025	2.273	1.767	0.743	2.450
10.3	129.0	0.037	0.61	6.186	1.501	1.500	5.453	0.489	3.010	2.521	1.021	2.260	1.771	0.750	2.468
10.7	130.7	0.038	0.64	6.188	1.521	1.520	5.477	0.512	3.049	2.536	1.017	2.289	1.777	0.760	2.495
11.1	132.2	0.040	0.66	6.189	1.538	1.537	5.494	0.529	3.078	2.549	1.012	2.310	1.781	0.768	2.518
11.5	133.6	0.041	0.68	6.190	1.554	1.552	5.508	0.544	3.103	2.559	1.007	2.327	1.783	0.776	2.540
11.9	134.9	0.042	0.71	6.192	1.568	1.566	5.519	0.554	3.124	2.570	1.004	2.341	1.787	0.783	2.561
12.3	136.2	0.045	0.75	6.194	1.583	1.581	5.528	0.563	3.143	2.580	0.999	2.353	1.790	0.790	2.582
12.7	137.5	0.046	0.77	6.196	1.597	1.595	5.533	0.569	3.160	2.591	0.996	2.362	1.794	0.798	2.602
13.1	138.7	0.047	0.79	6.197	1.612	1.610	5.536	0.571	3.174	2.603	0.993	2.369	1.798	0.805	2.622
13.5	140.1	0.049	0.82	6.199	1.628	1.626	5.539	0.575	3.190	2.615	0.989	2.377	1.802	0.813	2.643
14.0	141.4	0.050	0.84	6.200	1.642	1.640	5.542	0.578	3.205	2.627	0.987	2.385	1.807	0.820	2.663
14.4	143.1	0.052	0.86	6.201	1.661	1.659	5.547	0.583	3.226	2.643	0.984	2.397	1.814	0.830	2.686
16.0	147.6	0.058	0.96	6.208	1.712	1.710	5.525	0.560	3.244	2.683	0.973	2.389	1.828	0.855	2.757
17.6	152.0	0.064	1.07	6.215	1.761	1.758	5.548	0.584	3.311	2.727	0.968	2.431	1.848	0.879	2.816
19.3	156.9	0.070	1.16	6.220	1.816	1.813	5.545	0.580	3.358	2.777	0.964	2.451	1.871	0.907	2.881

Project: 174316204			Source: B-102, 16.2'-16.7'								Lab ID: 34B		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
20.9	161.5	0.075	1.26	6.226	1.867	1.864	5.534	0.569	3.395	2.826	0.961	2.463	1.894	0.932	2.939
22.6	165.7	0.081	1.36	6.233	1.914	1.911	5.527	0.562	3.435	2.873	0.962	2.480	1.917	0.955	2.986
24.2	169.9	0.088	1.47	6.240	1.960	1.957	5.495	0.531	3.451	2.920	0.964	2.473	1.942	0.978	3.030
25.8	174.6	0.094	1.56	6.246	2.012	2.009	5.518	0.554	3.528	2.974	0.966	2.524	1.970	1.004	3.079
27.5	179.3	0.099	1.66	6.252	2.065	2.061	5.517	0.552	3.583	3.031	0.970	2.553	2.000	1.030	3.125
29.1	182.9	0.106	1.76	6.258	2.105	2.100	5.515	0.550	3.626	3.075	0.975	2.575	2.025	1.050	3.154
30.8	187.0	0.112	1.86	6.265	2.149	2.144	5.479	0.514	3.640	3.126	0.982	2.568	2.054	1.072	3.185
32.4	191.6	0.117	1.95	6.270	2.201	2.196	5.499	0.535	3.718	3.184	0.988	2.620	2.086	1.098	3.223
34.0	195.9	0.124	2.07	6.278	2.246	2.241	5.494	0.529	3.766	3.237	0.996	2.645	2.116	1.121	3.251
35.7	199.9	0.129	2.15	6.283	2.291	2.285	5.489	0.524	3.813	3.289	1.003	2.670	2.146	1.143	3.278
37.3	203.8	0.135	2.26	6.290	2.332	2.327	5.444	0.480	3.819	3.340	1.013	2.656	2.176	1.163	3.297
38.9	207.7	0.141	2.35	6.296	2.375	2.369	5.464	0.499	3.890	3.391	1.022	2.706	2.207	1.185	3.318
40.6	212.0	0.147	2.46	6.303	2.421	2.415	5.456	0.491	3.938	3.447	1.032	2.731	2.240	1.208	3.340
42.2	216.3	0.153	2.56	6.309	2.469	2.462	5.449	0.485	3.989	3.504	1.042	2.758	2.273	1.231	3.363
43.9	221.0	0.159	2.66	6.316	2.519	2.513	5.397	0.433	3.999	3.567	1.054	2.743	2.311	1.256	3.383
45.5	224.2	0.165	2.76	6.323	2.553	2.547	5.419	0.455	4.067	3.612	1.065	2.794	2.339	1.273	3.391
47.1	228.1	0.171	2.86	6.329	2.595	2.588	5.409	0.445	4.110	3.665	1.077	2.816	2.371	1.294	3.403
48.8	232.2	0.177	2.96	6.335	2.639	2.631	5.402	0.438	4.159	3.721	1.089	2.843	2.405	1.316	3.416
50.4	236.3	0.183	3.06	6.342	2.682	2.675	5.335	0.370	4.147	3.777	1.102	2.810	2.439	1.337	3.427
52.0	240.5	0.189	3.16	6.349	2.728	2.720	5.367	0.402	4.237	3.834	1.115	2.877	2.474	1.360	3.440
53.7	244.7	0.195	3.26	6.355	2.772	2.764	5.357	0.392	4.285	3.893	1.129	2.903	2.511	1.382	3.449
55.3	249.0	0.201	3.36	6.362	2.818	2.809	5.350	0.385	4.336	3.951	1.142	2.932	2.546	1.405	3.461
57.0	252.7	0.207	3.46	6.368	2.857	2.849	5.274	0.310	4.312	4.002	1.154	2.888	2.578	1.424	3.469
58.6	257.3	0.213	3.55	6.374	2.906	2.897	5.307	0.342	4.409	4.067	1.170	2.961	2.619	1.448	3.476
60.2	261.7	0.219	3.66	6.381	2.953	2.944	5.300	0.336	4.464	4.128	1.184	2.992	2.656	1.472	3.486
61.9	265.4	0.226	3.76	6.389	2.992	2.982	5.291	0.327	4.508	4.181	1.199	3.017	2.690	1.491	3.488
63.5	269.6	0.232	3.87	6.395	3.036	3.026	5.263	0.298	4.536	4.237	1.211	3.023	2.724	1.513	3.498
65.1	274.2	0.237	3.95	6.401	3.084	3.074	5.241	0.277	4.579	4.303	1.229	3.042	2.766	1.537	3.502
66.8	279.2	0.243	4.05	6.408	3.137	3.127	5.240	0.276	4.647	4.371	1.243	3.083	2.807	1.564	3.515
68.4	282.5	0.249	4.16	6.415	3.171	3.160	5.231	0.267	4.686	4.419	1.259	3.106	2.839	1.580	3.511
70.1	286.2	0.255	4.26	6.422	3.209	3.198	5.216	0.251	4.724	4.473	1.275	3.125	2.874	1.599	3.509
71.7	289.9	0.262	4.37	6.429	3.247	3.236	5.174	0.209	4.736	4.527	1.290	3.118	2.908	1.618	3.508
73.3	294.5	0.267	4.46	6.435	3.295	3.284	5.177	0.212	4.803	4.591	1.306	3.161	2.949	1.642	3.514
75.0	298.5	0.273	4.56	6.442	3.336	3.325	5.167	0.202	4.849	4.647	1.322	3.187	2.984	1.663	3.515
76.6	302.7	0.279	4.66	6.449	3.380	3.368	5.113	0.148	4.853	4.705	1.337	3.169	3.021	1.684	3.520
78.2	306.8	0.285	4.76	6.455	3.422	3.410	5.139	0.175	4.941	4.766	1.356	3.236	3.061	1.705	3.515
79.9	311.6	0.292	4.86	6.462	3.471	3.459	5.117	0.152	4.981	4.829	1.370	3.252	3.100	1.730	3.525
84.0	321.9	0.306	5.11	6.479	3.578	3.565	5.032	0.067	5.045	4.978	1.413	3.263	3.195	1.783	3.524
88.1	332.5	0.321	5.35	6.496	3.685	3.672	5.006	0.041	5.172	5.130	1.458	3.336	3.294	1.836	3.518
92.1	343.6	0.336	5.61	6.514	3.798	3.784	4.979	0.014	5.301	5.287	1.503	3.409	3.395	1.892	3.517
96.2	354.1	0.351	5.85	6.530	3.904	3.890	4.946	-0.018	5.420	5.438	1.548	3.475	3.493	1.945	3.512
100.3	363.8	0.366	6.10	6.548	4.000	3.985	4.906	-0.059	5.521	5.580	1.594	3.528	3.587	1.993	3.499
104.4	373.1	0.380	6.34	6.564	4.093	4.077	4.861	-0.103	5.615	5.719	1.642	3.577	3.680	2.039	3.484
108.5	383.3	0.396	6.60	6.583	4.192	4.176	4.813	-0.152	5.712	5.864	1.688	3.624	3.776	2.088	3.474
112.6	393.1	0.410	6.84	6.600	4.288	4.271	4.718	-0.246	5.758	6.005	1.733	3.623	3.869	2.136	3.464
116.7	402.4	0.426	7.11	6.619	4.378	4.360	4.668	-0.296	5.849	6.145	1.785	3.669	3.965	2.180	3.443
120.8	412.3	0.440	7.35	6.636	4.474	4.455	4.639	-0.326	5.964	6.290	1.834	3.736	4.062	2.228	3.429
124.9	422.3	0.456	7.60	6.654	4.570	4.551	4.604	-0.360	6.073	6.433	1.882	3.797	4.158	2.276	3.418
129.0	432.8	0.470	7.85	6.672	4.671	4.652	4.566	-0.399	6.183	6.582	1.930	3.857	4.256	2.326	3.410
133.1	441.7	0.486	8.10	6.690	4.753	4.733	4.522	-0.443	6.267	6.710	1.977	3.901	4.343	2.367	3.394
137.1	451.5	0.500	8.35	6.708	4.847	4.826	4.477	-0.488	6.362	6.850	2.024	3.949	4.437	2.413	3.385
141.2	460.4	0.515	8.60	6.726	4.928	4.907	4.430	-0.535	6.443	6.978	2.071	3.990	4.525	2.454	3.370
145.3	468.8	0.530	8.85	6.745	5.004	4.982	4.384	-0.580	6.518	7.099	2.117	4.027	4.608	2.491	3.354
149.4	476.9	0.545	9.09	6.763	5.077	5.054	4.312	-0.653	6.560	7.212	2.158	4.032	4.685	2.527	3.343
153.5	484.3	0.560	9.35	6.782	5.142	5.119	4.241	-0.723	6.596	7.320	2.201	4.037	4.760	2.559	3.326
157.6	492.1	0.575	9.59	6.800	5.211	5.187	4.206	-0.759	6.676	7.434	2.247	4.082	4.841	2.594	3.308
161.7	499.9	0.590	9.84	6.819	5.278	5.254	4.180	-0.785	6.758	7.543	2.289	4.132	4.916	2.627	3.295
165.8	508.1	0.605	10.10	6.839	5.349	5.324	4.151	-0.813	6.841	7.654	2.330	4.179	4.992	2.662	3.285
169.9	514.8	0.620	10.34	6.857	5.405	5.380	4.117	-0.847	6.902	7.749	2.369	4.212	5.059	2.690	3.271
174.0	522.2	0.635	10.59	6.877	5.467	5.441	4.084	-0.881	6.969	7.849	2.408	4.248	5.129	2.721	3.260
178.1	529.8	0.650	10.84	6.896	5.532	5.506	4.049	-0.915	7.036	7.952	2.446	4.284	5.199	2.753	3.251
182.1	536.8	0.665	11.10	6.916	5.589	5.561	4.012	-0.953	7.092	8.045	2.484	4.311	5.264	2.781	3.239
186.2	542.7	0.680	11.34	6.934	5.635	5.607	3.974	-0.990	7.139	8.129	2.522	4.335	5.326	2.804	3.223
190.3	547.7	0.696	11.60	6.955	5.670	5.642	3.940	-1.024	7.173	8.197	2.555	4.352	5.376	2.821	3.208
194.4	551.8	0.710	11.84	6.974	5.697	5.668	3.911	-1.053	7.200	8.254	2.585	4.366	5.420	2.834	3.192
198.5	555.6	0.725	12.10	6.994	5.719	5.689	3.884	-1.081	7.222	8.302	2.613	4.377	5.458	2.845	3.177
202.6	558.1	0.741	12.36	7.015	5.728	5.698	3.852	-1.112	7.223	8.335	2.638	4.374	5.487	2.849	3.160
206.7	558.5	0.755	12.59	7.034	5.717	5.686	3.799	-1.166	7.180	8.345	2.659	4.337	5.502	2.843	3.138
210.8	558.3	0.771	12.86	7.055	5.698	5.666	3.751	-1.213	7.133	8.347	2.680	4.300	5.514	2.833	3.114

Project: 174316204			Source: B-102, 16.2'-16.7'								Lab ID: 34B		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
214.9	557.2	0.785	13.09	7.074	5.671	5.638	3.739	-1.225	7.115	8.340	2.702	4.296	5.521	2.819	3.087
219.0	555.4	0.801	13.36	7.096	5.635	5.602	3.737	-1.228	7.093	8.320	2.718	4.292	5.519	2.801	3.061
223.1	551.4	0.815	13.61	7.116	5.579	5.545	3.732	-1.232	7.047	8.279	2.734	4.274	5.506	2.773	3.028
227.1	546.8	0.830	13.85	7.137	5.517	5.483	3.730	-1.234	6.993	8.227	2.744	4.252	5.486	2.741	2.998
231.2	541.9	0.845	14.10	7.157	5.452	5.417	3.728	-1.236	6.933	8.169	2.752	4.225	5.461	2.708	2.968
235.3	537.9	0.860	14.36	7.179	5.395	5.360	3.725	-1.239	6.877	8.116	2.757	4.198	5.437	2.680	2.944
239.4	532.5	0.875	14.61	7.200	5.325	5.289	3.724	-1.241	6.808	8.049	2.760	4.164	5.404	2.644	2.916
243.5	527.4	0.890	14.86	7.221	5.259	5.222	3.724	-1.241	6.742	7.983	2.761	4.131	5.372	2.611	2.892
247.6	522.8	0.906	15.11	7.242	5.198	5.160	3.725	-1.239	6.681	7.920	2.760	4.101	5.340	2.580	2.870
251.7	520.2	0.920	15.35	7.263	5.157	5.119	3.711	-1.253	6.622	7.875	2.756	4.062	5.316	2.559	2.857
255.8	518.0	0.936	15.61	7.286	5.119	5.080	3.672	-1.292	6.541	7.833	2.753	4.001	5.293	2.540	2.845
259.9	514.6	0.950	15.86	7.307	5.071	5.032	3.662	-1.303	6.486	7.789	2.757	3.970	5.273	2.516	2.825
264.0	511.2	0.966	16.11	7.329	5.022	4.982	3.671	-1.294	6.448	7.741	2.759	3.957	5.250	2.491	2.806
268.1	507.7	0.980	16.35	7.350	4.973	4.933	3.692	-1.272	6.421	7.693	2.760	3.955	5.227	2.466	2.787
272.1	502.7	0.996	16.62	7.373	4.909	4.868	3.695	-1.269	6.359	7.628	2.760	3.925	5.194	2.434	2.764
275.9	497.9	1.009	16.84	7.393	4.849	4.808	3.669	-1.296	6.275	7.571	2.763	3.871	5.167	2.404	2.740

Consolidated Undrained Triaxial Compression

ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-103, 7.5'-8.0'
Description Lean Clay with Sand (CL), dark brown, moist, firm
Specimen Type Intact
Preparation Wet Mounting

Project No. 174316204
Lab ID 36
Test ID 36-A

Date Received 11/15/2017
Date Tested 12/13/2017

Specific Gravity 2.70
ASTM D 854, Dry

Liquid Limit 27
Plastic Limit 15
Plasticity Index 12
ASTM D 4318

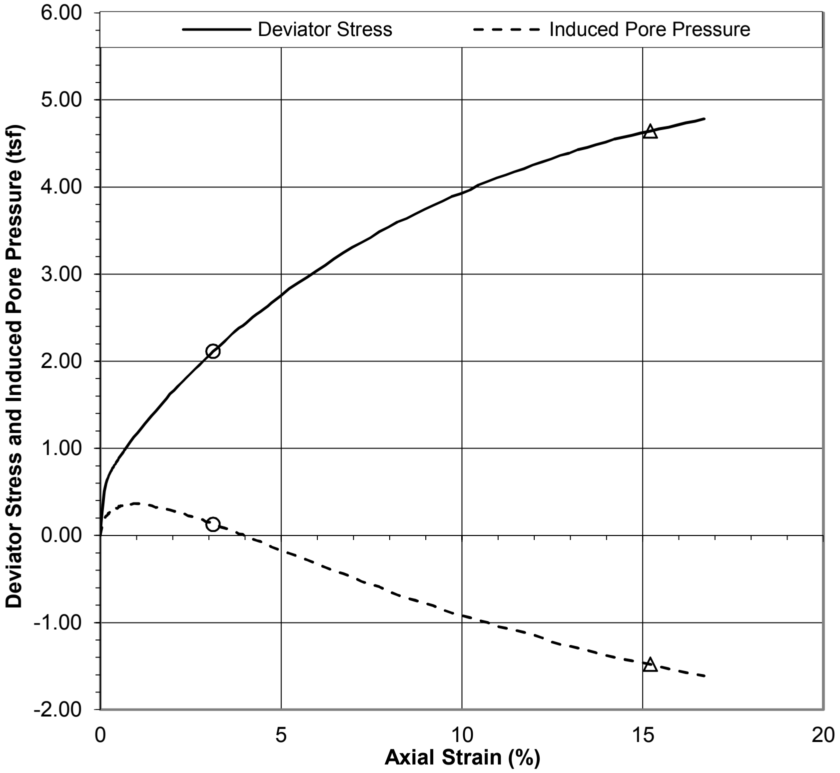
Target Test Parameters
Nominal Chamber Pressure (psi) 90
Nominal Back Pressure (psi) 75
Nominal Consolidation Pressure (psi) 15

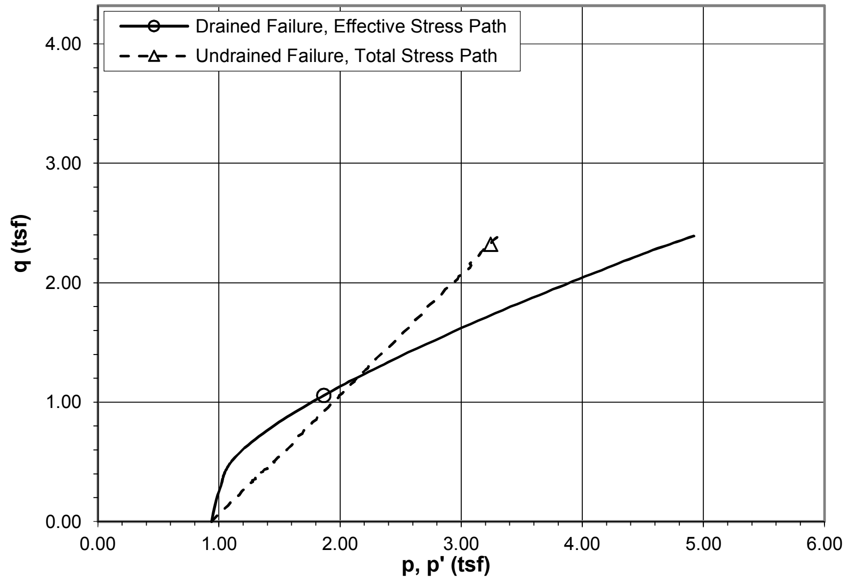
Saturation / Consolidation Results
Pore Pressure Parameter B 0.98
Measured Effective Consol. Stress (tsf) 0.938
Time to 50% Consolidation (min) 10.30
Actual Axial Strain Rate of Test (%/min) 0.029

Consolidated Specimen Conditions
Moist Unit Weight (pcf) 138.2
Moisture Content (%) 14.7
Dry Unit Weight (pcf) 120.5
Void Ratio 0.396
Degree of Saturation (%) 100.0

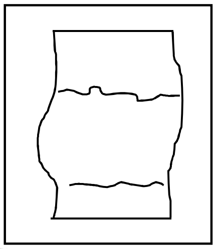
At Drained Failure
Failure Criterion: Max. Eff. Prin. Stress Ratio
Axial Strain (%) 3.117
Deviator Stress (tsf) 2.114
Induced Pore Pressure (tsf) 0.125
Minor Effective Stress, σ_3' (tsf) 0.810
Major Effective Stress, σ_1' (tsf) 2.924
Eff. Principal Stress Ratio, σ_1'/σ_3' 3.609
p' (tsf) 1.867
q (tsf) 1.057

At Consolidated Undrained Failure
Failure Criterion: 15% Axial Strain
Axial Strain (%) 15.215
Deviator Stress (tsf) 4.642
Minor Principal Stress, σ_3 (tsf) 0.922
Major Principal Stress, σ_1 (tsf) 5.564
p (tsf) 3.243
q (tsf) 2.321





Failure Sketch



Comments

Reviewed KG

Stantec

Consolidated Undrained Triaxial Compression

ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-103, 7.5'-8.0'
Description Lean Clay with Sand (CL), dark brown, moist, firm

Project No. 174316204
Lab ID 36
Test ID 36-A

Initial Specimen Conditions		Consolidated Specimen Conditions	
Average Height (in)	6.009	Calculated Height (in)	5.993
Average Diameter (in)	2.860	Calculated Diameter (in)	2.872
Calculated Area (in^2)	6.423	Calculated Area (in^2)	6.477
Moist Weight (lb)	3.097	Moist Weight (lb)	3.104
Moist Unit Weight (pcf)	138.7	Moist Unit Weight (pcf)	138.2
Moisture Content (%)	14.4	Moisture Content (%)	14.7
Dry Weight (lb)	2.707	Dry Weight (lb)	2.707
Dry Unit Weight (pcf)	121.2	Dry Unit Weight (pcf)	120.5
Void Ratio	0.388	Void Ratio	0.396
Degree of Saturation (%)	100.3	Degree of Saturation (%)	100.0

Specific Gravity 2.70
ASTM D 854, Dry

Liquid Limit 27
Plastic Limit 15
Plasticity Index 12
ASTM D 4318

Confining Stress
σ_3 (tsf) 0.940

Effective Consolidation Stress
σ_3' (tsf) 0.940

Moisture contents obtained using partial specimen.
Specimen consolidated cross-sectional area determined using method B.
Membrane corrections have been applied,where Em = 200 lbf/in and t = 0.012 in.
All other tests performed in association with this specimen are reported separately.

Project: 174316204			Source: B-103, 7.5'-8.0'								Lab ID: 36		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
0.0	0.0	0.000	0.00	6.477	0.000	0.000	5.547	0.000	0.940	0.940	0.940	0.940	0.940	0.000	1.000
0.8	13.5	0.001	0.02	6.478	0.150	0.150	5.603	0.056	1.084	1.027	0.878	1.009	0.953	0.075	1.170
1.7	24.3	0.003	0.04	6.479	0.270	0.270	5.656	0.109	1.210	1.101	0.831	1.075	0.966	0.135	1.325
2.6	33.1	0.004	0.07	6.481	0.368	0.368	5.680	0.134	1.297	1.164	0.796	1.114	0.980	0.184	1.462
3.4	39.8	0.005	0.09	6.482	0.442	0.442	5.723	0.177	1.389	1.212	0.770	1.168	0.991	0.221	1.574
4.3	45.8	0.007	0.11	6.484	0.508	0.508	5.734	0.187	1.443	1.256	0.747	1.189	1.001	0.254	1.680
5.2	50.4	0.008	0.14	6.485	0.559	0.559	5.756	0.209	1.498	1.289	0.731	1.219	1.010	0.279	1.765
6.0	54.3	0.010	0.17	6.487	0.602	0.602	5.772	0.225	1.543	1.317	0.716	1.242	1.017	0.301	1.841
6.9	57.3	0.011	0.19	6.489	0.636	0.636	5.776	0.230	1.569	1.339	0.703	1.251	1.021	0.318	1.904
7.7	60.0	0.013	0.21	6.490	0.666	0.666	5.801	0.255	1.612	1.358	0.692	1.279	1.025	0.333	1.962
8.6	62.2	0.014	0.23	6.492	0.690	0.689	5.795	0.248	1.620	1.372	0.682	1.275	1.027	0.345	2.010
9.4	64.2	0.015	0.26	6.493	0.712	0.711	5.818	0.271	1.658	1.386	0.675	1.302	1.031	0.356	2.054
10.3	66.0	0.017	0.29	6.495	0.732	0.731	5.816	0.269	1.667	1.398	0.667	1.301	1.032	0.366	2.097
11.2	67.9	0.018	0.31	6.497	0.753	0.752	5.825	0.279	1.691	1.412	0.660	1.315	1.036	0.376	2.138
12.0	69.6	0.020	0.33	6.498	0.771	0.770	5.836	0.289	1.713	1.424	0.654	1.328	1.039	0.385	2.177
12.9	71.1	0.022	0.36	6.500	0.788	0.787	5.831	0.285	1.719	1.434	0.648	1.326	1.041	0.393	2.215
13.7	72.8	0.023	0.38	6.501	0.806	0.805	5.852	0.305	1.754	1.448	0.643	1.351	1.046	0.403	2.252
14.6	74.1	0.025	0.42	6.504	0.821	0.820	5.842	0.295	1.752	1.457	0.637	1.342	1.047	0.410	2.287
15.5	75.8	0.026	0.43	6.505	0.840	0.838	5.859	0.312	1.784	1.471	0.633	1.364	1.052	0.419	2.325
16.3	77.3	0.027	0.46	6.506	0.855	0.854	5.857	0.311	1.793	1.482	0.628	1.366	1.055	0.427	2.359
17.2	78.7	0.029	0.49	6.508	0.871	0.870	5.862	0.316	1.810	1.495	0.625	1.375	1.060	0.435	2.391
18.0	80.3	0.031	0.51	6.510	0.888	0.887	5.884	0.337	1.845	1.508	0.621	1.402	1.065	0.443	2.428
18.9	81.7	0.032	0.53	6.511	0.903	0.902	5.875	0.328	1.848	1.519	0.618	1.397	1.068	0.451	2.460
19.7	83.0	0.034	0.56	6.513	0.918	0.917	5.891	0.345	1.876	1.532	0.615	1.418	1.074	0.458	2.490
20.6	84.5	0.035	0.59	6.515	0.933	0.932	5.887	0.341	1.885	1.544	0.612	1.419	1.078	0.466	2.523
21.5	85.6	0.037	0.61	6.517	0.946	0.944	5.889	0.342	1.896	1.554	0.610	1.424	1.082	0.472	2.549
22.3	87.0	0.038	0.64	6.518	0.961	0.959	5.898	0.351	1.918	1.566	0.607	1.438	1.087	0.480	2.579
23.2	88.4	0.040	0.66	6.520	0.976	0.975	5.889	0.342	1.922	1.579	0.605	1.435	1.092	0.487	2.611
24.0	89.9	0.041	0.68	6.521	0.992	0.990	5.904	0.358	1.952	1.594	0.604	1.457	1.099	0.495	2.640
24.9	90.9	0.042	0.70	6.522	1.004	1.002	5.895	0.348	1.951	1.603	0.601	1.450	1.102	0.501	2.668
25.8	92.3	0.044	0.73	6.524	1.019	1.017	5.900	0.353	1.970	1.617	0.600	1.462	1.108	0.509	2.696
29.2	97.5	0.050	0.83	6.531	1.075	1.073	5.901	0.354	2.022	1.668	0.595	1.486	1.132	0.537	2.803
32.6	102.6	0.055	0.93	6.537	1.130	1.128	5.913	0.367	2.088	1.721	0.594	1.524	1.158	0.564	2.899
36.1	107.3	0.062	1.03	6.544	1.180	1.178	5.912	0.365	2.137	1.772	0.594	1.548	1.183	0.589	2.982
39.5	112.2	0.068	1.14	6.551	1.233	1.231	5.910	0.364	2.190	1.827	0.596	1.575	1.211	0.615	3.065
42.9	117.1	0.074	1.23	6.557	1.285	1.282	5.906	0.360	2.242	1.882	0.600	1.601	1.241	0.641	3.138
46.3	121.5	0.080	1.33	6.564	1.333	1.330	5.898	0.352	2.286	1.934	0.604	1.621	1.269	0.665	3.203
49.8	126.0	0.085	1.42	6.570	1.381	1.378	5.887	0.340	2.328	1.988	0.610	1.639	1.299	0.689	3.258
53.2	130.5	0.092	1.53	6.577	1.429	1.425	5.867	0.321	2.362	2.042	0.616	1.650	1.329	0.713	3.312

Project: 174316204			Source: B-103, 7.5'-8.0'								Lab ID: 36		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
56.6	135.3	0.098	1.63	6.584	1.480	1.476	5.872	0.325	2.426	2.100	0.624	1.688	1.362	0.738	3.364
60.1	139.9	0.104	1.73	6.591	1.528	1.524	5.851	0.304	2.461	2.157	0.633	1.700	1.395	0.762	3.405
63.5	144.5	0.110	1.83	6.597	1.576	1.572	5.850	0.303	2.518	2.215	0.643	1.732	1.429	0.786	3.445
66.9	149.4	0.115	1.93	6.604	1.629	1.624	5.838	0.291	2.569	2.278	0.653	1.757	1.466	0.812	3.486
70.4	153.4	0.122	2.04	6.611	1.670	1.666	5.825	0.278	2.607	2.329	0.664	1.774	1.496	0.833	3.510
73.8	157.7	0.128	2.14	6.618	1.715	1.710	5.823	0.276	2.661	2.385	0.675	1.806	1.530	0.855	3.532
77.2	161.6	0.134	2.23	6.624	1.756	1.751	5.797	0.250	2.687	2.437	0.686	1.812	1.562	0.876	3.551
80.7	165.4	0.140	2.33	6.631	1.795	1.790	5.795	0.249	2.738	2.489	0.699	1.843	1.594	0.895	3.559
84.1	169.3	0.146	2.43	6.638	1.837	1.831	5.774	0.227	2.770	2.543	0.712	1.855	1.628	0.915	3.570
87.5	173.1	0.151	2.53	6.644	1.876	1.870	5.765	0.218	2.814	2.596	0.726	1.879	1.661	0.935	3.577
90.9	177.2	0.157	2.63	6.651	1.918	1.912	5.753	0.206	2.858	2.652	0.740	1.902	1.696	0.956	3.584
94.4	181.4	0.164	2.73	6.659	1.961	1.955	5.734	0.188	2.895	2.708	0.753	1.918	1.730	0.977	3.597
97.8	185.5	0.170	2.84	6.666	2.004	1.997	5.729	0.183	2.948	2.765	0.768	1.949	1.767	0.999	3.600
101.2	189.1	0.175	2.92	6.672	2.041	2.034	5.704	0.157	2.972	2.815	0.781	1.955	1.798	1.017	3.603
104.7	193.0	0.181	3.03	6.679	2.081	2.074	5.699	0.152	3.022	2.870	0.796	1.985	1.833	1.037	3.604
108.1	197.0	0.187	3.12	6.685	2.121	2.114	5.672	0.125	3.049	2.924	0.810	1.993	1.867	1.057	3.609
111.5	200.7	0.194	3.23	6.693	2.159	2.151	5.666	0.119	3.096	2.976	0.825	2.020	1.901	1.076	3.606
115.0	204.4	0.199	3.33	6.700	2.197	2.189	5.645	0.099	3.129	3.030	0.842	2.035	1.936	1.094	3.601
118.4	208.2	0.206	3.43	6.707	2.235	2.227	5.633	0.087	3.169	3.082	0.855	2.056	1.969	1.113	3.603
121.8	212.0	0.211	3.52	6.713	2.274	2.265	5.621	0.074	3.211	3.137	0.872	2.079	2.005	1.133	3.597
125.2	216.1	0.217	3.63	6.720	2.316	2.307	5.598	0.051	3.245	3.193	0.886	2.091	2.040	1.153	3.603
128.7	219.9	0.224	3.73	6.728	2.354	2.345	5.592	0.045	3.293	3.247	0.903	2.120	2.075	1.172	3.598
132.1	223.6	0.230	3.84	6.735	2.391	2.382	5.563	0.017	3.316	3.299	0.918	2.125	2.108	1.191	3.596
135.5	226.3	0.236	3.94	6.742	2.416	2.407	5.560	0.013	3.354	3.341	0.934	2.151	2.138	1.203	3.577
139.0	229.5	0.241	4.03	6.748	2.448	2.439	5.530	-0.016	3.373	3.389	0.950	2.154	2.170	1.219	3.566
142.4	232.9	0.247	4.12	6.755	2.482	2.472	5.525	-0.022	3.417	3.439	0.966	2.181	2.202	1.236	3.558
145.8	236.2	0.253	4.22	6.762	2.516	2.506	5.504	-0.043	3.446	3.489	0.983	2.194	2.236	1.253	3.548
149.3	239.8	0.259	4.32	6.769	2.551	2.541	5.488	-0.059	3.481	3.540	0.999	2.210	2.269	1.270	3.544
152.7	242.9	0.265	4.43	6.777	2.581	2.570	5.477	-0.070	3.517	3.587	1.017	2.232	2.302	1.285	3.528
156.1	246.4	0.272	4.53	6.784	2.615	2.604	5.450	-0.096	3.539	3.635	1.031	2.237	2.333	1.302	3.525
159.6	249.4	0.277	4.63	6.791	2.644	2.633	5.445	-0.101	3.580	3.681	1.048	2.263	2.364	1.316	3.512
163.0	253.1	0.283	4.72	6.798	2.681	2.670	5.416	-0.130	3.603	3.733	1.063	2.268	2.398	1.335	3.511
171.6	261.5	0.299	4.98	6.816	2.762	2.750	5.377	-0.170	3.683	3.853	1.103	2.308	2.478	1.375	3.492
180.1	270.0	0.313	5.22	6.834	2.845	2.833	5.342	-0.205	3.772	3.977	1.145	2.356	2.561	1.416	3.475
188.7	277.3	0.328	5.47	6.851	2.914	2.900	5.304	-0.243	3.843	4.086	1.185	2.393	2.635	1.450	3.447
197.3	284.5	0.343	5.72	6.870	2.982	2.968	5.266	-0.281	3.913	4.193	1.226	2.429	2.710	1.484	3.421
205.8	291.7	0.358	5.97	6.888	3.049	3.035	5.224	-0.323	3.979	4.301	1.266	2.461	2.784	1.517	3.396
214.4	299.1	0.373	6.23	6.907	3.118	3.103	5.182	-0.364	4.045	4.409	1.306	2.493	2.858	1.552	3.376
223.0	306.9	0.387	6.46	6.924	3.191	3.175	5.141	-0.406	4.113	4.519	1.344	2.526	2.932	1.588	3.363
231.6	314.6	0.403	6.72	6.943	3.262	3.246	5.108	-0.438	4.191	4.630	1.383	2.568	3.006	1.623	3.347
240.1	321.5	0.418	6.97	6.961	3.325	3.308	5.069	-0.477	4.253	4.731	1.422	2.599	3.076	1.654	3.326
248.7	327.8	0.433	7.22	6.981	3.381	3.363	5.020	-0.527	4.296	4.823	1.459	2.614	3.141	1.682	3.305
257.3	334.0	0.448	7.47	7.000	3.436	3.418	4.988	-0.559	4.356	4.915	1.497	2.647	3.206	1.709	3.283
265.9	341.9	0.462	7.72	7.018	3.508	3.489	4.956	-0.590	4.434	5.024	1.535	2.689	3.280	1.745	3.273
274.4	347.8	0.478	7.97	7.037	3.559	3.539	4.905	-0.642	4.470	5.112	1.572	2.700	3.342	1.770	3.252
283.0	354.7	0.492	8.21	7.056	3.619	3.599	4.863	-0.683	4.523	5.206	1.607	2.723	3.407	1.800	3.240
291.6	359.4	0.508	8.47	7.076	3.657	3.637	4.829	-0.717	4.562	5.279	1.642	2.743	3.460	1.818	3.215
300.2	365.7	0.522	8.71	7.094	3.711	3.691	4.800	-0.746	4.622	5.368	1.678	2.777	3.523	1.845	3.200
308.7	372.3	0.538	8.97	7.115	3.768	3.746	4.770	-0.776	4.682	5.458	1.712	2.808	3.585	1.873	3.189
317.3	377.7	0.552	9.21	7.133	3.812	3.790	4.738	-0.809	4.729	5.537	1.747	2.834	3.642	1.895	3.170
325.9	383.6	0.567	9.46	7.153	3.861	3.838	4.695	-0.851	4.768	5.619	1.781	2.849	3.700	1.919	3.155
334.4	389.8	0.582	9.71	7.173	3.912	3.889	4.659	-0.888	4.813	5.701	1.812	2.869	3.756	1.945	3.146
343.0	394.3	0.597	9.96	7.193	3.946	3.922	4.630	-0.917	4.850	5.767	1.844	2.889	3.806	1.961	3.127
351.6	399.9	0.613	10.22	7.214	3.992	3.967	4.604	-0.942	4.900	5.843	1.876	2.917	3.859	1.984	3.115
360.2	406.8	0.627	10.47	7.234	4.050	4.024	4.576	-0.971	4.962	5.933	1.908	2.950	3.921	2.012	3.109
368.7	412.1	0.642	10.72	7.254	4.090	4.065	4.544	-1.003	5.002	6.005	1.941	2.970	3.973	2.032	3.094
377.3	417.3	0.657	10.96	7.274	4.131	4.104	4.504	-1.043	5.030	6.073	1.969	2.978	4.021	2.052	3.085
385.9	421.9	0.672	11.21	7.294	4.164	4.137	4.484	-1.063	5.071	6.134	1.997	3.003	4.066	2.069	3.072
394.5	426.9	0.686	11.45	7.314	4.203	4.175	4.459	-1.087	5.114	6.201	2.026	3.026	4.114	2.088	3.061
403.0	431.6	0.702	11.72	7.336	4.236	4.208	4.436	-1.110	5.153	6.263	2.055	3.049	4.159	2.104	3.048
411.6	437.5	0.717	11.96	7.356	4.282	4.254	4.410	-1.137	5.201	6.338	2.085	3.075	4.211	2.127	3.041
420.2	442.2	0.732	12.22	7.378	4.316	4.286	4.374	-1.173	5.225	6.397	2.111	3.082	4.254	2.143	3.030
428.8	447.2	0.748	12.47	7.399	4.352	4.322	4.325	-1.222	5.232	6.453	2.132	3.071	4.292	2.161	3.027
437.3	452.6	0.762	12.72	7.420	4.392	4.361	4.294	-1.252	5.269	6.522	2.161	3.089	4.341	2.181	3.019
445.9	456.9	0.777	12.97	7.441	4.421	4.390	4.276	-1.270	5.310	6.580	2.190	3.115	4.385	2.195	3.005
454.5	462.2	0.791	13.21	7.462	4.459	4.428	4.255	-1.292	5.350	6.642	2.214	3.136	4.428	2.214	3.000
463.1	466.3	0.807	13.47	7.485	4.486	4.453	4.228	-1.318	5.373	6.691	2.238	3.146	4.464	2.227	2.990
471.6	471.0	0.822	13.71	7.506	4.518	4.485	4.200	-1.347	5.399	6.746	2.261	3.156	4.503	2.243	2.984
480.2	475.5	0.837	13.97	7.528	4.548	4.514	4.171	-1.376	5.422	6.797	2.283	3.164	4.540	2.257	2.977

Project: 174316204			**Source: B-103, 7.5'-8.0'**								**Lab ID: 36**		**Test ID**		
Test Time (min)	**Corr. Axial Load (lbf)**	**Axial Deform. (in)**	**Axial Strain (%)**	**Corr. Area (in^2)**	**Deviator Stress (tsf)**	**Corr. Deviator Stress (tsf)**	**Pore Pressure (tsf)**	**Induced Pore Pressure (tsf)**	**σ_1 (tsf)**	**σ_1' (tsf)**	**σ_3' (tsf)**	**p (tsf)**	**p' (tsf)**	**q (tsf)**	**Eff. Princ. Stress Ratio σ_1'/σ_3'**
488.8	480.6	0.852	14.21	7.550	4.583	4.549	4.147	-1.400	5.458	6.857	2.308	3.183	4.583	2.275	2.971
497.3	484.2	0.866	14.46	7.571	4.605	4.570	4.127	-1.420	5.484	6.903	2.333	3.199	4.618	2.285	2.958
505.9	488.1	0.882	14.71	7.593	4.628	4.592	4.109	-1.437	5.512	6.950	2.357	3.216	4.654	2.296	2.948
514.5	492.5	0.896	14.95	7.615	4.656	4.620	4.090	-1.456	5.545	7.001	2.381	3.234	4.691	2.310	2.941
523.1	496.4	0.912	15.21	7.639	4.678	4.642	4.067	-1.479	5.564	7.043	2.401	3.243	4.722	2.321	2.933
531.6	500.4	0.926	15.46	7.661	4.704	4.666	4.042	-1.505	5.581	7.086	2.420	3.248	4.753	2.333	2.929
540.2	504.0	0.942	15.71	7.684	4.723	4.685	4.015	-1.532	5.594	7.125	2.441	3.251	4.783	2.342	2.920
548.8	508.4	0.956	15.95	7.706	4.750	4.712	3.992	-1.555	5.621	7.175	2.464	3.265	4.819	2.356	2.913
557.4	512.5	0.971	16.21	7.729	4.774	4.735	3.971	-1.575	5.647	7.222	2.487	3.280	4.855	2.368	2.904
565.9	516.4	0.986	16.45	7.752	4.796	4.757	3.954	-1.592	5.674	7.266	2.509	3.296	4.888	2.378	2.895
574.3	520.7	1.001	16.70	7.775	4.822	4.781	3.935	-1.611	5.700	7.312	2.530	3.310	4.921	2.391	2.890

Stantec

Consolidated Undrained Triaxial Compression

ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-103, 11.3'-11.8'
Description Lean Clay with Sand (CL), dark brown, moist, firm
Specimen Type Intact
Preparation Wet Mounting

Project No. 174316204
Lab ID 37
Test ID 37-A

Date Received 11/15/2017
Date Tested 12/13/2017

Specific Gravity 2.70
ASTM D 854, Dry

Liquid Limit 27
Plastic Limit 15
Plasticity Index 12
ASTM D 4318

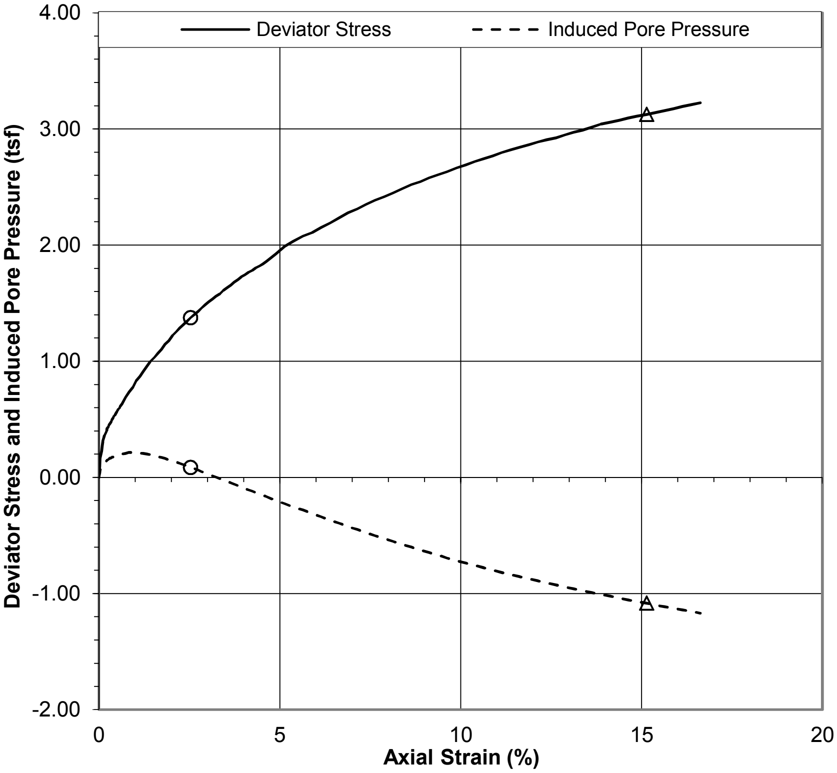
Target Test Parameters
Nominal Chamber Pressure (psi) 90
Nominal Back Pressure (psi) 80
Nominal Consolidation Pressure (psi) 10

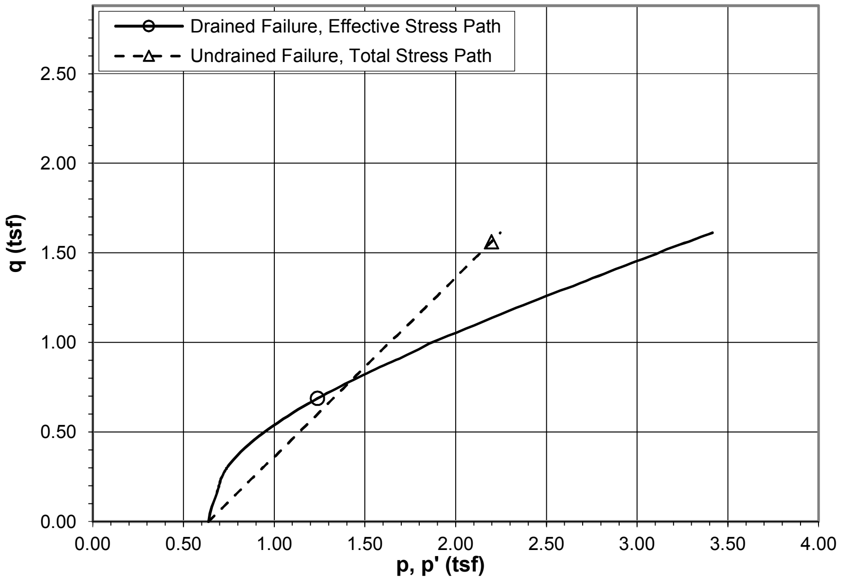
Saturation / Consolidation Results
Pore Pressure Parameter B 0.98
Measured Effective Consol. Stress (tsf) 0.637
Time to 50% Consolidation (min) 19.00
Actual Axial Strain Rate of Test (%/min) 0.016

Consolidated Specimen Conditions
Moist Unit Weight (pcf) 137.3
Moisture Content (%) 15.3
Dry Unit Weight (pcf) 119.1
Void Ratio 0.413
Degree of Saturation (%) 100.0

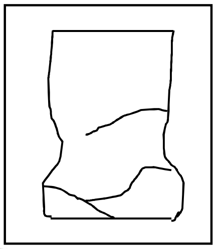
At Drained Failure
Failure Criterion: Max. Eff. Prin. Stress Ratio
Axial Strain (%) 2.536
Deviator Stress (tsf) 1.376
Induced Pore Pressure (tsf) 0.086
Minor Effective Stress, σ_3' (tsf) 0.551
Major Effective Stress, σ_1' (tsf) 1.927
Eff. Principal Stress Ratio, σ_1'/σ_3' 3.496
p' (tsf) 1.239
q (tsf) 0.688

At Consolidated Undrained Failure
Failure Criterion: 15% Axial Strain
Axial Strain (%) 15.143
Deviator Stress (tsf) 3.124
Minor Principal Stress, σ_3 (tsf) 0.635
Major Principal Stress, σ_1 (tsf) 3.759
p (tsf) 2.197
q (tsf) 1.562





Failure Sketch



Comments

Reviewed KG

Template: tmp_cu_input.xlsm
Version: 20170216
Approved By: RJ

Stantec Consulting Services Inc.
Lexington, Kentucky

Reported By: KG
Report Date: 12/22/2017

Stantec

Consolidated Undrained Triaxial Compression

ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-103, 11.3'-11.8'
Description Lean Clay with Sand (CL), dark brown, moist, firm

Project No. 174316204
Lab ID 37
Test ID 37-A

Initial Specimen Conditions		Consolidated Specimen Conditions	
Average Height (in)	6.081	Calculated Height (in)	6.108
Average Diameter (in)	2.850	Calculated Diameter (in)	2.878
Calculated Area (in^2)	6.379	Calculated Area (in^2)	6.508
Moist Weight (lb)	3.116	Moist Weight (lb)	3.158
Moist Unit Weight (pcf)	138.8	Moist Unit Weight (pcf)	137.3
Moisture Content (%)	13.8	Moisture Content (%)	15.3
Dry Weight (lb)	2.739	Dry Weight (lb)	2.739
Dry Unit Weight (pcf)	122.0	Dry Unit Weight (pcf)	119.1
Void Ratio	0.379	Void Ratio	0.413
Degree of Saturation (%)	98.1	Degree of Saturation (%)	100.0

Specific Gravity 2.70
ASTM D 854, Dry

Liquid Limit 27
Plastic Limit 15
Plasticity Index 12
ASTM D 4318

Confining Stress
σ_3 (tsf) 0.638

Effective Consolidation Stress
σ_3' (tsf) 0.638

Moisture contents obtained using partial specimen.
Specimen consolidated cross-sectional area determined using method B.
Membrane corrections have been applied,where Em = 200 lbf/in and t = 0.012 in.
All other tests performed in association with this specimen are reported separately.

Project: 174316204			Source: B-103, 11.3'-11.8'								Lab ID: 37		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
0.0	0.0	0.000	0.00	6.508	0.000	0.000	5.844	0.000	0.638	0.638	0.638	0.638	0.638	0.000	1.000
1.6	8.4	0.001	0.02	6.509	0.093	0.093	5.881	0.038	0.731	0.693	0.600	0.685	0.647	0.046	1.155
3.2	14.9	0.002	0.03	6.510	0.165	0.165	5.907	0.064	0.803	0.739	0.574	0.720	0.657	0.083	1.287
4.7	20.3	0.004	0.07	6.512	0.225	0.225	5.927	0.083	0.863	0.780	0.555	0.750	0.668	0.112	1.405
6.3	24.6	0.006	0.09	6.514	0.272	0.272	5.941	0.097	0.910	0.812	0.541	0.774	0.677	0.136	1.503
7.9	28.2	0.007	0.11	6.515	0.312	0.312	5.953	0.109	0.949	0.840	0.528	0.793	0.684	0.156	1.590
9.5	30.7	0.008	0.13	6.516	0.339	0.339	5.963	0.119	0.976	0.857	0.518	0.807	0.688	0.169	1.653
11.1	32.8	0.009	0.15	6.518	0.362	0.362	5.971	0.128	0.999	0.872	0.510	0.819	0.691	0.181	1.709
12.6	34.7	0.011	0.18	6.520	0.383	0.383	5.979	0.135	1.020	0.885	0.502	0.829	0.694	0.191	1.763
14.2	36.5	0.013	0.21	6.521	0.403	0.403	5.986	0.142	1.040	0.898	0.495	0.839	0.697	0.201	1.813
15.8	38.2	0.014	0.23	6.522	0.421	0.421	5.992	0.148	1.058	0.910	0.489	0.848	0.700	0.210	1.860
17.4	39.5	0.016	0.26	6.524	0.436	0.436	5.998	0.154	1.073	0.919	0.483	0.855	0.701	0.218	1.902
19.0	41.0	0.017	0.28	6.526	0.453	0.452	6.003	0.159	1.089	0.930	0.478	0.863	0.704	0.226	1.946
20.6	42.1	0.019	0.30	6.527	0.464	0.463	6.008	0.164	1.100	0.936	0.473	0.868	0.704	0.232	1.980
22.1	43.4	0.021	0.34	6.530	0.479	0.478	6.013	0.169	1.115	0.946	0.468	0.876	0.707	0.239	2.022
23.7	45.1	0.022	0.36	6.531	0.497	0.497	6.017	0.173	1.134	0.961	0.464	0.885	0.712	0.248	2.070
25.3	46.5	0.024	0.39	6.533	0.513	0.512	6.021	0.177	1.149	0.972	0.460	0.893	0.716	0.256	2.113
26.9	47.8	0.025	0.41	6.534	0.527	0.526	6.024	0.181	1.163	0.982	0.456	0.900	0.719	0.263	2.152
28.5	48.6	0.027	0.44	6.536	0.536	0.535	6.027	0.184	1.172	0.988	0.453	0.904	0.720	0.267	2.180
30.1	49.9	0.028	0.46	6.538	0.550	0.549	6.031	0.187	1.186	0.999	0.450	0.912	0.724	0.274	2.220
31.6	51.2	0.030	0.49	6.540	0.564	0.563	6.033	0.190	1.199	1.009	0.447	0.918	0.728	0.281	2.259
33.2	52.2	0.031	0.51	6.541	0.575	0.574	6.037	0.193	1.211	1.018	0.444	0.924	0.731	0.287	2.291
34.8	53.5	0.033	0.54	6.543	0.588	0.587	6.038	0.195	1.224	1.029	0.442	0.930	0.736	0.294	2.328
36.4	54.5	0.034	0.56	6.544	0.600	0.599	6.041	0.197	1.235	1.038	0.440	0.936	0.739	0.299	2.362
38.0	55.7	0.036	0.59	6.546	0.613	0.612	6.042	0.199	1.248	1.050	0.438	0.942	0.744	0.306	2.396
39.6	56.7	0.037	0.61	6.547	0.624	0.623	6.044	0.200	1.259	1.059	0.436	0.948	0.747	0.311	2.427
41.1	57.8	0.039	0.64	6.549	0.636	0.634	6.046	0.202	1.271	1.069	0.435	0.954	0.752	0.317	2.458
47.5	63.0	0.045	0.73	6.556	0.691	0.690	6.050	0.206	1.326	1.119	0.430	0.981	0.775	0.345	2.605
53.8	67.3	0.051	0.83	6.562	0.739	0.737	6.057	0.214	1.377	1.164	0.427	1.009	0.795	0.368	2.725
60.1	71.2	0.057	0.94	6.569	0.780	0.778	6.058	0.214	1.418	1.204	0.427	1.030	0.815	0.389	2.824
66.4	76.1	0.063	1.03	6.575	0.833	0.831	6.057	0.214	1.472	1.258	0.427	1.056	0.843	0.415	2.943
72.7	79.9	0.069	1.13	6.582	0.874	0.871	6.054	0.210	1.512	1.302	0.431	1.076	0.866	0.436	3.023
79.1	83.8	0.075	1.23	6.588	0.916	0.913	6.049	0.206	1.553	1.348	0.434	1.097	0.891	0.457	3.102
85.4	88.1	0.081	1.33	6.595	0.961	0.958	6.044	0.201	1.598	1.398	0.440	1.119	0.919	0.479	3.180
91.7	91.7	0.087	1.42	6.601	1.000	0.997	6.038	0.194	1.637	1.443	0.446	1.139	0.944	0.498	3.235
98.0	95.3	0.094	1.53	6.609	1.038	1.034	6.030	0.187	1.674	1.487	0.453	1.157	0.970	0.517	3.284
104.3	98.4	0.100	1.63	6.616	1.071	1.068	6.023	0.179	1.707	1.528	0.460	1.173	0.994	0.534	3.320
110.7	101.7	0.106	1.73	6.622	1.106	1.102	6.015	0.171	1.741	1.570	0.468	1.190	1.019	0.551	3.355
117.0	105.9	0.112	1.83	6.629	1.150	1.145	6.006	0.162	1.784	1.622	0.477	1.212	1.050	0.573	3.401

Project: 174316204			Source: B-103, 11.3'-11.8'									Lab ID: 37		Test ID	
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
123.3	108.9	0.118	1.93	6.636	1.182	1.177	5.996	0.152	1.816	1.664	0.487	1.228	1.075	0.589	3.418
129.6	113.2	0.124	2.04	6.643	1.227	1.222	5.986	0.142	1.861	1.719	0.497	1.250	1.108	0.611	3.460
135.9	116.2	0.131	2.14	6.650	1.258	1.252	5.975	0.131	1.891	1.760	0.507	1.265	1.134	0.626	3.468
142.3	119.4	0.137	2.24	6.656	1.292	1.286	5.964	0.121	1.925	1.804	0.518	1.282	1.161	0.643	3.483
148.6	122.2	0.142	2.33	6.663	1.321	1.315	5.953	0.109	1.953	1.844	0.529	1.296	1.187	0.658	3.486
154.9	125.1	0.149	2.43	6.670	1.351	1.345	5.941	0.098	1.982	1.885	0.540	1.310	1.212	0.672	3.490
161.2	128.2	0.155	2.54	6.677	1.382	1.376	5.930	0.086	2.014	1.927	0.551	1.326	1.239	0.688	3.496
167.5	131.0	0.161	2.64	6.684	1.411	1.405	5.918	0.074	2.043	1.969	0.564	1.340	1.266	0.703	3.492
173.9	133.6	0.168	2.74	6.691	1.438	1.431	5.906	0.063	2.069	2.006	0.575	1.353	1.290	0.716	3.489
180.2	136.1	0.173	2.84	6.698	1.463	1.457	5.894	0.050	2.094	2.044	0.587	1.366	1.316	0.728	3.480
186.5	138.8	0.179	2.94	6.704	1.491	1.484	5.882	0.039	2.121	2.083	0.599	1.379	1.341	0.742	3.478
192.8	141.6	0.185	3.04	6.711	1.519	1.511	5.870	0.026	2.149	2.123	0.611	1.393	1.367	0.756	3.473
199.1	144.0	0.192	3.14	6.718	1.543	1.535	5.857	0.014	2.172	2.159	0.623	1.404	1.391	0.768	3.463
205.5	146.4	0.197	3.23	6.725	1.568	1.560	5.845	0.002	2.196	2.195	0.635	1.416	1.415	0.780	3.457
211.8	148.7	0.204	3.35	6.733	1.590	1.582	5.833	-0.011	2.218	2.229	0.647	1.427	1.438	0.791	3.445
218.1	151.4	0.210	3.44	6.739	1.617	1.609	5.822	-0.022	2.246	2.268	0.659	1.441	1.463	0.805	3.442
224.4	153.7	0.216	3.53	6.746	1.640	1.632	5.809	-0.034	2.268	2.302	0.671	1.452	1.487	0.816	3.432
230.7	156.1	0.223	3.64	6.754	1.664	1.656	5.797	-0.046	2.292	2.338	0.683	1.464	1.511	0.828	3.425
237.1	158.6	0.228	3.74	6.760	1.689	1.680	5.785	-0.058	2.317	2.375	0.695	1.477	1.535	0.840	3.419
243.4	160.9	0.235	3.84	6.768	1.712	1.702	5.773	-0.071	2.339	2.409	0.707	1.487	1.558	0.851	3.408
249.7	163.4	0.241	3.94	6.775	1.736	1.727	5.761	-0.083	2.363	2.446	0.719	1.500	1.583	0.863	3.400
256.0	165.1	0.247	4.04	6.781	1.753	1.743	5.748	-0.096	2.378	2.474	0.731	1.507	1.603	0.871	3.383
262.3	167.5	0.253	4.14	6.788	1.776	1.767	5.736	-0.108	2.402	2.510	0.743	1.519	1.627	0.883	3.376
268.6	169.3	0.259	4.24	6.796	1.794	1.784	5.724	-0.120	2.420	2.539	0.756	1.528	1.647	0.892	3.361
275.0	171.6	0.265	4.34	6.803	1.816	1.806	5.711	-0.132	2.441	2.573	0.768	1.538	1.671	0.903	3.353
281.3	173.2	0.271	4.44	6.810	1.831	1.820	5.700	-0.144	2.456	2.600	0.779	1.546	1.690	0.910	3.335
287.6	175.1	0.277	4.53	6.817	1.850	1.839	5.688	-0.156	2.475	2.631	0.792	1.556	1.711	0.919	3.323
293.9	177.3	0.283	4.63	6.824	1.871	1.860	5.677	-0.167	2.496	2.663	0.803	1.566	1.733	0.930	3.317
309.7	183.9	0.298	4.89	6.842	1.935	1.924	5.646	-0.198	2.559	2.757	0.833	1.597	1.795	0.962	3.309
325.5	190.7	0.314	5.13	6.860	2.001	1.989	5.616	-0.227	2.625	2.852	0.863	1.630	1.857	0.995	3.306
341.3	195.3	0.328	5.38	6.877	2.045	2.032	5.587	-0.256	2.668	2.924	0.892	1.652	1.908	1.016	3.278
357.1	200.2	0.344	5.64	6.896	2.090	2.076	5.563	-0.280	2.716	2.997	0.921	1.678	1.959	1.038	3.255
372.9	203.7	0.360	5.89	6.915	2.121	2.107	5.533	-0.311	2.747	3.057	0.950	1.693	2.004	1.053	3.217
388.7	208.7	0.375	6.14	6.933	2.168	2.153	5.504	-0.339	2.793	3.132	0.979	1.716	2.056	1.076	3.199
404.5	212.9	0.390	6.39	6.952	2.205	2.190	5.476	-0.368	2.829	3.197	1.007	1.734	2.102	1.095	3.174
420.3	217.9	0.406	6.64	6.971	2.251	2.235	5.448	-0.395	2.874	3.269	1.034	1.757	2.152	1.117	3.161
436.1	222.7	0.421	6.89	6.989	2.294	2.277	5.420	-0.423	2.916	3.339	1.062	1.777	2.201	1.139	3.144
451.8	226.8	0.436	7.14	7.008	2.330	2.313	5.394	-0.450	2.951	3.401	1.088	1.795	2.245	1.156	3.125
467.6	231.1	0.451	7.38	7.026	2.368	2.350	5.366	-0.477	2.988	3.465	1.115	1.813	2.290	1.175	3.107
483.4	235.4	0.466	7.63	7.045	2.405	2.387	5.342	-0.502	3.025	3.527	1.140	1.832	2.334	1.193	3.094
499.2	238.8	0.482	7.88	7.065	2.434	2.415	5.316	-0.528	3.053	3.580	1.165	1.845	2.373	1.208	3.073
515.0	243.0	0.497	8.14	7.084	2.470	2.450	5.291	-0.552	3.089	3.641	1.190	1.864	2.416	1.225	3.058
530.8	247.1	0.512	8.38	7.103	2.505	2.484	5.267	-0.576	3.123	3.699	1.215	1.880	2.457	1.242	3.046
546.6	251.3	0.527	8.64	7.123	2.541	2.520	5.243	-0.600	3.159	3.759	1.239	1.899	2.499	1.260	3.033
562.4	254.7	0.543	8.88	7.142	2.568	2.547	5.219	-0.625	3.185	3.810	1.263	1.912	2.537	1.273	3.016
578.2	258.7	0.558	9.13	7.161	2.601	2.579	5.196	-0.648	3.218	3.866	1.287	1.928	2.577	1.289	3.003
594.0	262.2	0.573	9.38	7.181	2.629	2.606	5.173	-0.671	3.245	3.916	1.310	1.942	2.613	1.303	2.989
609.8	265.4	0.588	9.62	7.200	2.654	2.631	5.150	-0.694	3.270	3.964	1.333	1.954	2.648	1.315	2.974
625.6	269.5	0.604	9.88	7.221	2.687	2.663	5.127	-0.716	3.301	4.018	1.355	1.970	2.686	1.332	2.966
641.3	272.8	0.619	10.14	7.242	2.712	2.688	5.106	-0.738	3.326	4.064	1.376	1.982	2.720	1.344	2.954
657.1	276.8	0.635	10.39	7.262	2.744	2.719	5.085	-0.759	3.356	4.115	1.396	1.997	2.755	1.360	2.948
672.9	279.9	0.649	10.63	7.282	2.768	2.742	5.065	-0.779	3.380	4.158	1.416	2.009	2.787	1.371	2.936
688.7	283.3	0.665	10.89	7.302	2.793	2.767	5.045	-0.799	3.403	4.202	1.435	2.020	2.819	1.383	2.927
704.5	287.0	0.680	11.13	7.323	2.822	2.795	5.026	-0.818	3.432	4.250	1.454	2.034	2.852	1.398	2.922
720.3	290.3	0.695	11.38	7.344	2.846	2.819	5.007	-0.837	3.455	4.292	1.473	2.045	2.882	1.410	2.914
736.1	293.4	0.710	11.63	7.364	2.869	2.841	4.989	-0.854	3.477	4.332	1.491	2.057	2.911	1.420	2.905
751.9	296.5	0.726	11.88	7.385	2.891	2.862	4.971	-0.873	3.498	4.371	1.509	2.067	2.940	1.431	2.897
767.7	300.0	0.741	12.14	7.406	2.916	2.887	4.953	-0.891	3.523	4.414	1.527	2.080	2.970	1.444	2.891
783.5	302.9	0.757	12.39	7.428	2.936	2.907	4.935	-0.909	3.542	4.451	1.544	2.089	2.998	1.453	2.882
799.3	305.7	0.772	12.64	7.449	2.955	2.925	4.918	-0.926	3.561	4.486	1.562	2.098	3.024	1.462	2.873
815.0	309.1	0.787	12.88	7.470	2.979	2.948	4.901	-0.942	3.584	4.527	1.579	2.110	3.053	1.474	2.868
830.8	312.3	0.802	13.13	7.491	3.002	2.971	4.885	-0.959	3.607	4.566	1.595	2.121	3.080	1.485	2.862
846.6	315.2	0.817	13.38	7.512	3.021	2.989	4.868	-0.976	3.624	4.600	1.612	2.130	3.106	1.494	2.855
862.4	318.9	0.832	13.63	7.534	3.047	3.015	4.852	-0.992	3.651	4.643	1.628	2.143	3.135	1.507	2.852
878.2	322.6	0.848	13.88	7.556	3.074	3.041	4.835	-1.008	3.676	4.685	1.644	2.156	3.164	1.520	2.850
894.0	325.5	0.864	14.14	7.579	3.092	3.058	4.820	-1.023	3.694	4.717	1.659	2.165	3.188	1.529	2.843
909.8	328.4	0.879	14.39	7.601	3.111	3.076	4.804	-1.040	3.711	4.751	1.675	2.173	3.213	1.538	2.836
925.6	331.3	0.894	14.64	7.623	3.129	3.094	4.789	-1.055	3.730	4.785	1.691	2.183	3.238	1.547	2.830
941.4	334.0	0.909	14.89	7.646	3.145	3.109	4.773	-1.070	3.744	4.814	1.705	2.189	3.260	1.555	2.824

Project: 174316204			Source: B-103, 11.3'-11.8'								Lab ID: 37		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
957.2	336.6	0.925	15.14	7.669	3.160	3.124	4.759	-1.084	3.759	4.843	1.720	2.197	3.282	1.562	2.816
973.0	339.4	0.940	15.39	7.691	3.177	3.140	4.744	-1.100	3.775	4.875	1.734	2.205	3.305	1.570	2.811
988.8	342.4	0.955	15.64	7.714	3.196	3.158	4.730	-1.114	3.793	4.906	1.748	2.214	3.327	1.579	2.807
1004.5	345.3	0.970	15.89	7.737	3.213	3.175	4.716	-1.128	3.809	4.937	1.762	2.222	3.349	1.588	2.802
1020.3	348.4	0.985	16.13	7.759	3.232	3.194	4.702	-1.141	3.828	4.969	1.775	2.231	3.372	1.597	2.799
1036.1	351.2	1.001	16.39	7.783	3.249	3.210	4.688	-1.156	3.844	4.999	1.790	2.239	3.395	1.605	2.794
1051.1	353.9	1.016	16.63	7.805	3.265	3.225	4.674	-1.169	3.859	5.028	1.803	2.246	3.415	1.612	2.789

Stantec

Consolidated Undrained Triaxial Compression
ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-103, 14.5'-15.0'
Description Lean Clay with Sand (CL), dark brown, moist, firm
Specimen Type Intact
Preparation Wet Mounting

Project No. 174316204
Lab ID 38
Test ID 38-A

Date Received 11/15/2017
Date Tested 12/13/2017

Specific Gravity 2.69
ASTM D 854, Dry

Liquid Limit 29
Plastic Limit 16
Plasticity Index 13
ASTM D 4318

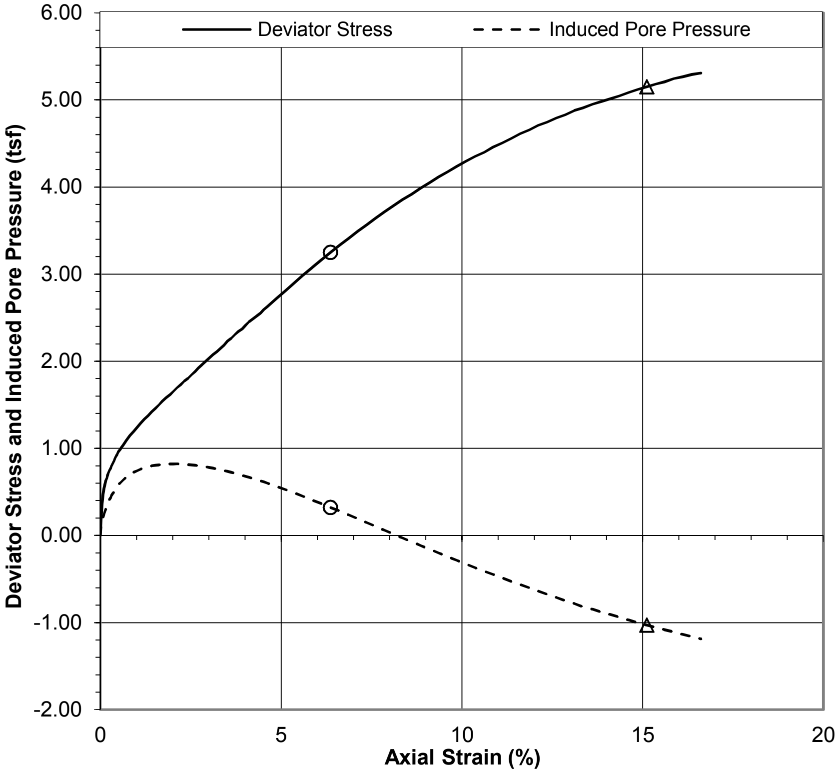
Target Test Parameters
Nominal Chamber Pressure (psi) 90
Nominal Back Pressure (psi) 60
Nominal Consolidation Pressure (psi) 30

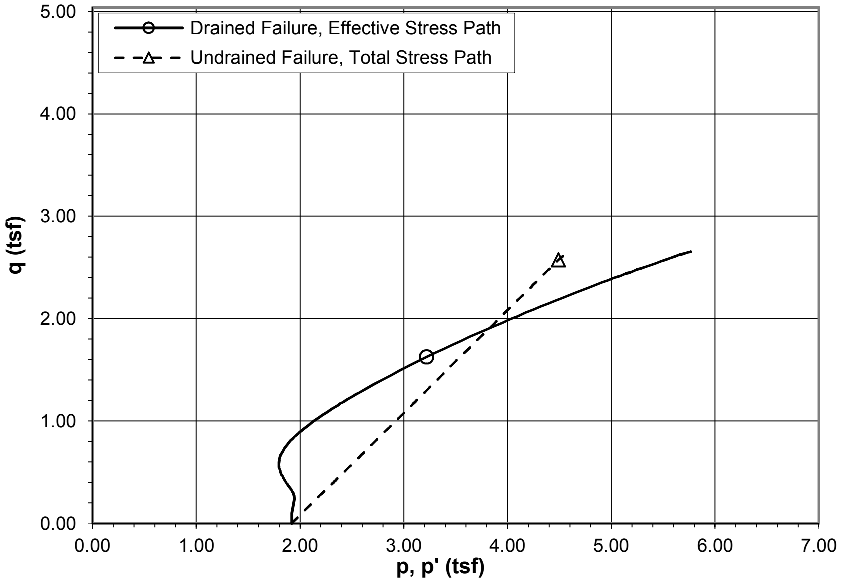
Saturation / Consolidation Results
Pore Pressure Parameter B 0.98
Measured Effective Consol. Stress (tsf) 1.921
Time to 50% Consolidation (min) 27.00
Actual Axial Strain Rate of Test (%/min) 0.011

Consolidated Specimen Conditions
Moist Unit Weight (pcf) 137.2
Moisture Content (%) 15.1
Dry Unit Weight (pcf) 119.3
Void Ratio 0.406
Degree of Saturation (%) 100.0

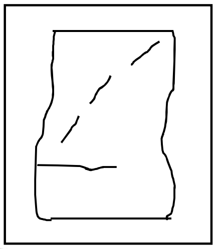
At Drained Failure
Failure Criterion: Max. Eff. Prin. Stress Ratio
Axial Strain (%) 6.369
Deviator Stress (tsf) 3.250
Induced Pore Pressure (tsf) 0.322
Minor Effective Stress, σ_3' (tsf) 1.594
Major Effective Stress, σ_1' (tsf) 4.844
Eff. Principal Stress Ratio, σ_1'/σ_3' 3.039
p' (tsf) 3.219
q (tsf) 1.625

At Consolidated Undrained Failure
Failure Criterion: 15% Axial Strain
Axial Strain (%) 15.112
Deviator Stress (tsf) 5.148
Minor Principal Stress, σ_3 (tsf) 1.917
Major Principal Stress, σ_1 (tsf) 7.065
p (tsf) 4.491
q (tsf) 2.574





Failure Sketch



Comments

Reviewed KG

Consolidated Undrained Triaxial Compression
ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-103, 14.5'-15.0'
Description Lean Clay with Sand (CL), dark brown, moist, firm

Project No. 174316204
Lab ID 38
Test ID 38-A

Initial Specimen Conditions	
Average Height (in)	6.087
Average Diameter (in)	2.827
Calculated Area (in^2)	6.278
Moist Weight (lb)	3.051
Moist Unit Weight (pcf)	137.9
Moisture Content (%)	14.5
Dry Weight (lb)	2.665
Dry Unit Weight (pcf)	120.5
Void Ratio	0.391
Degree of Saturation (%)	99.5

Consolidated Specimen Conditions	
Calculated Height (in)	6.050
Calculated Diameter (in)	2.851
Calculated Area (in^2)	6.384
Moist Weight (lb)	3.067
Moist Unit Weight (pcf)	137.2
Moisture Content (%)	15.1
Dry Weight (lb)	2.665
Dry Unit Weight (pcf)	119.3
Void Ratio	0.406
Degree of Saturation (%)	100.0

Specific Gravity 2.69
ASTM D 854, Dry

Liquid Limit 29
Plastic Limit 16
Plasticity Index 13
ASTM D 4318

Confining Stress
σ_3 (tsf) 1.920

Effective Consolidation Stress
σ_3' (tsf) 1.920

Moisture contents obtained using partial specimen.
Specimen consolidated cross-sectional area determined using method B.
Membrane corrections have been applied,where Em = 200 lbf/in and t = 0.012 in.
All other tests performed in association with this specimen are reported separately.

Project: 174316204			Source: B-103, 14.5'-15.0'								Lab ID: 38		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
0.0	0.0	0.000	0.00	6.384	0.000	0.000	4.558	0.000	1.920	1.920	1.920	1.920	1.920	0.000	1.000
2.2	18.0	0.001	0.02	6.385	0.203	0.203	4.657	0.099	2.122	2.023	1.821	2.021	1.922	0.101	1.111
4.5	32.6	0.003	0.05	6.387	0.368	0.368	4.726	0.167	2.287	2.120	1.752	2.103	1.936	0.184	1.210
6.7	42.1	0.004	0.07	6.388	0.475	0.474	4.769	0.211	2.394	2.183	1.708	2.157	1.946	0.237	1.278
9.0	48.0	0.006	0.10	6.390	0.541	0.541	4.804	0.246	2.460	2.214	1.674	2.190	1.944	0.270	1.323
11.2	52.3	0.008	0.13	6.392	0.589	0.589	4.836	0.278	2.508	2.230	1.641	2.214	1.936	0.295	1.359
13.5	55.8	0.009	0.15	6.393	0.628	0.628	4.867	0.309	2.547	2.238	1.611	2.233	1.924	0.314	1.390
15.7	58.7	0.011	0.18	6.395	0.661	0.660	4.898	0.340	2.584	2.244	1.584	2.254	1.914	0.330	1.417
17.9	61.5	0.012	0.20	6.396	0.692	0.692	4.925	0.367	2.615	2.248	1.557	2.270	1.902	0.346	1.444
20.2	64.1	0.013	0.22	6.398	0.721	0.720	4.949	0.391	2.644	2.253	1.532	2.284	1.892	0.360	1.470
22.4	66.5	0.015	0.25	6.400	0.748	0.747	4.973	0.414	2.670	2.256	1.509	2.297	1.882	0.373	1.495
24.6	68.7	0.017	0.28	6.402	0.773	0.772	4.994	0.436	2.696	2.260	1.487	2.309	1.874	0.386	1.519
26.9	70.8	0.018	0.30	6.403	0.796	0.796	5.014	0.456	2.719	2.263	1.467	2.321	1.865	0.398	1.542
29.1	72.8	0.020	0.33	6.405	0.819	0.818	5.032	0.473	2.740	2.267	1.449	2.331	1.858	0.409	1.564
31.4	74.8	0.021	0.35	6.406	0.841	0.840	5.049	0.491	2.763	2.272	1.432	2.343	1.852	0.420	1.587
33.6	76.9	0.023	0.38	6.408	0.864	0.863	5.066	0.508	2.785	2.277	1.414	2.354	1.846	0.431	1.610
35.8	78.6	0.024	0.40	6.409	0.883	0.882	5.082	0.524	2.805	2.281	1.399	2.364	1.840	0.441	1.631
38.1	80.6	0.026	0.42	6.411	0.905	0.904	5.097	0.539	2.826	2.287	1.383	2.374	1.835	0.452	1.653
40.3	82.4	0.027	0.45	6.412	0.925	0.924	5.112	0.554	2.846	2.292	1.369	2.384	1.831	0.462	1.675
42.6	83.7	0.029	0.48	6.414	0.939	0.938	5.125	0.567	2.860	2.293	1.355	2.391	1.824	0.469	1.692
44.8	85.3	0.030	0.49	6.415	0.957	0.956	5.138	0.580	2.878	2.299	1.343	2.401	1.821	0.478	1.712
47.0	86.7	0.031	0.52	6.417	0.973	0.972	5.151	0.593	2.895	2.302	1.330	2.409	1.816	0.486	1.731
49.3	88.4	0.033	0.55	6.419	0.992	0.991	5.163	0.605	2.914	2.309	1.318	2.418	1.813	0.495	1.752
51.5	89.9	0.035	0.58	6.421	1.009	1.007	5.174	0.616	2.930	2.314	1.307	2.427	1.811	0.504	1.770
53.8	91.5	0.036	0.60	6.422	1.025	1.024	5.184	0.626	2.947	2.321	1.297	2.435	1.809	0.512	1.790
56.0	92.6	0.038	0.63	6.424	1.038	1.036	5.194	0.636	2.960	2.324	1.287	2.441	1.806	0.518	1.805
65.0	97.6	0.044	0.72	6.430	1.093	1.091	5.228	0.670	3.014	2.344	1.253	2.469	1.799	0.546	1.871
73.9	102.7	0.050	0.82	6.436	1.149	1.147	5.258	0.700	3.070	2.370	1.223	2.497	1.796	0.573	1.938
82.9	107.2	0.056	0.92	6.443	1.198	1.195	5.282	0.724	3.119	2.395	1.200	2.521	1.797	0.598	1.997
91.9	111.7	0.062	1.02	6.449	1.247	1.245	5.302	0.744	3.167	2.424	1.179	2.545	1.801	0.622	2.056
100.8	115.9	0.068	1.12	6.456	1.293	1.290	5.319	0.761	3.213	2.452	1.162	2.568	1.807	0.645	2.111
109.8	120.1	0.074	1.22	6.462	1.338	1.335	5.334	0.776	3.257	2.482	1.147	2.590	1.814	0.667	2.164
118.7	124.0	0.080	1.32	6.469	1.380	1.377	5.345	0.787	3.300	2.513	1.135	2.611	1.824	0.689	2.213
127.7	128.1	0.086	1.42	6.475	1.424	1.421	5.356	0.797	3.344	2.547	1.126	2.634	1.836	0.710	2.262
136.6	131.6	0.092	1.52	6.482	1.462	1.458	5.363	0.805	3.382	2.577	1.119	2.652	1.848	0.729	2.303
145.6	135.5	0.098	1.62	6.489	1.504	1.500	5.369	0.811	3.423	2.612	1.112	2.673	1.862	0.750	2.349
154.6	139.4	0.104	1.71	6.495	1.545	1.541	5.374	0.816	3.463	2.647	1.107	2.693	1.877	0.770	2.392
163.5	143.2	0.110	1.82	6.502	1.585	1.581	5.377	0.819	3.504	2.685	1.104	2.713	1.894	0.790	2.433
172.5	146.6	0.117	1.93	6.509	1.621	1.617	5.379	0.821	3.539	2.718	1.102	2.731	1.910	0.808	2.468

Project: 174316204			**Source:**	**B-103, 14.5'-15.0'**							**Lab ID: 38**		**Test ID**		
Test Time (min)	**Corr. Axial Load (lbf)**	**Axial Deform. (in)**	**Axial Strain (%)**	**Corr. Area (in^2)**	**Deviator Stress (tsf)**	**Corr. Deviator Stress (tsf)**	**Pore Pressure (tsf)**	**Induced Pore Pressure (tsf)**	**σ_1 (tsf)**	**σ_1' (tsf)**	**σ_3' (tsf)**	**p (tsf)**	**p' (tsf)**	**q (tsf)**	**Eff. Princ. Stress Ratio σ_1'/σ_3'**
181.4	150.1	0.122	2.02	6.515	1.659	1.654	5.379	0.821	3.577	2.756	1.102	2.750	1.929	0.827	2.501
190.4	153.9	0.128	2.12	6.522	1.700	1.694	5.380	0.821	3.618	2.796	1.102	2.770	1.949	0.847	2.538
199.3	157.6	0.135	2.22	6.529	1.739	1.733	5.377	0.819	3.656	2.837	1.104	2.789	1.971	0.867	2.570
208.3	161.5	0.140	2.32	6.535	1.779	1.773	5.376	0.818	3.697	2.879	1.106	2.810	1.992	0.887	2.604
217.3	164.7	0.147	2.43	6.542	1.812	1.806	5.372	0.814	3.729	2.916	1.110	2.826	2.013	0.903	2.628
226.2	168.4	0.153	2.52	6.549	1.851	1.845	5.368	0.810	3.768	2.958	1.113	2.845	2.035	0.922	2.658
235.2	172.0	0.158	2.62	6.555	1.890	1.883	5.363	0.805	3.806	3.001	1.118	2.864	2.059	0.942	2.685
244.1	175.8	0.164	2.71	6.562	1.929	1.922	5.358	0.799	3.844	3.044	1.122	2.883	2.083	0.961	2.713
253.1	179.7	0.171	2.82	6.569	1.970	1.963	5.353	0.795	3.885	3.091	1.128	2.904	2.109	0.981	2.740
262.0	183.2	0.176	2.92	6.575	2.006	1.999	5.345	0.787	3.921	3.134	1.135	2.922	2.135	0.999	2.760
271.0	186.9	0.182	3.01	6.582	2.044	2.037	5.338	0.780	3.959	3.179	1.142	2.940	2.161	1.019	2.783
279.9	190.6	0.189	3.12	6.589	2.083	2.075	5.330	0.771	3.997	3.226	1.151	2.960	2.188	1.038	2.804
288.9	194.1	0.195	3.22	6.596	2.119	2.111	5.322	0.763	4.033	3.270	1.159	2.978	2.214	1.056	2.822
297.9	197.9	0.201	3.33	6.603	2.158	2.150	5.313	0.754	4.073	3.318	1.168	2.998	2.243	1.075	2.841
306.8	201.2	0.207	3.42	6.610	2.192	2.183	5.302	0.744	4.106	3.362	1.179	3.014	2.270	1.092	2.853
315.8	205.7	0.213	3.52	6.616	2.238	2.230	5.293	0.735	4.153	3.418	1.188	3.038	2.303	1.115	2.877
324.7	209.0	0.219	3.62	6.624	2.272	2.264	5.283	0.725	4.187	3.462	1.198	3.055	2.330	1.132	2.889
333.7	212.9	0.225	3.71	6.630	2.312	2.303	5.272	0.713	4.226	3.513	1.210	3.074	2.361	1.152	2.904
342.6	216.8	0.231	3.82	6.637	2.352	2.343	5.261	0.702	4.265	3.563	1.220	3.094	2.391	1.171	2.920
351.6	219.8	0.237	3.92	6.644	2.382	2.373	5.248	0.690	4.294	3.604	1.231	3.108	2.418	1.186	2.927
360.6	223.6	0.243	4.01	6.650	2.421	2.411	5.237	0.679	4.332	3.653	1.242	3.127	2.448	1.206	2.941
369.5	227.7	0.249	4.11	6.657	2.463	2.453	5.225	0.667	4.374	3.707	1.255	3.148	2.481	1.226	2.955
378.5	230.9	0.255	4.22	6.665	2.494	2.484	5.213	0.654	4.406	3.751	1.267	3.164	2.509	1.242	2.960
387.5	234.3	0.261	4.32	6.672	2.529	2.518	5.199	0.641	4.439	3.798	1.280	3.180	2.539	1.259	2.967
396.4	237.7	0.268	4.42	6.679	2.562	2.551	5.185	0.627	4.472	3.846	1.294	3.197	2.570	1.276	2.972
405.3	241.5	0.273	4.52	6.686	2.601	2.590	5.173	0.615	4.511	3.897	1.306	3.216	2.602	1.295	2.983
414.3	245.2	0.280	4.62	6.693	2.638	2.626	5.158	0.600	4.547	3.947	1.321	3.234	2.634	1.313	2.989
436.7	254.4	0.295	4.87	6.710	2.730	2.718	5.123	0.565	4.638	4.074	1.355	3.279	2.715	1.359	3.006
459.1	263.6	0.309	5.12	6.728	2.821	2.809	5.085	0.527	4.728	4.201	1.393	3.324	2.797	1.404	3.017
481.5	272.6	0.324	5.36	6.745	2.910	2.897	5.047	0.488	4.817	4.328	1.431	3.368	2.880	1.449	3.024
503.9	281.9	0.339	5.61	6.763	3.001	2.987	5.007	0.448	4.906	4.457	1.470	3.412	2.964	1.494	3.032
526.3	291.0	0.354	5.86	6.781	3.089	3.075	4.965	0.406	4.992	4.586	1.510	3.454	3.048	1.538	3.036
548.6	300.1	0.370	6.11	6.799	3.178	3.163	4.923	0.365	5.080	4.715	1.552	3.499	3.134	1.582	3.038
571.0	309.2	0.385	6.37	6.818	3.266	3.250	4.880	0.322	5.166	4.844	1.594	3.541	3.219	1.625	3.039
593.4	318.0	0.401	6.62	6.836	3.349	3.333	4.837	0.279	5.249	4.970	1.637	3.583	3.304	1.666	3.036
615.8	326.3	0.416	6.87	6.855	3.427	3.410	4.793	0.235	5.327	5.092	1.682	3.622	3.387	1.705	3.028
638.2	334.9	0.431	7.12	6.873	3.509	3.491	4.751	0.193	5.409	5.216	1.725	3.664	3.470	1.746	3.024
660.6	342.9	0.445	7.36	6.891	3.583	3.565	4.707	0.148	5.483	5.335	1.769	3.700	3.552	1.783	3.015
683.0	351.4	0.461	7.62	6.910	3.661	3.643	4.664	0.106	5.561	5.455	1.812	3.739	3.634	1.821	3.010
705.4	359.4	0.476	7.86	6.928	3.734	3.715	4.619	0.061	5.633	5.572	1.856	3.775	3.714	1.858	3.001
727.8	367.2	0.491	8.11	6.947	3.805	3.786	4.576	0.018	5.704	5.686	1.900	3.811	3.793	1.893	2.993
750.2	374.9	0.506	8.36	6.966	3.875	3.855	4.531	-0.027	5.772	5.799	1.944	3.845	3.872	1.927	2.982
772.6	382.0	0.521	8.61	6.985	3.938	3.917	4.487	-0.071	5.834	5.906	1.989	3.876	3.947	1.958	2.970
795.0	389.9	0.536	8.86	7.004	4.008	3.986	4.444	-0.115	5.903	6.018	2.031	3.910	4.025	1.993	2.962
817.3	397.1	0.551	9.11	7.024	4.070	4.048	4.400	-0.158	5.965	6.124	2.075	3.941	4.100	2.024	2.951
839.7	405.0	0.566	9.36	7.043	4.141	4.118	4.358	-0.200	6.035	6.235	2.117	3.976	4.176	2.059	2.945
862.1	411.9	0.581	9.61	7.062	4.199	4.176	4.314	-0.244	6.093	6.338	2.161	4.005	4.250	2.088	2.932
884.5	419.1	0.597	9.86	7.082	4.261	4.237	4.272	-0.286	6.154	6.440	2.203	4.035	4.321	2.118	2.923
906.9	426.1	0.612	10.12	7.102	4.320	4.295	4.230	-0.328	6.213	6.541	2.246	4.065	4.394	2.148	2.912
929.3	432.8	0.627	10.37	7.122	4.376	4.351	4.190	-0.368	6.269	6.637	2.286	4.093	4.461	2.175	2.903
951.7	438.9	0.642	10.62	7.142	4.425	4.399	4.149	-0.409	6.318	6.727	2.328	4.118	4.527	2.199	2.890
974.1	445.9	0.657	10.86	7.161	4.483	4.457	4.110	-0.448	6.375	6.823	2.366	4.147	4.595	2.229	2.884
996.5	452.1	0.672	11.11	7.182	4.532	4.506	4.071	-0.487	6.424	6.911	2.406	4.171	4.658	2.253	2.873
1018.8	458.5	0.688	11.36	7.202	4.584	4.556	4.031	-0.527	6.474	7.001	2.445	4.196	4.723	2.278	2.864
1041.2	465.3	0.703	11.61	7.223	4.639	4.610	3.994	-0.564	6.529	7.093	2.483	4.224	4.788	2.305	2.857
1063.6	471.2	0.718	11.87	7.243	4.684	4.655	3.956	-0.602	6.573	7.175	2.519	4.245	4.847	2.328	2.848
1086.0	477.8	0.733	12.11	7.263	4.736	4.707	3.919	-0.639	6.625	7.264	2.557	4.272	4.911	2.354	2.841
1108.4	482.9	0.748	12.36	7.284	4.773	4.744	3.882	-0.676	6.661	7.337	2.593	4.289	4.965	2.372	2.829
1130.8	489.4	0.763	12.61	7.305	4.823	4.793	3.847	-0.711	6.710	7.421	2.628	4.313	5.024	2.396	2.824
1153.2	494.4	0.778	12.86	7.325	4.860	4.829	3.810	-0.748	6.745	7.493	2.664	4.331	5.078	2.414	2.812
1175.6	500.9	0.793	13.11	7.347	4.909	4.877	3.777	-0.781	6.794	7.575	2.698	4.355	5.136	2.438	2.808
1198.0	505.2	0.808	13.35	7.367	4.938	4.905	3.741	-0.817	6.821	7.638	2.733	4.368	5.185	2.453	2.795
1220.4	511.6	0.823	13.61	7.389	4.985	4.952	3.710	-0.848	6.867	7.715	2.764	4.391	5.239	2.476	2.792
1242.8	516.0	0.838	13.86	7.410	5.013	4.980	3.680	-0.879	6.899	7.778	2.798	4.409	5.288	2.490	2.780
1265.1	521.1	0.854	14.11	7.433	5.048	5.014	3.648	-0.911	6.932	7.843	2.829	4.425	5.336	2.507	2.773
1287.5	525.9	0.869	14.36	7.454	5.080	5.045	3.617	-0.941	6.964	7.905	2.860	4.441	5.382	2.523	2.764
1309.9	531.7	0.884	14.62	7.477	5.121	5.085	3.586	-0.973	7.003	7.976	2.890	4.460	5.433	2.543	2.759
1332.3	536.9	0.899	14.86	7.497	5.156	5.120	3.557	-1.001	7.039	8.040	2.920	4.479	5.480	2.560	2.754
1354.7	541.5	0.914	15.11	7.520	5.184	5.148	3.526	-1.032	7.065	8.097	2.949	4.491	5.523	2.574	2.745

Project: 174316204			Source: B-103, 14.5'-15.0'								Lab ID: 38		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
1377.1	546.8	0.929	15.36	7.542	5.220	5.183	3.500	-1.058	7.103	8.161	2.978	4.511	5.570	2.591	2.740
1399.5	550.9	0.945	15.61	7.565	5.243	5.206	3.475	-1.083	7.129	8.213	3.007	4.527	5.610	2.603	2.731
1421.9	556.6	0.960	15.86	7.587	5.282	5.244	3.450	-1.108	7.168	8.276	3.033	4.546	5.654	2.622	2.729
1444.2	560.5	0.975	16.11	7.610	5.303	5.264	3.421	-1.137	7.188	8.325	3.061	4.556	5.693	2.632	2.720
1466.6	565.1	0.990	16.37	7.633	5.331	5.291	3.398	-1.160	7.217	8.377	3.086	4.571	5.731	2.645	2.715
1489.0	568.6	1.005	16.61	7.655	5.348	5.308	3.371	-1.187	7.232	8.419	3.111	4.578	5.765	2.654	2.706
1489.1	568.4	1.005	16.61	7.655	5.346	5.306	3.371	-1.187	7.231	8.418	3.112	4.578	5.765	2.653	2.705

Stantec

Consolidated Undrained Triaxial Compression

ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-104, 11.2'-11.7'
Description Silty Sand (SM), dark brown, wet, soft
Specimen Type Intact
Preparation Wet Mounting

Project No. 174316204
Lab ID 39
Test ID 39-A

Date Received 11/15/2017
Date Tested 12/13/2017

Specific Gravity 2.69
ASTM D 854, Dry

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
ASTM D 4318

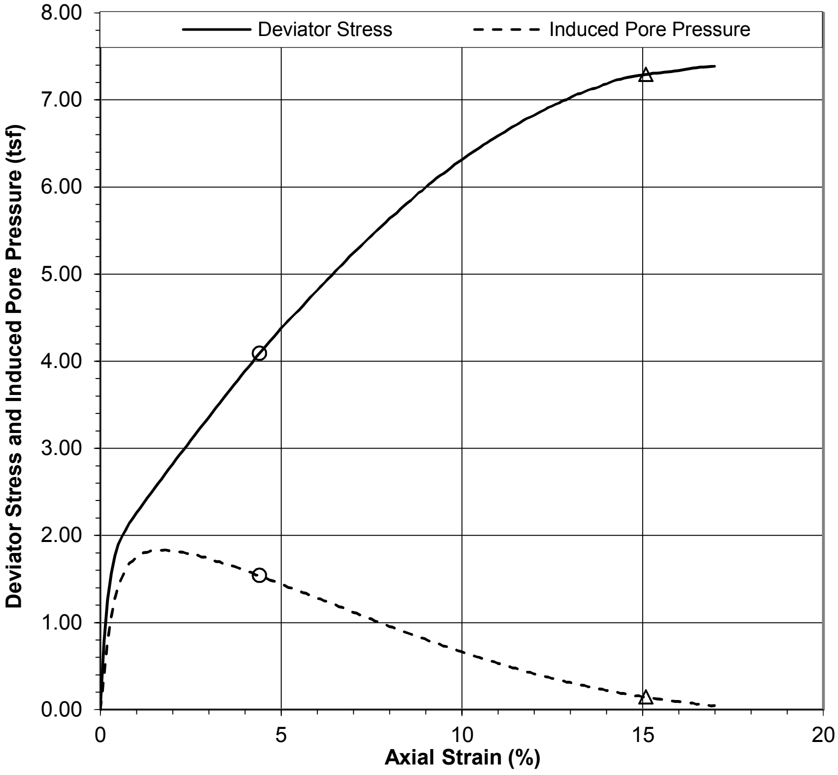
Target Test Parameters
Nominal Chamber Pressure (psi) 90
Nominal Back Pressure (psi) 50
Nominal Consolidation Pressure (psi) 40

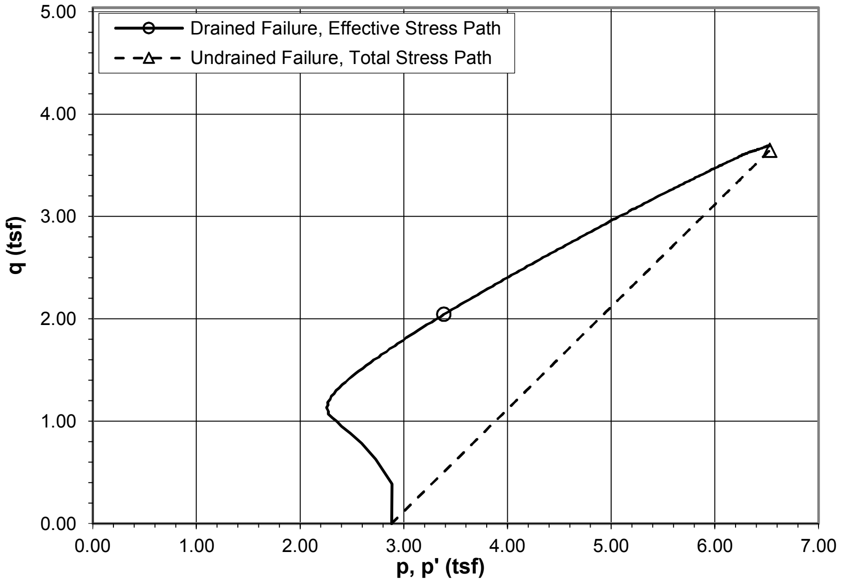
Saturation / Consolidation Results
Pore Pressure Parameter B 0.96
Measured Effective Consol. Stress (tsf) 2.882
Time to 50% Consolidation (min) 0.42
Actual Axial Strain Rate of Test (%/min) 0.092

Consolidated Specimen Conditions
Moist Unit Weight (pcf) 128.2
Moisture Content (%) 22.2
Dry Unit Weight (pcf) 104.9
Void Ratio 0.598
Degree of Saturation (%) 100.0

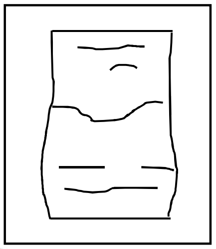
At Drained Failure
Failure Criterion: Max. Eff. Prin. Stress Ratio
Axial Strain (%) 4.396
Deviator Stress (tsf) 4.091
Induced Pore Pressure (tsf) 1.542
Minor Effective Stress, σ_3' (tsf) 1.340
Major Effective Stress, σ_1' (tsf) 5.431
Eff. Principal Stress Ratio, σ_1'/σ_3' 4.052
p' (tsf) 3.386
q (tsf) 2.045

At Consolidated Undrained Failure
Failure Criterion: 15% Axial Strain
Axial Strain (%) 15.090
Deviator Stress (tsf) 7.293
Minor Principal Stress, σ_3 (tsf) 2.882
Major Principal Stress, σ_1 (tsf) 10.176
p (tsf) 6.529
q (tsf) 3.647





Failure Sketch



Comments

Reviewed KG

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Approved By: RJ

Stantec Consulting Services Inc.
Lexington, Kentucky

Reported By: KG
Report Date: 12/22/2017

Consolidated Undrained Triaxial Compression

ASTM D 4767

Project Name HCFRR - Dams Preliminary
Source B-104, 11.2'-11.7'
Description Silty Sand (SM), dark brown, wet, soft

Project No. 174316204
Lab ID 39
Test ID 39-A

Initial Specimen Conditions		Consolidated Specimen Conditions	
Average Height (in)	6.087	Calculated Height (in)	6.013
Average Diameter (in)	2.784	Calculated Diameter (in)	2.764
Calculated Area (in^2)	6.087	Calculated Area (in^2)	5.999
Moist Weight (lb)	2.725	Moist Weight (lb)	2.677
Moist Unit Weight (pcf)	127.1	Moist Unit Weight (pcf)	128.2
Moisture Content (%)	24.4	Moisture Content (%)	22.2
Dry Weight (lb)	2.190	Dry Weight (lb)	2.190
Dry Unit Weight (pcf)	102.1	Dry Unit Weight (pcf)	104.9
Void Ratio	0.641	Void Ratio	0.598
Degree of Saturation (%)	102.4	Degree of Saturation (%)	100.0

Specific Gravity 2.69
ASTM D 854, Dry

Liquid Limit NP
Plastic Limit NP
Plasticity Index NP
ASTM D 4318

Confining Stress
σ_3 (tsf) 2.882

Effective Consolidation Stress
σ_3' (tsf) 2.882

Moisture contents obtained using partial specimen.
Specimen consolidated cross-sectional area determined using method B.
Membrane corrections have been applied,where Em = 200 lbf/in and t = 0.012 in.
All other tests performed in association with this specimen are reported separately.

Project: 174316204			**Source: B-104, 11.2'-11.7'**								**Lab ID: 39**		**Test ID**			
Test Time (min)	**Corr. Axial Load (lbf)**	**Axial Deform. (in)**	**Axial Strain (%)**	**Corr. Area (in^2)**	**Deviator Stress (tsf)**	**Corr. Deviator Stress (tsf)**	**Pore Pressure (tsf)**	**Induced Pore Pressure (tsf)**	**σ_1 (tsf)**	**σ_1' (tsf)**	**σ_3' (tsf)**	**p (tsf)**	**p' (tsf)**	**q (tsf)**	**Eff. Princ. Stress Ratio σ_1'/σ_3'**
0.0	0.0	0.000	0.00	5.999	0.000	0.000	3.598	0.000	2.882	2.882	2.882	2.882	2.882	0.000	1.000
0.9	64.7	0.006	0.10	6.005	0.776	0.776	3.981	0.383	3.658	3.275	2.499	3.270	2.887	0.388	1.310
1.8	105.0	0.012	0.20	6.011	1.258	1.258	4.379	0.781	4.140	3.359	2.101	3.511	2.730	0.629	1.599
2.6	131.0	0.018	0.30	6.017	1.568	1.567	4.670	1.072	4.450	3.377	1.810	3.666	2.594	0.784	1.866
3.4	147.8	0.024	0.40	6.023	1.767	1.766	4.877	1.279	4.648	3.369	1.603	3.765	2.486	0.883	2.101
4.2	159.0	0.030	0.50	6.029	1.899	1.898	5.030	1.432	4.780	3.348	1.450	3.831	2.399	0.949	2.309
4.9	167.3	0.036	0.60	6.035	1.996	1.995	5.121	1.524	4.877	3.354	1.359	3.880	2.356	0.997	2.468
5.7	173.4	0.042	0.70	6.041	2.067	2.065	5.201	1.603	4.947	3.344	1.279	3.915	2.311	1.032	2.614
6.7	180.0	0.048	0.80	6.047	2.143	2.141	5.278	1.680	5.023	3.343	1.202	3.953	2.272	1.070	2.781
7.5	184.9	0.054	0.90	6.053	2.199	2.197	5.306	1.708	5.079	3.371	1.174	3.981	2.273	1.098	2.871
8.5	190.5	0.060	1.00	6.059	2.264	2.261	5.355	1.757	5.144	3.387	1.125	4.013	2.256	1.131	3.009
9.4	195.3	0.066	1.10	6.065	2.318	2.315	5.368	1.770	5.198	3.427	1.112	4.040	2.270	1.158	3.082
10.3	200.3	0.072	1.20	6.071	2.376	2.373	5.399	1.801	5.255	3.454	1.081	4.069	2.267	1.186	3.194
11.3	205.7	0.078	1.30	6.078	2.437	2.433	5.404	1.806	5.316	3.509	1.076	4.099	2.293	1.217	3.262
12.3	210.4	0.084	1.40	6.084	2.490	2.486	5.423	1.825	5.369	3.543	1.057	4.125	2.300	1.243	3.352
13.2	215.2	0.090	1.50	6.090	2.545	2.541	5.423	1.825	5.423	3.598	1.057	4.153	2.328	1.270	3.403
14.2	220.3	0.096	1.60	6.096	2.602	2.598	5.431	1.834	5.480	3.647	1.049	4.181	2.348	1.299	3.477
15.2	225.2	0.102	1.70	6.102	2.657	2.652	5.428	1.830	5.535	3.704	1.052	4.209	2.378	1.326	3.522
16.2	230.4	0.108	1.80	6.109	2.715	2.711	5.431	1.834	5.593	3.759	1.049	4.238	2.404	1.355	3.585
17.1	235.2	0.114	1.90	6.115	2.770	2.765	5.424	1.827	5.648	3.821	1.056	4.265	2.438	1.383	3.619
18.1	240.3	0.120	2.00	6.121	2.826	2.821	5.422	1.825	5.703	3.879	1.058	4.293	2.468	1.411	3.667
19.0	245.4	0.126	2.10	6.127	2.883	2.878	5.419	1.822	5.760	3.938	1.061	4.321	2.500	1.439	3.713
20.0	250.1	0.132	2.20	6.134	2.936	2.931	5.409	1.811	5.813	4.002	1.071	4.348	2.536	1.465	3.737
21.0	254.4	0.138	2.30	6.140	2.984	2.978	5.406	1.808	5.860	4.052	1.074	4.371	2.563	1.489	3.773
21.9	259.4	0.144	2.40	6.146	3.038	3.032	5.390	1.792	5.915	4.122	1.090	4.398	2.606	1.516	3.782
22.9	264.7	0.150	2.50	6.152	3.098	3.092	5.390	1.792	5.974	4.182	1.090	4.428	2.636	1.546	3.836
23.9	269.4	0.156	2.60	6.159	3.150	3.143	5.372	1.774	6.026	4.252	1.108	4.454	2.680	1.572	3.837
24.9	274.7	0.162	2.70	6.165	3.208	3.202	5.370	1.773	6.084	4.311	1.110	4.483	2.710	1.601	3.885
25.8	279.5	0.168	2.80	6.172	3.261	3.254	5.348	1.750	6.136	4.386	1.132	4.509	2.759	1.627	3.874
26.8	284.0	0.174	2.90	6.178	3.310	3.303	5.349	1.751	6.185	4.434	1.131	4.534	2.782	1.651	3.920
27.8	288.8	0.180	3.00	6.184	3.363	3.355	5.323	1.726	6.238	4.512	1.157	4.560	2.834	1.678	3.901
28.7	294.0	0.186	3.10	6.190	3.419	3.412	5.324	1.727	6.294	4.567	1.156	4.588	2.862	1.706	3.952
29.7	299.1	0.192	3.20	6.197	3.475	3.467	5.298	1.701	6.349	4.649	1.182	4.616	2.915	1.734	3.934
30.6	303.7	0.198	3.30	6.203	3.525	3.516	5.299	1.702	6.399	4.697	1.181	4.641	2.939	1.758	3.978
31.6	308.9	0.204	3.40	6.210	3.582	3.574	5.272	1.675	6.456	4.781	1.208	4.669	2.994	1.787	3.959
32.6	313.7	0.210	3.50	6.216	3.633	3.625	5.275	1.677	6.507	4.830	1.205	4.695	3.018	1.812	4.007
33.6	318.9	0.216	3.60	6.223	3.690	3.681	5.254	1.656	6.563	4.907	1.226	4.723	3.066	1.841	4.003
34.5	323.4	0.222	3.70	6.229	3.738	3.729	5.243	1.645	6.611	4.966	1.237	4.747	3.101	1.865	4.015
35.5	328.3	0.228	3.80	6.235	3.790	3.781	5.228	1.630	6.663	5.033	1.252	4.773	3.142	1.890	4.020

Project: 174316204			**Source:**	**B-104, 11.2'-11.7'**							**Lab ID: 39**		**Test ID**		
Test Time (min)	**Corr. Axial Load (lbf)**	**Axial Deform. (in)**	**Axial Strain (%)**	**Corr. Area (in^2)**	**Deviator Stress (tsf)**	**Corr. Deviator Stress (tsf)**	**Pore Pressure (tsf)**	**Induced Pore Pressure (tsf)**	**σ_1 (tsf)**	**σ_1' (tsf)**	**σ_3' (tsf)**	**p (tsf)**	**p' (tsf)**	**q (tsf)**	**Eff. Princ. Stress Ratio σ_1'/σ_3'**
36.5	333.4	0.234	3.90	6.242	3.846	3.836	5.212	1.614	6.719	5.104	1.268	4.800	3.186	1.918	4.025
37.4	338.1	0.240	4.00	6.248	3.896	3.886	5.200	1.602	6.769	5.166	1.280	4.826	3.223	1.943	4.036
38.4	342.6	0.246	4.10	6.255	3.943	3.933	5.179	1.581	6.815	5.234	1.301	4.849	3.267	1.967	4.023
39.4	347.3	0.252	4.20	6.261	3.993	3.983	5.170	1.572	6.865	5.293	1.310	4.874	3.302	1.991	4.039
40.3	352.6	0.258	4.30	6.268	4.050	4.040	5.145	1.547	6.922	5.375	1.335	4.902	3.355	2.020	4.025
41.3	357.5	0.264	4.40	6.275	4.102	4.091	5.140	1.542	6.973	5.431	1.340	4.928	3.386	2.045	4.052
42.3	361.9	0.270	4.50	6.281	4.148	4.137	5.115	1.517	7.019	5.502	1.365	4.951	3.434	2.068	4.030
43.2	366.5	0.276	4.60	6.288	4.196	4.185	5.108	1.510	7.067	5.557	1.372	4.975	3.464	2.092	4.050
44.2	371.1	0.282	4.70	6.294	4.245	4.233	5.085	1.487	7.115	5.628	1.395	4.999	3.512	2.117	4.034
45.1	375.6	0.288	4.80	6.301	4.292	4.280	5.075	1.477	7.162	5.685	1.405	5.022	3.545	2.140	4.046
46.0	380.1	0.294	4.89	6.307	4.339	4.327	5.056	1.458	7.209	5.751	1.424	5.046	3.588	2.164	4.038
47.0	385.1	0.300	5.00	6.314	4.391	4.379	5.038	1.440	7.261	5.821	1.442	5.072	3.632	2.189	4.035
47.9	389.2	0.306	5.09	6.321	4.433	4.420	5.025	1.427	7.303	5.875	1.455	5.092	3.665	2.210	4.038
48.9	393.6	0.312	5.19	6.327	4.479	4.466	5.002	1.404	7.348	5.944	1.478	5.115	3.711	2.233	4.021
49.9	397.7	0.318	5.30	6.334	4.520	4.507	4.994	1.396	7.389	5.993	1.486	5.136	3.740	2.254	4.033
50.9	401.5	0.324	5.40	6.341	4.559	4.546	4.978	1.380	7.428	6.048	1.502	5.155	3.775	2.273	4.027
52.0	405.7	0.330	5.50	6.348	4.602	4.588	4.966	1.369	7.470	6.102	1.514	5.176	3.808	2.294	4.031
53.0	410.1	0.337	5.60	6.354	4.646	4.632	4.943	1.345	7.515	6.170	1.537	5.198	3.854	2.316	4.013
54.1	414.6	0.342	5.69	6.361	4.692	4.678	4.935	1.337	7.560	6.223	1.545	5.221	3.884	2.339	4.028
55.1	419.6	0.349	5.80	6.368	4.744	4.730	4.910	1.312	7.612	6.300	1.570	5.247	3.935	2.365	4.012
56.2	423.8	0.354	5.90	6.375	4.787	4.772	4.902	1.304	7.655	6.350	1.578	5.268	3.964	2.386	4.024
57.3	427.9	0.360	5.99	6.381	4.828	4.813	4.877	1.279	7.696	6.416	1.603	5.289	4.010	2.407	4.003
58.4	432.6	0.367	6.10	6.388	4.876	4.861	4.869	1.271	7.743	6.472	1.611	5.313	4.041	2.430	4.017
59.4	436.6	0.372	6.19	6.395	4.916	4.900	4.845	1.248	7.783	6.535	1.635	5.332	4.085	2.450	3.997
60.5	440.8	0.378	6.29	6.402	4.958	4.942	4.838	1.241	7.825	6.584	1.642	5.354	4.113	2.471	4.011
61.6	445.1	0.385	6.40	6.409	5.001	4.985	4.813	1.215	7.867	6.652	1.667	5.375	4.159	2.492	3.990
62.7	449.9	0.391	6.49	6.415	5.049	5.033	4.805	1.207	7.916	6.709	1.675	5.399	4.192	2.517	4.004
63.8	454.0	0.396	6.59	6.422	5.090	5.073	4.780	1.182	7.956	6.773	1.700	5.419	4.237	2.537	3.985
64.9	457.8	0.402	6.69	6.429	5.127	5.110	4.771	1.173	7.993	6.820	1.709	5.438	4.265	2.555	3.990
66.0	462.4	0.409	6.79	6.436	5.173	5.156	4.746	1.149	8.038	6.890	1.734	5.460	4.312	2.578	3.974
67.1	467.3	0.415	6.89	6.443	5.222	5.205	4.739	1.141	8.087	6.946	1.741	5.485	4.344	2.602	3.989
68.2	471.0	0.421	6.99	6.450	5.258	5.241	4.714	1.117	8.123	7.006	1.766	5.503	4.386	2.620	3.968
69.3	474.9	0.427	7.09	6.457	5.295	5.277	4.706	1.108	8.160	7.051	1.774	5.521	4.413	2.639	3.975
70.4	479.2	0.433	7.19	6.464	5.338	5.320	4.682	1.084	8.202	7.118	1.798	5.542	4.458	2.660	3.958
71.5	483.2	0.439	7.29	6.471	5.377	5.359	4.674	1.076	8.241	7.165	1.806	5.562	4.485	2.679	3.967
72.6	487.4	0.445	7.39	6.478	5.418	5.399	4.649	1.051	8.281	7.230	1.831	5.582	4.531	2.700	3.948
73.7	491.6	0.451	7.49	6.485	5.458	5.439	4.640	1.042	8.322	7.280	1.840	5.602	4.560	2.720	3.956
74.9	495.8	0.457	7.59	6.492	5.499	5.480	4.615	1.017	8.363	7.346	1.865	5.623	4.605	2.740	3.938
76.0	499.8	0.463	7.69	6.499	5.537	5.518	4.609	1.011	8.400	7.389	1.871	5.641	4.630	2.759	3.949
77.1	503.6	0.469	7.79	6.506	5.574	5.554	4.584	0.987	8.437	7.450	1.896	5.659	4.673	2.777	3.930
78.3	507.9	0.475	7.89	6.513	5.615	5.596	4.575	0.978	8.478	7.500	1.905	5.680	4.703	2.798	3.938
79.4	512.4	0.481	7.99	6.520	5.658	5.638	4.553	0.955	8.521	7.566	1.927	5.702	4.747	2.819	3.925
80.6	515.8	0.487	8.09	6.527	5.690	5.670	4.543	0.946	8.552	7.606	1.937	5.717	4.771	2.835	3.927
81.7	519.3	0.493	8.19	6.534	5.722	5.702	4.523	0.925	8.584	7.659	1.957	5.733	4.808	2.851	3.913
82.9	523.8	0.499	8.29	6.541	5.765	5.744	4.510	0.912	8.627	7.714	1.970	5.754	4.842	2.872	3.916
84.0	527.6	0.505	8.39	6.548	5.801	5.780	4.493	0.896	8.663	7.767	1.987	5.772	4.877	2.890	3.909
85.2	531.7	0.511	8.49	6.556	5.839	5.818	4.480	0.882	8.701	7.819	2.000	5.791	4.910	2.909	3.909
86.3	535.1	0.517	8.59	6.563	5.870	5.849	4.465	0.867	8.731	7.864	2.015	5.807	4.939	2.924	3.903
87.5	539.2	0.523	8.69	6.570	5.909	5.887	4.448	0.850	8.769	7.919	2.032	5.826	4.975	2.944	3.897
88.6	543.8	0.529	8.80	6.577	5.953	5.931	4.437	0.839	8.813	7.974	2.043	5.848	5.009	2.966	3.903
89.8	546.7	0.535	8.89	6.584	5.978	5.956	4.418	0.820	8.838	8.018	2.062	5.860	5.040	2.978	3.888
90.9	551.0	0.541	8.99	6.592	6.019	5.996	4.407	0.809	8.878	8.069	2.073	5.880	5.071	2.998	3.893
92.1	554.8	0.547	9.09	6.599	6.054	6.031	4.386	0.788	8.913	8.125	2.094	5.898	5.110	3.015	3.880
93.2	558.5	0.553	9.19	6.606	6.087	6.064	4.359	0.761	8.946	8.185	2.121	5.914	5.153	3.032	3.859
94.4	562.6	0.559	9.29	6.613	6.125	6.102	4.360	0.763	8.984	8.222	2.120	5.933	5.171	3.051	3.879
95.5	566.0	0.565	9.39	6.621	6.155	6.132	4.350	0.753	9.014	8.261	2.130	5.948	5.195	3.066	3.879
96.6	568.7	0.571	9.49	6.628	6.178	6.155	4.328	0.731	9.037	8.306	2.152	5.960	5.229	3.077	3.860
97.8	572.2	0.577	9.59	6.635	6.209	6.185	4.322	0.724	9.068	8.344	2.158	5.975	5.251	3.093	3.866
99.0	575.9	0.583	9.69	6.643	6.242	6.218	4.300	0.702	9.100	8.399	2.180	5.991	5.290	3.109	3.852
100.1	580.3	0.589	9.79	6.650	6.283	6.259	4.290	0.692	9.141	8.449	2.190	6.012	5.320	3.129	3.858
101.3	583.5	0.595	9.89	6.657	6.310	6.286	4.272	0.674	9.168	8.494	2.208	6.025	5.351	3.143	3.846
102.4	586.4	0.601	9.99	6.665	6.335	6.310	4.263	0.665	9.193	8.528	2.217	6.037	5.372	3.155	3.846
103.6	590.0	0.607	10.09	6.672	6.366	6.341	4.246	0.648	9.223	8.575	2.234	6.053	5.405	3.171	3.838
104.7	593.5	0.613	10.19	6.680	6.397	6.372	4.236	0.638	9.254	8.616	2.244	6.068	5.430	3.186	3.839
105.9	596.9	0.619	10.29	6.687	6.427	6.401	4.221	0.624	9.283	8.660	2.259	6.083	5.459	3.200	3.834
107.0	599.8	0.625	10.39	6.694	6.452	6.426	4.208	0.610	9.308	8.698	2.272	6.095	5.485	3.213	3.828
108.2	602.8	0.631	10.49	6.702	6.476	6.450	4.195	0.597	9.332	8.735	2.285	6.107	5.510	3.225	3.822
109.3	606.8	0.637	10.59	6.709	6.511	6.485	4.179	0.582	9.367	8.786	2.301	6.125	5.543	3.242	3.819
110.5	609.6	0.643	10.69	6.717	6.534	6.507	4.171	0.573	9.390	8.816	2.309	6.136	5.563	3.254	3.818

Project: 174316204			Source: B-104, 11.2'-11.7'								Lab ID: 39		Test ID		
Test Time (min)	Corr. Axial Load (lbf)	Axial Deform. (in)	Axial Strain (%)	Corr. Area (in^2)	Deviator Stress (tsf)	Corr. Deviator Stress (tsf)	Pore Pressure (tsf)	Induced Pore Pressure (tsf)	σ_1 (tsf)	σ_1' (tsf)	σ_3' (tsf)	p (tsf)	p' (tsf)	q (tsf)	Eff. Princ. Stress Ratio σ_1'/σ_3'
111.6	612.9	0.649	10.79	6.724	6.562	6.535	4.154	0.556	9.417	8.861	2.326	6.150	5.594	3.268	3.809
112.7	616.0	0.655	10.89	6.732	6.588	6.561	4.146	0.549	9.443	8.894	2.334	6.163	5.614	3.280	3.811
113.9	619.0	0.661	10.99	6.740	6.613	6.585	4.129	0.531	9.468	8.936	2.351	6.175	5.644	3.293	3.801
115.1	622.0	0.667	11.09	6.747	6.638	6.610	4.123	0.525	9.492	8.967	2.357	6.187	5.662	3.305	3.805
116.2	625.1	0.673	11.19	6.755	6.663	6.635	4.103	0.506	9.518	9.012	2.377	6.200	5.694	3.318	3.792
117.4	628.4	0.679	11.29	6.762	6.691	6.663	4.097	0.500	9.545	9.045	2.383	6.214	5.714	3.331	3.796
118.5	631.7	0.685	11.39	6.770	6.718	6.689	4.077	0.479	9.572	9.093	2.403	6.227	5.748	3.345	3.783
119.7	634.5	0.691	11.49	6.778	6.741	6.712	4.073	0.475	9.594	9.119	2.407	6.238	5.763	3.356	3.788
120.8	637.4	0.697	11.59	6.785	6.764	6.735	4.053	0.455	9.617	9.162	2.427	6.250	5.794	3.367	3.775
122.0	640.9	0.703	11.69	6.793	6.793	6.763	4.048	0.451	9.646	9.195	2.432	6.264	5.813	3.382	3.782
123.2	643.6	0.709	11.79	6.801	6.814	6.785	4.029	0.432	9.667	9.235	2.451	6.275	5.843	3.392	3.769
124.3	646.1	0.715	11.89	6.808	6.833	6.803	4.026	0.428	9.685	9.257	2.454	6.284	5.856	3.401	3.772
125.5	648.5	0.721	11.99	6.816	6.850	6.820	4.009	0.412	9.703	9.291	2.471	6.293	5.881	3.410	3.761
126.6	651.4	0.727	12.09	6.824	6.873	6.843	4.002	0.404	9.725	9.321	2.478	6.304	5.900	3.421	3.761
127.8	654.3	0.733	12.19	6.832	6.896	6.865	3.990	0.392	9.747	9.355	2.490	6.315	5.923	3.433	3.757
129.0	657.0	0.739	12.29	6.839	6.917	6.886	3.979	0.381	9.768	9.387	2.501	6.325	5.944	3.443	3.753
130.2	660.4	0.745	12.39	6.847	6.944	6.913	3.971	0.373	9.796	9.423	2.509	6.339	5.966	3.457	3.755
131.4	662.7	0.751	12.49	6.855	6.961	6.930	3.957	0.360	9.812	9.453	2.523	6.347	5.988	3.465	3.747
132.6	665.5	0.757	12.59	6.863	6.981	6.950	3.953	0.356	9.832	9.476	2.527	6.357	6.001	3.475	3.751
133.8	667.8	0.763	12.69	6.871	6.998	6.966	3.937	0.339	9.848	9.510	2.543	6.365	6.026	3.483	3.739
134.9	671.0	0.769	12.79	6.879	7.023	6.991	3.933	0.335	9.873	9.538	2.547	6.378	6.043	3.496	3.745
136.1	672.9	0.775	12.89	6.886	7.035	7.003	3.914	0.316	9.885	9.569	2.566	6.384	6.067	3.501	3.729
137.3	675.6	0.781	12.99	6.894	7.055	7.023	3.913	0.315	9.905	9.590	2.567	6.394	6.078	3.511	3.736
138.5	678.5	0.787	13.09	6.902	7.077	7.044	3.895	0.297	9.927	9.630	2.585	6.405	6.108	3.522	3.725
139.7	681.4	0.793	13.19	6.910	7.099	7.066	3.892	0.294	9.949	9.654	2.588	6.415	6.121	3.533	3.730
140.8	683.2	0.799	13.29	6.918	7.110	7.077	3.879	0.281	9.959	9.678	2.601	6.421	6.140	3.538	3.721
142.0	685.5	0.805	13.39	6.926	7.126	7.092	3.874	0.277	9.975	9.698	2.606	6.429	6.152	3.546	3.722
143.2	688.1	0.811	13.49	6.934	7.145	7.111	3.862	0.265	9.994	9.729	2.618	6.438	6.173	3.556	3.717
144.4	690.3	0.817	13.59	6.942	7.159	7.125	3.853	0.255	10.008	9.752	2.627	6.445	6.190	3.563	3.712
145.5	691.9	0.823	13.69	6.950	7.168	7.134	3.847	0.250	10.016	9.766	2.633	6.449	6.200	3.567	3.710
146.7	694.3	0.829	13.79	6.958	7.184	7.150	3.836	0.238	10.032	9.793	2.644	6.457	6.219	3.575	3.704
147.9	697.0	0.835	13.89	6.966	7.204	7.169	3.832	0.235	10.052	9.817	2.648	6.467	6.232	3.585	3.708
149.0	699.1	0.841	13.99	6.975	7.217	7.182	3.818	0.220	10.065	9.845	2.662	6.473	6.253	3.591	3.698
150.2	701.7	0.847	14.09	6.983	7.236	7.200	3.818	0.220	10.083	9.862	2.662	6.483	6.262	3.600	3.705
151.4	704.2	0.853	14.19	6.991	7.253	7.217	3.802	0.204	10.099	9.895	2.678	6.491	6.287	3.609	3.695
152.5	706.2	0.859	14.29	6.999	7.265	7.230	3.800	0.203	10.112	9.909	2.680	6.497	6.295	3.615	3.698
153.7	707.7	0.865	14.39	7.007	7.272	7.236	3.784	0.187	10.118	9.932	2.696	6.500	6.314	3.618	3.684
154.8	709.5	0.871	14.49	7.015	7.282	7.246	3.785	0.187	10.128	9.941	2.695	6.505	6.318	3.623	3.689
155.9	711.5	0.877	14.59	7.023	7.294	7.257	3.768	0.170	10.139	9.969	2.712	6.511	6.340	3.629	3.676
157.1	713.1	0.883	14.69	7.032	7.302	7.265	3.771	0.173	10.148	9.974	2.709	6.515	6.341	3.633	3.682
158.2	714.9	0.889	14.79	7.040	7.311	7.274	3.757	0.159	10.157	9.998	2.723	6.520	6.361	3.637	3.671
159.4	716.3	0.895	14.89	7.048	7.317	7.280	3.757	0.159	10.162	10.003	2.723	6.522	6.363	3.640	3.673
160.5	717.7	0.901	14.99	7.056	7.323	7.285	3.743	0.145	10.168	10.023	2.737	6.525	6.380	3.643	3.662
161.7	719.3	0.907	15.09	7.065	7.331	7.293	3.743	0.145	10.176	10.030	2.737	6.529	6.384	3.647	3.665
162.8	720.3	0.913	15.19	7.073	7.332	7.294	3.730	0.132	10.176	10.044	2.750	6.529	6.397	3.647	3.652
164.0	722.6	0.919	15.29	7.082	7.347	7.308	3.729	0.132	10.191	10.059	2.751	6.536	6.405	3.654	3.657
165.1	723.3	0.925	15.39	7.090	7.345	7.306	3.721	0.124	10.189	10.065	2.759	6.536	6.412	3.653	3.649
166.3	724.4	0.931	15.49	7.098	7.348	7.309	3.719	0.121	10.191	10.070	2.761	6.537	6.416	3.654	3.647
167.4	726.0	0.937	15.59	7.107	7.356	7.317	3.711	0.113	10.199	10.086	2.769	6.541	6.427	3.658	3.642
168.6	727.2	0.943	15.69	7.115	7.359	7.319	3.707	0.109	10.202	10.092	2.773	6.542	6.433	3.660	3.639
169.7	728.8	0.949	15.79	7.124	7.366	7.326	3.701	0.103	10.209	10.105	2.779	6.545	6.442	3.663	3.636
170.9	730.2	0.956	15.89	7.132	7.371	7.331	3.694	0.096	10.214	10.118	2.786	6.548	6.452	3.666	3.631
172.0	731.5	0.961	15.99	7.140	7.376	7.336	3.692	0.094	10.219	10.124	2.788	6.551	6.456	3.668	3.631
173.2	733.2	0.967	16.09	7.149	7.384	7.344	3.684	0.086	10.226	10.140	2.796	6.554	6.468	3.672	3.626
174.4	734.8	0.973	16.19	7.157	7.392	7.352	3.683	0.085	10.234	10.148	2.797	6.558	6.473	3.676	3.628
175.6	736.4	0.980	16.29	7.166	7.399	7.358	3.673	0.075	10.241	10.165	2.807	6.562	6.486	3.679	3.622
176.7	737.9	0.985	16.39	7.175	7.406	7.365	3.674	0.077	10.247	10.170	2.806	6.565	6.488	3.682	3.625
177.9	739.4	0.992	16.49	7.183	7.412	7.370	3.661	0.063	10.253	10.190	2.819	6.567	6.505	3.685	3.614
179.1	740.9	0.998	16.59	7.192	7.418	7.376	3.663	0.066	10.259	10.193	2.817	6.571	6.505	3.688	3.619
180.2	741.7	1.004	16.69	7.200	7.416	7.375	3.649	0.051	10.257	10.206	2.831	6.570	6.519	3.687	3.605
181.4	743.3	1.010	16.79	7.209	7.423	7.381	3.653	0.055	10.264	10.208	2.827	6.573	6.518	3.691	3.611
182.6	744.3	1.016	16.89	7.218	7.425	7.383	3.643	0.045	10.265	10.220	2.837	6.574	6.529	3.691	3.602
183.8	745.6	1.022	16.99	7.226	7.429	7.386	3.646	0.048	10.269	10.221	2.834	6.575	6.528	3.693	3.606

APPENDIX C
SEEPAGE AND STABILITY ANALYSES

EAGLE CREEK DAM

Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

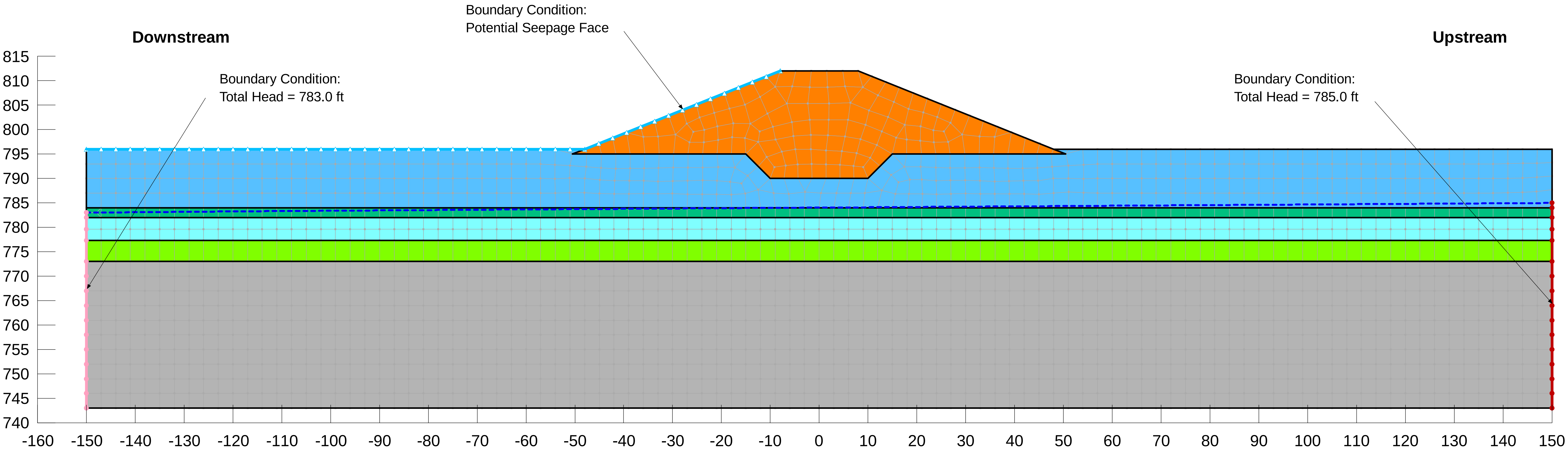
Eagle Creek Dam - Shorter Section

Seepage Analysis - Boundary Conditions and Mesh

01_normal_bc
Normal Water Level

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

	Material	Kh-sat (ft/sec)	Kratio Kv/Kh	Sat. Water Content ft^3/ft^3
🟧	Embankment Fill	1e-008	0.2	0.42
🟦	Upper Fine-Grained	3.3e-009	0.1	0.36
🟩	Upper Coarse-Grained	0.0016	1	0.32
🟦	Lower Fine-Grained	5.6e-009	0.1	0.31
🟩	Lower Coarse-Grained	0.0016	1	0.32
⬜	Fractured Bedrock	8.2e-007	1	0.25



Project No. 174316204

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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

Eagle Creek Dam - Shorter Section

Seepage Analysis - Contours of Total Head (ft)

01_normal_th
Normal Water Level

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

Material	Kh-sat (ft/sec)	Kratio Kv/Kh	Sat. Water Content ft^3/ft^3
Embankment Fill	1e-008	0.2	0.42
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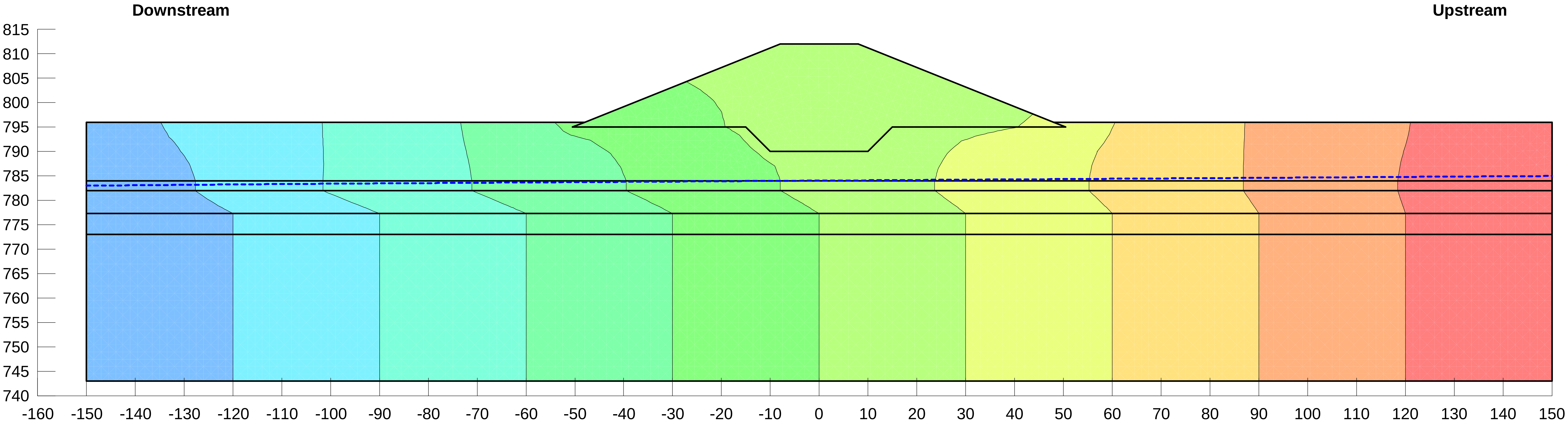
Upper Coarse-Grained	0.0016	1	0.32
Lower Fine-Grained	5.6e-009	0.1	0.31
Lower Coarse-Grained	0.0016	1	0.32
Fractured Bedrock	8.2e-007	1	0.25

Total Head

- 🟦 ≤ 783 - 783.2 ft
- 🟦 783.2 - 783.4 ft
- 🟩 783.4 - 783.6 ft
- 🟩 783.6 - 783.8 ft
- 🟩 783.8 - 784 ft
- 🟩 784 - 784.2 ft
- 🟨 784.2 - 784.4 ft
- 🟨 784.4 - 784.6 ft
- 🟧 784.6 - 784.8 ft
- 🟥 ≥ 784.8 ft



Project No. 174316204

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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

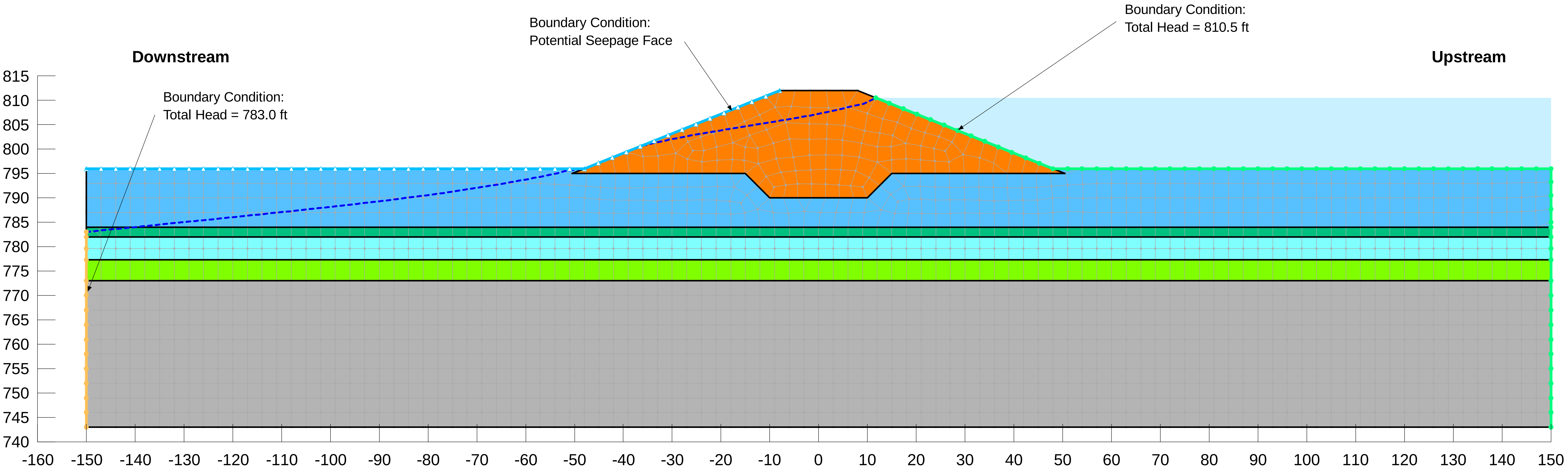
Eagle Creek Dam - Shorter Section

Seepage Analysis - Boundary Conditions and Mesh

02_flood_bc
Flood Water Level

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

	Material	Kh-sat (ft/sec)	Kratio Kv/Kh	Sat. Water Content ft^3/ft^3
🟧	Embankment Fill	1e-008	0.2	0.42
🟦	Upper Fine-Grained	3.3e-009	0.1	0.36
🟩	Upper Coarse-Grained	0.0016	1	0.32
🟦	Lower Fine-Grained	5.6e-009	0.1	0.31
🟩	Lower Coarse-Grained	0.0016	1	0.32
⬜	Fractured Bedrock	8.2e-007	1	0.25



Project No. 174316204

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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

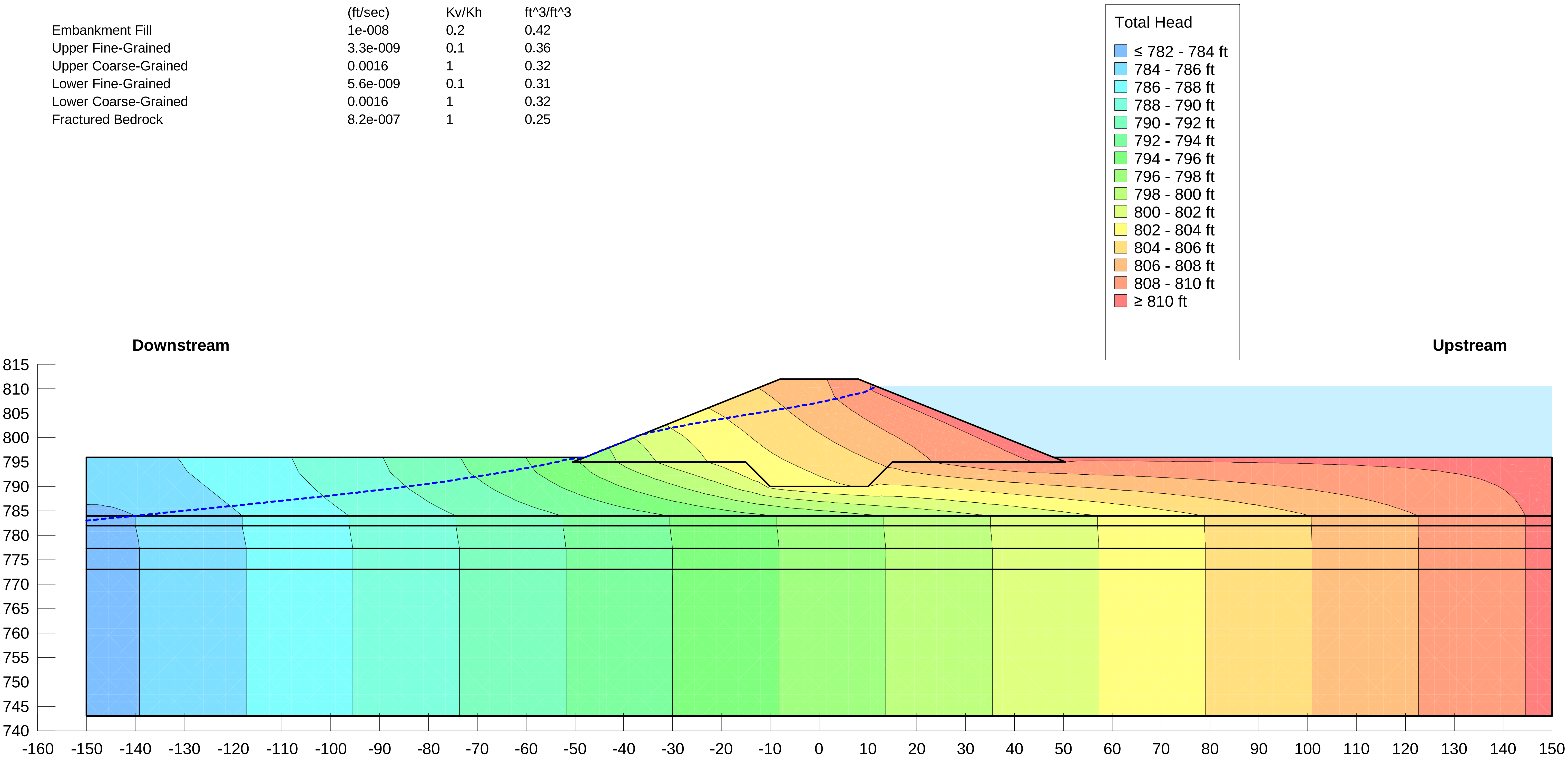
Eagle Creek Dam - Shorter Section

Seepage Analysis - Contours of Total Head (ft)

02_flood_th
Flood Water Level

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

Material	Kh-sat (ft/sec)	Kratio Kv/Kh	Sat. Water Content ft^3/ft^3
Embankment Fill	1e-008	0.2	0.42
Upper Fine-Grained	3.3e-009	0.1	0.36
Upper Coarse-Grained	0.0016	1	0.32
Lower Fine-Grained	5.6e-009	0.1	0.31
Lower Coarse-Grained	0.0016	1	0.32
Fractured Bedrock	8.2e-007	1	0.25



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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

Eagle Creek Dam - Shorter Section

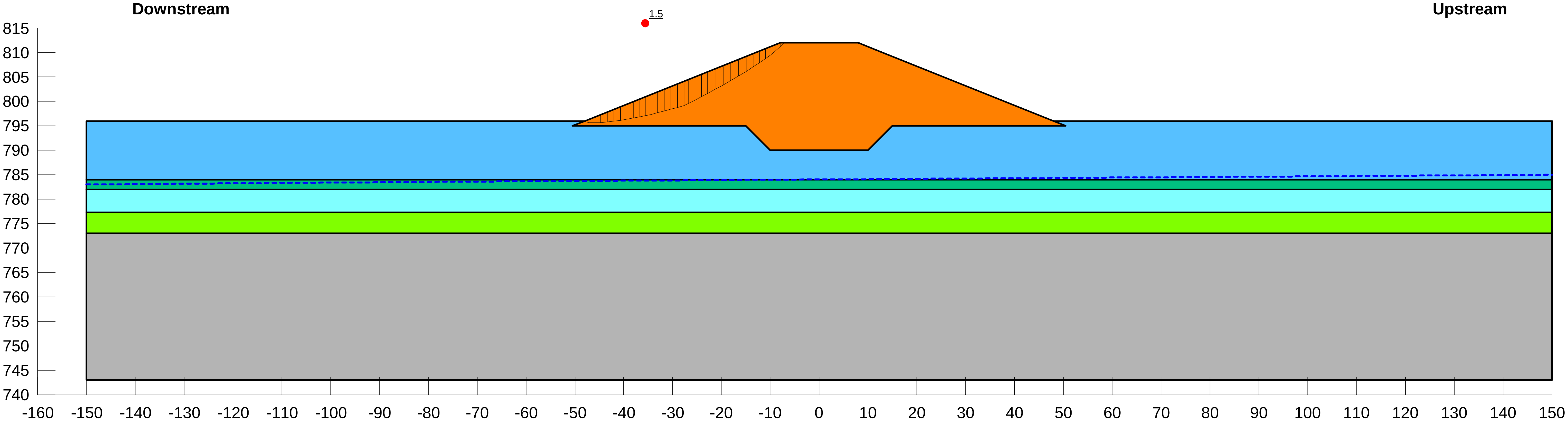
Slope Stability Analysis – FS = 1.5

03_normal_total stresses_ds
Normal Pool; Undrained, Static Strengths;
Incipient Motion: Downstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

			Drained Strength Parameters		**Undrained Strength Parameters**	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Undrained)	125	29	0	15	500
🟦	Upper Fine-Grained (Undrained)	131	34	0	32	400
🟩	Upper Coarse-Grained (Undrained)	132	32	0	32	0
🟦	Lower Fine-Grained (Undrained)	138	34	0	32	400
🟩	Lower Coarse-Grained (Undrained)	132	32	0	32	0
⬜	Fractured Bedrock	-	Impenetrable		Impenetrable	

At a given effective stress, the lesser of the drained and undrained strengths is used.



Project No. 174316204

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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

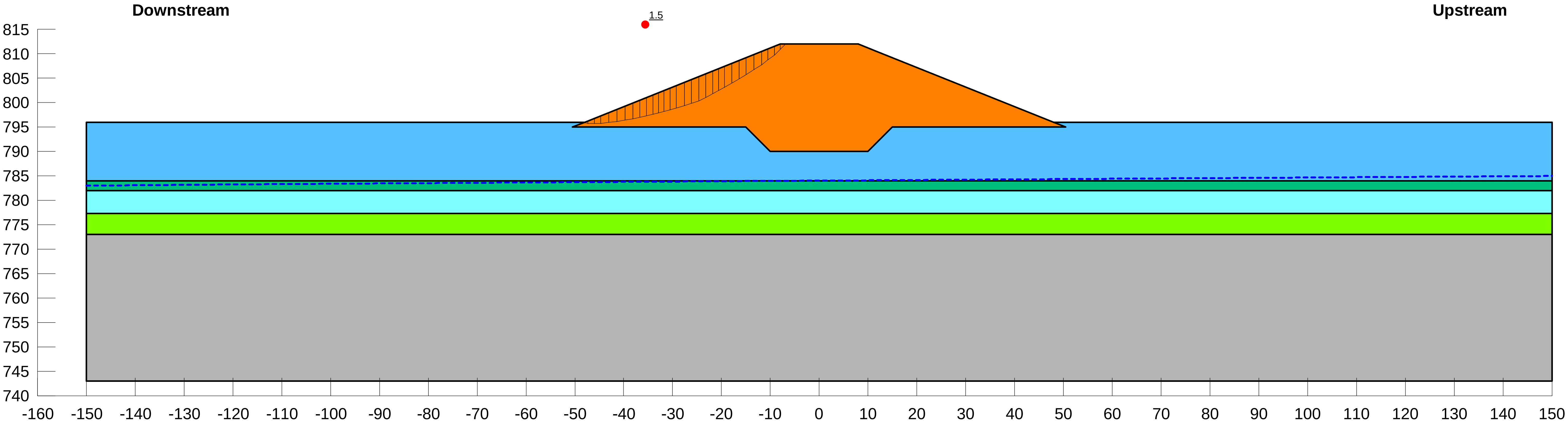
Eagle Creek Dam - Shorter Section

Slope Stability Analysis – FS = 1.5

04_normal_effective stresses_ds
Normal Pool; Drained, Static Strengths;
Incipient Motion: Downstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

	Material	Unit Weight (pcf)	**Drained Strength Parameters** Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Drained)	125	29	0
🟦	Upper Fine-Grained (Drained)	131	34	0
🟩	Upper Coarse-Grained (Drained)	132	32	0
🟦	Lower Fine-Grained (Drained)	138	34	0
🟩	Lower Coarse-Grained (Drained)	132	32	0
⬜	Fractured Bedrock	-	Impenetrable	



Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

Eagle Creek Dam - Shorter Section

Slope Stability Analysis – FS = 1.5

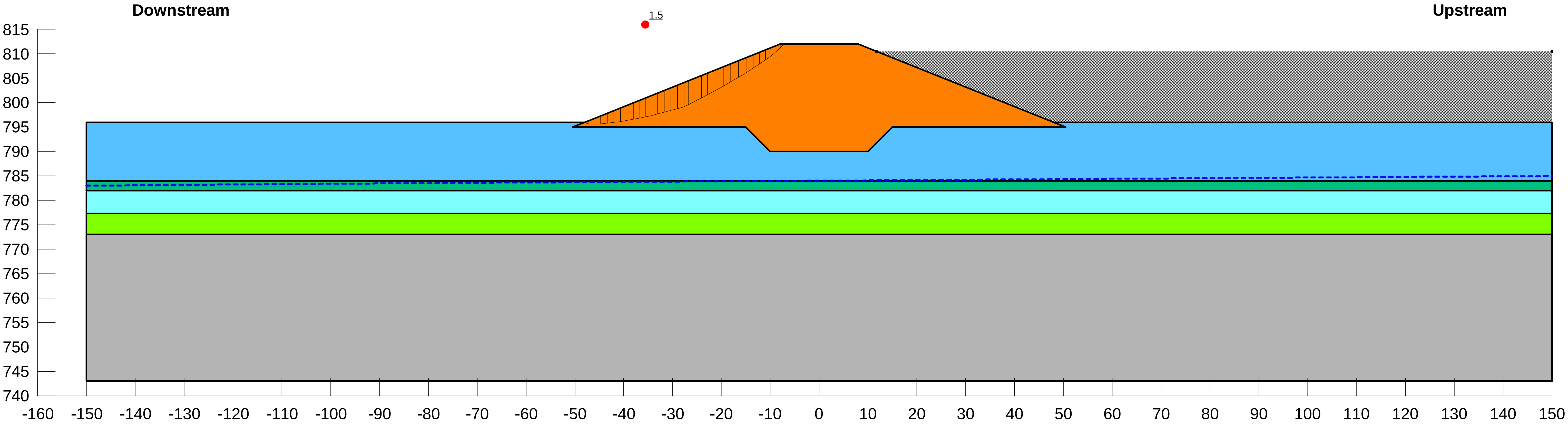
05_flood surcharge_total stresses_ds

Normal Pool with Flood Surcharge; Undrained, Static Strengths;
Incipient Motion: Downstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

			Drained Strength Parameters		**Undrained Strength Parameters**	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Undrained)	125	29	0	15	500
🟦	Upper Fine-Grained (Undrained)	131	34	0	32	400
🟩	Upper Coarse-Grained (Undrained)	132	32	0	32	0
🟦	Lower Fine-Grained (Undrained)	138	34	0	32	400
🟩	Lower Coarse-Grained (Undrained)	132	32	0	32	0
⬜	Fractured Bedrock	-	Impenetrable		Impenetrable	

At a given effective stress, the lesser of the drained and undrained strengths is used.



Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

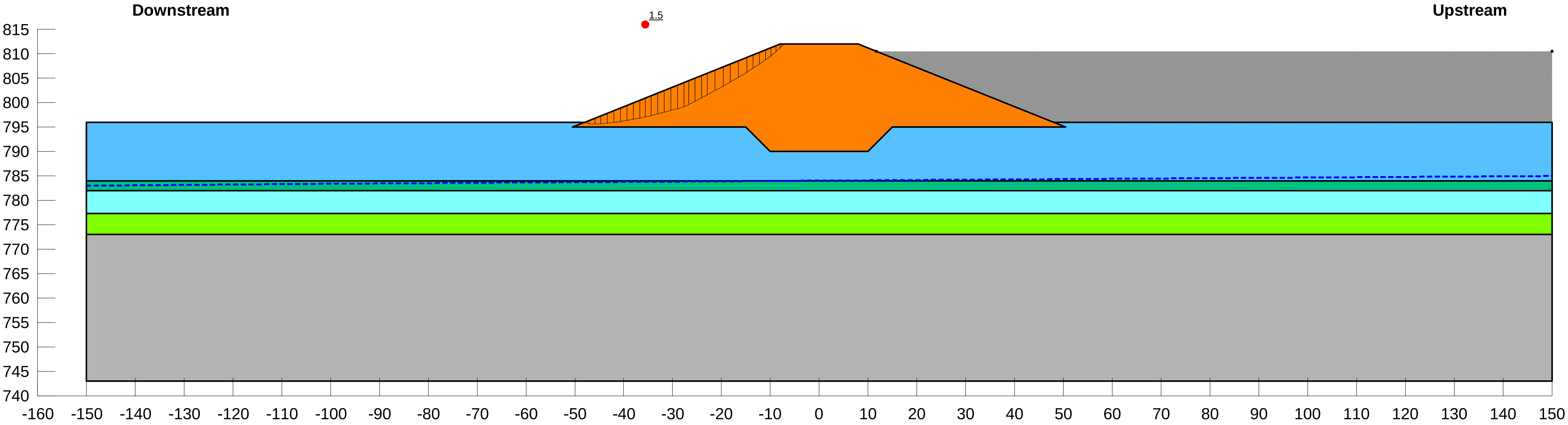
Eagle Creek Dam - Shorter Section

Slope Stability Analysis – FS = 1.5

06_flood surcharge_effective stresses_ds
Normal Pool with Flood Surcharge; Drained, Static Strengths;
Incipient Motion: Downstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

			Drained Strength Parameters	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Drained)	125	29	0
🟦	Upper Fine-Grained (Drained)	131	34	0
🟩	Upper Coarse-Grained (Drained)	132	32	0
🟦	Lower Fine-Grained (Drained)	138	34	0
🟩	Lower Coarse-Grained (Drained)	132	32	0
⬜	Fractured Bedrock	-	Impenetrable	



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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

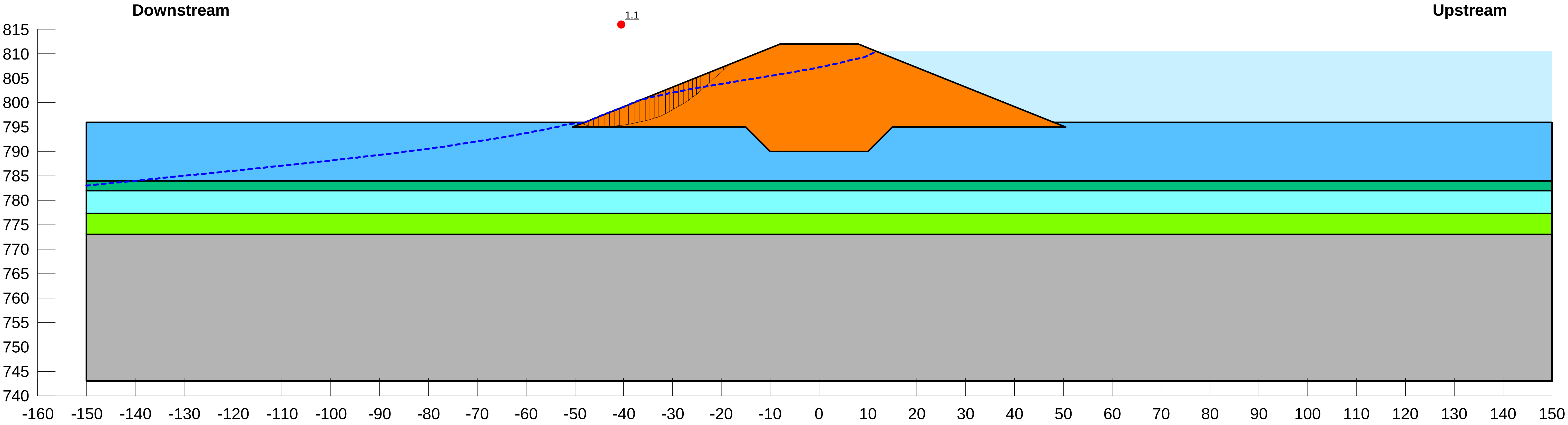
Eagle Creek Dam - Shorter Section

Slope Stability Analysis – FS = 1.1

07_flood_effective stresses_ds
Flood Pool; Drained, Static Strengths;
Incipient Motion: Downstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

			Drained Strength Parameters	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Drained)	125	29	0
🟦	Upper Fine-Grained (Drained)	131	34	0
🟩	Upper Coarse-Grained (Drained)	132	32	0
🟦	Lower Fine-Grained (Drained)	138	34	0
🟩	Lower Coarse-Grained (Drained)	132	32	0
⬜	Fractured Bedrock	-	Impenetrable	



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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

Eagle Creek Dam - Shorter Section

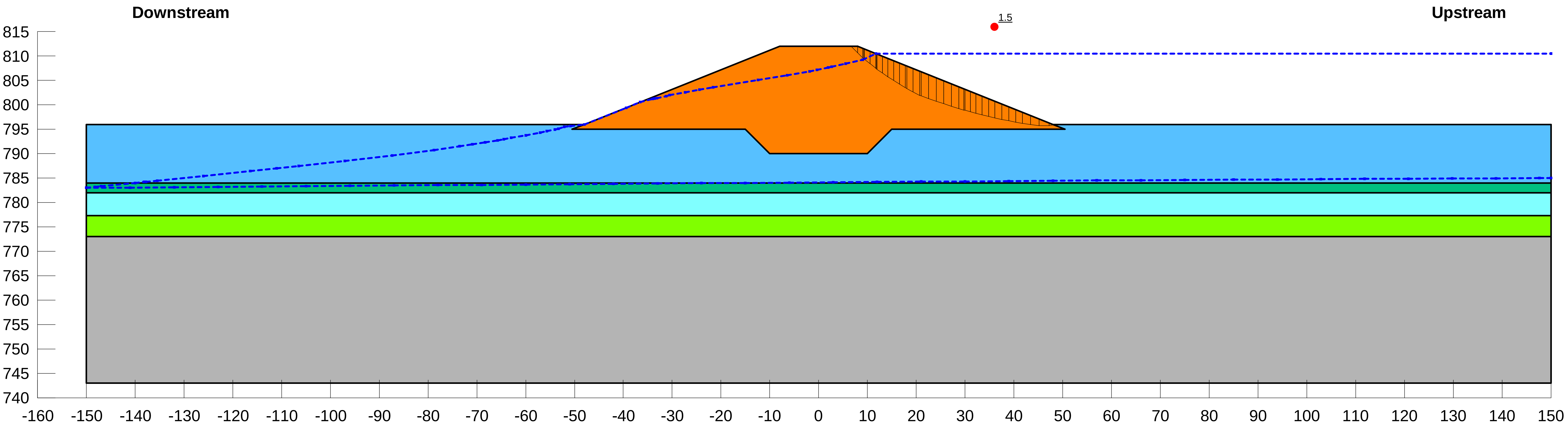
Slope Stability Analysis – FS = 1.5

08_rapid drawdown_us
Flood to Normal Pool SDD; Undrained, SDD Strengths;
Incipient motion: Upstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

			Drained Strength Parameters		**Isotropically Consolidated, Undrained Strength Parameters**	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (SDD)	125	29	0	15	500
🟦	Upper Fine-Grained (SDD)	131	34	0	32	400
🟩	Upper Coarse-Grained (SDD)	132	32	0	32	0
🟦	Lower Fine-Grained (SDD)	138	34	0	32	400
🟩	Lower Coarse-Grained (SDD)	132	32	0	32	0
⬜	Fractured Bedrock	-	Impenetrable		Impenetrable	

At a given effective stress, the lesser of the drained and undrained strengths is used.



Project No. 174316204

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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

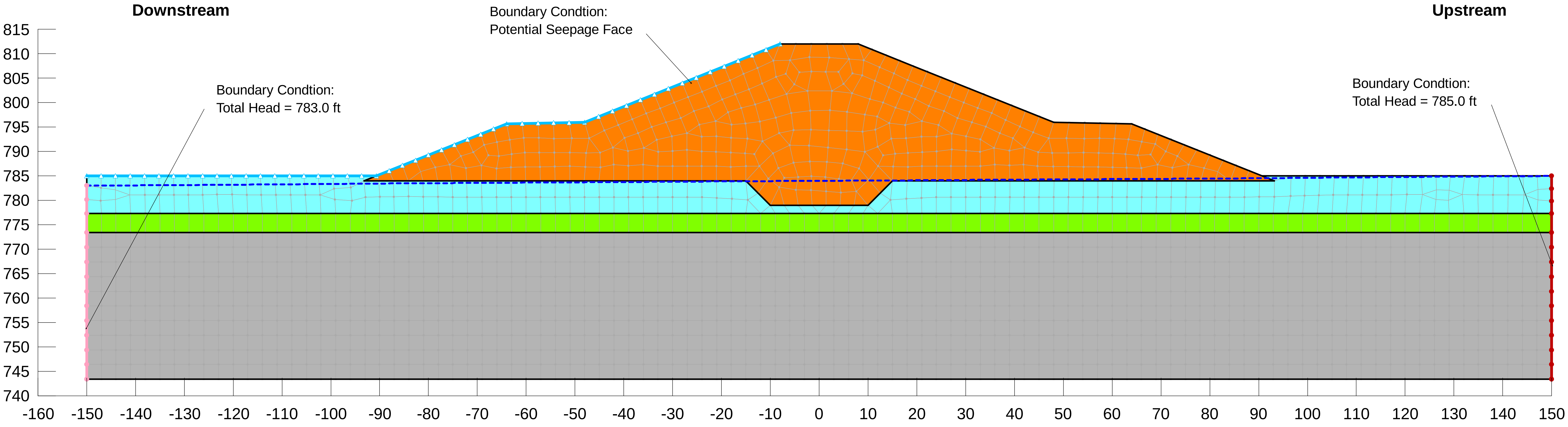
Eagle Creek Dam - Taller Section

Seepage Analysis - Boundary Conditions and Mesh

01_normal_bc
Normal Water Level

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

	Material	Kh-sat (ft/sec)	Kratio Kv/Kh	Sat. Water Content ft^3/ft^3
🟧	Embankment Fill	1e-008	0.2	0.42
🟦	Lower Fine-Grained	5.6e-009	0.1	0.31
🟩	Lower Coarse-Grained	0.0016	1	0.32
⬜	Fractured Bedrock	8.2e-007	1	0.25



Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

Eagle Creek Dam - Taller Section

Seepage Analysis - Contours of Total Head (ft)

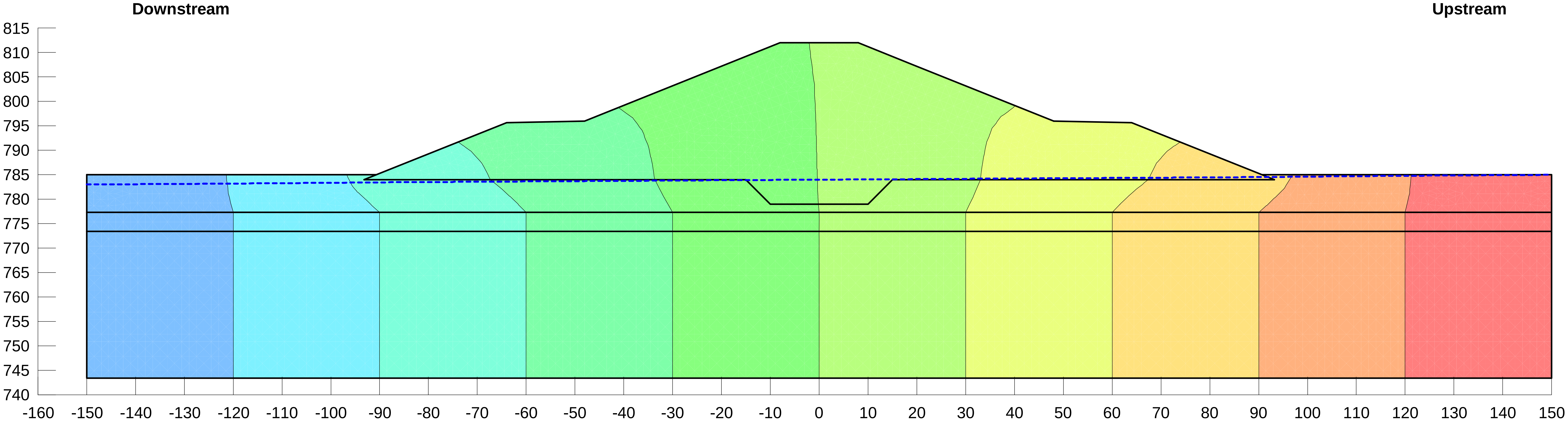
01_normal_th
Normal Water Level

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

Material	Kh-sat (ft/sec)	Kratio Kv/Kh	Sat. Water Content ft^3/ft^3
Embankment Fill	1e-008	0.2	0.42
Lower Fine-Grained	5.6e-009	0.1	0.31
Lower Coarse-Grained	0.0016	1	0.32
Fractured Bedrock	8.2e-007	1	0.25

Total Head

- 🟦 ≤ 783 - 783.2 ft
- 🟦 783.2 - 783.4 ft
- 🟩 783.4 - 783.6 ft
- 🟩 783.6 - 783.8 ft
- 🟩 783.8 - 784 ft
- 🟩 784 - 784.2 ft
- 🟨 784.2 - 784.4 ft
- 🟨 784.4 - 784.6 ft
- 🟧 784.6 - 784.8 ft
- 🟥 ≥ 784.8 ft



Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

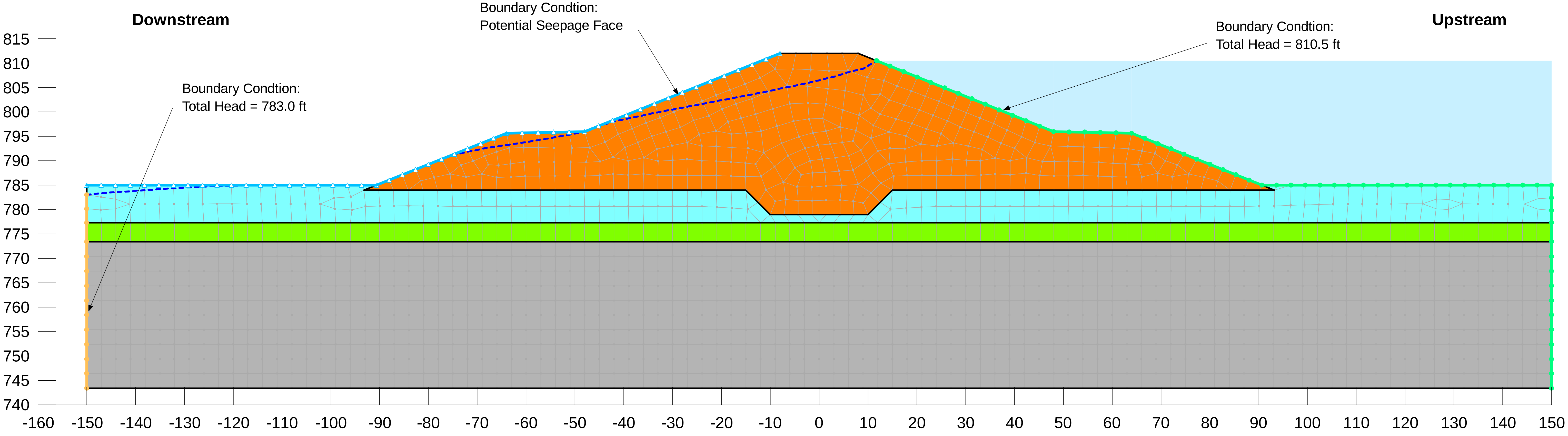
Eagle Creek Dam - Taller Section

Seepage Analysis - Boundary Conditions and Mesh

02_flood_bc
Flood Water Level

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

	Material	Kh-sat (ft/sec)	Kratio Kv/Kh	Sat. Water Content ft^3/ft^3
🟧	Embankment Fill	1e-008	0.2	0.42
🟦	Lower Fine-Grained	5.6e-009	0.1	0.31
🟩	Lower Coarse-Grained	0.0016	1	0.32
⬜	Fractured Bedrock	8.2e-007	1	0.25



Boundary Condtion:
Potential Seepage Face

Boundary Condtion:
Total Head = 810.5 ft

Boundary Condtion:
Total Head = 783.0 ft

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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

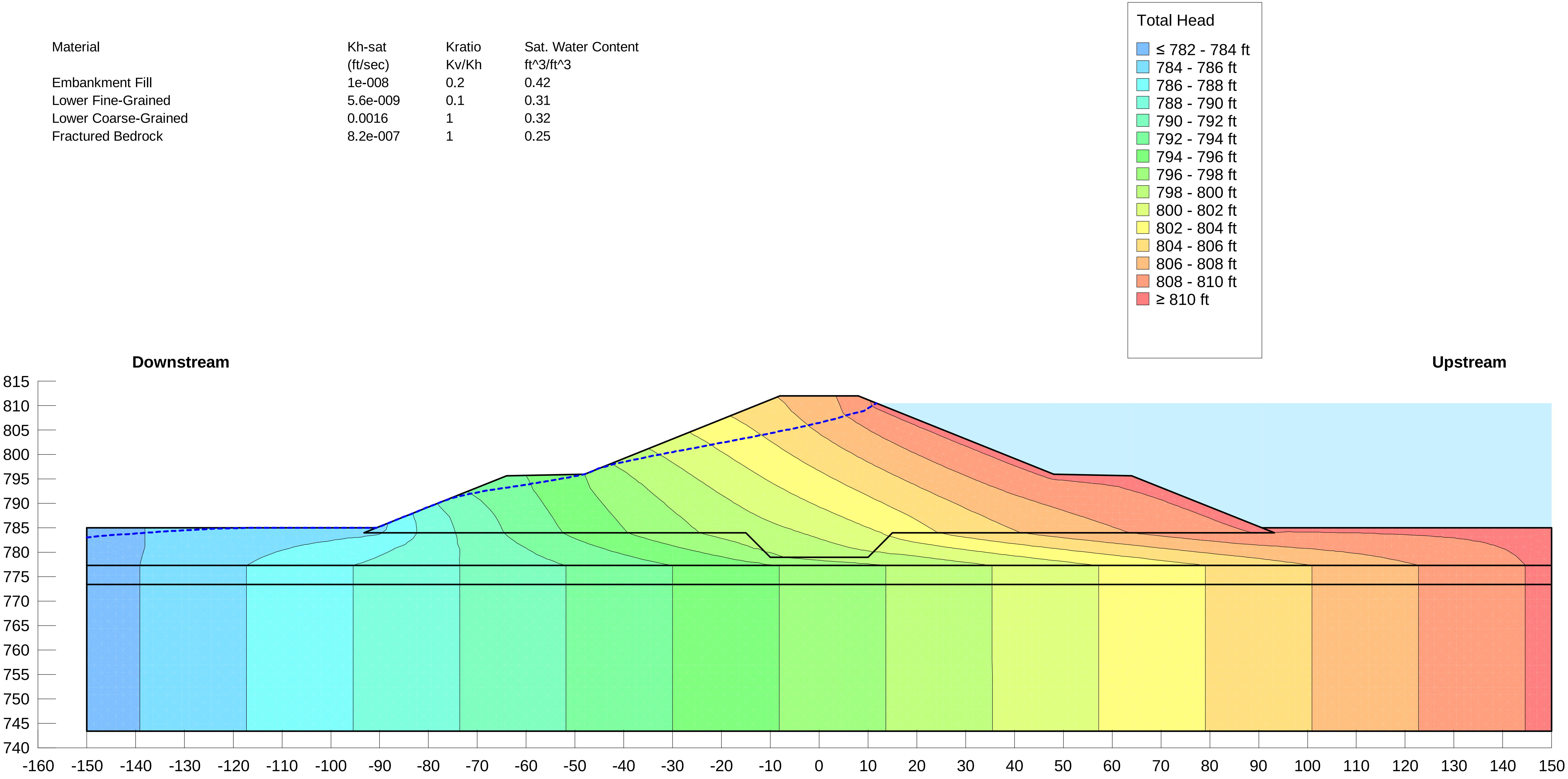
Eagle Creek Dam - Taller Section

Seepage Analysis - Contours of Total Head (ft)

02_flood_th
Flood Water Level

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

Material	Kh-sat (ft/sec)	Kratio Kv/Kh	Sat. Water Content ft^3/ft^3
Embankment Fill	1e-008	0.2	0.42
Lower Fine-Grained	5.6e-009	0.1	0.31
Lower Coarse-Grained	0.0016	1	0.32
Fractured Bedrock	8.2e-007	1	0.25



Project No. 174316204

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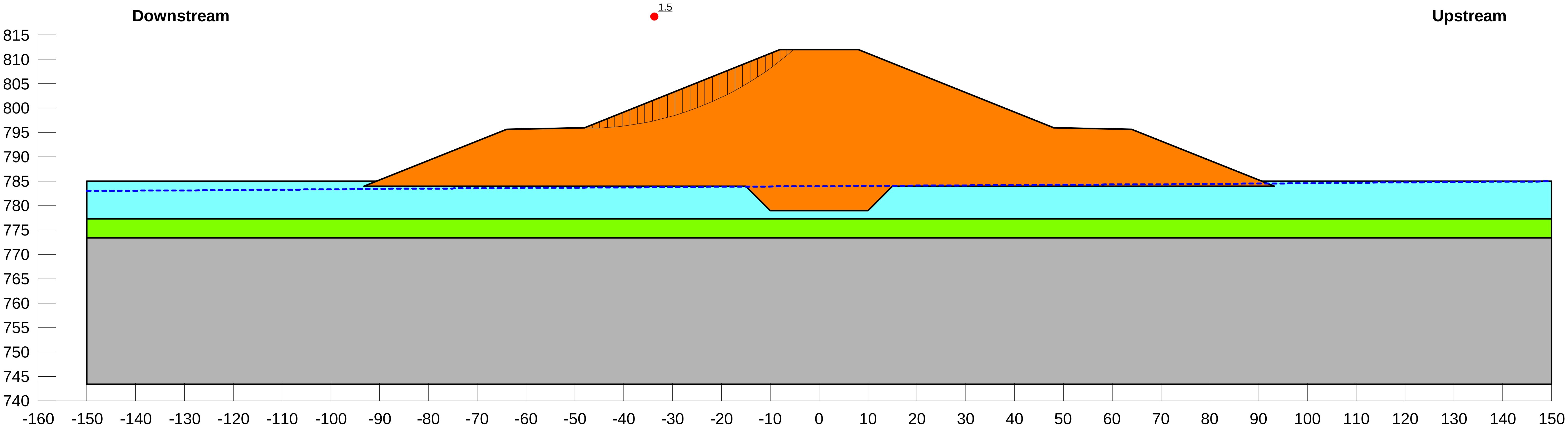
Hancock County Flood Risk Reduction Program	**Slope Stability Analysis – FS = 1.5**	Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.
Preliminary Dam Analysis	03_normal_total stresses_ds Normal Pool; Undrained, Static Strengths; Incipient Motion: Downstream Direction	
Eagle Creek Dam - Taller Section		

			Drained Strength Parameters		**Undrained Strength Parameters**	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Undrained)	125	29	0	15	500
🟦	Lower Fine-Grained (Undrained)	138	34	0	32	400
🟩	Lower Coarse-Grained (Undrained)	132	32	0	32	0
⬜	Fractured Bedrock	-	Impenetrable		Impenetrable	

At a given effective stress, the lesser of the drained and undrained strengths is used.



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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

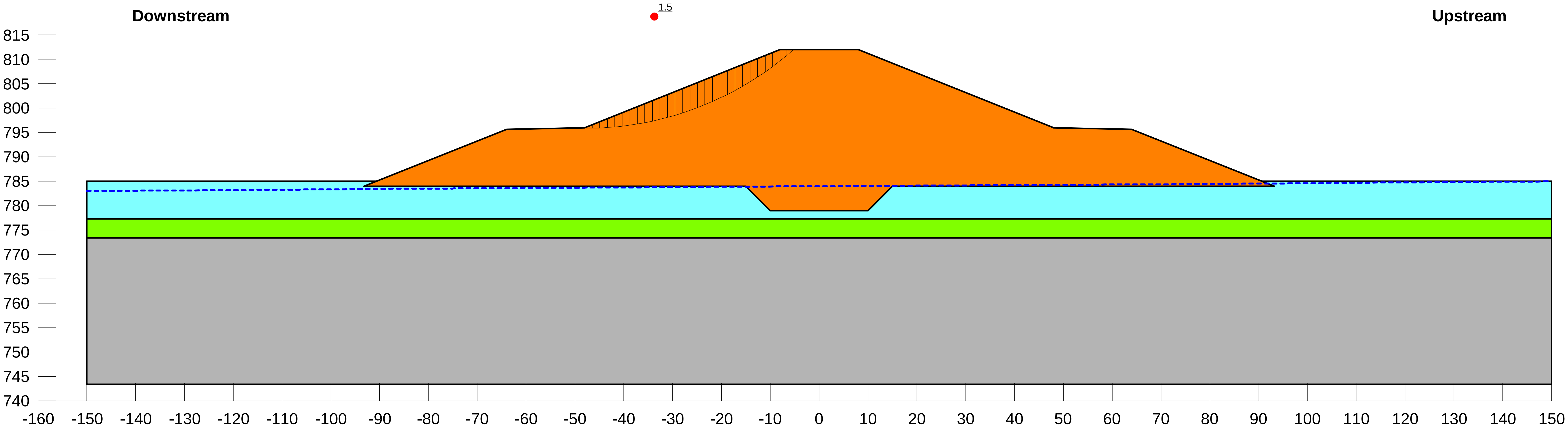
Eagle Creek Dam - Taller Section

Slope Stability Analysis – FS = 1.5

04_normal_effective stresses_ds
Normal Pool; Drained, Static Strengths;
Incipient Motion: Downstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

			Drained Strength Parameters	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Drained)	125	29	0
🟦	Lower Fine-Grained (Drained)	138	34	0
🟩	Lower Coarse-Grained (Drained)	132	32	0
⬜	Fractured Bedrock	-	Impenetrable	



Project No. 174316204

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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

Eagle Creek Dam - Taller Section

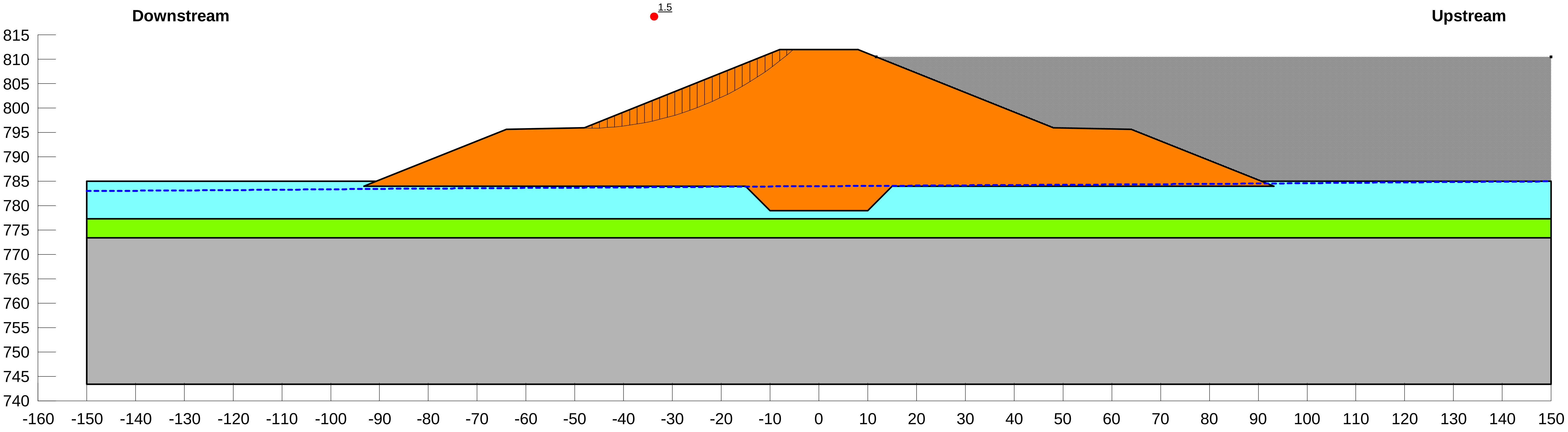
Slope Stability Analysis – FS = 1.5

05_flood surcharge_total stresses_ds
Normal Pool with Flood Surcharge; Undrained, Static Strengths;
Incipient Motion: Downstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

			Drained Strength Parameters		**Undrained Strength Parameters**	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Undrained)	125	29	0	15	500
🟦	Lower Fine-Grained (Undrained)	138	34	0	32	400
🟩	Lower Coarse-Grained (Undrained)	132	32	0	32	0
⬜	Fractured Bedrock	-	Impenetrable		Impenetrable	

At a given effective stress, the lesser of the drained and undrained strengths is used.



Project No. 174316204

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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

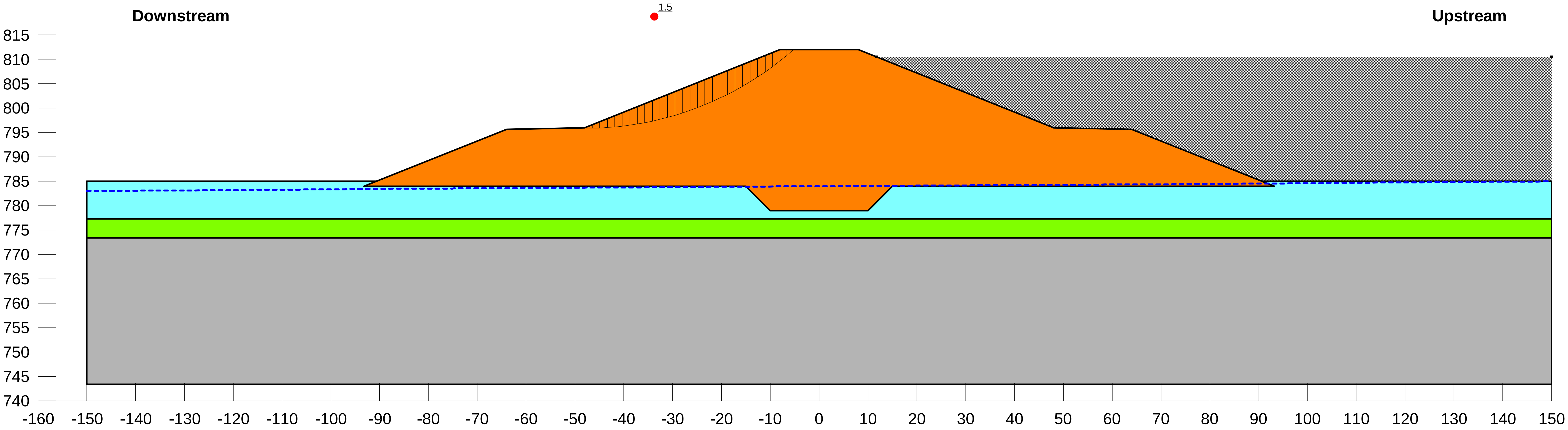
Eagle Creek Dam - Taller Section

Slope Stability Analysis – FS = 1.5

06_flood surcharge_effective stresses_ds
Normal Pool with Flood Surcharge; Drained, Static Strengths;
Incipient Motion: Downstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

			Drained Strength Parameters	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Drained)	125	29	0
🟦	Lower Fine-Grained (Drained)	138	34	0
🟩	Lower Coarse-Grained (Drained)	132	32	0
⬜	Fractured Bedrock	-	Impenetrable	



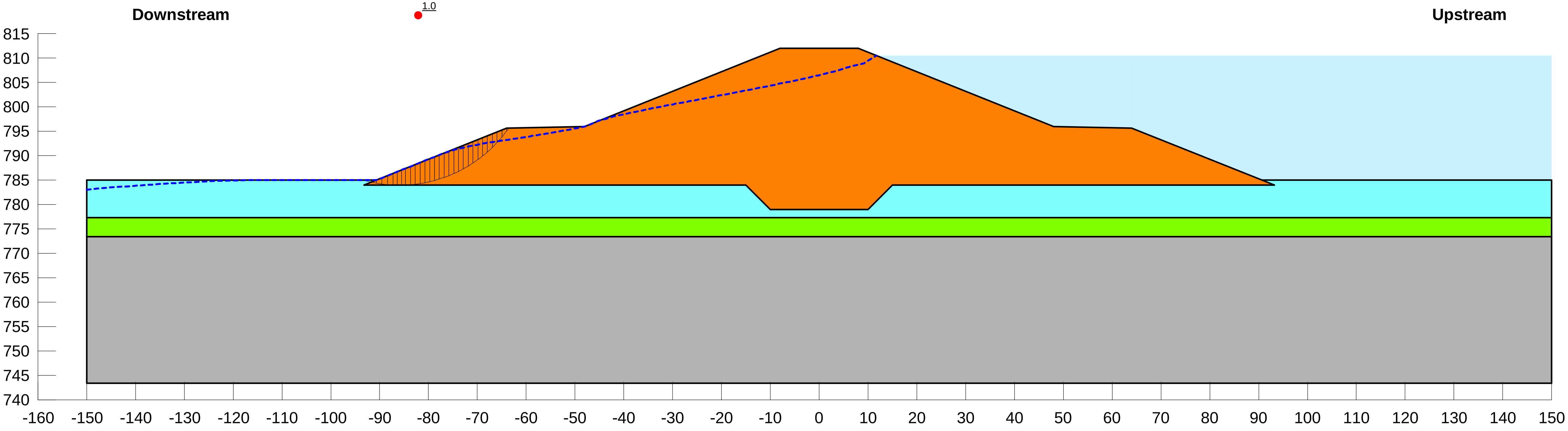
Hancock County Flood Risk Reduction Program
Preliminary Dam Analysis
Eagle Creek Dam - Taller Section

Slope Stability Analysis – FS = 1.0

07_flood_effective stresses_ds
Flood Pool; Drained, Static Strengths;
Incipient Motion: Downstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

	Material	Unit Weight (pcf)	**Drained Strength Parameters** Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Drained)	125	29	0
🟦	Lower Fine-Grained (Drained)	138	34	0
🟩	Lower Coarse-Grained (Drained)	132	32	0
⬜	Fractured Bedrock	-	Impenetrable	



Project No. 174316204

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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

Eagle Creek Dam - Taller Section

Slope Stability Analysis – FS = 1.5

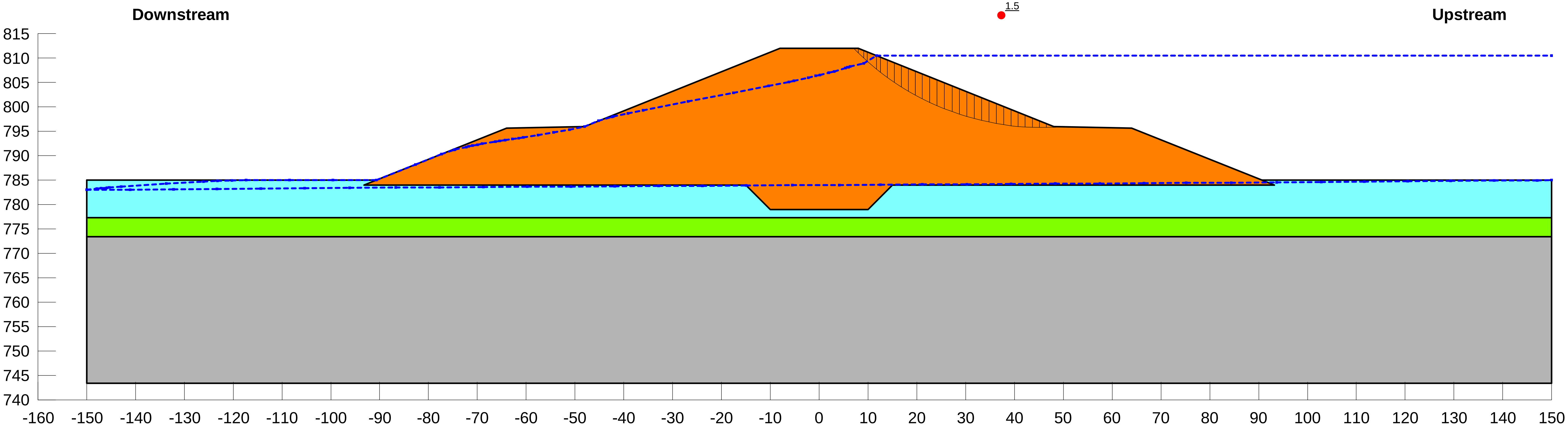
08_rapid drawdown_us

Flood to Normal Pool SDD; Undrained, SDD Strengths;
Incipient motion: Upstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

			Drained Strength Parameters		**Isotropically Consolidated, Undrained Strength Parameters**	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (SDD)	125	29	0	15	500
🟦	Lower Fine-Grained (SDD)	138	34	0	32	400
🟩	Lower Coarse-Grained (SDD)	132	32	0	32	0
⬜	Fractured Bedrock	-	Impenetrable		Impenetrable	

At a given effective stress, the lesser of the drained and undrained strengths is used.



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BLANCHARD RIVER AND POTATO RUN DAMS

Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

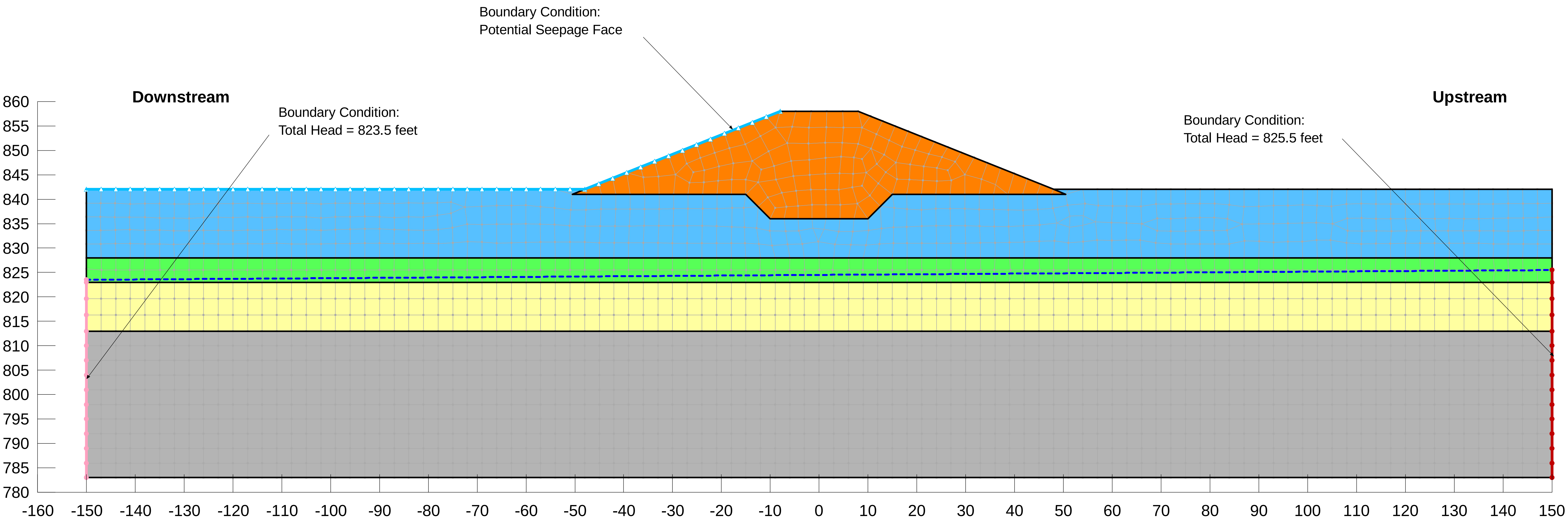
Blanchard River Dam - Shorter Section

Seepage Analysis - Boundary Conditions and Mesh

01_normal_bc
Normal Water Level

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

	Material	Kh-sat (ft/sec)	Kratio Kv/Kh	Sat. Water Content ft^3/ft^3
🟧	Embankment Fill	1e-008	0.2	0.42
🟦	Fine-Grained	5.9e-009	0.1	0.29
🟩	Coarse-Grained	4.9e-008	1	0.39
🟨	Fractured Bedrock	8.2e-007	1	0.25
▨	Bedrock	8.2e-008	1	0.25



Project No. 174316204

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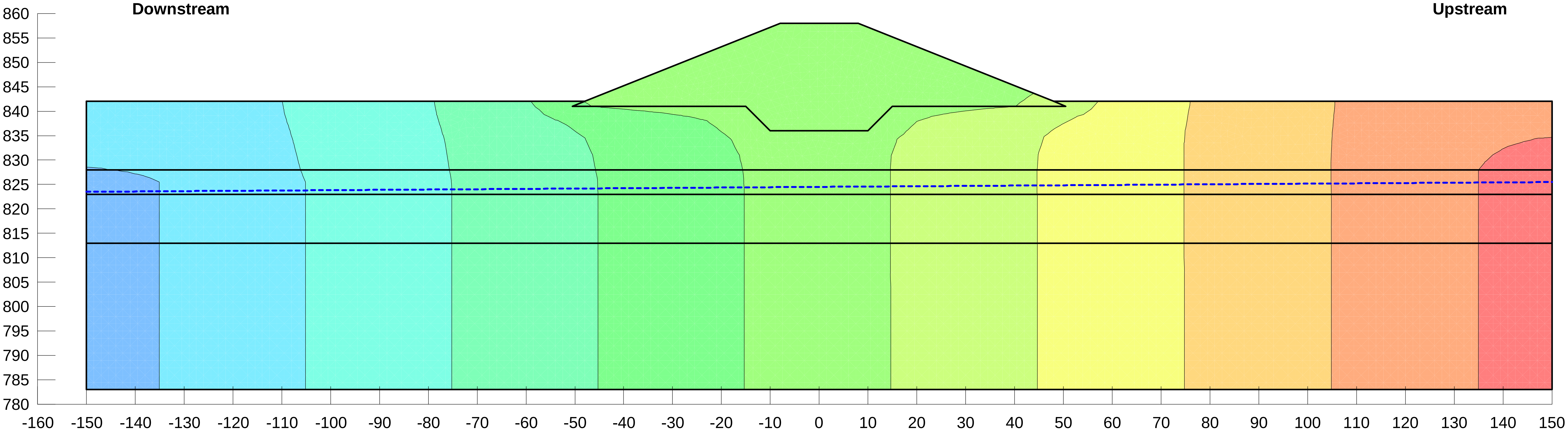
Hancock County Flood Risk Reduction Program	**Seepage Analysis - Contours of Total Head (ft)**	Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.
Preliminary Dam Analysis	01_normal_th Normal Water Level	
Blanchard River Dam - Shorter Section		

Material	Kh-sat (ft/sec)	Kratio Kv/Kh	Sat. Water Content ft^3/ft^3
Embankment Fill	1e-008	0.2	0.42
Fine-Grained	5.9e-009	0.1	0.29
Coarse-Grained	4.9e-008	1	0.39
Fractured Bedrock	8.2e-007	1	0.25
Bedrock	8.2e-008	1	0.25

Total Head

🟦 ≤ 823.4 - 823.6 ft
🟦 823.6 - 823.8 ft
🟦 823.8 - 824 ft
🟩 824 - 824.2 ft
🟩 824.2 - 824.4 ft
🟩 824.4 - 824.6 ft
🟩 824.6 - 824.8 ft
🟨 824.8 - 825 ft
🟧 825 - 825.2 ft
🟧 825.2 - 825.4 ft
🟥 ≥ 825.4 ft



Project No. 174316204

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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

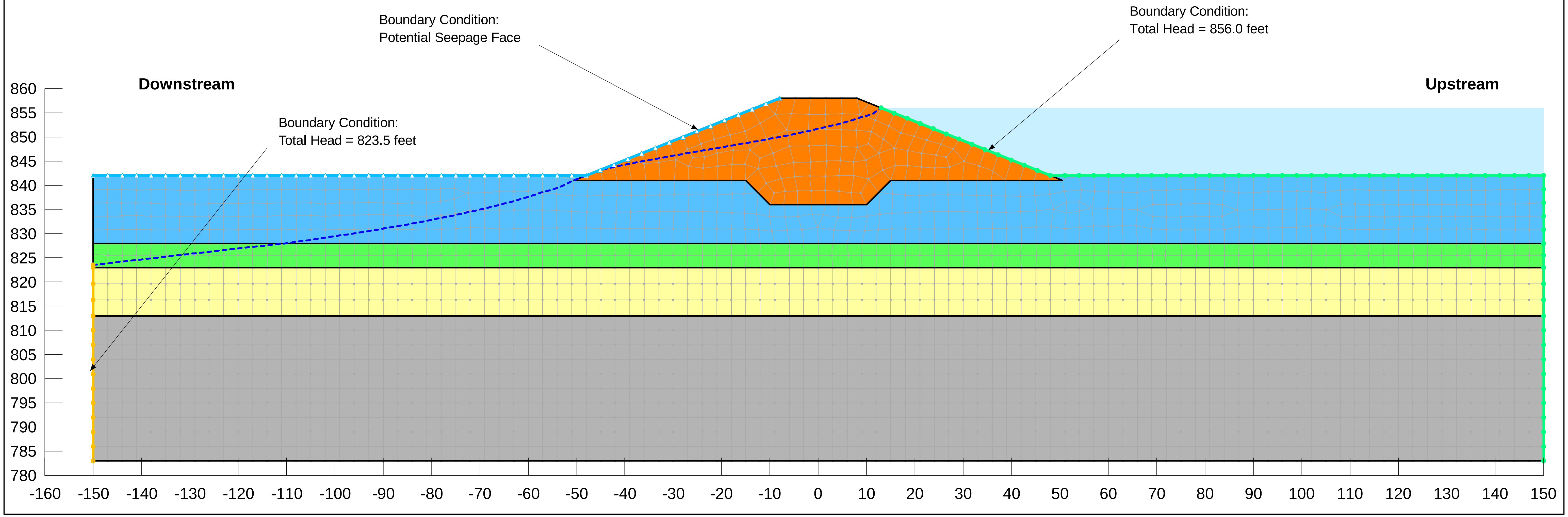
Blanchard River Dam - Shorter Section

Seepage Analysis - Boundary Conditions and Mesh

02_flood_bc
Flood Water Level

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

	Material	Kh-sat (ft/sec)	Kratio Kv/Kh	Sat. Water Content ft^3/ft^3
🟧	Embankment Fill	1e-008	0.2	0.42
🟦	Fine-Grained	5.9e-009	0.1	0.29
🟩	Coarse-Grained	4.9e-008	1	0.39
🟨	Fractured Bedrock	8.2e-007	1	0.25
⬜	Bedrock	8.2e-008	1	0.25



Boundary Condition:
Potential Seepage Face

Boundary Condition:
Total Head = 856.0 feet

Boundary Condition:
Total Head = 823.5 feet

Project No. 174316204

1/8/2018: 4:53:27 PM

Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

Blanchard River Dam - Shorter Section

Seepage Analysis - Contours of Total Head (ft)

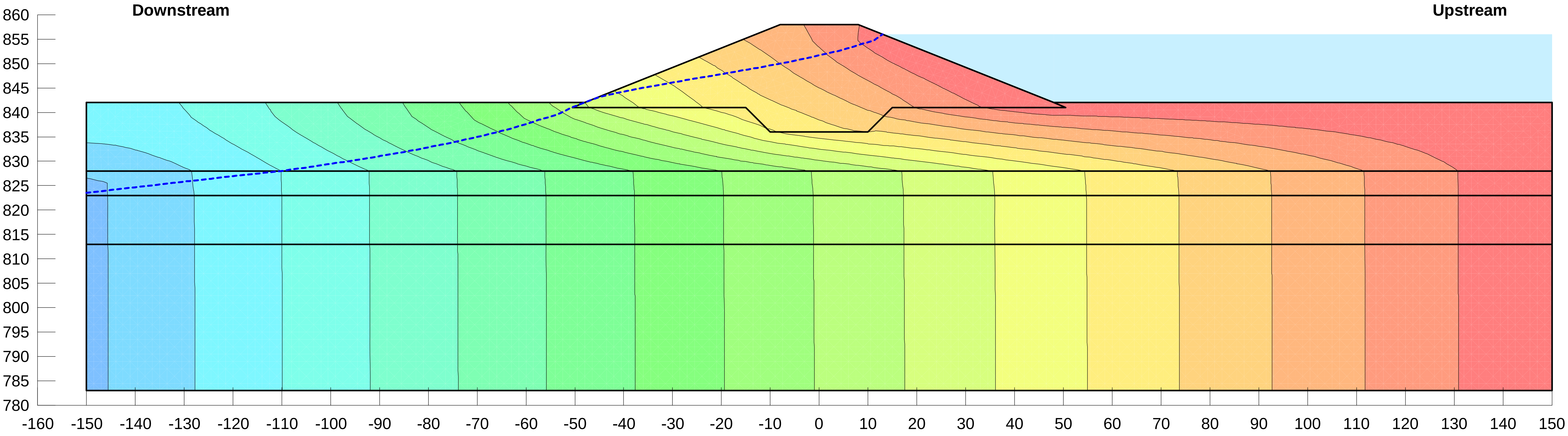
02_flood_th
Flood Water Level

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

Material	Kh-sat (ft/sec)	Kratio Kv/Kh	Sat. Water Content ft^3/ft^3
Embankment Fill	1e-008	0.2	0.42
Fine-Grained	5.9e-009	0.1	0.29
Coarse-Grained	4.9e-008	1	0.39
Fractured Bedrock	8.2e-007	1	0.25
Bedrock	8.2e-008	1	0.25

Total Head

- 🟦 ≤ 822 - 824 ft
- 🟦 824 - 826 ft
- 🟦 826 - 828 ft
- 🟦 828 - 830 ft
- 🟩 830 - 832 ft
- 🟩 832 - 834 ft
- 🟩 834 - 836 ft
- 🟩 836 - 838 ft
- 🟩 838 - 840 ft
- 🟩 840 - 842 ft
- 🟨 842 - 844 ft
- 🟨 844 - 846 ft
- 🟨 846 - 848 ft
- 🟧 848 - 850 ft
- 🟧 850 - 852 ft
- 🟧 852 - 854 ft
- 🟥 ≥ 854 ft



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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

Blanchard River Dam - Shorter Section

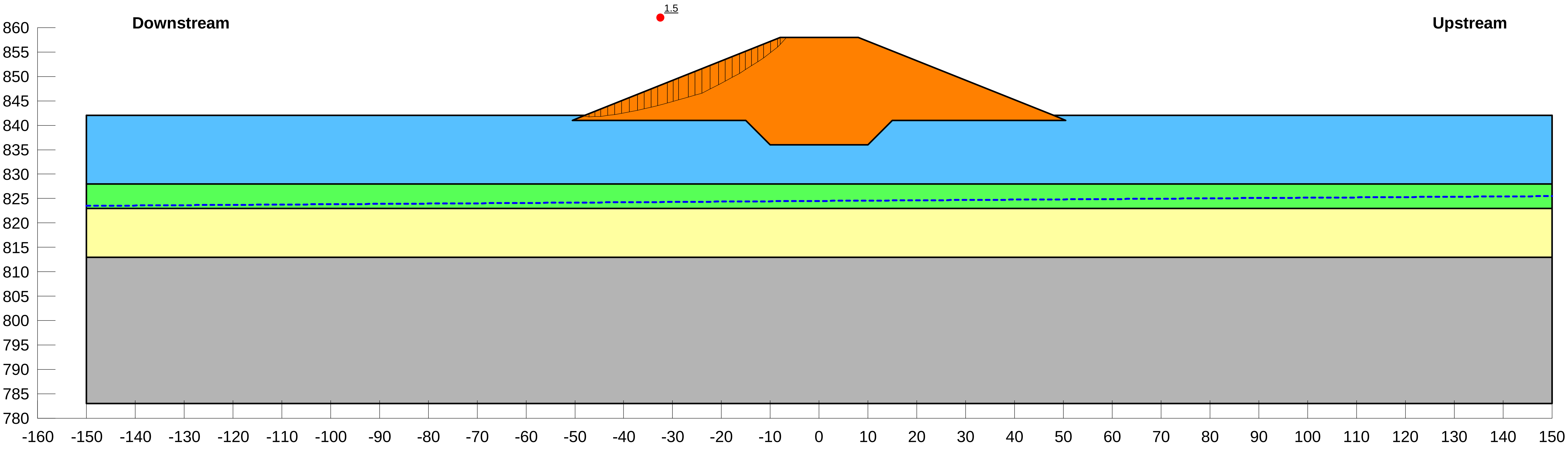
Slope Stability Analysis – FS = 1.5

03_normal_total stresses_ds
Normal Pool; Undrained, Static Strengths;
Incipient Motion: Downstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

			Drained Strength Parameters		**Undrained Strength Parameters**	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Undrained)	125	29	0	15	500
🟦	Fine-Grained (Undrained)	138	34	0	32	400
🟩	Coarse-Grained (Undrained)	127	34	0	32	400
🟨	Fractured Bedrock	-	Impenetrable		Impenetrable	
⬜	Bedrock	-	Impenetrable		Impenetrable	

At a given effective stress, the lesser of the drained and undrained strengths is used.



Project No. 174316204

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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

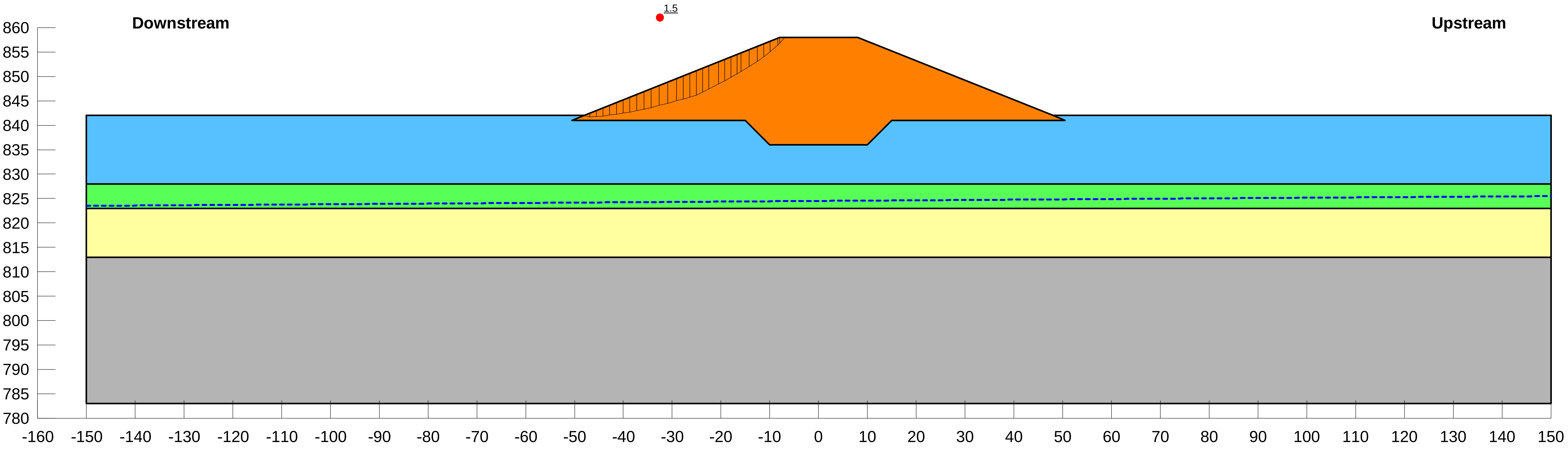
Blanchard River Dam - Shorter Section

Slope Stability Analysis – FS = 1.5

04_normal_effective stresses_ds
Normal Pool; Drained, Static Strengths;
Incipient Motion: Downstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

	Material	Unit Weight (pcf)	**Drained Strength Parameters**	
			Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Drained)	125	29	0
🟦	Fine-Grained (Drained)	138	34	0
🟩	Coarse-Grained (Drained)	127	34	0
🟨	Fractured Bedrock	-	Impenetrable	
⬜	Bedrock	-	Impenetrable	



Project No. 174316204

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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

Blanchard River Dam - Shorter Section

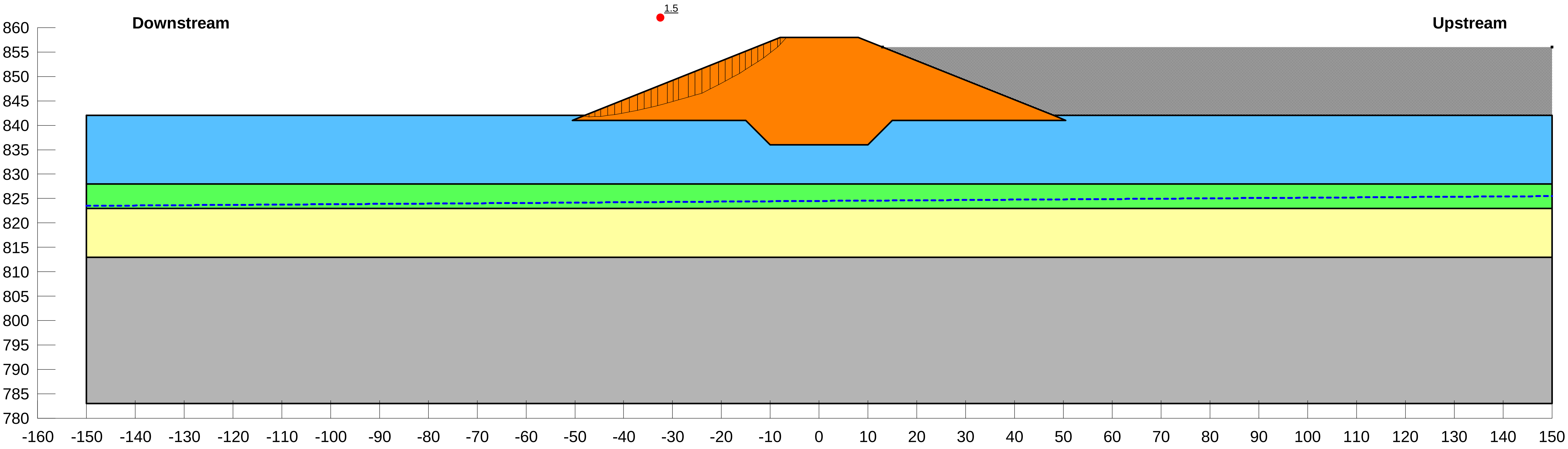
Slope Stability Analysis – FS = 1.5

05_flood surcharge_total stresses_ds
Normal Pool with Flood Surcharge; Undrained, Static Strengths;
Incipient Motion: Downstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

			Drained Strength Parameters		**Undrained Strength Parameters**	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Undrained)	125	29	0	15	500
🟦	Fine-Grained (Undrained)	138	34	0	32	400
🟩	Coarse-Grained (Undrained)	127	34	0	32	400
🟨	Fractured Bedrock	-	Impenetrable		Impenetrable	
⬜	Bedrock	-	Impenetrable		Impenetrable	

At a given effective stress, the lesser of the drained and undrained strengths is used.



Project No. 174316204

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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

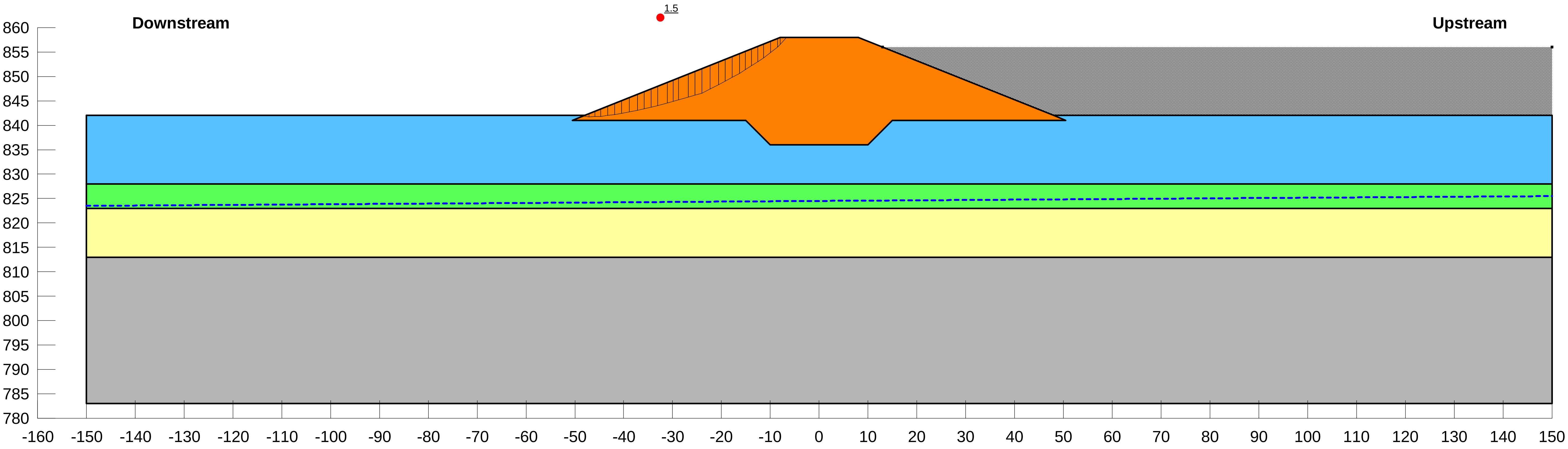
Blanchard River Dam - Shorter Section

Slope Stability Analysis – FS = 1.5

06_flood surcharge_effective stresses_ds
Normal Pool with Flood Surcharge; Drained, Static Strengths;
Incipient Motion: Downstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

	Material	Unit Weight (pcf)	**Drained Strength Parameters** Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Drained)	125	29	0
🟦	Fine-Grained (Drained)	138	34	0
🟩	Coarse-Grained (Drained)	127	34	0
🟨	Fractured Bedrock	-	Impenetrable	
⬜	Bedrock	-	Impenetrable	



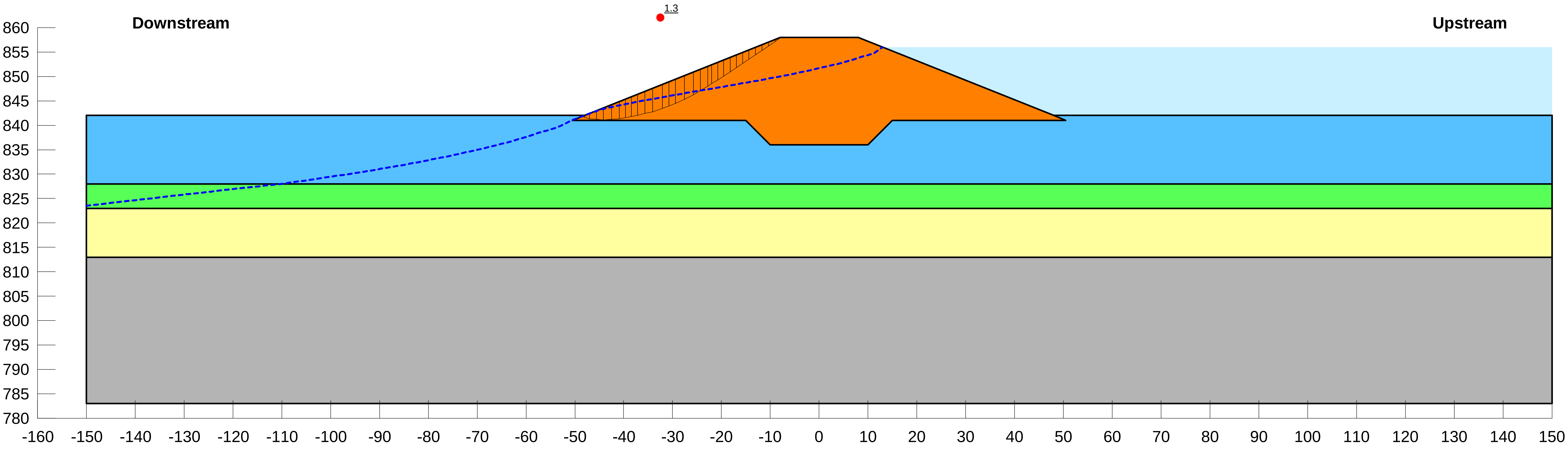
Hancock County Flood Risk Reduction Program
Preliminary Dam Analysis
Blanchard River Dam - Shorter Section

Slope Stability Analysis – FS = 1.3

07_flood_effective stresses_ds
Flood Pool; Drained, Static Strengths;
Incipient Motion: Downstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

			Drained Strength Parameters	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Drained)	125	29	0
🟦	Fine-Grained (Drained)	138	34	0
🟩	Coarse-Grained (Drained)	127	34	0
🟨	Fractured Bedrock	-	Impenetrable	
▒	Bedrock	-	Impenetrable	



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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

Blanchard River Dam - Shorter Section

Slope Stability Analysis – FS = 1.5

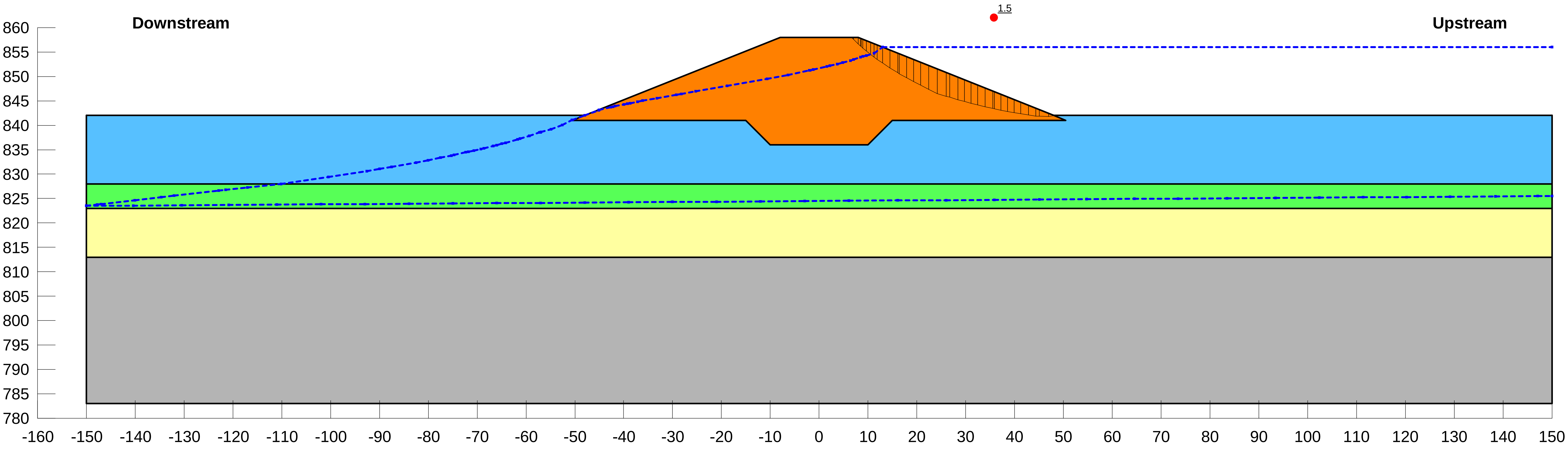
08_rapid drawdown_us

Flood to Normal Pool SDD; Undrained, SDD Strengths;
Incipient motion: Upstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

			Drained Strength Parameters		**Isotropically Consolidated, Undrained Strength Parameters**	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (SDD)	125	29	0	15	500
🟦	Fine-Grained (SDD)	138	34	0	32	400
🟩	Coarse-Grained (SDD)	127	34	0	32	400
🟨	Fractured Bedrock	-	Impenetrable		Impenetrable	
⬜	Bedrock	-	Impenetrable		Impenetrable	

At a given effective stress, the lesser of the drained and undrained strengths is used.



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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

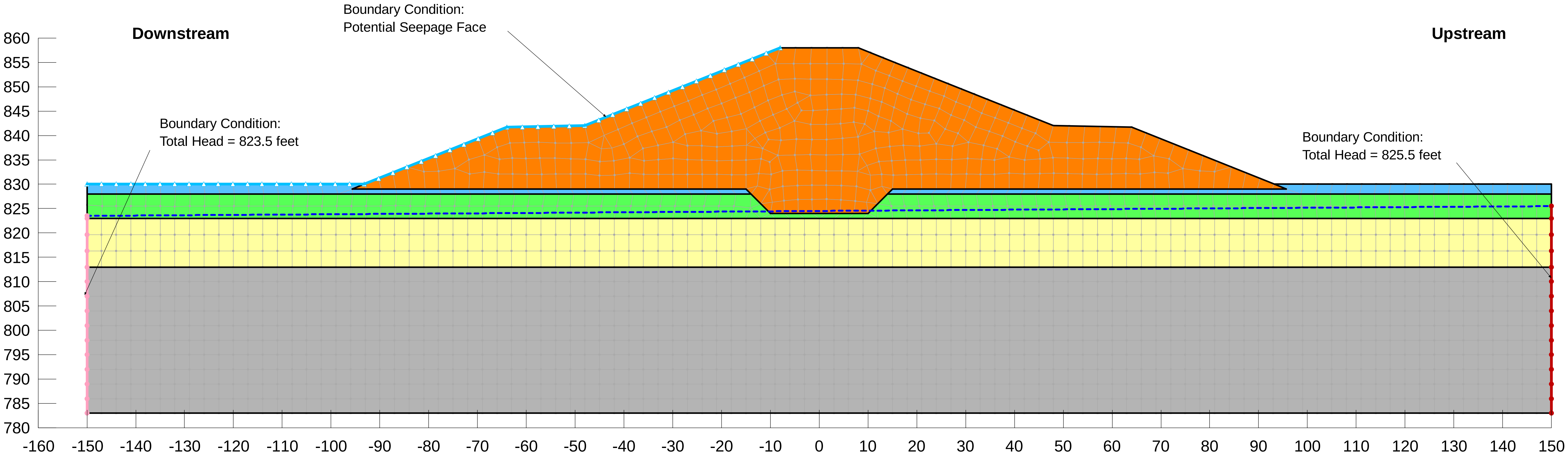
Blanchard River Dam - Taller Section

Seepage Analysis - Boundary Conditions and Mesh

01_normal_bc
Normal Water Level

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

	Material	Kh-sat (ft/sec)	Kratio Kv/Kh	Sat. Water Content ft^3/ft^3
🟧	Embankment Fill	1e-008	0.2	0.42
🟦	Fine-Grained	5.9e-009	0.1	0.29
🟩	Coarse-Grained	4.9e-008	1	0.39
🟨	Fractured Bedrock	8.2e-007	1	0.25
▨	Bedrock	8.2e-008	1	0.25



Project No. 174316204

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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

Blanchard River Dam - Taller Section

Seepage Analysis - Contours of Total Head (ft)

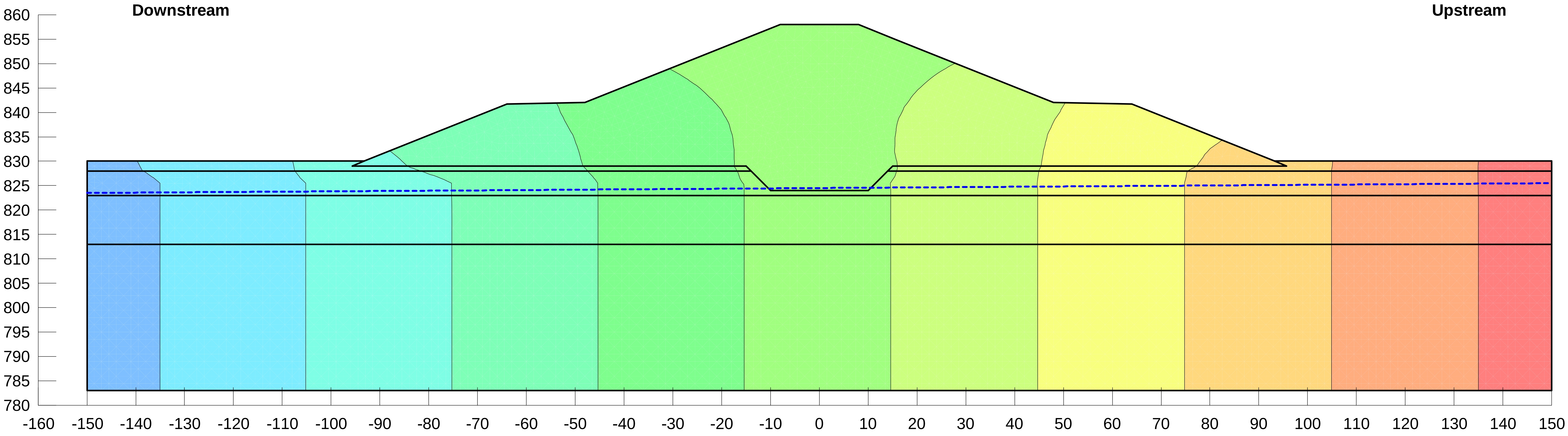
01_normal_th
Normal Water Level

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

Total Head

- 🟦 ≤ 823.4 - 823.6 ft
- 🟦 823.6 - 823.8 ft
- 🟩 823.8 - 824 ft
- 🟩 824 - 824.2 ft
- 🟩 824.2 - 824.4 ft
- 🟩 824.4 - 824.6 ft
- 🟨 824.6 - 824.8 ft
- 🟨 824.8 - 825 ft
- 🟧 825 - 825.2 ft
- 🟧 825.2 - 825.4 ft
- 🟥 ≥ 825.4 ft

Material	Kh-sat (ft/sec)	Kratio Kv/Kh	Sat. Water Content ft^3/ft^3
Embankment Fill	1e-008	0.2	0.42
Fine-Grained	5.9e-009	0.1	0.29
Coarse-Grained	4.9e-008	1	0.39
Fractured Bedrock	8.2e-007	1	0.25
Bedrock	8.2e-008	1	0.25



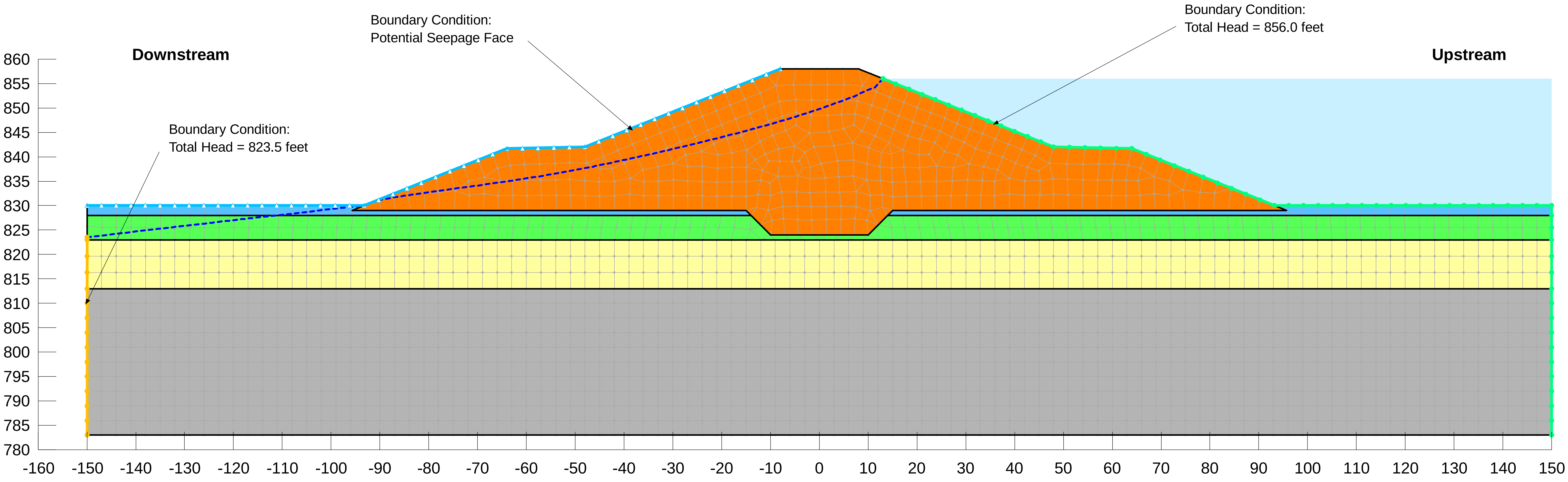
Hancock County Flood Risk Reduction Program
Preliminary Dam Analysis
Blanchard River Dam - Taller Section

Seepage Analysis - Boundary Conditions and Mesh

02_flood_bc
Flood Water Level

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

	Material	Kh-sat (ft/sec)	Kratio Kv/Kh	Sat. Water Content ft^3/ft^3
🟧	Embankment Fill	1e-008	0.2	0.42
🟦	Fine-Grained	5.9e-009	0.1	0.29
🟩	Coarse-Grained	4.9e-008	1	0.39
🟨	Fractured Bedrock	8.2e-007	1	0.25
⬛	Bedrock	8.2e-008	1	0.25

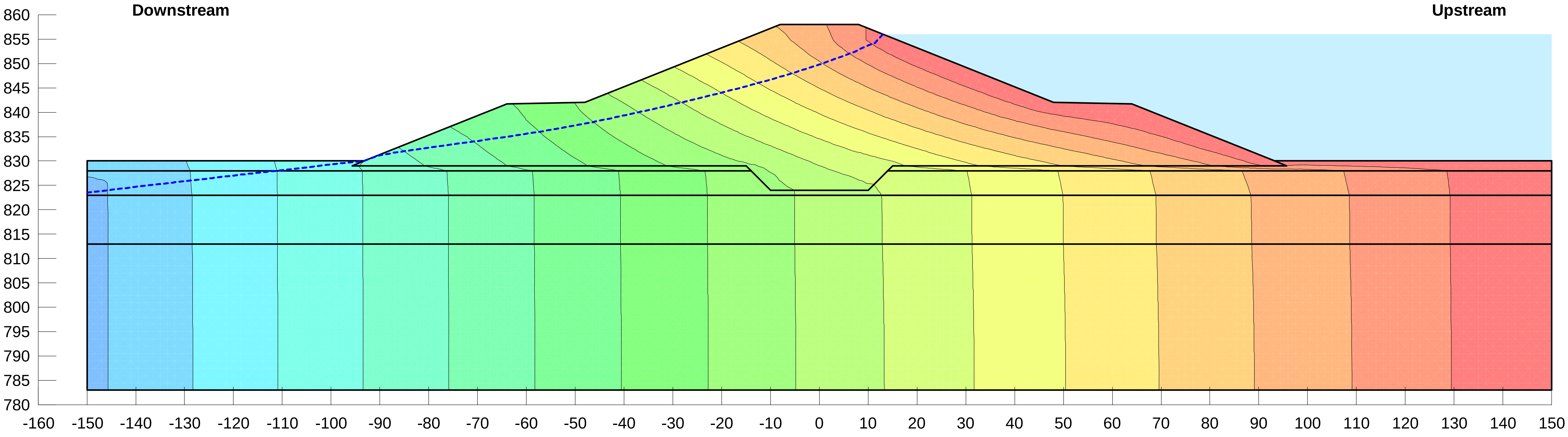


Hancock County Flood Risk Reduction Program	**Seepage Analysis - Contours of Total Head (ft)**	Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.
Preliminary Dam Analysis	02_flood_th Flood Water Level	
Blanchard River Dam - Taller Section		

Material	Kh-sat (ft/sec)	Kratio Kv/Kh	Sat. Water Content ft^3/ft^3
Embankment Fill	1e-008	0.2	0.42
Fine-Grained	5.9e-009	0.1	0.29
Coarse-Grained	4.9e-008	1	0.39
Fractured Bedrock	8.2e-007	1	0.25
Bedrock	8.2e-008	1	0.25

Total Head

- 🟦 ≤ 822 - 824 ft
- 🟦 824 - 826 ft
- 🟦 826 - 828 ft
- 🟦 828 - 830 ft
- 🟩 830 - 832 ft
- 🟩 832 - 834 ft
- 🟩 834 - 836 ft
- 🟩 836 - 838 ft
- 🟩 838 - 840 ft
- 🟩 840 - 842 ft
- 🟨 842 - 844 ft
- 🟨 844 - 846 ft
- 🟨 846 - 848 ft
- 🟧 848 - 850 ft
- 🟧 850 - 852 ft
- 🟥 852 - 854 ft
- 🟥 ≥ 854 ft



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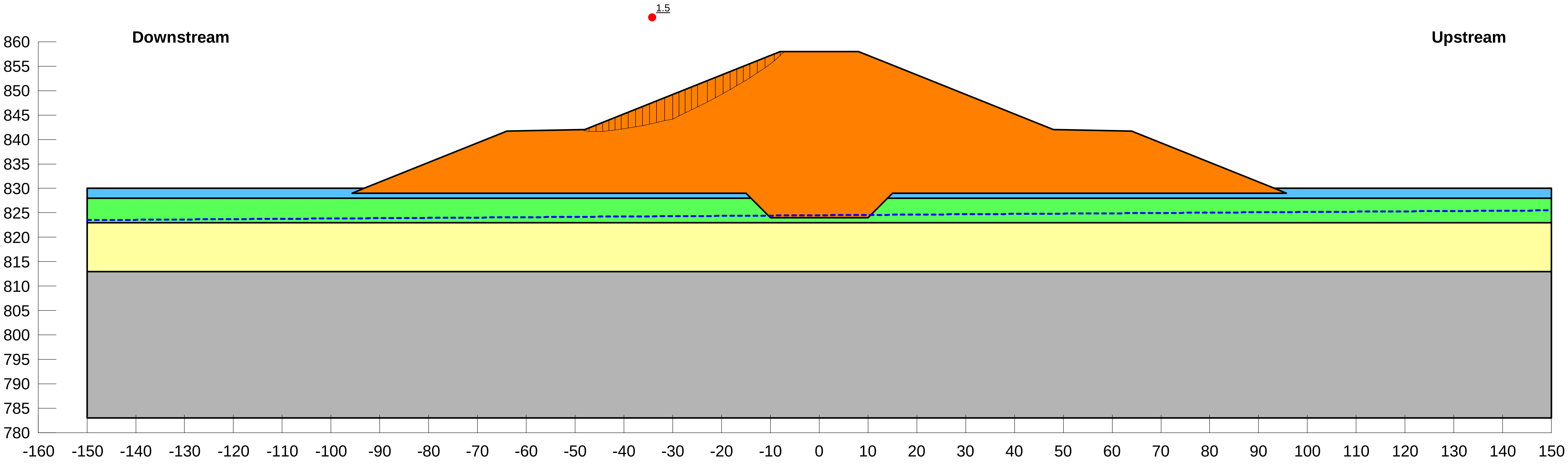
Hancock County Flood Risk Reduction Program	**Slope Stability Analysis – FS = 1.5**
Preliminary Dam Analysis	03_normal_total stresses_ds Normal Pool; Undrained, Static Strengths; Incipient Motion: Downstream Direction
Blanchard River Dam - Taller Section	

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

			Drained Strength Parameters		**Undrained Strength Parameters**	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Undrained)	125	29	0	15	500
🟦	Fine-Grained (Undrained)	138	34	0	32	400
🟩	Coarse-Grained (Undrained)	127	34	0	32	400
🟨	Fractured Bedrock	-	Impenetrable		Impenetrable	
⬜	Bedrock	-	Impenetrable		Impenetrable	

At a given effective stress, the lesser of the drained and undrained strengths is used.



Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

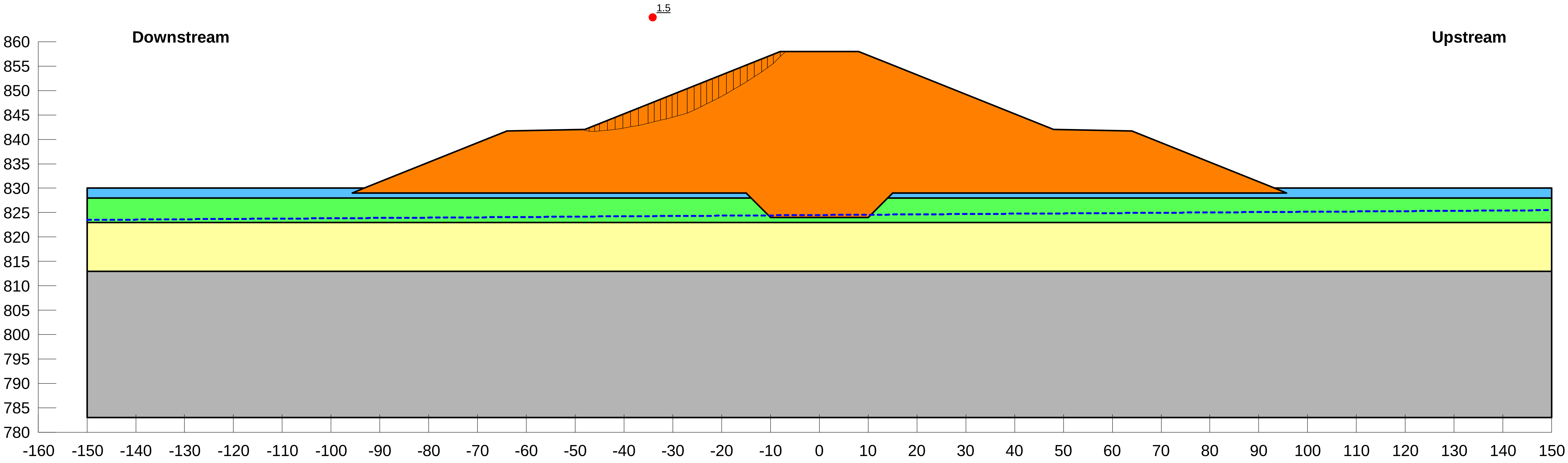
Blanchard River Dam - Taller Section

Slope Stability Analysis – FS = 1.5

04_normal_effective stresses_ds
Normal Pool; Drained, Static Strengths;
Incipient Motion: Downstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

			Drained Strength Parameters	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Drained)	125	29	0
🟦	Fine-Grained (Drained)	138	34	0
🟩	Coarse-Grained (Drained)	127	34	0
🟨	Fractured Bedrock	-	Impenetrable	
⬜	Bedrock	-	Impenetrable	



Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

Blanchard River Dam - Taller Section

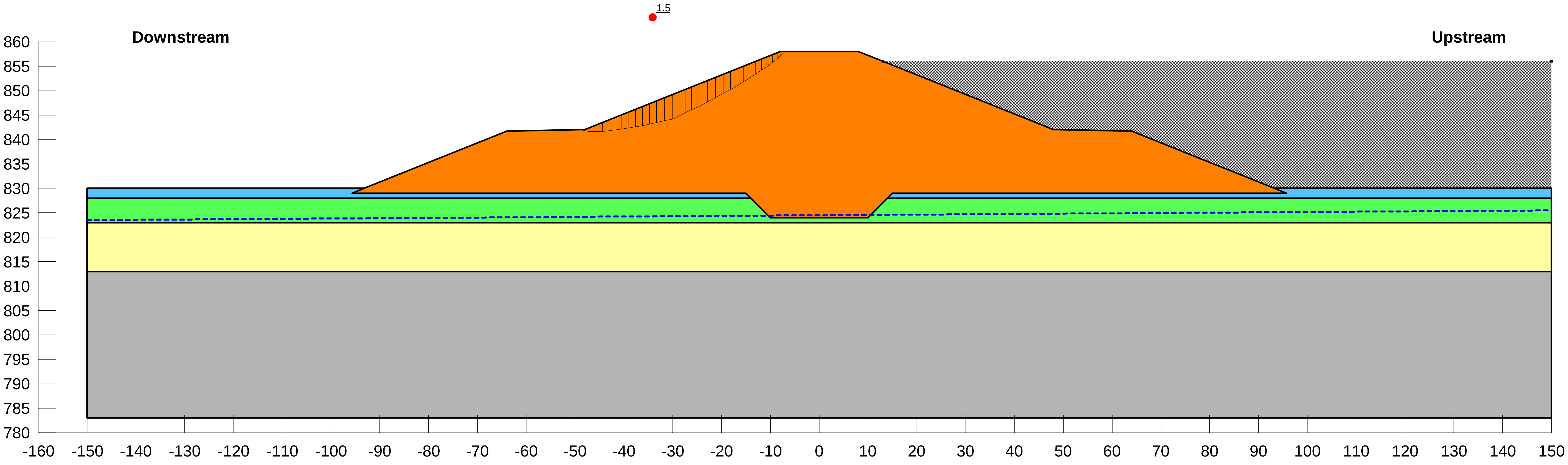
Slope Stability Analysis – FS = 1.5

05_flood surcharge_total stresses_ds

Normal Pool with Flood Surcharge; Undrained, Static Strengths;
Incipient Motion: Downstream Direction

			Drained Strength Parameters		**Undrained Strength Parameters**	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Undrained)	125	29	0	15	500
🟦	Fine-Grained (Undrained)	138	34	0	32	400
🟩	Coarse-Grained (Undrained)	127	34	0	32	400
🟨	Fractured Bedrock	-	Impenetrable		Impenetrable	
⬜	Bedrock	-	Impenetrable		Impenetrable	

At a given effective stress, the lesser of the drained and undrained strengths is used.



Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

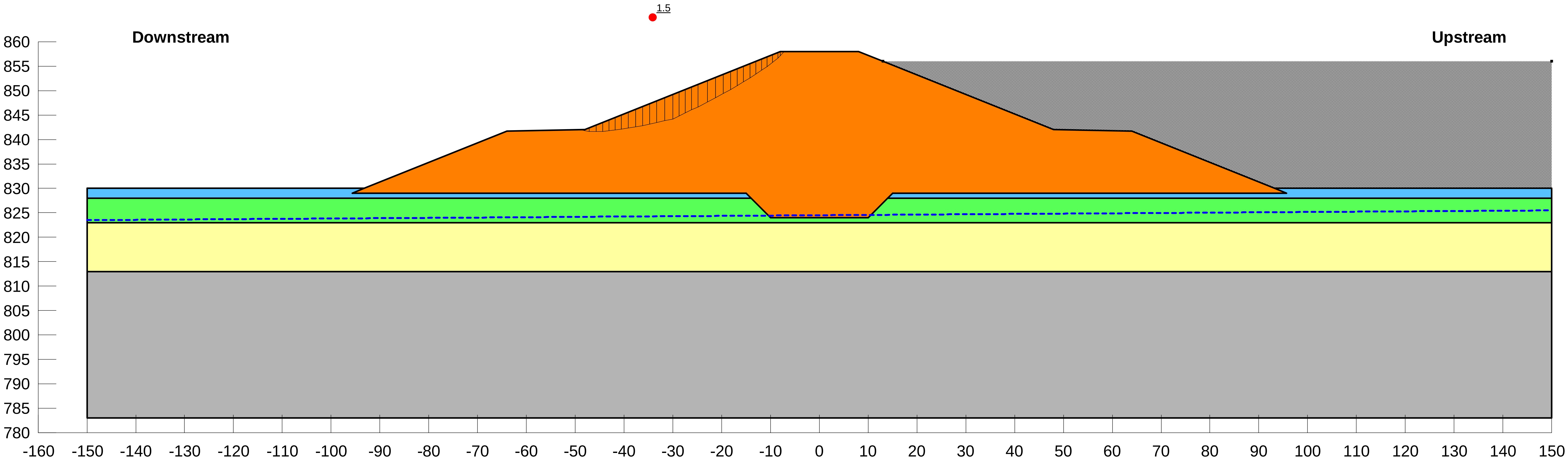
Blanchard River Dam - Taller Section

Slope Stability Analysis – FS = 1.5

06_flood surcharge_effective stresses_ds
Normal Pool with Flood Surcharge; Drained, Static Strengths;
Incipient Motion: Downstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

	Material	Unit Weight (pcf)	**Drained Strength Parameters**	
			Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Drained)	125	29	0
🟦	Fine-Grained (Drained)	138	34	0
🟩	Coarse-Grained (Drained)	127	34	0
🟨	Fractured Bedrock	-	Impenetrable	
⬜	Bedrock	-	Impenetrable	



Project No. 174316204

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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

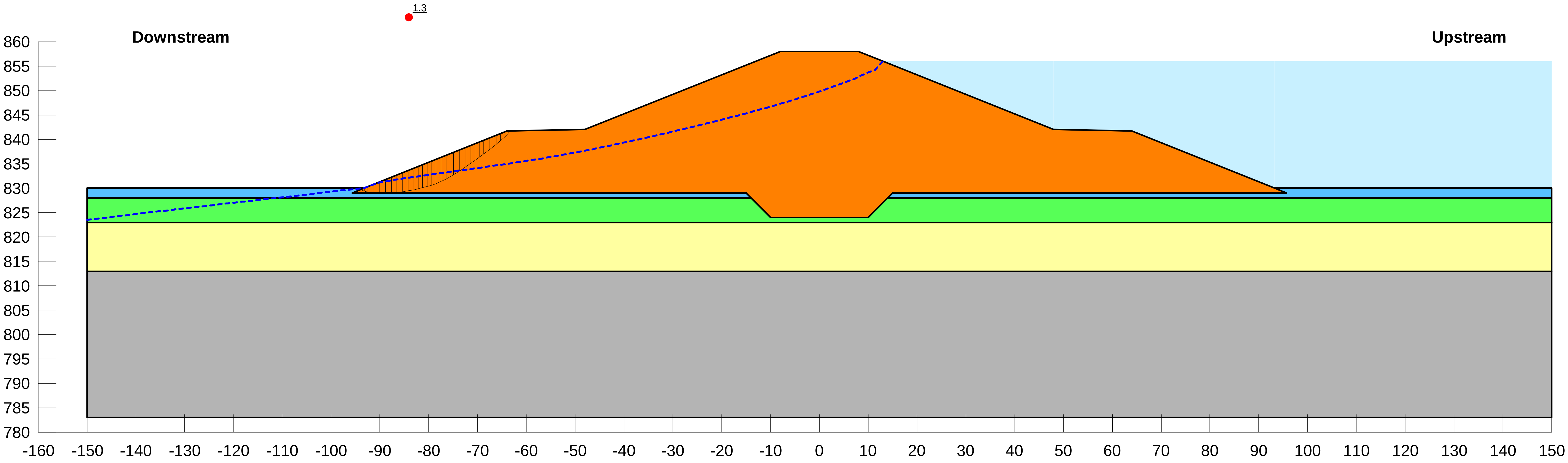
Blanchard River Dam - Taller Section

Slope Stability Analysis – FS = 1.3

07_flood_effective stresses_ds
Flood Pool; Drained, Static Strengths;
Incipient Motion: Downstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

			Drained Strength Parameters	
	Material	Unit Weight (pcf)	Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (Drained)	125	29	0
🟦	Fine-Grained (Drained)	138	34	0
🟩	Coarse-Grained (Drained)	127	34	0
🟨	Fractured Bedrock	-	Impenetrable	
⬜	Bedrock	-	Impenetrable	



Project No. 174316204

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Hancock County Flood Risk Reduction Program

Preliminary Dam Analysis

Blanchard River Dam - Taller Section

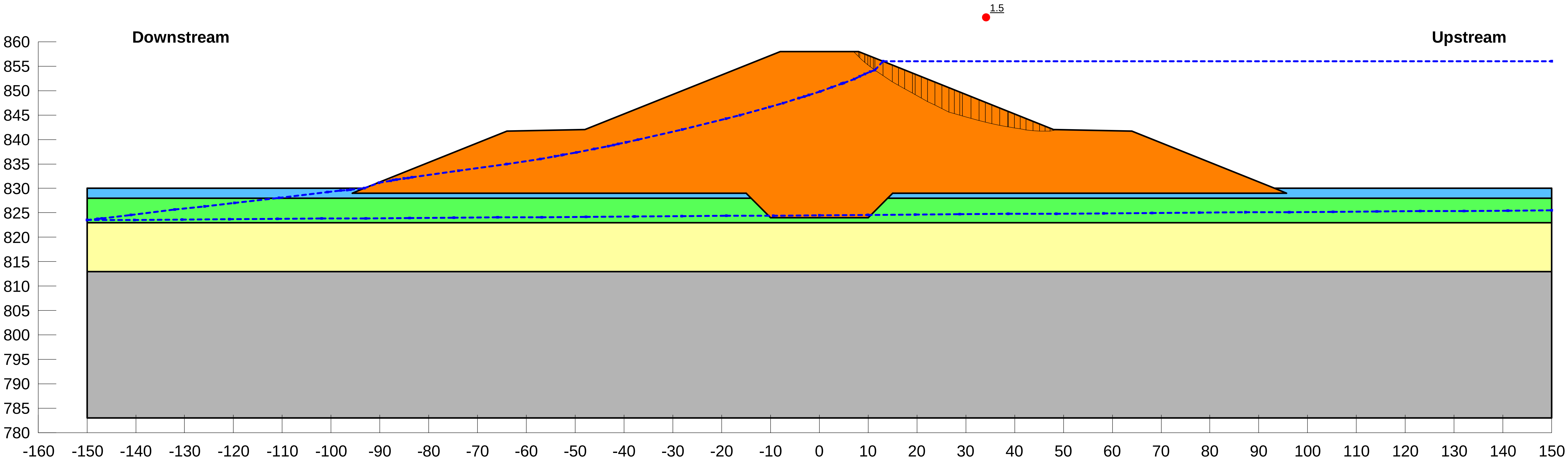
Slope Stability Analysis – FS = 1.5

08_rapid drawdown_us
Flood to Normal Pool SDD; Undrained, SDD Strengths;
Incipient motion: Upstream Direction

Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.

	Material	Unit Weight (pcf)	**Drained Strength Parameters** Phi (deg.)	Cohesion (psf)	**Isotropically Consolidated, Undrained Strength Parameters** Phi (deg.)	Cohesion (psf)
🟧	Embankment Fill (SDD)	125	29	0	15	500
🟦	Fine-Grained (SDD)	138	34	0	32	400
🟩	Coarse-Grained (SDD)	127	34	0	32	400
🟨	Fractured Bedrock	-	Impenetrable		Impenetrable	
⬜	Bedrock	-	Impenetrable		Impenetrable	

At a given effective stress, the lesser of the drained and undrained strengths is used.



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Appendix C – PRELIMINARY ENVIRONMENTAL REVIEW

Hancock County Flood Risk Reduction Program –

Preliminary Environmental Review

June 1, 2018

Prepared for:
Maumee Watershed Conservancy District
1464 Pinehurst Dr.
Defiance, OH 43512

Prepared by:
Stantec Consulting Services Inc.

Revision	Description	Author		Quality Check		Independent Review	
0	DRAFT	RFB	4/8/18	CF	4/19/18	DTH	5/26/18

Sign-off Sheet

This document entitled **Preliminary Environmental Review** was prepared by Stantec Consulting Services Inc. (“Stantec”) for the account of Maumee Watershed Conservancy District (the “Client”). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec’s professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Rick Bolliger

Prepared by ____

(signature)

Cody Fleece

Reviewed by ____

(signature)

David Hayson

Approved by ____

(signature)

Table of Contents

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1.0 INTRODUCTION

Hancock County and the City of Findlay, Ohio experience frequent and significant overbank flooding from the Blanchard River and its major tributaries, Eagle Creek and Lye Creek. The U.S. Army Corps of Engineers, Buffalo District (USACE) proposed a 9.2-mile flood diversion channel to alleviate flooding in downtown Findlay, which the USACE advanced through the preliminary planning stages from 2007 to 2016. In 2016, the Hancock County Commissioners and City of Findlay, in cooperation with the Maumee Watershed Conservancy District (MWCD), took over the project. Stantec Consulting Services Inc. (Stantec) was asked to complete a Gap Analysis (Phase I) as an initial review and assessment of the prior efforts completed by the USACE. Stantec's review resulted in recommending a flood risk reduction program that differs from the original USACE design. The recommended designs are independent projects that consist of channel improvements to the Blanchard River in the City of Findlay and three dry storage basins with low-flow bypasses located upstream of the City of Findlay on the Blanchard River, Eagle Creek, and Potato Run. This report provides supplemental analysis of the potential environmental and regulatory impacts of the recommended program.

1.1 OBJECTIVES

The objective of this report is to provide a high level supplemental environmental review of the flood risk reduction program recommended by Stantec. Descriptions of existing environmental conditions in the watershed, in addition to limited site-specific data in the vicinity of the proposed project features, are used as the basis for identifying potential impacts to environmental resources. The potential impacts are then broadly compared to environmental regulations and potential mitigation measures are identified that may apply to the proposed projects.

2.0 PROJECT DESCRIPTION

2.1 PROGRAM HISTORY

USACE proposed a 9.2-mile flood diversion channel to be constructed to the south and west of the City of Findlay to alleviate flooding. The diversion channel was proposed to convey flood flows from Eagle Creek and discharge them back into the Blanchard River downstream of Township Road 130, approximately 2.5 miles west of the City of Findlay. The USACE project advanced through the planning stages, including preparation of a Draft Detailed Project Report / Environmental Impact Statement (USACE 2015) and an unpublished Draft "Final EIS" dated March 2016. The most recent cost estimate for the project proposed by the USACE was approximately $81 million for the 25-year conveyance option.

In 2016, the project changed from one led by the USACE to a community-driven project locally-led by the Hancock County Commissioners and the City of Findlay, in cooperation with the MWCD. Stantec was asked to complete a Gap Analysis (Phase I) as an initial review and assessment of the prior efforts completed by the USACE. The Gap Analysis shifted Stantec's work from advancing the USACE diversion channel design to a more comprehensive risk-based review and exploring conceptual alternatives. Stantec's reviews and analyses are detailed in a "Proof of

Concept" report from April 2017 (Stantec 2017). That report is being revised to incorporate additional data and analyses. The revised "Proof of Concept Update" Report is anticipated to be completed in June 2018.

2.2 DESCRIPTION OF CURRENTLY PROPOSED PROJECTS

Stantec's recommendation to MWCD in the April 2017 report was to advance with a flood risk reduction program consisting of channel improvements within the City of Findlay and dry storage basins at various locations in the watershed. The locations of the proposed improvements are shown on Attachment A-1.

2.2.1 Channel Improvements

The improvements include removal of four low head dams or riffle structures on the Blanchard River in the City of Findlay, widening the floodplain bench between the Norfolk-Southern railroad bridge and Broad Avenue, and modifying the Norfolk Southern railroad bridge downstream of Cory Street (Figure 1). These improvements can be made independently of the storage alternatives.

Figure 1. *Proposed Locations of Channel and Floodplain Improvements in the City of Findlay*

2.2.2 Dry Storage Basins on Eagle Creek, Blanchard River, and Potato Run

Each dry storage basin would consist of an elongated embankment (Figure 2) penetrated by a culvert to allow for continuous stream flow. During large storm events, the culvert would restrict flow and the embankments would temporarily hold back water. The embankments would be designed to retain up to the 1% Annual Chance Exceedance (ACE) event, temporarily storing water within the reservoir footprint before draining within a few days.

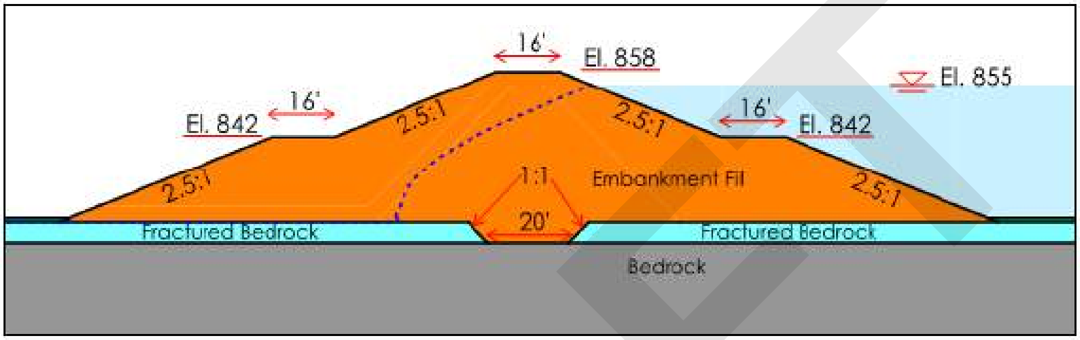


Figure 2. *Potential Embankment Cross Section*

Eagle Creek. Reductions in flow on Eagle Creek during large storm events would directly correlate to reduced flooding along Eagle Creek and along the Blanchard River through Findlay. The proposed Eagle Creek reservoir would intercept about 51 square miles of Eagle Creek's headwaters. The project is expected to reduce peak flows during the 1% ACE event from about 4,900 cubic feet per second (cfs) to about 625 cfs.

Blanchard River and Potato Run. Two storage basins are proposed upstream of Mt. Blanchard. Providing storage at these locations reduces the secondary peak of the flood wave that occurs in Findlay due to singular storms and also reduces the risk of out-of-bank flooding along the reach of the Blanchard River between Mt. Blanchard and Findlay. Reducing the risk of flooding along that reach has the ancillary benefits of reducing flood frequency to agricultural areas and reducing flood potential along Lye Creek due to potential overflow between the Blanchard River and Lye Creek during large flood events. The proposed Blanchard River Reservoir has a contributing drainage area of 109 square miles of Blanchard River headwaters and would reduce peak flow from about 7,500 cfs to about 6,000 cfs. The proposed Potato Run Reservoir has a contributing drainage area of 25 square miles and would reduce peak flow from 2,600 cfs to 750 cfs.

The preliminary opinion of probable costs developed for dry storage basins on Eagle Creek, the Blanchard River, and Potato Run is approximately $138 million. Including the Blanchard River channel modifications in Findlay results in a total preliminary opinion of probable cost of approximately $155 million. The hydraulic improvements contain a contingency of 10%. The other preliminary opinions of probable cost include a 25% contingency factor. The contingency covers potential administrative and legal fees and obstacles that may arise during the detailed design and construction phases, such as minor utility relocations or site drainage.

3.0 SUPPLEMENTAL REVIEW

3.1 EXISTING CONDITIONS

The following descriptions of existing conditions rely primarily on descriptions provided in the 2015 Draft EIS (USACE 2015), except as otherwise noted. Descriptions of the Blanchard River watershed and Hancock County are included either verbatim or summarized from the Draft EIS. Supplemental information is provided for the project area for selected environmental resources.

3.1.1 Land Use

Using 2011 National Land Cover Database (NLCD) Data, land use in the Blanchard River Watershed is predominantly agricultural (81.4% cultivated crops or hay/pastures), followed by developed open space (6.4%), forest (5.5%), and low intensity development (2.8%). Median and high intensity development together account for 1.4% of the watershed land use.

According to the NLCD, there was an increase in developed impervious surfaces in the City of Findlay between 2006 and 2011. Increases in impervious surfaces can lead to lower water quality, higher nutrient loads, and increased stormwater runoff. During the same period, there were no notable changes outside of Findlay and land uses largely remained unchanged.

Soybeans and corn make up the majority of agricultural products grown within the watershed, which comprise approximately 40 percent and 30 percent of agricultural activities, respectively. Other major agricultural activities include grass/pasture lands (6%), winter wheat (5%), and alfalfa (1%).

For this analysis, land use within the project footprint was not quantified. Reviewing recent aerial photographs of the three reservoir footprints clearly shows a predominance of agricultural land use at the project site, with corridors of forested lands along the stream alignments. The proposed floodplain widening improvements in the City of Findlay downstream of the Norfolk-Southern railroad bridge would primarily take place in existing open space areas adjacent to parkland, industrial, and single-family home residential land uses.

3.1.2 Geology and Soils

Northern Ohio, which includes Hancock County, has been significantly impacted by North American continental glaciation occurring mostly during the formation of the Great Lakes and adjacent Lake Erie. The study area was once covered by the Laurentide Ice Sheet (LIS), which was up to 10,000 feet thick, and it fully receded by about 8,000 years before present.

Morainal deposition processes have significantly impacted the geomorphology of the region. The Blanchard River Watershed is bounded on the north by the Defiance Terminal Moraine and on the south by portions of the Fort Wayne Terminal Moraine. The depth to bedrock below the ground surface is generally very shallow (10-60 feet). The Blanchard River watershed is characterized by alluvial flatlands prone to flooding that contribute to repeated flood damages.

Three natural karst features (sinkholes) are documented in the watershed in Crawford Township, Wyandot County. Dolomite and calcareous dolomite underlying the watershed can be prone to the formation of karst features. Areas where glacial drift is less than 20 feet thick will be more susceptible to the formation of solution features than are areas having thicker drift. Large areas containing thin drift are present in central Hancock County, southern Putnam County, and northeastern Allen County. Although no karst has been documented in these areas, they represent sites that likely exhibit buried karst features.

The soils of the Blanchard River Watershed were formed from many sources including glacial till, lacustrine and beach deposits, recent alluvium, material weathered from bedrock, and organic material. Key landforms include the river flood plains with alluvium, adjacent terraces, ground moraines, wave-planed ground moraines, ridge or terminal moraines, remnant beach ridges, and lake beds. The soils are heterogeneous relative to grain size ranging from clay to cobble and boulder size, typical of glacial deposits. Soil thicknesses, or conversely bedrock depths, range from less than 10 feet to 60 feet.

Glacial soils cover the watershed and consist of clay and silt, with lesser amounts of sand and gravel. Moraine deposits cover most of the area and have a characteristically flat to gently undulating topography. Lakes once existed east of Findlay, and east and west of Dunkirk which resulted in the deposition of clay-rich material at the surface. Clays in the area are generally medium to very stiff deposits, with low to moderate compressibility. Recent alluvial deposits are anticipated to be localized near the rivers and major streams and to consist of loose to medium dense sands and gravels.

Using Geographic Information System (GIS) datasets of soils mapped by the Natural Resources Conservation Service (NRCS), hydric soils and prime farmland soils within the footprints of the three proposed dry reservoirs were calculated (Tables 3-1 and 3-2). Hydric soils form under conditions of saturation, flooding, or ponding during the growing season that develop anaerobic conditions within the upper part of the soil column. These hydric soils can indicate conditions favorable for former or current wetland development. Hydric soils types can be dominated by hydric components or have minor hydric components. The majority of soils within the reservoir footprints have minor hydric inclusions or are primarily hydric.

Prime farmland is a designation assigned by the U.S. Department of Agriculture to indicate soils that have the best characteristics for agricultural production. These high-quality farmlands are protected from conversion to non-agricultural uses. The majority of the soils within the reservoir footprints are prime farmland or prime farmland if drained.

Table 3-1 Hydric Soil Summary

Hydric Soil Type	Blanchard Reservoir	Potato Run Reservoir	Eagle Creek Reservoir
Hydric	13.3%	51.0%	25.7%
Minor Hydric Inclusions	78.5%	44.4%	73.5%
Not Hydric	8.2%	4.5%	0.9%

Table 3-2 Prime Farmland Soil Summary

Prime Farmland Soil Type	Blanchard Reservoir	Potato Run Reservoir	Eagle Creek Reservoir
Prime Farmland	53.9%	36.7%	26.9%
Prime Farmland if Drained	29.9%	54.5%	72.2%
Prime Farmland if Protected from Flood	5.9%	1.8%	0.1%
Not Prime	10.3%	6.9%	0.9%

3.1.3 Groundwater

The project area in Findlay is underlain by a regional carbonate bedrock aquifer, which is commonly found underlying glacial till. In addition to glacial till, overlying soils consisting of glacial lake deposits and recent alluvium are widespread. This carbonate bedrock aquifer serves as a primary source of groundwater for much of the area's rural population. Domestic wells in the bedrock aquifer are usually developed at depths of less than 150 feet.

3.1.4 Streams

The Blanchard River originates in central Hardin County, approximately five miles northwest of Kenton, Ohio. It flows in a northerly direction for the first 25 miles into eastern Hancock County, where it turns sharply to the west and flows through the City of Findlay. The 771 square mile Blanchard River Watershed drains into the Auglaize River near the village of Dupont in Putnam County. The Blanchard River Watershed is delineated by the United States Geological Survey (USGS) as 8-digit hydrologic unit code (HUC) 04100008. Six sub-basins comprise the watershed and contain waters that are designated by the State of Ohio as Warmwater Habitats (WWH) and Modified Warmwater Habitats with modified channels (MWH-C).

Portions of the six sub-basins are listed on the Clean Water Act Section 303(d) list of impaired waters. These waters are considered too polluted or otherwise degraded to meet applicable Ohio's water quality standards, set forth in Chapter 3745-1 of the Ohio Administrative Code. The list of impairments includes: dissolved oxygen; flow alterations; habitat alterations, nitrite/nitrate, nutrients; organic enrichment (sewage) biological indicators; PCB(s) in fish tissue, pathogens; total phosphorus; temperature; and total ammonia. A TMDL report was issued by the United States Environmental Protection Agency (USEPA) for the Blanchard River watershed in 2009 – refer to the Water Quality section of this report for more details.

Focusing more specifically on the project area, Table 3-3 summarizes the National Hydrography Dataset (NHD) stream lengths that are within the footprints of the reservoirs. Additional characterization of the stream channel morphology, substrates, in-stream habitat, riparian habitat, tree cover, and flows was not provided in the Draft EIS. Habitat evaluations from the 2007 Blanchard River Basin Biological and Water Quality Study (OEPA 2007) should be analyzed for the impacted areas and supplemented with current characterizations of streams within the project areas as the project progresses, including Qualitative or Headwaters Habitat Evaluation Index (QHEI/HHEI) characterization.

Table 3-3 NHD Stream Summary

Proposed Reservoir	NHD Flowline Length within the Reservoir Footprint(ft)	NHD Flowline Length within the Embankment Footprint (ft)*
Blanchard	47,820	199
Potato Run	39,981	219
Eagle Creek	19,514	188

*This includes the NHD flowline length within the embankment footprint plus a 100-foot buffer

3.1.5 Floodplains

The City of Findlay and Hancock County are impacted by flows from the Blanchard River, Eagle Creek and Lye Creek. While flooding can be isolated to the listed river and creeks, flooding in the watershed is typically due to overbank flow and is experienced on an almost annual basis within the watershed. Frequent flooding by overland flow damages commercial and residential structures as well as agricultural lands. Due the area's flat terrain, the low areas along both sides of the Blanchard River both upstream and downstream of the City of Findlay are the first areas to be impacted by flooding. The rise and fall of the crests on the Blanchard River generally last for about two or three days, can last longer during severe flood events, and typically occurs within one to two days after a major rain event.

The City of Findlay and Hancock County participate in the National Flood Insurance Program (NFIP) which is administered by the Federal Emergency Management Agency (FEMA). The City of Findlay's initial acceptance date into participation in the NFIP was on January 23, 1974 and Hancock County began participation on December 30, 1977. As part of the Map Modernization Program, FEMA migrated to a county-wide map production process and the maps for Hancock County, including the City of Findlay, were updated in 2011. The floodplains for the Blanchard River, and Lye and Eagle Creeks were updated as part of the FEMA Map Modernization process.

Areas currently mapped as 1% ACE floodplain respectively comprise 39%, 45%, and 48% of the proposed Eagle Creek, Blanchard, and Potato Run reservoir footprints. Construction of the proposed projects would intentionally modify the mapped floodplain. Future studies should include detailed analyses of structures within the existing and proposed modified floodplains.

3.1.6 Wetlands

A large portion of the Blanchard River Watershed lies within the historic range of the Great Black Swamp. Originally 100 miles long and 20 to 30 miles wide, the swamp was located within the Maumee River Watershed. By the early 1900s virtually the entire Great Black Swamp was drained and converted to agriculture. This change in the landscape and land use is a major contributor to the water quality and flooding issues in the watershed today.

Wetlands were delineated in accordance with the USACE Wetland Delineation Manual and applicable Regional Supplement along the proposed USACE diversion channel route, which includes a portion of the Eagle Creek Reservoir. Wetlands have not yet been delineated throughout the remainder of the project areas. In order to estimate existing wetland acreage, National Wetland Inventory (NWI) and Ohio Wetland Inventory (OWI) GIS data, which estimate the presence of wetlands, were summarized for each reservoir footprint (Table 3-4 and Attachments A-2 and A-3). To avoid double counting wetlands between the two datasets, a layer was created in ArcGIS which reclassified any overlapping areas as NWI wetlands and erased these areas from the OWI area. In addition, the OWI has a category for "woods on hydric soil". In areas dominated by agricultural land use, remnant woods, especially those that overlap with mapped hydric soils, are likely to be wet and for this analysis are considered to be forested wetlands.

Wetlands are predominantly riverine in the Potato Run reservoir, and riverine or forested in the Eagle Creek reservoir. In the Blanchard reservoir area, forested wetlands are most abundant, followed by riverine wetlands.

Table 3-4 NWI and OWI Wetland Summary

Wetland Type	**Wetland Area (ac) within Reservoir and Dam Footprint**		
	Blanchard	**Potato Run**	**Eagle Creek**
NWI Emergent	5.49	1.50	0.31
NWI Forested/Scrub Shrub	21.49	-	1.09
NWI Pond	0.75	0.22	3.93
NWI Riverine	29.82	22.00	20.41
OWI (only) Woods on Hydric Soil (forested)	16.64	3.69	20.88
OWI (only) Open Water	0.66	-	1.03
OWI (only) Farmed Wetlands	-	0.20	1.64
OWI (only) Shallow Marsh	-	-	0.80
Total Acreage	**74.85**	**27.61**	**50.09**
Reservoir Acreage	732.32	569.20	822.10
% of Reservoir Footprint	**10.2%**	**4.9%**	**6.1%**

When wetlands are delineated at the site, Ohio Rapid Assessment Method (ORAM) should be used to characterize and assign a qualitative value for each wetland. Category 1 wetlands are low quality, Category 2 wetlands are medium quality and Category 3 wetlands are high quality. Due to the functions and values that Category 3 wetlands possess, permit requirements for impacts to Category 3 systems are quite rigorous and public need must be demonstrated.

3.1.7 Vegetation

The Blanchard River Watershed lies within the Eastern Corn Belt Plains and Huron/Erie Lake Plains Ecoregions. The Eastern Corn Belt Plains are primarily composed of rolling till plain with local end moraines. The Huron/Erie Lake Plain is a broad, fertile, relatively flat plain with soil drainage that was generally poorer than in the adjacent Eastern Corn Belt Plains. Elm-ash swamp and beech forests were dominant in this subecoregion. Today, most of the area has been cleared and artificially drained and contains highly productive farms producing corn, soybeans, livestock, and vegetables; urban and industrial areas are also present. Woodlands, wetlands and grasslands are limited to approximately 10 percent of total land cover within the watershed. The remaining forested areas in the watershed are primarily scattered woodlots that range from five to more than 50 acres in size, with the average size being approximately 20 acres. Predominant tree species include oaks (red, white, bur, swamp white, and chinkapin), green and white ash, maples (red, sugar, silver, and boxelder), basswood, elm, black walnut, honeylocust, hackberry and other hardwoods. Aside from the woodlots, many of the forested areas are found along streams in the watershed at locations that were not as easily developed as the upland areas. Most of the forested areas in the Blanchard River Watershed are privately owned, with the small percentage of publicly owned forests belonging primarily to the counties and their respective park districts. There are no state or federally owned forest lands in the watershed.

3.1.8 Wildlife

Wildlife habitat in the Blanchard River watershed is heavily influenced by the predominance of land devoted to row crops and original native vegetation that, for the most part, has been removed. Most of the agricultural land provides marginal habitat for common edge- or disturbance-adapted species. In addition, winter cover and food for resident species is severely limited.

Wildlife species that are expected to occur within the project area based on the habitat available include rabbits, raccoons, white-tailed deer, squirrels, and various grassland birds. A relatively low diversity of songbirds (e.g., warblers and vireos) as well as some smaller mammals (e.g., voles and mice) are expected to occur within the remnant forested patches that occur within the project area. Some of the more common amphibians and reptiles expected to occur within the riparian areas of the project area include American toads, western chorus frogs, green frogs, bull frogs, garter snakes, and painted turtles. Twenty-nine species of freshwater mussels are known to occur in the Blanchard River and Eagle Creek.

3.1.9 Threatened and Endangered Species

According to the United States Fish and Wildlife Service (USFWS), there are four Federally listed and candidate species within Hancock County, including Indiana bat (*Myotis sodalis*), northern long-eared bat (*Myotis septentrionalis*), rayed bean (*Villosa fabalis*), and clubshell (*Pleurobema clava*). While the bald eagle (*Haliaeetus leucocephalus*) is no longer a Federally-listed species, it is afforded protection under both the Bald & Golden Eagle Protection Act and the Migratory Bird Treaty Act and may also be present in Hancock County.

State-listed species in Hancock County include seven endangered, three threatened, and 18 species of concern. The endangered (E) and threatened (T) species are listed below.

- Blue-spotted salamander (*Ambystoma laterale,* E)
- Western banded killifish (*Fundulus diaphanous menona,* E)
- Plains clubtail (G*omphus externus,* E)
- Clubshell (E)
- Purple Lilliput (*Toxolasma lividus,* E)
- Rayed bean (E)
- Indiana bat (T)
- Black sandshell (*Ligumia recta,* T)
- Pondhorn (*Unimoerus tetralasmus,* T)
- Kirtland’s snake (*Clonophis kirtlandii,* T)

Geospatial data provided from the Ohio Natural Heritage Database regarding locations of federally listed and state-listed species along the Blanchard River and vicinity are shown in Attachment A-4. Two of the sampling points were located within the Blanchard Reservoir, but listed species were not identified at those points. There are, however, rayed bean and other state-listed species identified at the Blanchard River at locations upstream and downstream of the Blanchard Reservoir. In addition, there are "various state listed species" identified at locations in the Blanchard River near the proposed channel improvements in the City of Findlay. There were no sampling sites nor listed species identified in the proposed Eagle Creek Reservoir or the proposed Potato Run Reservoir.

3.1.10 Air Quality

In accordance with Clean Air Act (CAA) requirements, air quality in a given region is measured by the concentration of criteria pollutants in the atmosphere. The air quality in a region is a result of not only the types and quantities of atmospheric pollutants and pollutant sources but also surface topography, the size of the topographical "air basin," and the prevailing meteorological conditions.

Under the CAA, the USEPA has developed numerical concentration-based standards, or National Ambient Air Quality Standards (NAAQS), for pollutants that have been determined to affect human health and the environment. NAAQS represent the maximum allowable concentrations for ozone (O_3) that is measured as either volatile organic compounds (VOCs) or total nitrogen oxides (NO_x), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur oxides (SO_2), respirable particulate matter (including particulate matter equal or less than 10 microns in diameter [PM_{10}] and particulate matter equal to or less than 2.5 microns in diameter [$PM_{2.5}$], and lead (Pb) (40 CFR Part 50). CAA also gives the authority to states to establish air quality rules and regulations. The State of Ohio has adopted the NAAQS and promulgated additional State Ambient Air Quality Standards (SAAQS) for criteria pollutants. Areas that do not meet NAAQS are designated as being in "nonattainment" for that criteria pollutant. Based on NAAQS or SAAQS, Hancock County is designated as an attainment area for all criteria pollutants.

3.1.11 Water Quality

This section includes an overview of existing water quality issues in the Blanchard River Watershed. The information presented in this section is based upon text from the Biological and Water Quality Study of the Blanchard River (OEPA, 2007) and the Total Maximum Daily Load (TMDL) for the Blanchard River Watershed (OEPA, 2009).

Data collected at 115 locations within the Blanchard River Watershed in 2005 were evaluated by OEPA (OEPA 2007). Assessments of aquatic life use attainment were completed for 84 of the sampling sites, including some locations within or adjacent to the proposed reservoirs and channel improvements. Downstream from the City of Findlay, the Blanchard River channel was consistently evaluated to have a full attainment status for aquatic life use. Of the five Blanchard River sampling sites within the City of Findlay, four have partial attainment and one has non-attainment status. However, sampling sites in the Blanchard River channel from the headwaters to the City of Findlay, in addition to contributing tributaries, resulted in a mix of full, partial, and non-attainment designations.

- Near the proposed channel improvements in the City of Findlay, two sampling sites were non-attainment and one was partial attainment. Causes for impairments included thermal modification, organic enrichment/DO, direct habitat alteration, siltation, and nutrients. Sources of these causes were identified as dam construction, urban runoff, combined sewer overflows, and channelization.

- Of the four sampling sites located within the Blanchard Reservoir footprint, the one Blanchard River site was classified as being in partial attainment and the three tributary sites were non-attainment. Causes for impairments included organic enrichment/DO, ammonia, nutrients, direct habitat alteration, and temperature. Sources of these causes were identified as agriculture-related channelization, crop production, and minor municipal waste water sources.

- Two sampling sites in Potato Run, including one within the reservoir footprint, were both non-attainment. Causes for impairments included direct habitat alteration, temperature, nutrients, and organic enrichment/DO. Sources of these causes were identified as agriculture-related channelization and crop production.

- Six sampling sites were located in Eagle Creek, including two downstream and four upstream of the reservoir footprint. Three sites were partial attainment, two were non-attainment, and one was full attainment. Causes for impairments included flow alteration, nutrients, and ammonia. Sources of these causes were identified as crop production and minor municipal point source.

Although numerous causes of water quality impairment in the Blanchard River watershed were identified in the OEPA study (OEPA, 2007), the most prevalent causes of impairment included nutrient enrichment (including phosphorus and nitrates/nitrites), organic enrichment, flow alteration, habitat alteration, siltation, presence of excessive pathogens, and low dissolved oxygen. In addition to the combined sewer overflows (CSOs) and septic systems described below, sources of these impairments have been found to include stream channelization, runoff associated with livestock production, and crop production with subsurface drainage. A number of cities and municipalities throughout the Blanchard River Watershed have combined sewer systems (CSSs). These systems carry both storm water and wastewater in a single pipe to a treatment facility, and when flows exceed the treatment plant's capacity, a bypass is activated and combined sewer flows are routed to receiving surface waters. Wastes in CSSs are untreated and, consequently, discharges from CSOs can contain a variety of pollutants such as pathogens, suspended solids, nutrients, toxics, and floatable solids. The Blanchard River Watershed currently has 36 known CSOs in five communities, ranging from small rural villages to large metropolitan areas (Bluffton-2; Findlay-18; Dunkirk-6; Forest-3; and Pandora-7).

In addition, the 2009 TMDL report summarizes impairments with sub-watersheds that correspond with project features:

- The Blanchard and Potato Run reservoirs are located within the sub-watershed HUC 04100008-010, Blanchard River headwaters. This subwatershed was identified in the TMDL report to be impaired by pathogens and bacteria from unsewered villages and CSOs, nutrients and organic enrichment from wastewater and non-point sources, and habitat alteration from channelization and removal of stream-side vegetation. This water is used as a drinking water source for the City of Findlay, and upstream waters contribute excess nutrients, pesticides, and microorganisms.

- The Eagle Creek Reservoir is located within subwatershed HUC 04100008-030, Eagle Creek. This subwatershed was identified in the TMDL report to be impaired by pathogens and bacteria from inadequately treated wastewater and unsewered areas and nutrients from wastewater. Additional impairments including habitat and flow alterations and sediment/siltation focus on areas in the subwatershed downstream of the proposed reservoir.

- The Blanchard River in the City of Findlay is impaired for organic enrichment, dissolved oxygen, nutrients, thermal modification, and habitat alteration. The report suggests that removal of the low-head dam near Osborn Avenue and subsequent reforestation of the basin would alleviate some water temperature and dissolved oxygen issues. In addition, the TMDL recommends that the City of Findlay continue to abate CSO impacts on phosphorus loading.

3.1.12 Noise

The Noise Control Act of 1972 (P.L. 92-574) directs Federal agencies to comply with applicable Federal, state, interstate, and local noise control regulations. In 1974, USEPA provided information suggesting that continuous and long-term noise levels in excess of day-night sound level 65 A-weighted decibels (dBA) are normally unacceptable for noise-sensitive land uses such as residences, schools, churches, and hospitals. Ohio has no statewide noise regulations; however, Section 505.172 of the Ohio Revised Code (ORC) states that townships may adopt noise control regulations within their unincorporated territory.

Ambient noise levels within the study area are influenced by land uses that include industrial, commercial, residential, and agricultural areas. Noise sources include primarily vehicular traffic, which includes agricultural equipment and large transport vehicles that travel along county and township roads. Significant noise sources within the area include Interstate 75 and the Norfolk Southern Railway line.

Existing and proposed noise conditions and sources should be considered in more detail during subsequent environmental reviews.

3.1.13 Cultural Resources

Several Indian Nations were identified that have interest in the general Western Lake Erie Basin area, but none currently have established land interests in the area. Table 3-5 lists federally recognized Indian Nations with an historic presence and/or prospective interest in the Western Lake Erie Basin. The Wyandotte Nation is the only Indian Nation so far to formally request status as a consulting party.

Table 3-5 Federally Recognized American Indian Nations with Interest in the Western Lake Erie Basin

Nation	Tribal Name
Miami	Miami Tribe of Oklahoma
Ottawa	1. Little River Band of Ottawa Indians, Michigan 2. Little Traverse Bay Bands of Odawa Indians, Michigan 3. Ottawa Tribe of Oklahoma
Shawnee	1. Absentee-Shawnee Tribe of Indians of Oklahoma 2. Eastern Shawnee Tribe of Oklahoma 3. Shawnee Tribe, Oklahoma
Wyandotte	Wyandotte Nation, Oklahoma

For cultural resources considerations during a federal undertaking, the Area of Potential Effects (APE) is the geographic area within which an undertaking may directly or indirectly cause alterations in the character or use of historic properties (e.g., National Register of Historic Places eligible or listed archaeological sites, standing structures). Depending on the nature of the various project components and the resources that may be affected, the APE may be different for the different kinds of effects caused by the project.

Prior to initiating cultural resources surveys (archaeological and architectural) on any portion of the study, an APE will be designated. The APE should consider the direct area of impact for ground-disturbing activities during construction as well as staging areas for heavy equipment and possible areas for flood storage/wetland and stream mitigation.

A review of SHPO records was performed using online GIS data in March 2018 by an archaeological subcontractor, Mannik Smith Group, with a two-mile buffer around the Aurand Run/Eagle Creek areas of concern (AOCs) and another 2-mile buffer around the Blanchard River/Potato Run AOCs. Preliminary results from that query follow, however, a memorandum summarizing the finding has not yet been provided.

- There are no previously recorded cultural resources of any kind within the Aurand Run AOC, although there are several archaeological sites and one National Register-listed farmstead close by.
- There are 20 previously recorded archaeological sites within the Eagle Creek AOC. There are also additional archaeological sites and historic cemeteries close by this AOC.
- There are 27 previously recorded archaeological sites, 1 historic cemetery, and 3 properties listed in the Ohio Historic Inventory within the Blanchard River AOC. All of the archaeological sites were recorded during a single survey for a road realignment and bridge replacement on Township Road 187.
- There are no previously recorded archaeological sites within the Potato Run AOC. However, there is one historic cemetery within this AOC.
- Notably, surveys conducted in the 1990s for the new U.S. Route 30 corridor (about a mile to the south of the project AOCs) recorded dozens of archaeological sites.

3.1.14 Utilities and Infrastructure

Locations of existing utilities and infrastructure including pipelines, oil and gas wells, aqueducts, water wells, and fiber optic lines were briefly reviewed for this analysis but should be reviewed in detail in subsequent analyses. Based on information from the National Pipeline Mapping System (https://pvnpms.phmsa.dot.gov/PublicViewer/), there are no major pipelines in the immediate vicinity of the three proposed reservoirs or the channel improvements in the City of Findlay. According to ODNR GIS data for water wells Hancock County, there are 12 mapped water wells, and five mapped oil/gas wells located within the three reservoir footprints. There are approximately 7,500 oil and gas wells within Hancock County that are mapped by the ODNR, however, most of these wells were under operation during the oil and gas boom of the late 1800s and are currently abandoned. The current activity status of each water and oil/gas well has not been determined. There are no aqueducts located in the immediate vicinity of the project features, but there is an aqueduct located near the Findlay Reservoir. Finally, the Draft EIS identified six underground fiber optic lines, which are located along Township Roads 50, 67, and 76 and County Roads 9 and 313. The western edge of the proposed Eagle Creek Reservoir follows Township Road 76, but no other potential conflicts with fiber optic lines were identified. Infrastructure and utilities such as power lines, phone lines, sewers, and agricultural drainage tiles were not reviewed.

3.1.15 Transportation

Major transportation routes within the project area include Interstate 75 (I-75), US 68, US 224, US 30, and State Route 15, which offer convenient links with several key cities including Cleveland, Cincinnati, Columbus, and Lima, Ohio, Detroit, Michigan and Fort Wayne, Indiana. The region's accessibility has significantly contributed to its economic growth. While the county is largely rural, it is also home to many businesses that export manufactured goods using these state routes and interstates. The proposed Eagle Creek Reservoir is located approximately a half mile south of State Route 15. The proposed Blanchard and Potato Run Reservoirs are located approximately 2.5 miles north of US 30. Channel improvements in the City of Findlay are located approximately three-fourths of a mile southeast of I-75.

Rail access is also critical to the local and regional economy. A network of key freight lines allows for easy movement of the study area's manufactured goods and agricultural products (most notably corn and soybeans). Two railroads cross in the City of Findlay: Norfolk Southern, oriented southwest-northeast and CSX Transportation, oriented north-south. The proposed channel improvements include modification of the Norfolk Southern bridge in downtown Findlay. The CSX Transportation rail passes approximately a half mile east of the proposed Eagle Creek Reservoir.

There is one regional airport and several privately-owned airports in the vicinity of the project. The Findlay Airport is located approximately 1.5 miles north-northwest of the proposed Eagle Creek Reservoir. Weaver Airport, Ferrell Airport, Lutz Airport, and Schaller Airport are privately owned airports with turf runways located within five miles of Findlay. The Ferrell Airport is closest to the project facilities, located approximately a half mile east of the proposed Eagle Creek Reservoir.

3.1.16 Aesthetics

Visual resources present in the Blanchard River Watershed vary greatly depending on location. The watershed ranges from high intensity urban development to agricultural areas. The landscape within Hancock County generally consists of flat agricultural areas that were originally part of the Great Black Swamp, which was drained for human use. Some of the water bodies present within the watershed possess a narrow riparian buffer, but the vast majority of the land is cropland with little to no tree cover. While most of the non-urbanized areas within the Blanchard River Watershed are agricultural, some scattered wooded parcels still persist in the area.

The proposed Blanchard and Potato Run Reservoirs are located at an elevation approximately 100 feet higher than the channel improvement area in the City of Findlay. The proposed Eagle Creek reservoir is located at an elevation approximately 60 feet higher than the channel improvement area. In general, the county is flat with gentle undulations from morainal deposition.

The National River Inventory (NRI) lists two stretches of the Blanchard River as having outstanding remarkable cultural, historic, and recreational values. The proposed Blanchard Reservoir is located along the NRI-designated 28-river-mile reach between the headwaters and Mount Blanchard. The channel improvement area in the City of Findlay is located along the NRI-designated 26-river-mile reach between Findlay and Ottawa. The NRI provides the following description of these reaches:

> *Very little visible development. Banks mostly wooded. A popular canoe stream. Many 19th century buildings along river being restored. Flows through gently rolling central Ohio farmland. Provided inspiration for composition of song "Down by the Old Mill Stream".*

3.1.17 Recreation

Outdoor recreation within the Blanchard River Watershed includes activities such as boating, hunting, fishing, hiking, and passive outdoor activities. Local parks and recreation areas offer opportunities for passive outdoor recreation and serve as venues for sports, festivals, family activities and various seasonal events, and many of these are notably tied directly to water features such as the Blanchard River. Townships maintain some natural areas for fishing and hunting.

Recreational boating is largely limited to small, non-motorized boats. Limited power boating opportunities exist on local reservoirs, with Hancock County Park on Findlay Reservoir operating the watershed's only marina. There are 18 boating access points along the Blanchard River. Boating opportunities on local waterways are often limited or dangerous due to existing low-head dams, log jams, and shallow water depths. Existing county programs provide for log jam removal to facilitate boating and to ensure a free-flowing condition on local streams and ditches. Reservoirs and watercourses provide recreational fishing opportunities. Hunting is limited to fence rows and woodlots, and along streams and ditches where only minimal habitat exists.

There is one state park in Hancock County, Van Buren State Park, located approximately six miles north of the City of Findlay. There are no state or federal parks or wildlife areas located within the near vicinity of the three reservoirs. The channel improvement work in the City of Findlay is located adjacent to Swale Park and across the river from Rawson Park, which are both City of Findlay parks.

The Hancock County Recreation Department has designated 37.6 river miles of the Blanchard River as a water trail and nature preserve. It is not clear what area the nature preserve encompasses or what protections are in place. The Hancock County Recreation Department also manages several conservation areas, including five along the Blanchard River within the vicinity of the Findlay Reservoir, just east of the City of Findlay.

3.1.18 Hazardous Substances/Petroleum Products

Phase I Environmental Site Assessments have not been conducted in the project areas. The next phase of site investigation should include identifying recognized environmental conditions (RECs).

3.1.19 Socioeconomics

Five-year average (2008-2012) American Community Survey (ACS) data was queried to obtain relevant socioeconomic data for the analysis presented in the Draft EIS. The following information is a summary of that analysis.

- Findlay has a total population of 41,301.
- The median age within Findlay is 36.2 years of age.
- Hancock County and the state of Ohio are increasing in population.

- The housing vacancy rate in Findlay is slightly higher than the county average, but lower than the state and national averages.
- The median home value within Findlay is $122,900, which is lower than the county ($129,800), state ($133,700), and national median value ($181,400).
- While ethnic diversity in Findlay is much lower than the state and national levels, there seems to be an upward trend in the ratio of minority residents to white residents. The largest three races by proportion are White (91.3%), Black or African American (2.7%), and Asian (2.6%).
- Of those residents within the City of Findlay over 25 years of age, 89.8 percent have a high school degree or greater and 23.3 percent of the population have a bachelor's degree or greater.
- The median household income for the City of Findlay ($43,101) is lower than the county, state, and federal median incomes of $49,350, $48,246, and $53,046, respectively.
- The unemployment rate is 10.2 percent, which is slightly higher than the county, state, and national averages.

3.1.20 Environmental Justice

In order to identify whether the potential alternatives may disproportionately affect minorities or impoverished citizens, the next phase of project analysis should include utilizing census block group maps for the study area, utilizing the USEPA's environmental justice viewer, or similar tool.

3.1.21 Human Health and Safety

The Blanchard River Watershed has experienced flooding events throughout the past century. The biggest concern in the area is the frequent and serious flooding which inundates much of the high value downtown business districts as well as a large amount of the valuable farming community surrounding Findlay. The frequency and severity of these floods—most recently in 2006, 2007, 2008, 2011, 2013 and 2017—has caused extensive damage to the city and surrounding area. It has been common for water levels to remain above flood stage for several days during these historic flood events.

Two individuals have died in recent flooding events in the Blanchard River Watershed, one in 2007 and one in 2013. Loss of life is a significant concern regarding future flood events in the area. It is also important to note that workers associated with the post-flooding cleanup efforts can potentially be exposed to mold, waste materials, and other noxious irritants due to the floodwater inundating houses and commercial areas. With continued high-water events, the risk for loss of life and exposure to hazards is expected to remain constant or increase.

3.1.22 Sustainability, Greening, and Climate Change

Projects that require permits from federal agencies must comply with applicable laws and Executive Order guidance. Climate change, in spite of abundant scientific evidence of its existence, is currently a politicized issue and Executive Order guidance fluctuates with political affiliations.

Greenhouse gases (GHGs) are components of the atmosphere that trap heat relatively near the surface of the earth and contribute to the greenhouse effect (or heat-trapping) and climate change. Most GHGs occur naturally in the atmosphere from natural processes and events but increases in their concentration result from human activities such as burning fossil fuels. Global temperatures are expected to continue to rise as human activities continue to add carbon dioxide (CO_2), methane, nitrous oxides, and other GHGs to the atmosphere. Whether rainfall increases or decreases remains difficult to project for specific regions.

Climate change impacts within the study area would likely revolve around increased temperatures and further altered hydrologic conditions. Any changes in hydrologic conditions occurring within the basin would likely result from less frequent but more intense warm-weather precipitation events, moderately to severely reduced summer flow conditions, degraded water quality, less winter ice cover, and more cold-weather erosion events. Extreme rainfall events and flooding trends are expected to impact the region by causing erosion, declining water quality, and negative impacts on transportation, agriculture, human health, and infrastructure. The range and distribution of fish, other aquatic species, and riparian habitat may change with altered climate conditions.

In the next few decades, it is expected that longer growing seasons and rising CO_2 levels would increase yields of some crops, though such benefits will be progressively offset by extreme weather events. Though adaptation options can reduce some of the detrimental effects, in the long term, the combined stresses associated with climate change are expected to decrease agricultural productivity.

3.2 POTENTIAL IMPACTS

The construction and operation of three dry storage basins and channel improvements in the City of Findlay have been analyzed at a high level for potential environmental impacts in this section. More detailed analyses should be prepared at later stages in the project development – this section also attempts to identify data gaps and need for additional studies. The intent of this analysis is to highlight resources and impacts that merit additional analysis. Potential impacts are listed in bulleted format, including both temporary construction-based impacts and permanent impacts.

3.2.1 Land Use

- Construction activities would temporarily limit land use options within the construction zones.
- Land uses within the reservoir footprints may be significantly impacted with the project in place. Agricultural land uses currently dominate the reservoir footprints. While it could still be possible to actively farm the land within the reservoir footprints during a growing season with no major flooding events, crop production would likely be negatively impacted when water temporarily ponds in the reservoirs. Depth and duration of ponding would affect the degree of impacts to agricultural practices. Certain crops may be more robust than others under this modified hydrologic regime.
- If drain tiles within the reservoir footprints are modified, use of land for agriculture may be impacted.
- Modifications to the flood bench and channel improvements in the City of Findlay may provide new recreational land use opportunities in the area, providing more parkland between Swale Park and Blanchard River except when river levels increase, and the flood bench is inundated.

3.2.2 Geology and Soils

- Soils in the construction areas would be temporarily impacted by construction activities.
- Soils within the reservoir footprints will be permanently impacted by more frequent ponding and deposition of sediment during ponding.
- Further analysis of land use options within the reservoir footprints and anticipated reservoir operation will be necessary to estimate how the modified hydrologic regime would impact erosion. Variable water levels within the reservoir footprint could potentially increase local erosion.
- Any modifications to drain tiles within the reservoir footprints has the potential to impact soils.
- Geotechnical investigations will be required at the embankments. Presence of a karst formation, for example, could significantly impact project design.

3.2.3 Groundwater

- Temporary impacts to groundwater during construction are not anticipated, if construction-related impacts to existing wells (oil and gas, water) are avoided.
- Water ponding during reservoir operation may increase local groundwater infiltration.

3.2.4 Streams

- Stream segments within the construction zone could be temporarily impacted by construction activities. Regulatory agencies will require that temporary stream impacts are avoided or minimized.
- The low-flow culvert passage for each stream through the reservoir embankment will allow for continuous stream flow, while also restricting downstream flows during flood events. The presence of continuous flows with regulated peak flows should reduce project impacts to downstream aquatic habitat and species. In addition, the reduction in downstream flood flows should reduce the potential for streambank erosion.
- The culverted passages through the embankments would permanently impact those stream segments. Further analysis should be performed to determine if the culverts would have a negative impact on aquatic life, for example, by decreasing upstream fish passage.
- When flood waters back up into the reservoirs, the habitat will be temporarily converted from riverine to lacustrine.
- Impacts to streams will require permits and will most likely require mitigation. Additional stream studies and characterizations, including both mainstem and non-mainstem streams, will be required to determine quantities of impacts and mitigation requirements. The minimum quantity of direct stream impact would be the culverted section of each stream passing through the embankment (Table 3-6).
- Locations of borrow areas for embankment materials, which have not yet been determined, could potentially have temporary or permanent direct or indirect impacts to streams.

Table 3-6 Minimum Direct Impacts to Streams

Reservoir	**Minimum Direct Stream Impact (LF)**
Eagle Creek	188
Blanchard	199
Potato Run	219

3.2.5 Floodplains

- Construction activities may have temporary impacts to the floodplain in the vicinity of the construction activities. Construction phasing information would be required to better understand temporary impacts to floodplains.
- The intent of the project is to reduce the risk of flooding in Hancock County and the City of Findlay. Floodplain widths will increase in the vicinity of the reservoirs and decrease downstream of the reservoirs. Detailed hydrologic and hydraulic modeling allows for quantification of impacts to the floodplain. A detailed structure analysis was performed to quantify flooding impacts to flood-prone structures. See the Proof of Concept Update Report for more detail.

3.2.6 Wetlands

- Permanent impacts to wetlands would occur where embankments are constructed on top of existing wetlands or where the project permanently eliminates wetland hydrology. Table 3-7 summarizes the estimated minimum direct impacts of proposed embankments on wetlands mapped by NWI and OWI.

Table 3-7 Minimum Direct Impacts to Wetlands

Reservoir	**Estimated Direct Impact of Embankment on Mapped NWI and OWI Wetlands (ac)**
Eagle Creek	1.32
Blanchard	0.55
Potato Run	0.33

- The modified hydrologic regime within the reservoir footprints may impact wetlands, by increasing or decreasing wetland size, and by potentially creating new wetlands or eliminating existing wetlands. Modified hydrology could also change the type of an existing wetland. Models of reservoir hydraulics should help inform estimates of wetland impacts.
- Borrow areas for embankment construction have not yet been identified. The locations of borrow areas could directly or indirectly impact existing wetlands.

- Further analysis should include delineating existing wetlands within the project footprint and in adjacent areas where modified hydrology could impact wetlands, in addition to characterizing the quality of the wetlands (Q/HHEI, ORAM). Impacts to wetlands will need to be quantified for project permits processes.

3.2.7 Vegetation

- Construction activities have the potential to disturb existing vegetation and create habitat for invasive and/or aggressive pioneer native species.
- Vegetated areas within the reservoir footprints may be impacted by the modified hydrology. For example, species in the forested riparian areas lining the streams may not be adapted to the durations or depths of flooding in the reservoirs.
- Vegetation within the footprints of the embankments and within the footprint of the channel improvements would be permanently impacted. Additional analysis should be performed to determine existing vegetation communities and how areas will be revegetated following construction.

3.2.8 Wildlife

- Construction activities may temporarily impact terrestrial and aquatic species, from vegetation clearing, earthmoving, noise, and water quality impacts. Contractors would be required to prepare and implement plans for reducing and controlling erosion and sedimentation. Any work performed within the streams will require an approved in-water work plan.
- The embankments are not anticipated to create movement barriers for terrestrial species. However, the culverts passing through the embankments could potentially create movement barriers for some aquatic species.
- Impacts to state and federally listed species are addressed in the next section.

3.2.9 Threatened and Endangered Species

- There are no identified hibernacula in the project area, but removal of trees could potentially impact Indiana bat or northern long-eared bat maternity or roosting habitat. Tree removal schedule will likely be constrained by permitting agencies.
- The proposed project could potentially impact listed freshwater mussel species. The next phase of analysis should aim to estimate and quantify impacts.
    - Detailed mussel surveys will be required to help quantify direct impacts and estimate indirect impacts.
    - Mussels located in areas that would be directly impacted by construction would likely be relocated in accordance with permit requirements.
    - Project operational impacts on mussels would depend on mussel location, impacts on sediment transport, availability of preferred substrate, impacts on the movement of host fish, and impacts on

    stream flows. It is likely that some areas would experience positive impacts and other areas would experience negative impacts to mussel habitat.

  - Altered high flow durations downstream of the proposed embankments could affect geomorphic processes.
  - If embankments isolate mussel populations, the exchange of genetic material could be impaired.
  - The relatively short residence time of ponded flood water in the reservoirs may encourage deposition of larger sediment particles (gravel, sand), but may not impact deposition of smaller particles (clay, silt).
- Locations of extant blue-spotted salamander, western banded killifish, plains clubtail, and Kirtland's snake populations or individuals have not been identified. It is not clear how the proposed project features could impact these species. If there are individuals or populations located near construction activities, there is the potential for direct impacts. If there are individuals or populations located in areas where their preferred habitat could be modified by the new stream flows, this could also impact these listed species.

3.2.10 Air Quality

- Construction activities, associated fuel consumption, and increased construction-related dust could potentially have short-term negative impacts on local air quality.
- There are not any anticipated long-term air quality impacts.

3.2.11 Water Quality

- Construction activities, including vegetation clearing, earth disturbance, in-water work, and temporary flow re-routing have the potential to negatively and temporarily impact water quality. Regulatory agencies will require plans for controlling erosion and sedimentation, preventing spills, and minimizing impacts during in-water work.
- Permanent water quality impacts will depend on the duration and frequency of events that pond water in the reservoirs. Ponded water in shallow reservoirs and/or reduced tree cover along stream channels could lead to increased water temperatures. Ponding water could potentially reduce dissolved oxygen levels, although the presence of a constant flow through the culverted low flow bypass may keep downstream waters adequately oxygenated. Ponding water in reservoirs should allow some sediment to settle out. Reducing downstream flows during large storm events may decrease the amount of erosion and bank scouring downstream, but increasing the durations of higher flows may exacerbate erosion and bank scouring. More detailed models on anticipated project operation will help to estimate long-term impacts on water quality. Regulatory agencies may require a short-term post-construction water quality monitoring program.

3.2.12 Noise

- Construction activities could potentially have short-term negative impacts on noise in the area due to increased traffic and construction equipment activity.

- There are not any anticipated long-term noise impacts due to the proposed project.

3.2.13 Cultural Resources

- Temporary construction impacts and associated increases in traffic, noise, and air pollution could temporarily and negatively impact archaeological or historic sites near the construction sites.
- There are 47 previously recorded archaeological sites, two historic cemeteries, and three Ohio Historic Inventory properties located within the areas of concern searched by Mannik Smith Group. Additional investigations will almost certainly be required by regulatory agencies. Results from the online data search and possible future site investigations will inform a more detailed analysis of impacts, and associated need for avoidance or mitigation.

3.2.14 Utilities and Infrastructure

- Preliminary analyses of utilities and infrastructure in the vicinity of the project footprint indicate that there are no known pipelines, aqueducts or fiber optic lines that would be directly impacted by project activity.
- There are twelve mapped water wells and five mapped oil/gas wells within the project footprint, and many more mapped wells in the vicinity of the project. More information will need to be collected on wells within or near the project footprint to identify which wells are still active and how the project could impact use of those wells.
- Detailed mapping and/or surveying of local utilities should be performed in subsequent stages of project planning.

3.2.15 Transportation

- Temporary construction impacts from increased construction related-traffic and local road closures could negatively impact local traffic flow.
- During flooding events, full access to some roads would be temporarily restricted.
- Construction of reservoir embankments will permanently impact some local roads, requiring permanent road closures and re-routing of traffic patterns. Detailed traffic and emergency access studies should be performed to minimize the impacts of the proposed changes.

3.2.16 Aesthetics

- Construction impacts from vegetation clearing, earthmoving, traffic, noise, and dust may have a temporary negative impact on local aesthetics.
- Permanent impacts may include views of permanent embankment structures from culturally significant or recreational sites.

- The NRI identifies two reaches of the Blanchard River that pass through the Blanchard Reservoir and the channel improvements in the City of Findlay as having outstanding aesthetic values. Additional analysis of the stream reach would be required to estimate aesthetic impacts.

3.2.17 Recreation

- During construction, recreation opportunities at or in the vicinity of the construction projects may be negatively impacted. Boating/kayaking on the streams during construction may require portaging around the construction sites. Hunting and fishing in the vicinity of the construction sites may be impacted by construction activity, noise, and restrictions.

- Permanent impacts may include limitations on boating/kayaking through embankment culverts, restricted fishing access, and ability to access recreational sites during flood events. Loss of wildlife habitat (e.g., reduction in woodlot vegetation), could impact hunting and passive recreational opportunities. Reducing downstream flows during flood events could improve habitat by reducing negative impacts to aquatic and riparian habitat due to extreme flood flows.

3.2.18 Hazardous Substances/Petroleum Products

- Phase I ESA investigations will be required to help quantify potential impacts to sites with recognized environmental conditions. Without additional information, it is difficult to estimate potential impacts.

3.2.19 Socioeconomics

- Temporary construction impacts on socioeconomic values may include increased construction traffic, commuter impacts, and construction jobs created.

- Land acquisition required for the projects should be reviewed for socioeconomic impacts.

- Permanent impacts may include loss of farmland, increased economic benefits from decreased flooding, and commuter impacts due to rerouted local streets.

- Depending on how the projects are funded, there may be long-term local tax increases required to pay for the projects.

3.2.20 Environmental Justice

- Temporary construction impacts could include increased traffic, noise, and dust from construction activities.

- Land acquisition required for the projects should be reviewed for environmental justice impacts.

- Permanent project impacts could include decreased flooding in the City of Findlay and loss of farmland production within the footprint of the three reservoirs.

- These temporary and permanent impacts should be reviewed in more detail in subsequent project analyses to determine if the project could disproportionately affect minorities or impoverished citizens. Data for census block groups can be obtained from the USEPA's environmental justice viewer, or similar tool.

3.2.21 Human Health and Safety

- Temporary construction impacts may include increased traffic, noise, and dust from construction activities.
- Permanent project impacts may include decreased flooding in the City of Findlay, decrease in loss of life due to flooding events, and modifications to emergency access to areas where streets are re-routed. The reservoir embankments are dam-like structures and may require additional studies of probable maximum flood event and overtopping, to analyze potential failure scenarios and how that could impact downstream areas.

3.2.22 Sustainability, Greening, and Climate Change

- Temporary construction impacts may include increased greenhouse gas production by construction equipment.
- If climate change brings less frequent, but more intense storm events to the region, the City of Findlay would be subject to an increase in flood event occurrence and would benefit even more from the project.

3.3 ENVIRONMENTAL COMPLIANCE

This section briefly addresses the potential applicability of environmental regulations and guidance documents. Protection, mitigation, and enhancement measures that could be required by regulatory agencies are addressed, where appropriate.

3.3.1 Clean Water Act (Section 401, Section 404)

The proposed project will impact waters of the US and will require Clean Water Act permits under Section 404 (Fill in Waters of the US) and Section 401 (Water Quality Certification). The Blanchard River is not considered to be Section 10 waters by the USACE Buffalo District. It is likely that individual Section 404 and Section 401 permits will be required for this project. Mitigation will be required for impacts to streams and to wetlands. Linear feet of stream impacts and acreages/types of wetland impacts need to be quantified. For estimation purposes, a 3:1 mitigation ratio for stream or wetland impacts should be assumed. In lieu fee costs per linear foot of stream impact are estimated to be $330. Wetland bank costs for mitigation are estimated to be $40,000 per acre.

3.3.2 National Environmental Policy Act

Assuming the USACE would be the lead federal agency involved in the permitting process, the individual permit would trigger a federal nexus and require the USACE to prepare an Environmental Assessment or Environmental Impact Statement as part of the permitting process. Another potential federal nexus to NEPA would be the use of federal funding for the project.

3.3.3 Fish and Wildlife Coordination Act

It is not anticipated that the fish and wildlife coordination act will impact project development.

3.3.4 Endangered Species Act

Federally-listed threatened or endangered species are known to be present in the vicinity of the project. In particular, listed mussel species known to occur in the Blanchard River could potentially be impacted by project construction and operation. Formal consultation with the United States Fish and Wildlife Service to address the potential taking of listed species would likely be required. The USACE joint permit process requires coordination with the USEPA and state agencies regarding impacts to sensitive species. Protection, mitigation, and enhancement (PME) measures may be required.

3.3.5 Farmland Protection Policy Act

A large portion of each reservoir footprint is mapped with soils that are either characterized as Prime Farmland or Prime Farmland, If Drained. Episodic inundation of the dry storage basins is expected to reduce the acreage of farmable ground. Initial analyses suggest that approximately 300 of 728 acres classified as agricultural could remain in production at the Eagle Creek location. Similarly, it is estimated that 413 acres could remain in production at the Blanchard River and Potato Run locations, a reduction from an initial total of 894 acres.

3.3.6 CERCLA and RCRA

Phase I studies of project areas will be required to determine if any recognized environmental conditions are present in the vicinity of the project locations. The results of those studies will help determine if there are any contaminated sites that may fall under the jurisdiction of the Resource Conservation and Recovery Act of 1976 (RCRA) or the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA).

3.3.7 Toxic Substances Control Act

It is not anticipated that the Toxic Substances Control Act will be relevant to the proposed project.

3.3.8 Federal Insecticide, Fungicide, and Rodenticide Act

It is not anticipated that the project will involve the use of pesticides. The Federal Insecticide, Fungicide, and Rodenticide Act is not anticipated to be relevant to the proposed project.

3.3.9 National Historic Preservation Act

If there are any sites or structures located within the project areas that are determined to fall under jurisdiction of the National Historic Preservation Act, the permittee will need to coordinate with the US Department of Interior and the Ohio State Historic Preservation Office (SHPO). Coordination with regulatory agencies will determine if PME measures are required.

3.3.10 Clean Air Act

It is not anticipated that the proposed project will trigger Clean Air Act requirements.

3.3.11 Wild and Scenic Rivers Act

There are no designated Wild and Scenic Rivers located within the project area. However, there are segments of the Blanchard River within the project area that are listed in the National River Inventory and, therefore, are candidates for listing as Wild and Scenic Rivers. Additional analysis will be required to determine if the proposed projects will impact any of the outstanding characteristics of these NRI-designated stream segments.

3.3.12 Migratory Bird Act and Executive Order 13186 (Responsibilities of Federal Agencies to Protect Migratory Birds)

The project is not anticipated to impact migratory birds. However, additional consultation with USFWS and ODNR will be required for the permit process, which will help determine if there is habitat for any migratory birds that may be disrupted by the proposed project.

3.3.13 Executive Order 11988 (Flood Plain Management)

The intent of the proposed project is to reduce flooding in the City of Findlay. The floodplain would increase within the footprint of the reservoirs and decrease in areas downstream of the reservoirs.

3.3.14 Executive Order 11990 (Protection of Wetlands)

Wetland impacts will be addressed through the USACE CWA Section 404 permitting.

3.3.15 Executive Order 12898 (Environmental Justice)

Additional environmental justice analysis is required, but it is not anticipated that the proposed project would trigger environmental justice requirements.

3.3.16 Executive Order 13045 (Protection of Children from Environmental Health and Safety Risks)

This Executive Order is not anticipated to be applicable to the proposed project.

3.3.17 Executive Order 13432 (Strengthening Federal Environmental, Energy, and Transportation Management)

This Executive Order is not anticipated to be applicable to the proposed project.

3.3.18 Executive Order 13514 (Federal Leadership in Environmental, Energy, and Economic Performance)

This Executive Order is not anticipated to be applicable to the proposed project.

3.3.19 Executive Order 13653 (Preparing the US for the Impacts of Climate Change)

This Executive Order is not anticipated to be applicable to the proposed project.

3.3.20 Executive Order 13175 (Consultation and Coordination with Tribal Governments)

This Executive Order is not anticipated to be applicable to the proposed project.

3.3.21 Executive Order 13112 (Invasive Species)

Disturbance of land for construction and temporary ponding within the reservoir footprint could potentially create habitat for invasive and/or aggressive native species. The project should come up with a plan for managing vegetation within the reservoirs.

3.3.22 Obstruction Evaluation/Airport Airspace Analysis

This Executive Order is not anticipated to be applicable to the proposed project.

4.0 SUMMARY

The proposed flood risk reduction program may pose temporary or permanent environmental impacts that require additional study, permitting, and/or PME measures. Several resources were identified as needing additional site-specific studies to be able to quantify potential project impacts to features such as wetlands, streams, threatened and endangered species, vegetative communities, cultural resources, geotechnical, utilities, changes to transportation, Phase I ESA, and aesthetics related to NRI stream segments. In addition, as the program progresses, planning choices should be continuously filtered through the lens of environmental impacts. Construction methods, borrow areas for embankment material, land acquisition, and funding mechanisms, for example, could each pose additional environmental impacts for consideration. Engaging regulatory agencies and the public early in the planning process is suggested.

5.0 PERMITTING AND MITIGATION

During the early stages of project design, some permitting requirements and associated costs are predictable, while others are not predictable. Table 5-1 and the following text provide a brief summary of potential permitting requirements and associated costs, including additional field studies, desktop analyses, preparation of permit applications, and coordination and communication with both regulatory agencies and the design team. The biggest drivers of costs associated with permitting are for mitigation for impacts to jurisdictional waters of the U.S. This factor is applicable for all of the proposed dry storage basins. As noted in the assumptions below, mitigation costs were estimated using desktop methods, not field surveys, and impacts may be considerably larger depending on the location of aquatic resources relative to project elements. The presence of federally listed mussels in the Blanchard River would affect estimated permitting and mitigation costs for projects on the Blanchard River and Potato Run.

Assumptions:

- Chosen borrow areas for embankment material will avoid or minimize impacts to environmental resources.
- Quantities of impacts to wetlands and streams need to be confirmed.
- Mitigation will be performed entirely using bank credits and/or in-lieu fee arrangements.
- Regulatory agencies will not consider temporary inundation to be impacts.
- Self-mitigation of wetlands will not occur.
- Access to private property will be coordinated by client.
- Tree removal will be restricted to specific periods.
- The lead agency (e.g., USACE) will only require minor desktop analysis and text input for resource areas not listed in the Table for additional field study (e.g. water quality, fish, invertebrates, traffic, aesthetics, recreation, environmental justice, and socioeconomics).

Table 5-1 Estimated Permitting and Mitigation Requirements

Permit	Task	Eagle Creek	Blanchard/ Potato Run
Individual CWA Section 404	**Delineate wetlands** within project footprints – Blanchard, Potato Run, and Eagle Creek Reservoirs and Embankments. Prepare reports and submit to USACE, including ORAM forms, general vegetative community descriptions, and notes on potential bat roosting trees. Record wetland boundaries with sub-meter accuracy GPS.	$16,500	$33,500
	Characterize streams – Perform detailed physical characterization of streams near embankments and selected segments/points upstream and downstream of reservoir footprint. Perform limited fish and invertebrate sampling at embankment sites, if required.	$16,500	$33,500
	Phase I Cultural resource study and Section 106 consultation – A qualified archaeologist shall perform a Phase I cultural resources study.	*	*
	Prepare Individual Joint Permit Application – meet with regulatory agencies, prepare individual permit application, and submit permit application. Assume that resources not listed in this table do not require additional field studies (e.g., water quality, fish, invertebrates, traffic, aesthetics, recreation, environmental justice, and socioeconomics). Includes mitigation plan based on in-lieu-fee and mitigation bank options (no on-site mitigation).	$50,000	$70,000
Individual CWA Section 401	**Prepare Individual CWA Section 401 permit application** – meet with regulatory agencies, prepare individual permit application, and submit permit	$50,000	$70,000

	application. Assume that desktop analyses using existing water quality data will be sufficient for permit process.		
Endangered Species	**T&E Baseline Field Studies (mussels) -**	$15,000	$100,000
	T&E Formal Section 7 Consultation – including permit for relocation or taking of T&E species.	#	$75,000
	Salvage and Relocation	$25,000	$20,000
	Reasonable and Prudent Measures	#	$75,000
SESC	**Soil Erosion and Sedimentation Control Plan** – prepare SESC plan and submit to local soil and water conservancy district for review and approval.	*	*
Floodplain	**Local floodplain permit** – prepare and submit local floodplain permit application, including hydrologic and hydraulic modelling results.	*	*
Hazardous materials	**Phase I Environmental Site Assessment** – Perform Phase I ESA for to determine if any recognized environmental conditions are present at or in the near vicinity of the project sites.	*	*
Mitigation Credits - Wetlands	**Purchase Wetland Credits –** Estimated direct wetland impacts of 2.18 acres, mitigated at a ratio of 3:1 using wetland bank credits at $40,000 per acre.	$158,400	$105,600
Mitigation Credits - Streams	**Purchase Stream Credits –** Estimated direct stream impacts to 606 linear feet of stream at a ratio of 3:1 using in-lieu fee credits of $330 per linear foot	$718,740	$413,820
	Contingency 25%	$262,535	$249,105
	Total	$1,312,675	$1,245,525

*Noted here but costs estimated in other planning documents

#Not anticipated for this location

6.0 REFERENCES

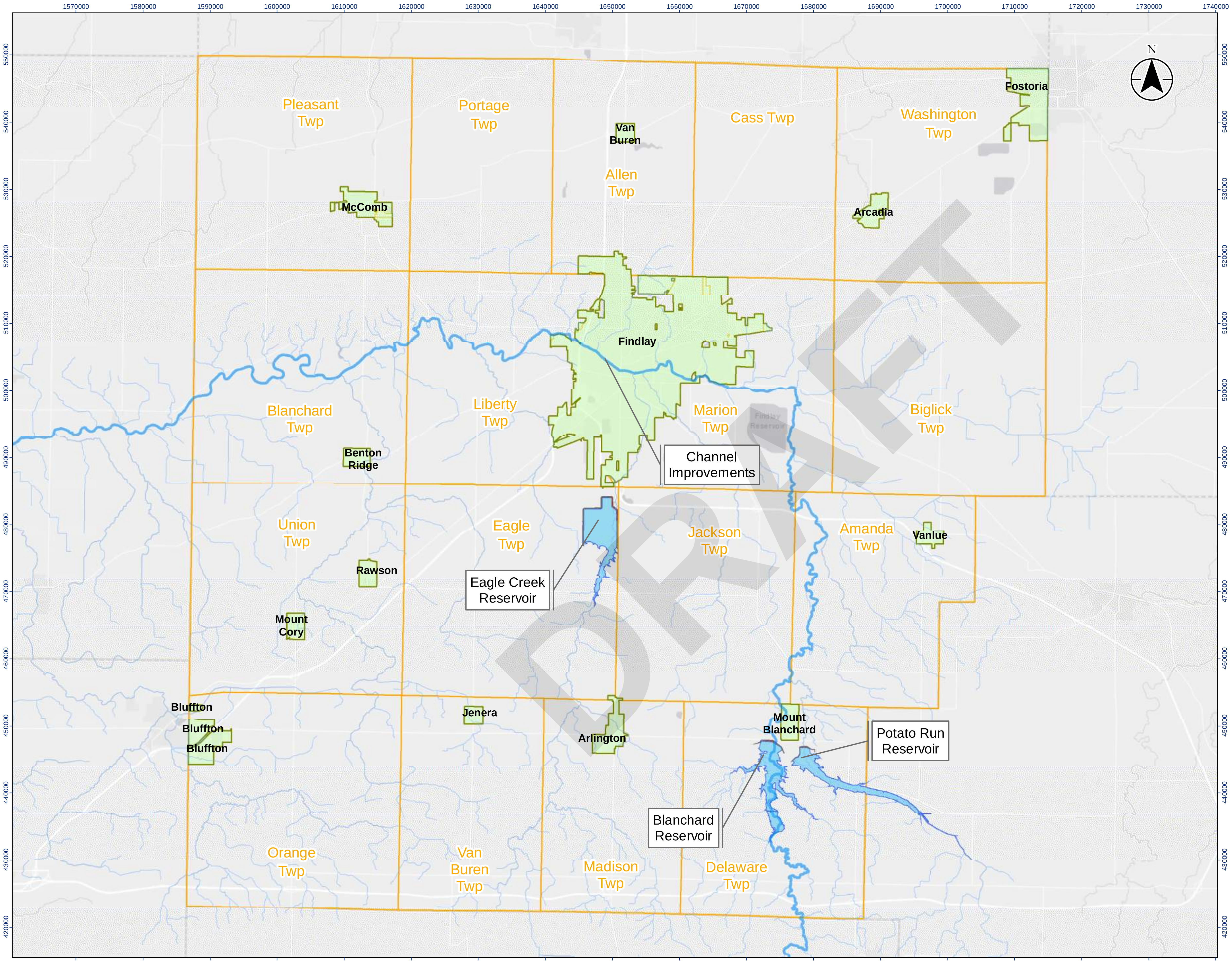
OEPA. 2007. Biological and Water Quality Study of the Blanchard River. OEPA Technical Report EAS/2007-6-2.

OEPA. 2009. Total Maximum Daily Loads for the Blanchard River Watershed.

Stantec. 2017. Final Report: Data Review, Gap Analysis, USACE Plan and Alternatives Review, and Program Recommendation.

USACE, Buffalo District. 2015. DRAFT Detailed Project Report/Environmental Impact Statement, Western Lake Erie Basin (WLEB) Blanchard River Watershed Study. Section 441 of the Water Resource Development Act of 1999.

ATTACHMENTS



Stantec

Legend

- Proposed Dry Storage Reservoir
- NHD Streams in HUC 04100008
- Blanchard River
- Municipality
- Hancock County Township

0 1 2 3 4 Miles
1:176,707 (At original document size of 11x17)

Notes
1. Coordinate System: NAD 1983 StatePlane Ohio North FIPS 3401 Feet
2. Light Gray Canvas Base: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community.
3. Streams from the National Hydrography Dataset HUC 04100008 uploaded in March 2018, Political boundaries are from the Ohio DNR GIS website in March 2018.

Project Location
Hancock County, OH

Project #: 174316204
Prepared by RFB on 2018-05-14
Technical Review by WCF on 2018-04-19
Independent Review by DTH on 2018-05-26

Client/Project
Hancock County, City of Findlay, and Maumee Watershed Conservancy District
Hancock County Flood Risk Reduction Program - Supplemental Environmental Review

Figure No.
A-1

Title
Project Area

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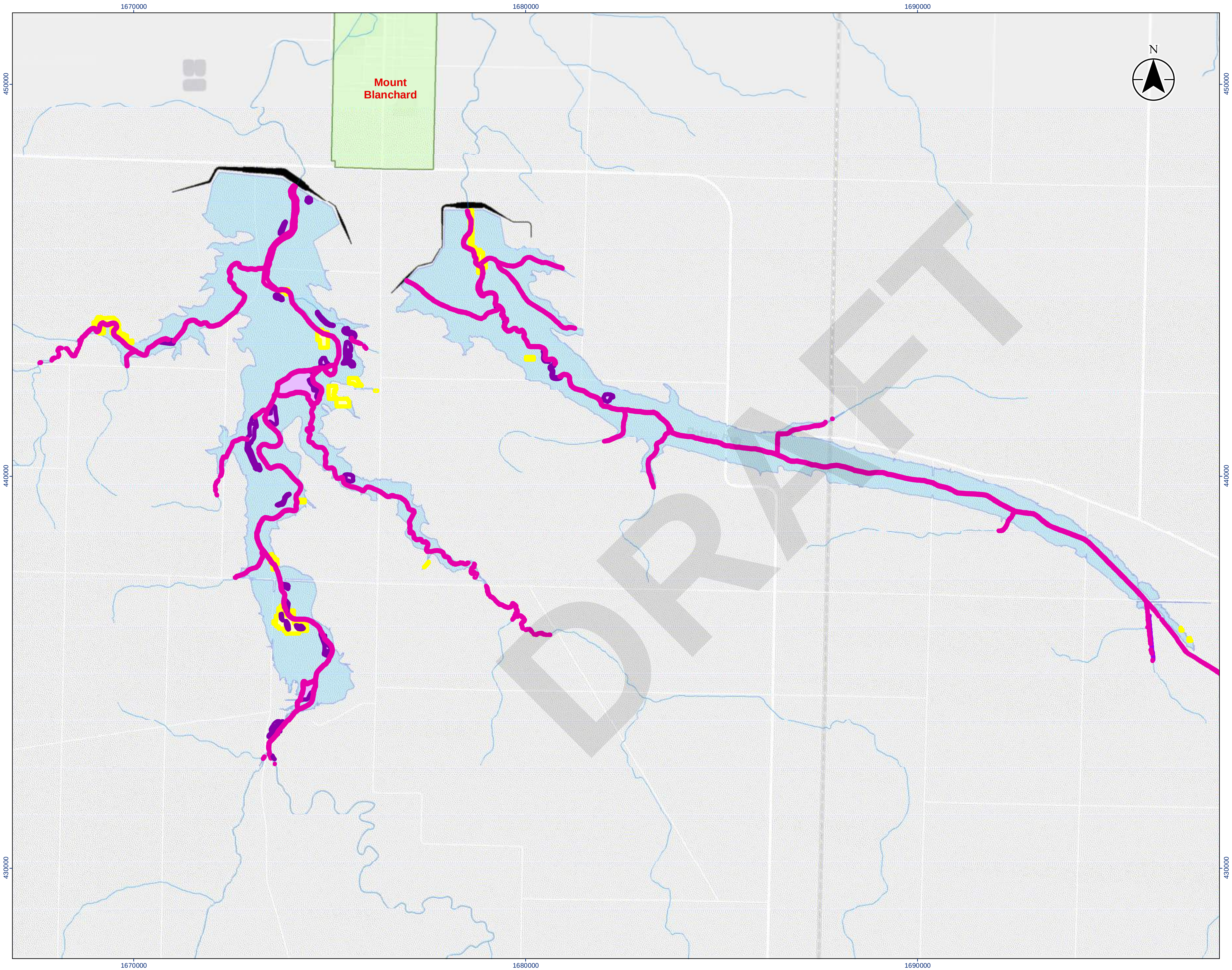

Legend

- Proposed Dry Reservoir
- ■ Embankment
- NWI Riverine Wetland
- Other OWI and NWI Wetlands
- Woods on Hydric Soils
- NHD Streams in HUC 0410008

0 0.5 1 Miles
1:30,282 (At original document size of 11x17)

Notes
1. Coordinate System: NAD 1983 StatePlane Ohio North FIPS 3401 Feet
2. Light Gray Canvas Base: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community.
3. Streams from the National Hydrography Dataset HUC 04100008 uploaded in March 2018, NWI is from USFWS and OWI is from Ohio DNR, both uploaded in March 2018.

Project Location

Hancock County, OH

Project #: 174316204
Prepared by RFB on 2018-05-14
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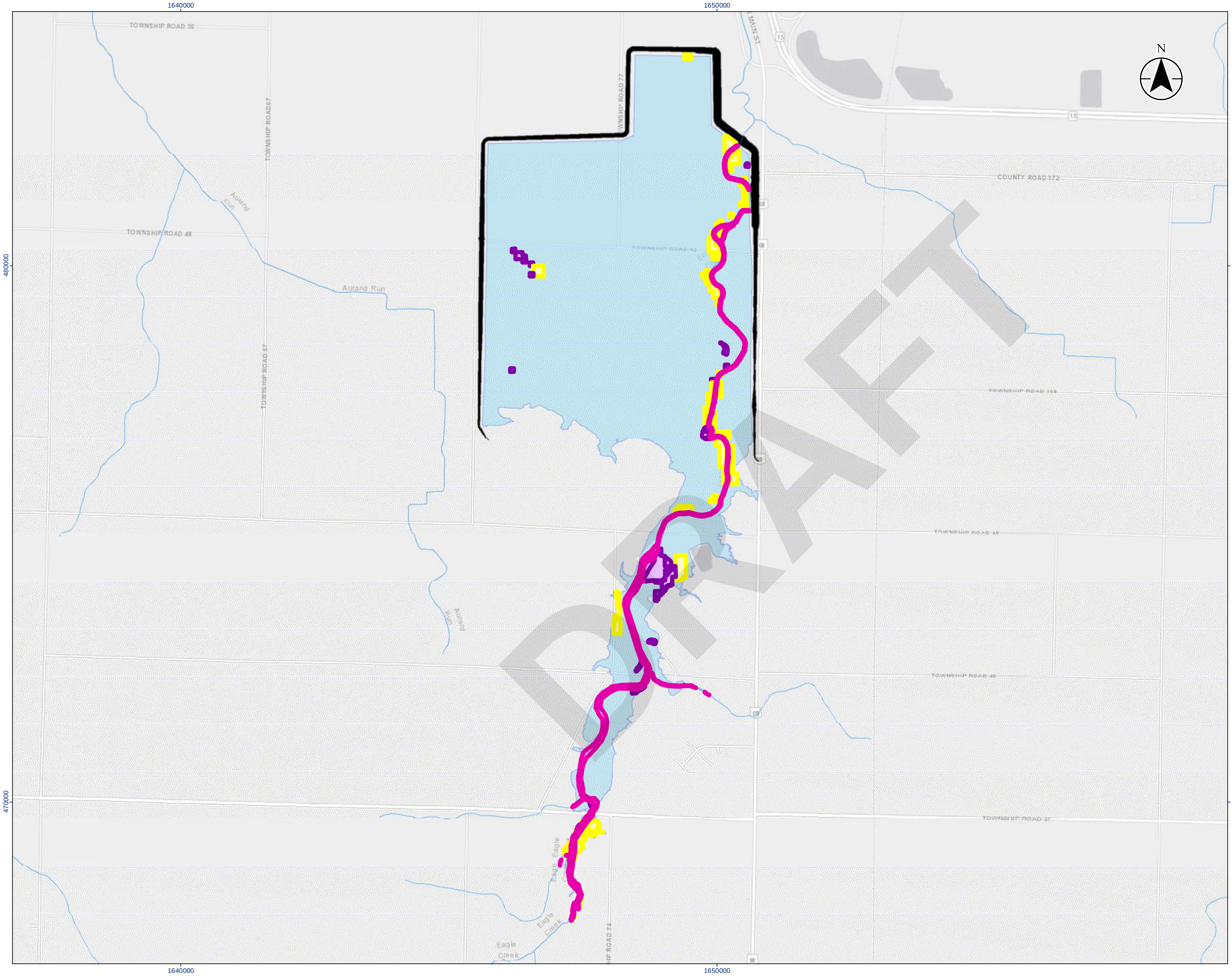
Client/Project
Hancock County, City of Findlay, and Maumee Watershed Conservancy District
Hancock County Flood Risk Reduction Program - Supplemental Environmental Review

Figure No.
A-2

Title
NWI and OWI Wetlands in Blanchard and Potato Run Reservoirs

\\uschi4s02\public\Bedross\Findlay OH Floodplain 2018\GIS\mxd\Fig_A-2_Hancock_Co_Blanchard_and_Potato_Run_Wetlands.mxd Revised: 2018-05-31 By: rbolliger



Stantec

Legend

- 🟦 Proposed Dry Reservoir
- ■ Proposed Embankment
- ▢ NWI Riverine Wetland
- ▢ Other OWI and NWI Wetlands
- ▢ Woods on Hydric Soils
- 〰 NHD Stream in HUC 04100008

0 0.25 0.5
Miles
1:22,282 (At original document size of 11x17)

Notes
1. Coordinate System: NAD 1983 StatePlane Ohio North FIPS 3401 Feet
2. Light Gray Canvas Base: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community.
3. Streams from the National Hydrography Dataset HUC 04100008 uploaded in March 2018, NWI is from USFWS and OWI is from Ohio DNR, both uploaded in March 2018.

Project Location

Hancock County, OH

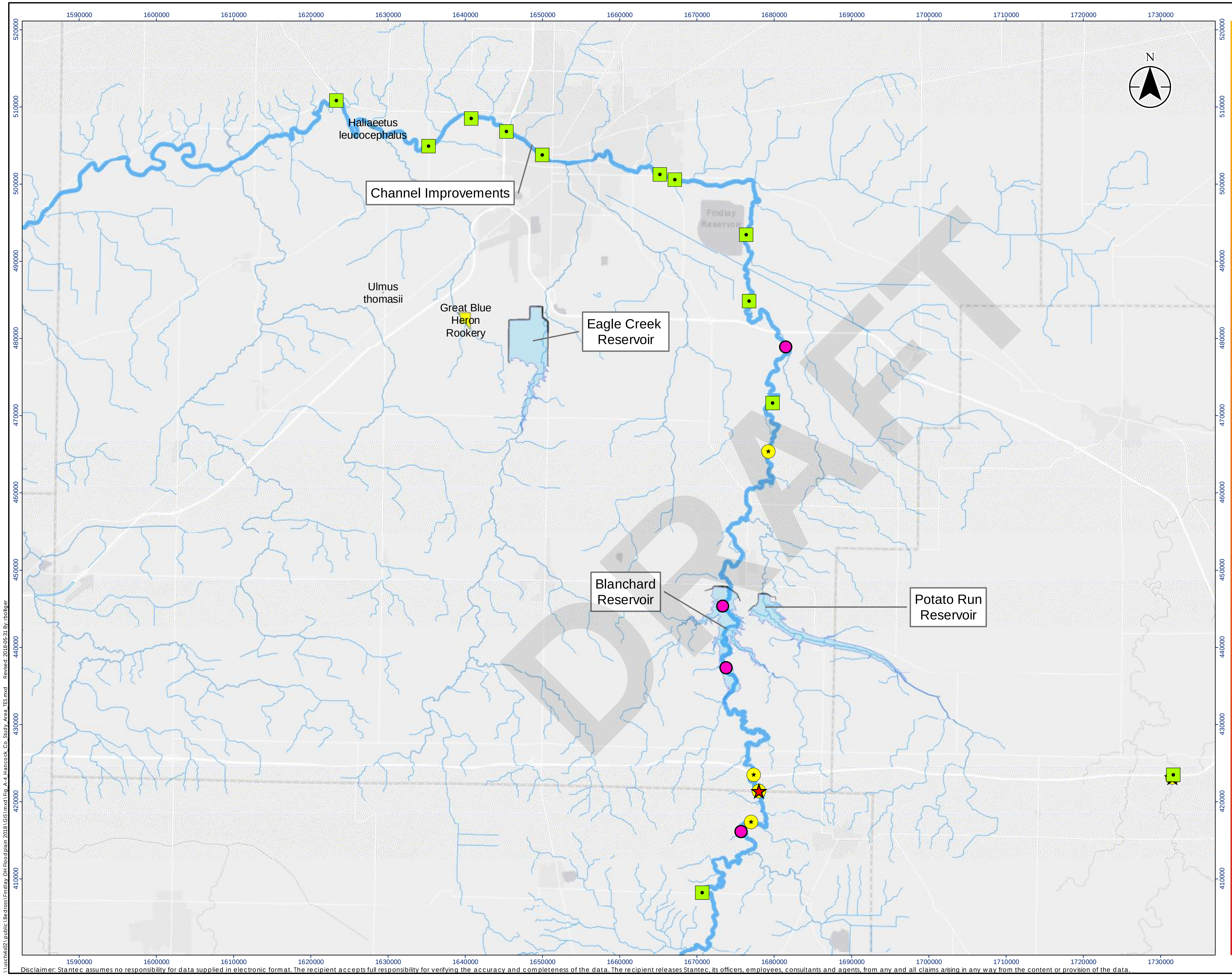
Project #: 174316204
Prepared by RFB on 2018-05-14
Technical Review by WCF on 2018-04-19
Independent Review by DTH on 2018-05-26

Client/Project
Hancock County, City of Findlay, and Maumee Watershed Conservancy District
Hancock County Flood Risk Reduction Program - Supplemental Environmental Review

Figure No.
A-3

Title
NWI and OWI Wetlands in Eagle Creek Reservoir

\\uschi4s02\public\Bedross\Findlay OH Floodplain 2018\GIS\mxd\Fig_A-3_Hancock_Co_Eagle_Creek_Wetlands.mxd Revised: 2018-05-31 By: rbolliger



Stantec

Legend

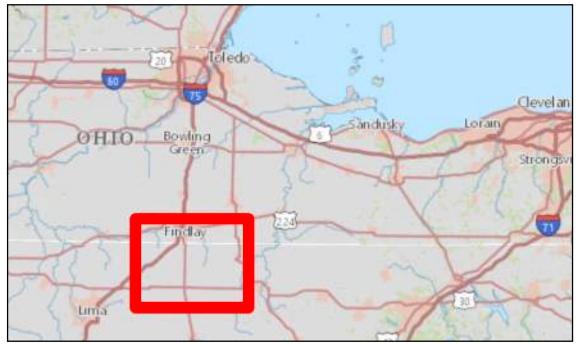
- ▨ Proposed Dry Reservoir
- ~ Other NHD Streams in HUC 04100008
- ~ Blanchard River

Threatened and Endangered Species

- ● No TES Finds
- ★ Rayed Bean Only
- ★ Rayed Bean and Various State-Listed Species
- 🟩 Various State-Listed Species

0 0.5 1
Miles
1:151,851 (At original document size of 11x17)

Notes
1. Coordinate System: NAD 1983 StatePlane Ohio North FIPS 3401 Feet
2. Light Gray Canvas Base: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community.
3. Streams from the National Hydrography Dataset HUC 04100008 uploaded in March 2018, TES data from Ohio Natural Heritage Database uploaded in March 2018.



Project Location

Hancock County, OH

Project #: 174316204
Prepared by RFB on 2018-05-14
Technical Review by WCF on 2018-04-19
Independent Review by DTH on 2018-05-26

Client/Project
Hancock County, City of Findlay, and Maumee Watershed Conservancy District
Hancock County Flood Risk Reduction Program - Supplemental Environmental Review

Figure No.

A-4

Title

Threatened and Endangered Species near Blanchard River

\\uschi4s02\public\Bedross\Findlay OH Floodplain 2018\GIS\mxd\Fig_A-4_Hancock_Co_Study_Area_TES.mxd Revised: 2018-05-31 By: rbolliger

Appendix D – PRELIMINARY CULTURAL RESOURCES REVIEW

March 16, 2018

Adam Hoff, PE
Stantec
4540 Heatherdowns Blvd., Suite A
Toledo, Ohio 43615

Re: Cultural Resources Literature Review for Four Areas of Concern for the Hancock County Flood Risk Reduction Project, Hancock and Wyandot Counties, Ohio

Dear Mr. Hoff:

In February 2018, Stantec contracted The Mannik & Smith Group, Inc. (MSG) to conduct a cultural resources literature review for four Areas of Concern (AOC) currently being evaluated as part of the Hancock County Flood Risk Reduction Program (HCFRRP) (Figure 1). The four AOCs include the Aurand Run AOC in Eagle and Liberty townships, Hancock County; the Eagle Creek AOC in Eagle, Jackson, Liberty, and Marion townships, Hancock County; the Blanchard River AOC in Delaware Township, Hancock County; and the Potato Run AOC in Delaware Township, Hancock County and Richland Township, Wyandot County (Figure 2-3).

MSG conducted the literature review using the Ohio State Historic Preservation Office's (OSHPO) Online Mapping website, as well as historic atlas, plat, and topographic maps and published secondary sources on local history. The purpose of the literature review is to identify the types and locations of previously recorded cultural resources within the study area and to gather information about the environmental and cultural variables likely to influence the location of other archaeological and architectural resources in this region that are not yet identified.

The literature review was conducted by Project Archaeologist Kate Hayfield, B.S. Ms. Hayfield also prepared the historic map figures in Attachment C. Bryan Agosti, M.A., prepared the figures in Attachment A. Dr. Robert Chidester, RPA, a federally qualified archaeologist (36 CFR 61), served as Principal Investigator and is the primary author of this report, with assistance from Project Manager Maura Johnson, M.A.

STUDY AREAS

For the purposes of this literature review, MSG examined two study areas, one comprising a 2.0-mile (3.2-mile) buffer around the Aurand Run and Eagle Creek AOCs and one comprising a 2.0-mile (3.2-mile) buffer around the Blanchard River and Potato Run AOCs. These buffers were chosen in order to obtain a representative sample of cultural resources in the vicinity of the AOCs.

The majority of the Aurand Run/Eagle Creek study area is characterized by the Pewamo-Glynwood-Blount soil association (s6043) (Figure 4). This soil association includes very deep soils that were formed in glacial till; range from nearly level to strongly sloping; and range from very poorly drained to moderately well drained. The northern edge of this study area also includes the Millgrove-Mermill (s6036) and Randolph-Milton-Millsdale-Miamian (s6054) soil associations. Millgrove-Mermill association soils are deep, very poorly to somewhat poorly drained, and formed in water-deposited materials over glacial outwash or till. Randolph-Milton-Millsdale-Miamian association soils are somewhat shallower, range from very poorly drained to well drained, and were formed in glacial till (Rapparlie and Urban 1973; Robbins et al. 2006). Current aerial mapping indicates that the Aurand Run and Eagle Creek AOCs are characterized almost exclusively by residential and agricultural land uses, with the Boy Scouts of America's Camp Berry and the University of Findlay's Western Equestrian Farm also occupying large parcels in the southeastern quadrant of the Eagle Creek AOC. Three major roadways pass through this study area: Interstate 75, State Route 15, and U.S. Route 68 (see Figure 2).

The entirety of the Blanchard River/Potato Run study area is characterized by the Pewamo-Glynwood-Blount soil association (s6043) (Figure 5). Current aerial mapping indicates that the Blanchard River and Potato Run AOCs are also characterized almost exclusively by agricultural and residential land uses, with only the southern end of the Village of Mt. Blanchard and the Riverdale High School campus presenting small exceptions. Two major roadways are present within this study area: State Routes 37 and 103. In addition, U.S. Route 30 passes east-west through the southern end of the study area, approximately 1.0 mile (1.6 km) south of the AOCs (see Figure 3).

The results of the literature review and historic research for the Aurand Run/Eagle Creek study area and the Blanchard River/Potato Run study area are presented separately below.

AURAND RUN/EAGLE CREEK STUDY AREA

Previously Recorded Cultural Resources

The results of the literature review for this study area are presented graphically in Figure 6, and in tabulated form in Attachment B, Tables B1-B6.

Above-Ground Cultural Resources

Within the 2.0-mile buffer study area, 22 individual resources and one historic district are present. The historic district is the Findlay Downtown Historic District, which contains 263 individual properties and was listed on the National Register of Historic Places (NRHP) in 1985 under Criterion C for its architectural significance. Only the very southern tip of this historic district is present within the study area, but it does not extend into either the Aurand Run or Eagle Creek AOCs. There is also one individual property listed on the NRHP within the study area. The Andrew Powell Homestead, located at 9821 County Road 313, was listed in 1986 under Criteria A, B, and C for its association with an important local individual, the gas and oil boom of the late 19th century, and its Italianate architecture. This property is not located within either of the AOCs, but is located within 200 m (656 ft) on the northern end of the Aurand Run AOC.

Fifteen individual properties listed on the Ohio Historic Inventory (OHI) are present within the study area. These include five residential properties in the City of Findlay, five properties located on McPherson Avenue in Findlay that are associated with the late 19th-century Byal Park Holiness Camp (and which appear to have been demolished), one township bridge in Findlay, a one-room schoolhouse in Liberty Township, and three rural farmsteads/homesteads (one each in Eagle, Jackson and Liberty townships). Of these 15 properties, two are located within the Eagle Creek AOC: HAN0066812 (the Light House, 13747 US Route 68) and HAN0066912 (the Hoopman House, 13754 US Route 68). Both of these properties were recorded by MSG as part of a Phase I history/architecture survey of the proposed Western Diversion Corridor (Johnson et al. 2015). No OHI properties are located within the Aurand Run AOC.

Finally, six historic cemeteries are present within the study area – four in Eagle Township, one in Jackson Township, and one in Liberty Township. All six cemeteries are either closed or abandoned, and range in condition from "neglected" to "highly maintained." None of these cemeteries are within the Aurand Run or Eagle Creek AOCs.

Within the study area, there were no sites or structures formally determined to be eligible for the NRHP and no bridges listed on the Ohio Historic Bridge Inventory.

Archaeological Resources

A total of 34 archaeological sites recorded in the Ohio Archaeological Inventory (OAI) are located within the Aurand Run/Eagle Creek study area. Of these sites, 15 represent prehistoric occupations (including Paleoindian through Early Woodland components), 5 represent both prehistoric and historic occupations and 14 represent historic occupation of the vicinity. All of the prehistoric sites and components are described as unknown site types located in open settings. A majority of these sites and components, however, date to the Early Archaic period (n=8), and 11 of them are isolated finds. The historic sites and components are all associated with Euro-American settlement. The majority of these sites are of unknown historic function (i.e., artifact scatters in locations unassociated with any documented historic occupation), but six are associated with historic farmsteads.

Twenty of the 34 archaeological sites within the study area are located within the Eagle Creek AOC. The majority of these (n=17) were documented by MSG during its 2016 Phase I archaeological survey of the proposed Western Diversion Corridor (Chidester et al. 2017). The majority of these sites were recommended not eligible for the NRHP; however, four historic sites/components (33HK0796, 33HK0803, 33HK0808, and 33HK0809) likely extend outside of the 2016 survey area and should be re-evaluated if future HCFRRP survey efforts document additional portions of these sites. Furthermore, one site recorded during the 2016 survey (33HK0805) was recommended potentially eligible for the NRHP and additional Phase II test excavations were conducted. However, laboratory processing and analysis of the resulting artifact assemblage, archival/oral historical research on the property, and reporting was not completed for the Phase II investigation. At such time as this investigation can be completed, MSG will be able to make a formal recommendation of eligibility for this site.

The three archaeological sites located within the Eagle Creek AOC that were not documented by MSG (33HK0161-0163) are all located in Eagle Township and were recorded by local amateur archaeologist Richard Carles. 33HK0161 and 33HK0162 both date to the Early Archaic period, while 33HK0163 dates to the Middle Archaic period. 33HK0161 and 33HK0163 are both isolated finds, while 33HK0162 yielded just two artifacts. While these sites have not been evaluated by professional archaeologists, it appears unlikely that any of the three would be recommended eligible or potentially eligible for the NRHP.

In addition to the OSHPO's Online Mapping website, MSG consulted William C. Mills' *Archaeological Atlas of Ohio* (1914). This atlas represents a compilation of sites throughout Ohio which had been, or currently are, associated with prehistoric mounds, earthwork enclosures, petroglyphs, burials, or villages. The atlas only references location, however, and does not provide detail about the archaeological components themselves. Furthermore, these sites were largely reported by local informants and most have never been field-verified by professional archaeologists, and therefore their exact locations are often unknown. The Mills map for Hancock County does not depict any archaeological sites within or adjacent to the Aurand Run or Eagle Creek AOCs (see Attachment C, Figure C1).

Previous Cultural Resource Surveys

The literature review also revealed that seven previous cultural resource survey reports have been completed for projects within the study area. Five of these surveys were conducted in and around the City of Findlay, including MSG's 2010 Phase I archaeological and history/architecture surveys for the Northwest Ohio Flood Mitigation Partnership (Chidester et al. 2011; Johnson et al. 2011). The other two surveys were MSG's Phase I archaeological and history/architecture surveys for the proposed Western Diversion Corridor (Chidester et al. 2017; Johnson et al. 2015), both of which passed through the Aurand Run and Eagle Creek AOCs (see Figure 6).

Historic Maps

Historic atlas, plat and topographic maps were also consulted as part of the literature review. Atlas and plat maps of Hancock County dating to 1863 (Lake), 1875 (Hardesty), and 1902 (Republican Company) depict the project area as predominantly rural during the late 19th and early 20th centuries (see Attachment C, Figures C2-C9). The modern county and township road grid was essentially in place by 1863, but no other major transportation routes passed through either the Aurand Run or Eagle Creek AOCs. The Clement Post Office is shown in the southeastern corner of the Eagle Creek AOC, although this appears to have been a rural post office without an associated settlement. On both the 1863 and 1875 maps, most structures (mostly farmhouses) were depicted adjacent to roads. On the 1863 map, 14 structures (apparently all farmhouses) are shown within the Aurand Run AOC and 53 structures are shown within the Eagle Creek AOC (mostly farmhouses, but including one schoolhouse). On the 1875 map, 16 structures (all apparently houses) are shown within the Aurand Run AOC and 37 structures are shown within the Eagle Creek AOC (mostly farmhouses, but including one church and two schoolhouses). By 1902, at least three electric inter-urban rail lines passed through the two AOCs, as well as the Toledo & Ohio Central Railway, which ran parallel to the eastern edge of the Eagle Creek AOC. The 1902 map does not depict structure locations.

The 1903 Findlay, OH and 1907 Arlington, OH 15’ topographic quadrangles (USGS 2018a, b) were also reviewed (see Attachment C, Figure C10). While quadrangle maps do not show parcel boundaries, they do indicate structure locations and provide other clues as to land uses. As with the atlas and plat maps, the 1903 and 1907 quadrangles depict structures primarily along roads, although a few structures are located in the middle of parcels. These maps also clearly depict the extent to which natural streams had been channelized into agricultural ditches by that time through the Aurand Run and Eagle Creek AOCs. A total of 13 structures are depicted within the Aurand Run AOC (all apparently farmhouses) and 57 structures (mostly farmhouses, but including one church) are shown within the Eagle Creek AOC.

BLANCHARD RIVER/POTATO RUN STUDY AREA

Previously Recorded Cultural Resources

The results of the literature review for this study area are presented graphically in Figure 7, and in tabulated form in Attachment B, Tables B7-B10.

Above-Ground Cultural Resources

Within the 2.0-mile buffer study area, 69 previously recorded above-ground resources are present. Fifty-nine of these resources are properties listed on the OHI, while ten are historic cemeteries.

The 59 OHI properties represent a range of time periods and site functions. Thirty of them are properties located in the Village of Wharton (Wyandot County), including many single-family houses, a hotel, a social fraternity, a railroad depot, and township government building. The remaining properties are all rural farmsteads or homesteads, mostly located in Delaware Township (Hancock County) and Richland Township (Wyandot County). (One property located in Madison Township [Hancock County] is also included.) Two Italianate-style houses are present (one each in Delaware and Richland townships), but the rest of the properties are recorded as vernacular structures. The OHI properties range in date from 1850-1925, although it should be noted that with a single exception the properties located in Wharton do not have recorded dates.

Only three of the OHI properties are located within the Blanchard River AOC, and none are located within the Potato Run AOC. The three properties within the Blanchard River AOC are all vernacular farmhouses located along State Route 103 or Township Road 270 in Delaware Township. They were all recorded during a Phase I cultural resources survey conducted by ASC Group, Inc. in 2002 for a bridge replacement and the associated realignment of Township Road 187 (Mustain et al. 2002). All three properties were described as lacking physical integrity and historical significance and were recommended not eligible for the NRHP, although it is currently unknown whether the OSHPO concurred with these recommendations.

Nine of the ten historic cemeteries within the study area are located in Hancock County (distributed among Amanda, Delaware, and Jackson townships), although they are spread out around the study area. The remaining cemetery is located in Richland Township. Only two of the cemeteries are specifically listed as inactive, but it is likely that several more are also closed to new burials. One of the cemeteries is described as endangered (presumably due to neglect), four are described as neglected, one is moderately maintained, and four are highly maintained.

One historic cemetery is located within the Blanchard River AOC. The Earlywine Cemetery is located on the north side of Township Road 151 just west of Township Road 184, at the western edge of the AOC, and is listed as neglected. Current aerial mapping, however, indicates that the cemetery occupies approximately a half-acre and appears to be mowed. Well over 50 headstones are visible, although an exact count cannot be determined from aerial imagery.

One historic cemetery is located in the Potato Run AOC as well. The Adams Cemetery is located on the north side of Township Road 105 just west of the county line in Delaware Township, near the center of the AOC, and is listed as being moderately maintained. Current aerial mapping indicates that the cemetery occupies approximately a half-acre and appears to be mowed. Approximately 30 headstones are visible, although an exact count cannot be determined from aerial imagery.

Within the study area, there were no historic districts, sites or structures listed in or formally determined to be eligible for the NRHP and no bridges listed on the Ohio Historic Bridge Inventory.

Archaeological Resources

A total of 146 archaeological sites recorded in the OAI are located within the Blanchard River/Potato Run study area. Of these sites, 126 represent prehistoric occupations (including Paleoindian through Late Prehistoric components), 7 represent both prehistoric and historic occupations and 13 represent historic occupation of the vicinity. All of the prehistoric sites and components are described as unknown site types located in open settings; 77 of them are isolated finds. A majority of these sites and components date to unknown periods of prehistory (n=101). The historic sites and components are all associated with Euro-American settlement. The majority of these sites are associated with historic farmsteads or rural homesteads (n=11); two former railroad beds are also present.

None of the previously recorded archaeological sites are located within the Potato Run AOC, but 26 of the sites are located within the Blanchard River AOC. Twenty-five of these (33HK0658 – 33HK0682) were recorded during the Phase I cultural resources survey conducted by ASC Group, Inc. in 2002 for a bridge replacement and the associated realignment of Township Road 187, referenced above (Mustain et al. 2002). None of these 25 sites were recommended eligible for the NRHP, although it is currently unknown whether the OSHPO concurred with these recommendations. The remaining archaeological site located within the Blanchard River AOC, 33HK0700 is a prehistoric isolated find located just north of State Route 103 near the northern edge of the AOC. This site was recorded in 2003 during a Phase I archaeological survey conducted by Professional Archaeological Services Team for a water treatment plant (Keener 2003). As an isolated find, this site is not eligible for the NRHP.

In addition to the OSHPO's Online Mapping website, MSG consulted Mills' *Archaeological Atlas of Ohio* (1914). The Mills map for Hancock County depicts two "ordinary interments" within the study area – one located in the village of Mt. Blanchard just west of Potato Run, and the other located within the Blanchard River AOC between the Blanchard River and County Road 17, just south of Township Road 152 (see Attachment C, Figure C11). This latter site is relatively close to the location of a mound described briefly in the Mt. Blanchard sesquicentennial history book (Mt. Blanchard Historical Society 1980), which was supposedly located "a few rods north-northwest of the Wolford Mill (later Fahl Mill)…" near or on the Mitchell farm at 19535 Township Road 187. It is likely that the site depicted by Mills is the same as this reported mound. Whether the mound still exists is currently unknown, although if it was a burial mound then it seems likely that prehistoric human remains are still present, even if the mound itself has been plowed into oblivion (as often happens in northwest Ohio). The Mills map for Wyandot County does not depict any archaeological sites within or adjacent to the Potato Run AOC (see Attachment C, Figure C12).

Previous Cultural Resource Surveys

The literature review also revealed that 11 previous cultural resource investigations have been completed for projects within the study area (see Figure 7). Five of these investigations (three Phase I surveys and two Phase II evaluation studies) were conducted in the 1990s for the U.S. Route 30 relocation project. The remaining surveys were conducted for wastewater treatment plant, cell tower, and gas pipeline projects, as well as the aforementioned survey conducted for the bridge replacement and realignment of Township Road 187. Apart from this last survey, which covered approximately 180 acres, only a small linear portion of one of the wastewater treatment plant surveys included any portion of the Blanchard River/Potato Run AOCs.

Historic Maps

Atlas and plat maps of Hancock County dating to 1863 (Lake), 1875 (Hardesty), and 1902 (Republican Company), and of Wyandot County dating to 1879 (Hare) and 1939 (Hixson), depict the Blanchard River and Potato Run AOCs as predominantly rural during the late 19th century (see Attachment C, Figures C13-C17). The modern county and township road grid was essentially in place by 1863 in Hancock County and by 1879 in Wyandot County, but no other major transportation routes passed through either the Blanchard River or Potato Run AOCs. On the 1863 and 1875 Hancock County and 1879 Wyandot County maps, most structures (mostly farmhouses) were depicted adjacent to roads, with only a few located further towards the center of parcels. On the 1863 Hancock County map, 41 structures (all apparently farmhouses) are shown within the Blanchard River AOC. On the 1875 Hancock County map, 48 structures (mostly farmhouses, but including one schoolhouse and a stock scale) are shown within the Blanchard River AOC and 29 structures are shown within the Potato Run AOC (mostly farmhouses, but including one schoolhouse). On the 1879 Wyandot County map, 14 structures (mostly farmhouses, but including a "scale") are depicted within the Potato Run AOC. By 1902, the Mt. Blanchard electric inter-urban rail line ran in a loop from Mt. Blanchard through the northeastern corner of the Blanchard River AOC and the central part of the Potato Run AOC before turning back west and running just south of the AOCs, then through the southwestern corner of the Blanchard River AOC and back north again. The 1902 Hancock County map and the 1939 Wyandot County map do not depict structure locations.

The 1907 Arlington, OH and 1907 Upper Sandusky, OH 15' topographic quadrangles (USGS 2018b, c) were also reviewed (see Attachment C, Figure C18). As with the atlas and plat maps, the 1907 quadrangles depict structures primarily along roads. The extent of stream channelization for agricultural irrigation was significantly less within the Blanchard River and Potato Run AOCs than it was in the Aurand Run and Eagle Creek AOCs. A total of 38 structures are depicted within the Blanchard River AOC (mostly farmhouses, but including one church) and 40 structures (all apparently farmhouses) are shown within the Potato Run AOC. The locations of both the Earlywine and Adams cemeteries are also depicted.

SUMMARY AND RECOMMENDATIONS

Aurand Run/Eagle Creek AOCs

Based on the results of this cultural resources literature review, the Aurand Run and Eagle Creek AOCs exhibit a generally moderate to high probability of containing both prehistoric and historic archaeological resources. In particular, those areas close to county and township roads that have been in existence since the 19th century, and areas in close proximity to Eagle Creek, Aurand Run, and their tributaries, exhibit the highest probability for archaeological resources. The archaeological site types most likely to be present within these AOCs are small, single-component prehistoric archaeological sites representing Archaic-period activity dispersed across the landscape, and 19th-20th-century farmsteads.

There is also a high probability that historic buildings and structures are present in the Aurand Run and Eagle Creek AOCs. Because these areas remain largely rural, many of the buildings shown on 19th-century maps will be farmhouses, and the farmstead complex associated with it may include other types of agricultural outbuildings, such as barns, granaries, and other specialized buildings. Most 19th- and early 20th-century rural residences will be vernacular types, although more popular national styles (e.g., Gothic Revival, Italianate, etc.) may also occur. By the 1930s, architecture has become more standardized, even in rural settings, and bungalows, Cape Cod cottages, and Ranch type homes will occur with greater frequency, either replacing older buildings or built on the smaller lots created as farmsteads are subdivided.

In order to aid planning efforts for the HCFRRP, MSG has developed general estimates for cultural resources investigations of the Aurand Run and Eagle Creek AOCs. These estimates are presented in Table 1.

Table 1. Estimated Costs, Aurand Run and Eagle Creek AOCs

	Archaeological Investigations			Architectural Investigations	
	Aurand Run	Eagle Creek		Aurand Run	Eagle Creek
Total Acreage	713	5297		713	5297
Phase I Survey of Entire AOC	$200,000	$1,100,000		$15,325	$19,750
Phase I Survey Cost/Acre	$280.50	$207.66		NA	NA
Geomorphological Assessment / Deep Testing	$15,000	$30,000		NA	NA
Estimated # of Phase II Investigations	2	17		5	8
Cost per Phase II Investigation	$35,000	$22,000		$11,400	$11,400
Estimated # of Phase III Investigations	1	2		1	1
Cost per Phase III Investigation	$100,000 - $400,000	$100,000 - $400,000		$14,000	$14,000

These general estimates are based on the following assumptions:

- Approximately 10% of the ground surface in both AOCs has been disturbed by modern activity.
- Approximately 55% of the acreage of agricultural fields in both AOCs will require archaeological shovel testing, while 45% of the agricultural acreage will require archaeological pedestrian surface survey.
- The OSHPO will accept the use of a similar predictive modeling technique as has been used in prior surveys for the HCFRRP to help guide archaeological survey intensity and methods.
- No more than 35 archaeological sites will be identified within the Aurand Run AOC during Phase I survey (assuming survey coverage of the entire AOC), and no more than 280 archaeological sites will be identified within the Eagle Creek AOC during Phase I survey (assuming survey coverage of the entire AOC).
- No more than 18 architectural sites will be documented for the Phase I survey in the Aurand Run AOC, and no more than 5 sites will be recorded on OHI forms ;
- No more than 30 architectural sites will be documented for the Phase I survey in the Eagle Creek AOC, and no more than 8 sites will be recorded on OHI forms;
- The survey and documentation methodology for Phase I architectural investigations will follow the same methods presented in MSG's 2010 study plan (Johnson et al. 2010).

Blanchard River/Potato Run AOCs

Based on the results of this cultural resources literature review, the Blanchard River and Potato Run AOCs exhibit a generally high probability of containing both prehistoric and historic archaeological resources. In particular, those areas close to county and township roads that have been in existence since the 19th century, and areas in close proximity to the Blanchard River, Potato Run, and their tributaries exhibit the highest probability for archaeological resources. The archaeological site types most likely to be present within these AOCs are small, single-component prehistoric archaeological sites representing Archaic-period activity dispersed across the landscape; larger, seasonal base camps representing Woodland-period activity; and 19th-20th-century farmsteads.

There is also a high probability that historic buildings and structures are present in the Blanchard River and Potato Run AOCs. Because these areas remain largely rural, many of the buildings shown on 19th-century maps will be farmhouses, and the farmstead complex associated with them may include other types of agricultural outbuildings, such as barns, granaries, and other specialized buildings. Most 19th- and early 20th-century rural residences will be vernacular types, although more popular national styles (e.g., Gothic Revival, Italianate, etc.) may also occur. By the 1930s, architecture became more standardized, even in rural settings, and bungalows, Cape Cod cottages, and

Ranch type homes will occur with greater frequency, either replacing older buildings or built on the smaller lots created as farmsteads are subdivided.

In order to aid planning efforts for the HCFRRP, MSG has developed general estimates for cultural resources investigations of the Blanchard River and Potato AOCs. These estimates are presented in Table 2.

Table 2. Estimated Costs, Blanchard River and Potato Run AOCs

	Archaeological Investigations			Architectural Investigations	
	Blanchard River	Potato Run		Blanchard River	Potato Run
Total Acreage	3668	3384		3668	3384
Phase I Survey of Entire AOC	$860,000	$780,000		$29,825	$22,450
Phase I Survey Cost/Acre	$234.46	$230.50		NA	NA
Geomorphological Assessment / Deep Testing	$30,000	$30,000		NA	NA
Estimated # of Phase II Investigations	12	11		8	8
Cost per Phase II Investigation	$26,000	$26,000		$11,400	$11,400
Estimated # of Phase III Investigations	2	2		1	1
Cost per Phase III Investigation	$100,000 - $400,000	$100,000 - $400,000		$14,000	$14,000
Estimated # of Historic Cemetery Removals	1	1			
Cost per Cemetery Removal	$100,000	$100,000			

These general estimates are based on the following assumptions:

- Approximately 2% of the ground surface in the Blanchard River AOC and 3% of the ground surface in the Potato Run AOC have been disturbed by modern activity.
- Approximately 55% of the acreage of agricultural fields in both AOCs will require archaeological shovel testing, while 45% of the agricultural acreage will require archaeological pedestrian surface survey.
- The OSHPO will accept the use of a similar predictive modeling technique as has been used in prior surveys for the HCFRRP to help guide archaeological survey intensity and methods.
- No more than 200 archaeological sites will be identified within the Blanchard River AOC during Phase I survey (assuming survey coverage of the entire AOC), and no more than 185 archaeological sites will be identified within the Potato Run AOC during Phase I survey (assuming survey coverage of the entire AOC).
- No more than 36 architectural sites will be documented for the Phase I survey in the Potato Creek AOC, and no more than 8 sites will be recorded on OHI forms ;
- No more than 40 architectural sites will be documented for the Phase I survey in the Blanchard River AOC, and no more than 8 sites will be recorded on OHI forms;
- The survey and documentation methodology for Phase I architectural investigations will follow the same methods presented in MSG's 2010 study plan (Johnson et al. 2010).

If you have any questions about the information presented in this report, or our recommendations and estimates for cultural resource investigations within the four AOCs, please do not hesitate to contact us at 419-891-2222.

Sincerely,

Robert C. Chidester, Ph.D., RPA	Maura Johnson, M.A.
Principal Investigator	Project Manager

Chidester, R. C., P. R. Bauschard, K. J. Hayfield, J. P. Molenda, A. Darkow, and D. R. Hayes
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ATTACHMENT A

FIGURES

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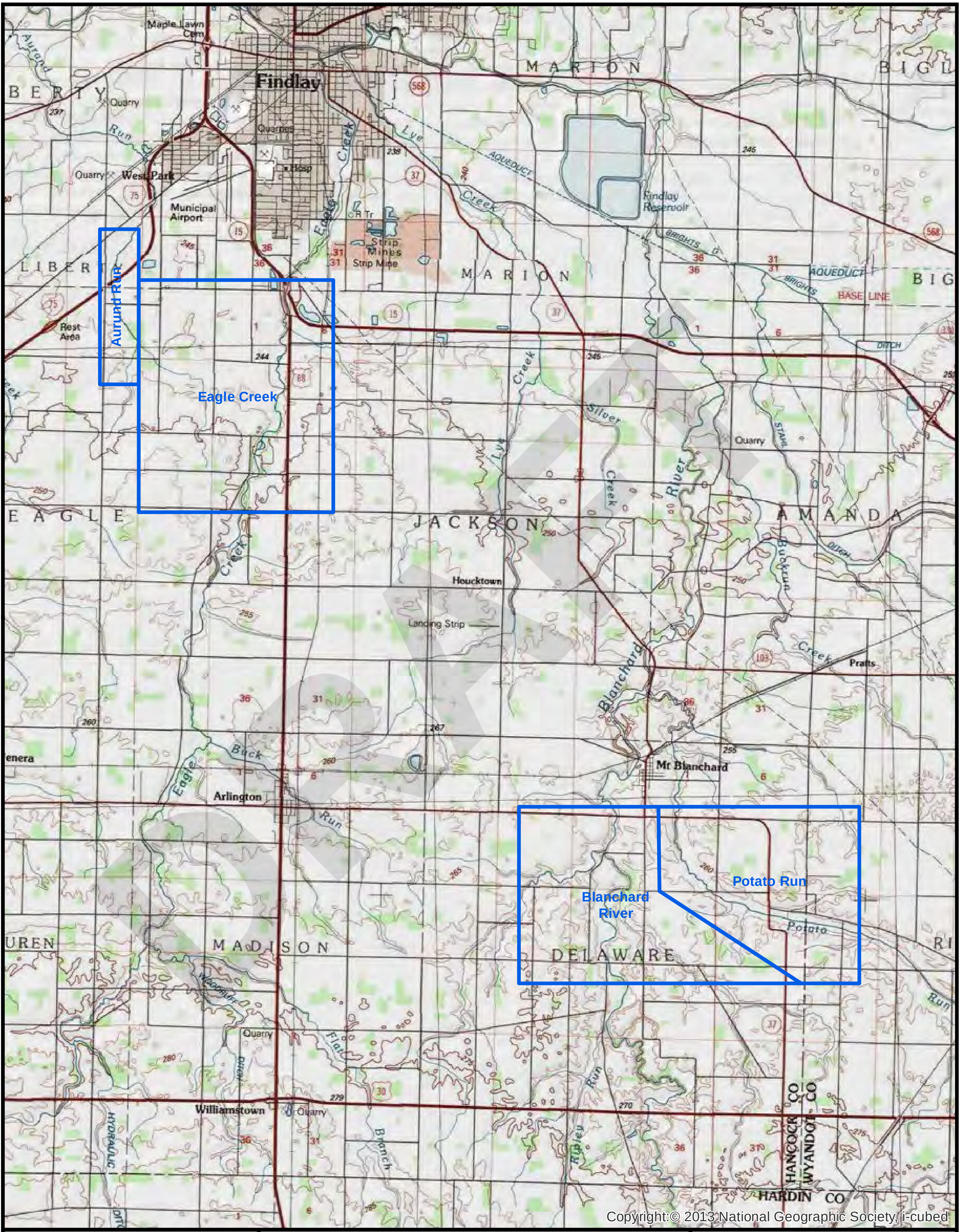

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Figure 1: Project Location
Areas of Concern
HCFRRP
Hancock & Wyandot Counties, Ohio

Notes

USGS Quadrangle
30 x 60' Minute Series Topographic
Marion, OH 1986, Revised 1989

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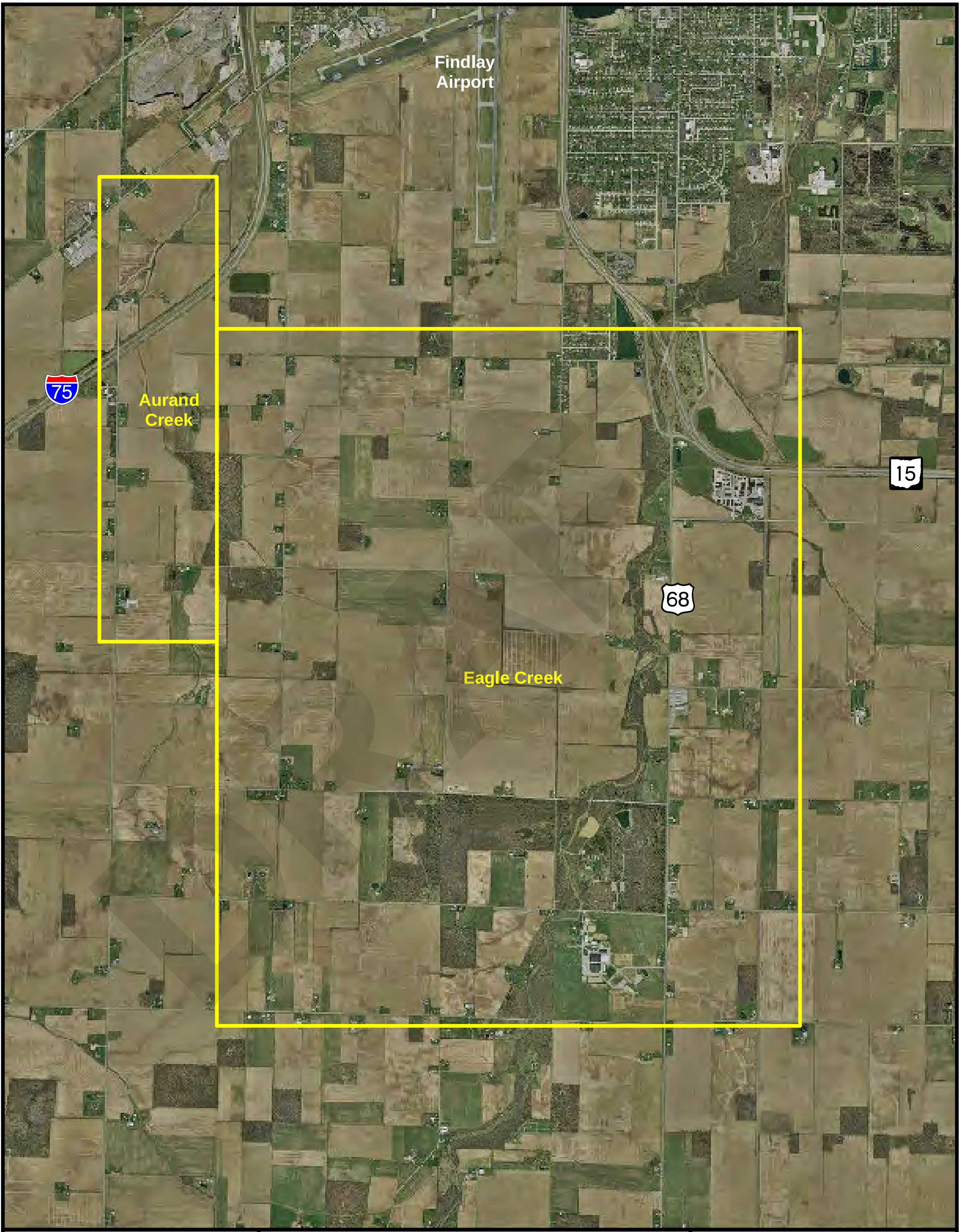

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Figure 2: Aurand Run & Eagle Creek
Areas of Concern
HCFRRP
Hancock & Wyandot Counties, Ohio

Notes

The arerial dated Spring 2013 is provided by OGRIP as part of the Ohio Statewide Imagery Program

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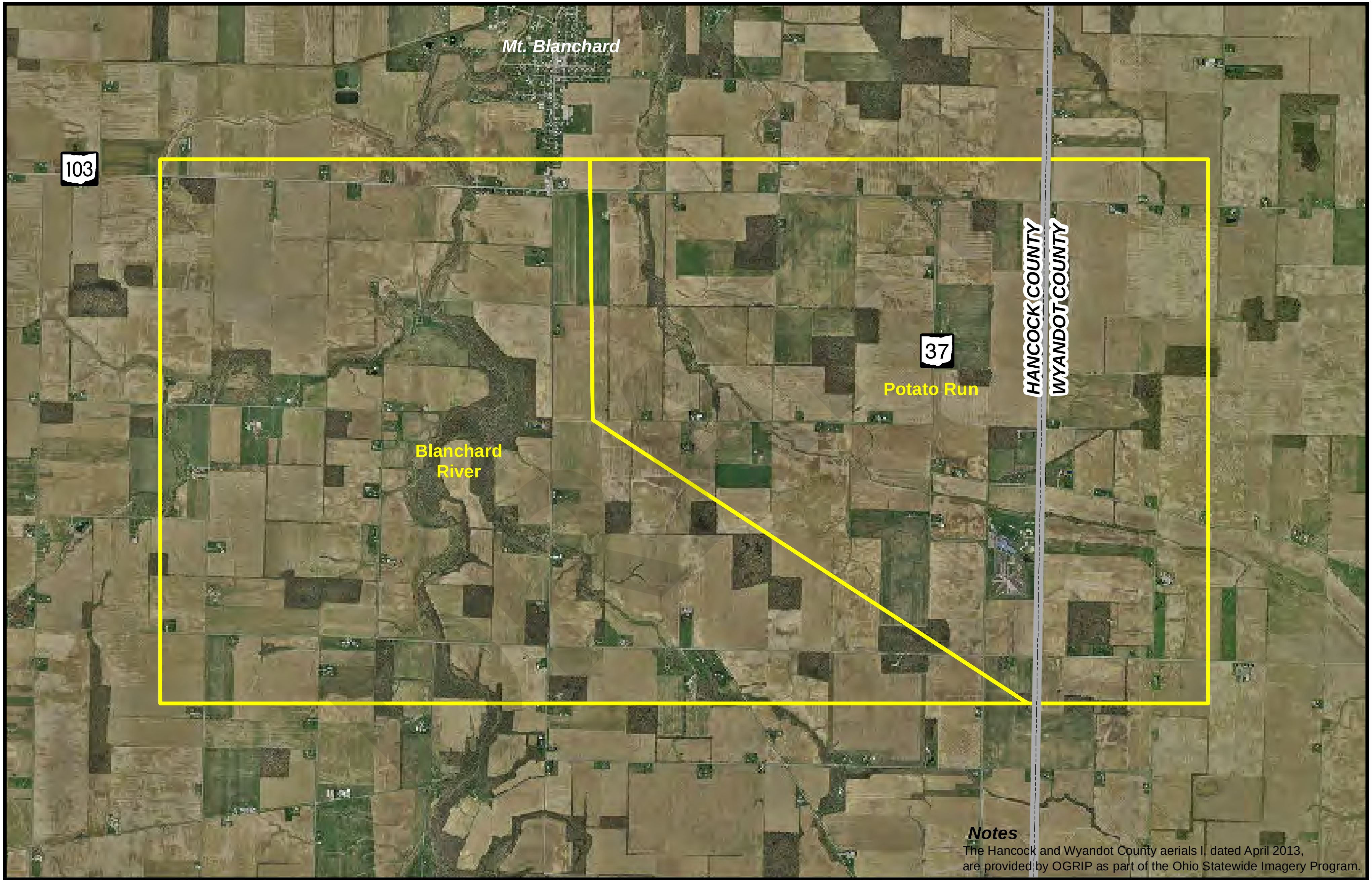

Notes

The Hancock and Wyandot County aerials I, dated April 2013, are provided by OGRIP as part of the Ohio Statewide Imagery Program.

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Figure 3: Blanchard River and Potato Run Areas of Concern HCFRRP Hancock & Wyandot Counties, Ohio

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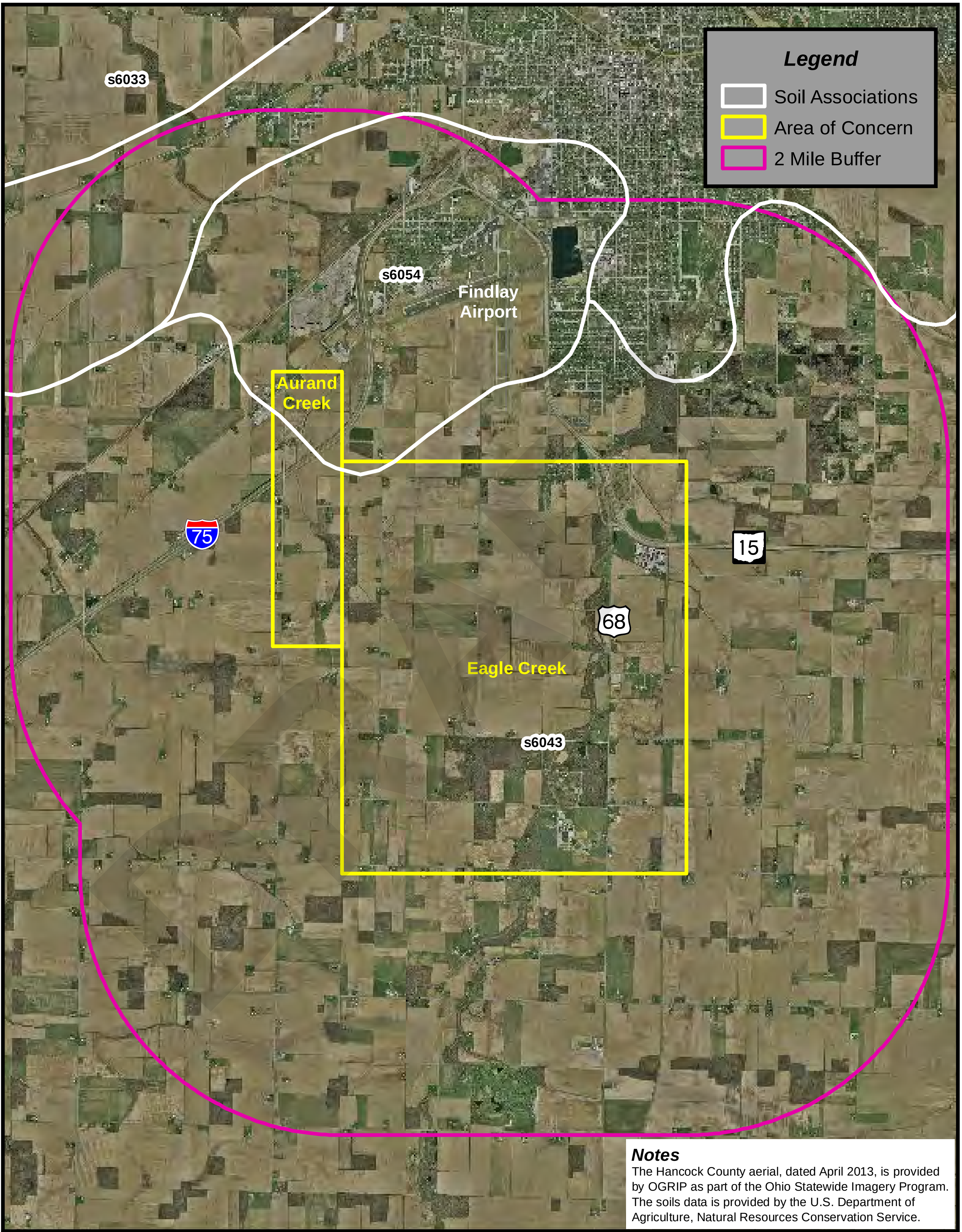

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The Hancock County aerial, dated April 2013, is provided by OGRIP as part of the Ohio Statewide Imagery Program. The soils data is provided by the U.S. Department of Agriculture, Natural Resources Conservation Service.

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Figure 4: Soil Associations
Aurand Run & Eagle Creek AOC
HCFRRP
Hancock & Wyandot Counties, Ohio

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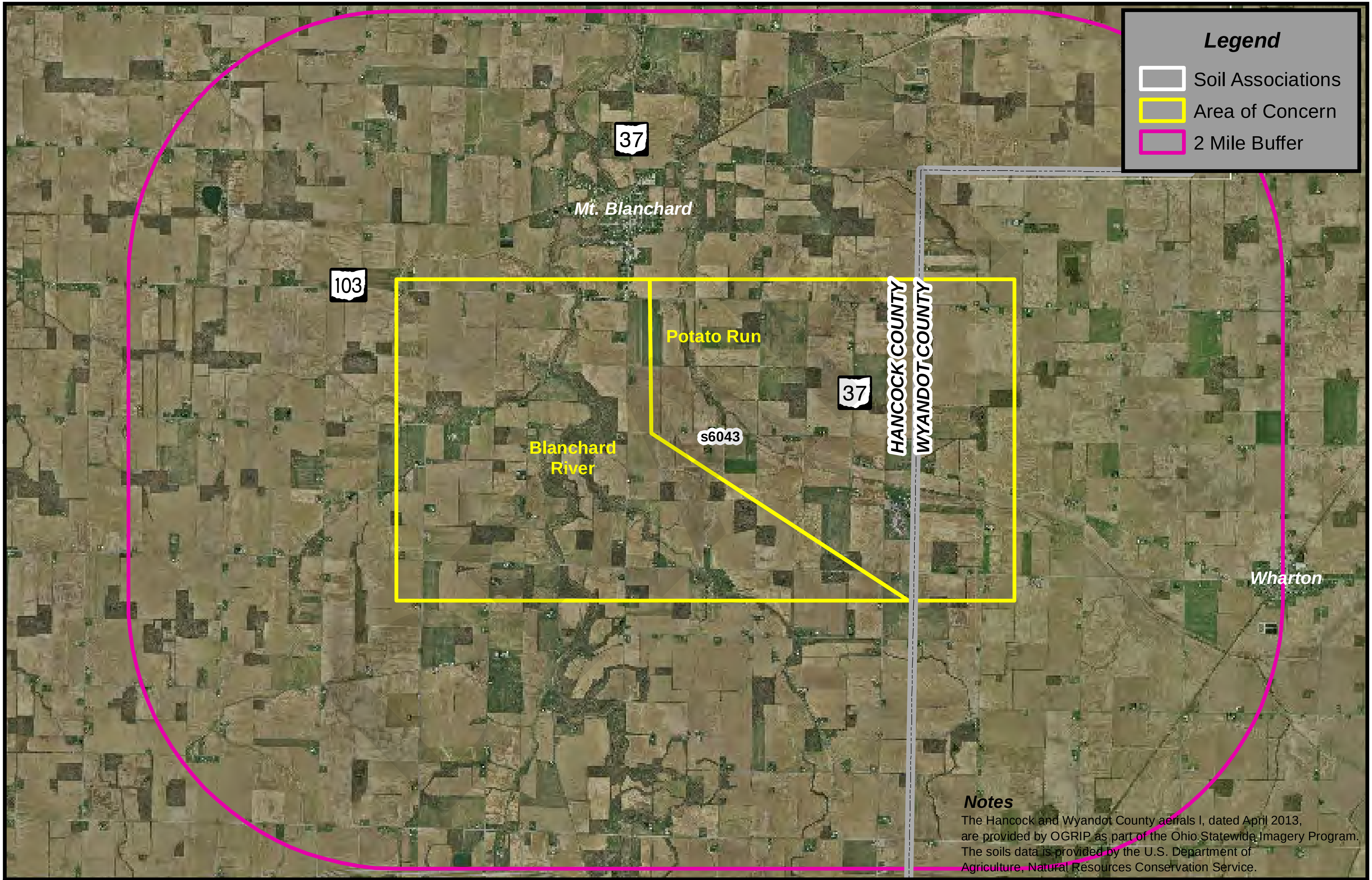

Notes

The Hancock and Wyandot County aerials l, dated April 2013, are provided by OGRIP as part of the Ohio Statewide Imagery Program. The soils data is provided by the U.S. Department of Agriculture, Natural Resources Conservation Service.

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Figure 5: Soil Associations
Blanchard River and Potato Run AOC
HCFRRP
Hancock & Wyandot Counties, Ohio

0 2,500 5,000 Feet

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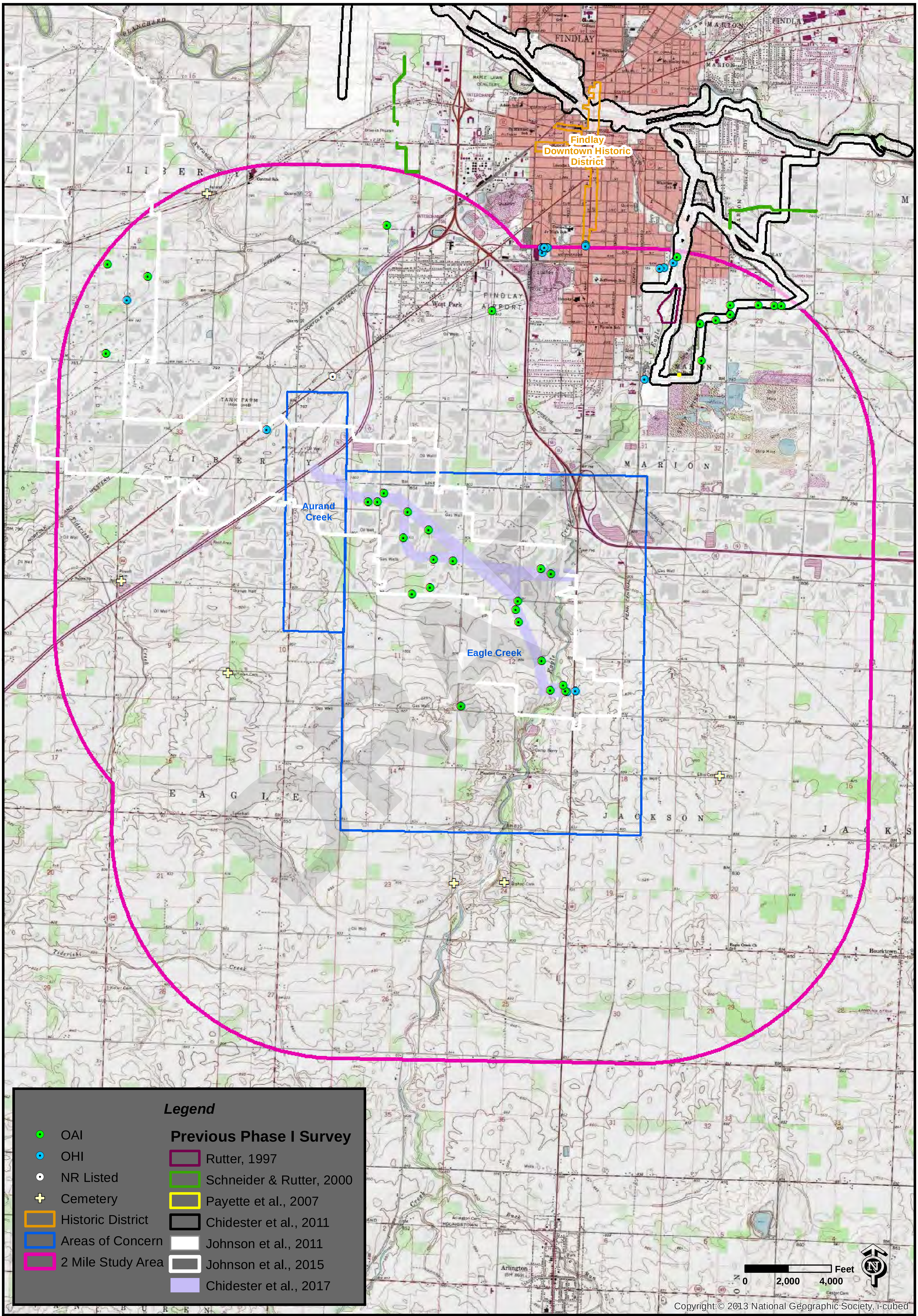

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Figure 6: Literature Review
Aurand Run and Eagle Creek Areas of Concern
HCFRRP
Hancock & Wyandot Counties, Ohio

Notes
USGS Quadrangle, 7.5' Series Topographic
Arcadia, Hancock Co., OH 1960, Revised 1972
Arlington, Hancock Co., OH 1959, Revised 1977
Findlay, Hancock Co., OH 1959, Revised 1977
Mount Blanchard, OH 1960, Revised 1980

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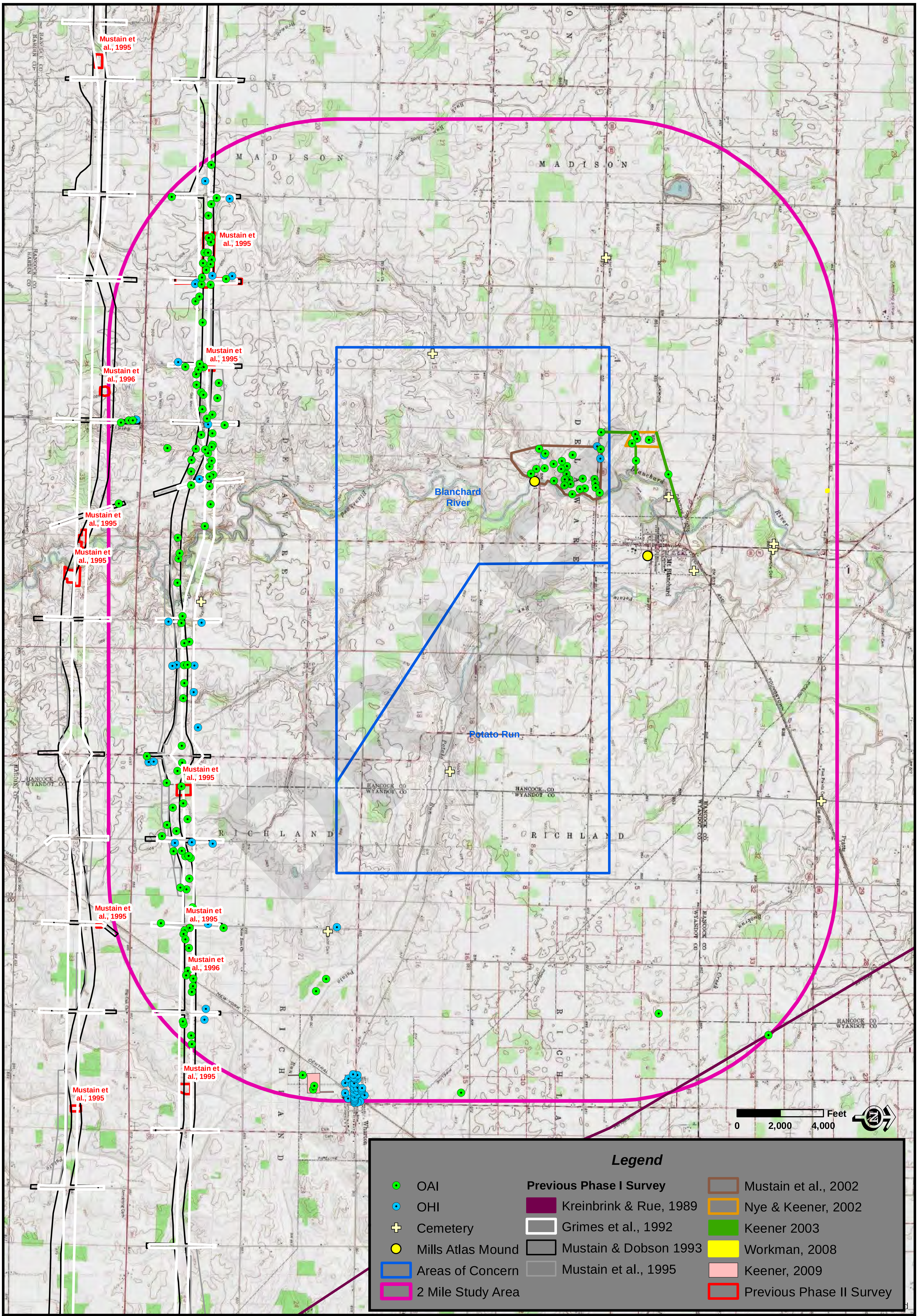

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Figure 7: Literature Review
Blanchard River and Potato Run Areas of Concern
HCFRRP
Hancock & Wyandot Counties, Ohio

Notes

USGS Quadrangle, 7.5' Series Topographic
Carey, OH 1961, Revised 1980
Forest, OH 1961, Revised 1980
Mount Blanchard, OH 1960, Revised 1980
Wharton, OH 1959, Revised 1977

ATTACHMENT B

TABLES

Table B1
Aurand Run/Eagle Creek Study Area
NRHP - Historic Districts

Reference #	District Name	# of Properties	Place Name	County	Within AOC?
85000402	Findlay Downtown Historic District	263	Findlay	Hancock	No

Table B2
Aurand Run/Eagle Creek Study Area
NRHP - Individual Properties

Reference #	UTM Zone	Easting	Northing	Resource Name	Address	City	County	Primary Historic Function	Applicable Criteria	Within AOC?
86003449	17	273562	4542805	Powell, Andrew, Homestead	9821 CR 313	Findlay	Hancock	Domestic	A, B, C	No

Table B3
Aurand Run/Eagle Creek Study Area
Ohio Historic Inventory

OHI #	UTM Zone	Easting	Northing	Present Name	Other Name	Address	Place Name	County	Architectural Style	Primary Historic Function	Date	Within AOC?
HAN0034508	17	277129	4544663	Mary Marks Lea House		1300 S Main St	Findlay	Hancock	Colonial Revival	Single Dwelling	1916	No
HAN0034608	17	277129	4544648	James & Barbara Pelowski House	John H Decker House	1304 S Main St	Findlay	Hancock	Second Empire / Mansard	Single Dwelling	1885	No
HAN0042408	17	276515	4544626	Byal Park Camp Mtg Main Bldg	Hancock Co Holiness Camp Meeting	McPherson Ave at Stadium Dr	Findlay	Hancock	Vernacular	Social	1893	No
HAN0042508	17	276523	4544558	Byal PK Camp Mtg Tabernacle	Hancock Co Holiness Camp Meeting	McPherson Ave at Stadium Dr	Findlay	Hancock	Vernacular	Social	1893	No
HAN0042608	17	276588	4544626	Byal PK Camp Mtg Cottage	Hancock Co Holiness Camp Meeting	McPherson Ave at Stadium Dr	Findlay	Hancock	Vernacular	Social	1895	No
HAN0042708	17	276539	4544626	Byal Park Camp Mtg Cottage	Hancock Co Holiness Camp Meeting	McPherson Ave at Stadium Dr	Findlay	Hancock	Vernacular	Social	1895	No
HAN0042808	17	276555	4544626	Byal Park Camp Mtg Cottage	Hancock Co Holiness Camp Meeting	McPherson Ave at Stadium Dr	Findlay	Hancock	Vernacular	Social	1895	No

Table B4
Aurand Run/Eagle Creek Study Area
Historic Cemeteries

OGS ID #	UTM Zone	Easting	Northing	Cemetery Name	City / Twp	County	Twp/Range	Section	Burial Status	Burial Condition	Location Confidence	Within AOC?
4803	17	275969	4535661	Bishop	Eagle	Hancock	T1S:R10E	SW1/4 of S24	Inactive	Moderate Maintenance	Yes	No
4804	17	272075	4538620	Hartman	Eagle	Hancock	T1S:R10E	SE1/4 of S9	Inactive	Neglected	Yes	No
4806	17	275260	4535658	Line	Eagle	Hancock	T1S:R10E	SW1/4 of S24	Inactive	Moderate Maintenance	Yes	No
4807	17	270570	4539917	Powell	Eagle	Hancock	T1S:R10E	SW1/4 corner of S4	Inactive	Moderate Maintenance	Yes	No
4813	17	279009	4537170	Ellis	Jackson	Hancock	T1S:R11E	NW1/4 of S17	Inactive	Moderate Maintenance	Yes	No
4817	17	271778	4545387	Aurand-Schoonover-Wagner	Liberty	Hancock	T1N:R10E	E center of S21	Closed	Highly Maintained	Yes	No

Table B5
Aurand Run/Eagle Creek Study Area
Ohio Archaeological Inventory

OAI #	UTM Zone	Easting	Northing	Quad Name	Temporal Affiliation	Cultural Affiliation	Site Function	County	Site Area (m2)	Setting	Within AOC?
33HK0161	17	274687	4539741	Arlington	Prehistoric	Early Archaic	Unknown	Hancock	1	Open	Yes - Eagle Creek
33HK0162	17	274942	4539826	Arlington	Prehistoric	Early Archaic	Unknown	Hancock		Open	Yes - Eagle Creek
33HK0163	17	275373	4538155	Arlington	Prehistoric	Middle Archaic	Unknown	Hancock	1	Open	Yes - Eagle Creek
33HK0596	17	274328	4544945	Findlay	Prehistoric	Early Archaic	Unknown	Hancock	1	Open	No
33HK0597	17	270956	4544216	Findlay	Prehistoric	Early Archaic	Unknown	Hancock	1	Open	No
33HK0598	17	270387	4544397	Findlay	Prehistoric	Early Archaic	Unknown	Hancock		Open	No
33HK0599	17	270370	4543130	Findlay	Prehistoric	Early Archaic	Unknown	Hancock	1	Open	No
33HK0605	17	275807	4543733	Findlay	Prehistoric	Early Archaic	Unknown	Hancock		Open	No
33HK0729	17	279573	4543813	Arcadia	Historic	Euro-American	Unknown	Hancock	438	Open	No
33HK0730	17	279792	4543806	Arcadia	Historic	Euro-American	Unknown	Hancock	995	Open	No
33HK0731	17	279890	4543803	Arcadia	Historic	Euro-American	Unknown	Hancock	25	Open	No
33HK0733	17	278424	4544493	Findlay	Historic	Euro-American	Unknown	Hancock	186	Open	No
33HK0738	17	278748	4543550	Findlay	Prehistoric and Historic	Prehistoric - Unknown; Euro-American	Prehistoric - Unknown; Historic - Unknown	Hancock	625	Open	No
33HK0739	17	278968	4543599	Findlay	Prehistoric and Historic	Early Archaic; Euro-American	Prehistoric - Unknown; Historic - Unknown	Hancock	14109	Open	No
33HK0741	17	279176	4543678	Findlay	Historic	Euro-American	Unknown	Hancock	15	Open	No
33HK0747	17	278766	4543028	Findlay	Prehistoric and Historic	Prehistoric - Unknown; Euro-American	Prehistoric - Unknown; Historic - Unknown	Hancock	17763	Open	No
33HK0748	17	279176	4543817	Findlay	Prehistoric	Late Archaic	Unknown	Hancock	1	Open	No
33HK0793	17	276147	4539510.9	Arlington	Prehistoric	Unknown	Unknown	Hancock	1	Open	Yes - Eagle Creek
33HK0794	17	276497	4540092.3	Arlington	Historic	Euro-American	Unknown	Hancock	502	Open	Yes - Eagle Creek

Table B5
Aurand Run/Eagle Creek Study Area
Ohio Archaeological Inventory

OAI #	UTM Zone	Easting	Northing	Quad Name	Temporal Affiliation	Cultural Affiliation	Site Function	County	Site Area (m2)	Setting	Within AOC?
33HK0795	17	274060	4541040.7	Arlington	Historic	Euro-American	Unknown	Hancock	475	Open	Yes - Eagle Creek
33HK0796	17	276846	4538371.4	Arlington	Prehistoric and Historic	Prehistoric - Unknown; Euro-American	Prehistoric - Unknown; Historic - Farmstead	Hancock	5520	Open	Yes - Eagle Creek
33HK0797	17	276815	4538446	Arlington	Prehistoric	Unknown	Unknown	Hancock	854	Open	Yes - Eagle Creek
33HK0798	17	276637	4538380.6	Arlington	Prehistoric and Historic	Prehistoric - Unknown; Euro-American	Prehistoric - Unknown; Historic - Unknown	Hancock	803	Open	Yes - Eagle Creek
33HK0799	17	276516	4538793	Arlington	Prehistoric	Unknown	Unknown	Hancock	1	Open	Yes - Eagle Creek
33HK0800	17	276176	4539634.1	Arlington	Historic	Euro-American	Unknown	Hancock	607	Open	Yes - Eagle Creek
33HK0801	17	276187	4539341.1	Arlington	Prehistoric	Late Paleoindian	Unknown	Hancock	1	Open	Yes - Eagle Creek
33HK0802	17	276648	4540022.2	Arlington	Prehistoric	Unknown	Unknown	Hancock	1	Open	Yes - Eagle Creek
33HK0803	17	275270	4540202.4	Arlington	Historic	Euro-American	Farmstead	Hancock	4834	Open	Yes - Eagle Creek
33HK0804	17	274985	4540226.4	Arlington	Prehistoric	Early Woodland	Unknown	Hancock	1	Open	Yes - Eagle Creek
33HK0805	17	274916	4540651.9	Arlington	Historic	Euro-American	Farmstead	Hancock	14088	Open	Yes - Eagle Creek
33HK0806	17	274561	4540535.3	Arlington	Historic	Euro-American	Unknown	Hancock	583	Open	Yes - Eagle Creek
33HK0807	17	274618	4540895.7	Arlington	Historic	Euro-American	Farmstead	Hancock	981	Open	Yes - Eagle Creek
33HK0808	17	274291	4541157.3	Arlington	Historic	Euro-American	Farmstead	Hancock	2932	Open	Yes - Eagle Creek

Table B5
Aurand Run/Eagle Creek Study Area
Ohio Archaeological Inventory

OAI #	UTM Zone	Easting	Northing	Quad Name	Temporal Affiliation	Cultural Affiliation	Site Function	County	Site Area (m2)	Setting	Within AOC?
33HK0809	17	274194	4541038.3	Arlington	Historic	Euro-American	Farmstead	Hancock	1051	Open	Yes - Eagle Creek

Table B6
Aurand Run/Eagle Creek Study Area
Previous Cultural Resources Investigations

NADB #	Phase	Title	Primary Author	Secondary Author(s)	Conducted by	County	Year	Acres
13791	1	Phase I Archaeological Survey, Natureworks Grants Program, Emory Adams Sports Park Expansion 19 Acres West of Brookside Drive, City of Findlay, Hancock County, Ohio	Rutter, William E.		Midwest Environmental Consultants, Inc.	Hancock	1997	23.43
14707	1	Phase I Archaeological Reconnaissance of the Southwest, Southeast, Hillcrest, and Bright Road Interceptor Corridors, Wastewater System Upgrade, Liberty Township Sections 2, 14, and 23, and Marion Township Sections 9 and 20, Hancock County, Ohio	Schneider, Andrew M.	William E. Rutter	Midwest Environmental Consultants, Inc.	Hancock	2000	20.86
17709	1	Phase I Cultural Resource Investigation of a Proposed OH-Findlay Airport Telecommunications Tower Project Area, Findlay, Marion Township, Hancock County, Ohio	Payette, Jacquie	Patrick Hendrix, Angela Behner	Environmental Resources Management	Hancock	2007	0.24
19874	1	Phase I Archaeological Survey for the Proposed Columbia Gas Transmission, LLC Leach Xpress Project Fairfield, Hocking, Jackson, Lawrence, Monroe, Morgan, Muskingum, Noble, Perry, and Vinton Counties, Ohio	Hornum, Michael B.	et al.	R. Christopher Goodwin and Associates, Inc.	Multiple	2015	583.60
N/A	1	Report of a Phase I Archaeological Reconnaissance Survey in Three Proposed Flood Mitigation Corridors, Findlay (Hancock County) and Ottawa (Putnam County), Ohio	Chidester, Robert C.	et al.	The Mannik & Smith Group, Inc.	Multiple	2011	1882.00
N/A	1	A Phase I Archaeological Reconnaissance Survey of Approximately 317 Acres for the Proposed Western Diversion of Eagle Creek, Eagle and Liberty Townships, Hancock County, Ohio	Chidester, Robert C.	et al.	The Mannik & Smith Group, Inc.	Hancock	2017	317.00

Table B7
Blanchard River/Potato Run Study Area
Ohio Historic Inventory

OHI #	UTM Zone	Easting	Northing	Present Name	Other Name	Address	Place Name	County	Architectural Style	Primary Historic Function	Secondary Historic Function	Date	Within AOC?
HAN0048418	17	279645	4524513	Lowell Staller House	R Felder House	TR 181 N of TR 148	Delaware (Township of)	Hancock	Vernacular	Single Dwelling	Barn	1870	No
HAN0048517	17	279388	4524171	Tim Graydon House	JW Shaw House	13865 TR 148	Madison (Township of)	Hancock	Vernacular	Single Dwelling	Barn	1875	No
HAN0048818	17	280823	4524032	Carl Miller House	N Dean House	CR 183 N of US 30	Delaware (Township of)	Hancock	Vernacular	Single Dwelling	Barn	1850	No
HAN0049018	17	281939	4523750	Matthew Benner House		TR 184 S of US 30	Delaware (Township of)	Hancock	Vernacular	Single Dwelling	Barn	1890	No
HAN0049118	17	280840	4524007	F Richard Rose Barn		22580 TR 185	Delaware (Township of)	Hancock	Vernacular	Barn		1920	No
HAN0049218	17	282828	4524157	Ralph Klinger House		22431 TR 185	Delaware (Township of)	Hancock	Vernacular	Single Dwelling	Barn	1855	No
HAN0049518	17	283595	4524017	Lucille Peterson House		22490 TR 186	Delaware (Township of)	Hancock	Vernacular	Single Dwelling	Secondary Structure (Residential)	1875	No
HAN0049618	17	285625	4524016	Andrew Thomas House	R Johnson House	22661 CR 17	Delaware (Township of)	Hancock	Vernacular	Single Dwelling	Barn	1875	No
HAN0049718	17	286225	4523902	Isabel I Miller House	WW Chase House	18124 TR 147	Delaware (Township of)	Hancock	Vernacular	Single Dwelling	Coop	1875	No
HAN0049818	17	286210	4523654	Keith & Loretta Bower House	N Poorman House	18118 TR 147	Delaware (Township of)	Hancock	Italianate	Single Dwelling	Barn	1865	No
HAN0049918	17	286604	4523888	Lowell Miller		18318 TR 147	Delaware (Township of)	Hancock	Vernacular	Single Dwelling	Barn	1890	No
HAN0050018	17	287100	4523941	Greg Jolliff		146 TR 154	Delaware (Township of)	Hancock	Vernacular	Single Dwelling	Barn	1900	No
HAN0050618	17	286226	4523595	Keith & Loretta Bower Barn	N Poorman Barn	18118 TR 147	Delaware (Township of)	Hancock	Vernacular	Barn		1865	No
HAN0051218	17	280740	4524529			CR 183 N of US 30	Delaware (Township of)	Hancock	Vernacular	Barn		1900	No
HAN0051318	17	285602	4523547	Picket House	PR Calvin House	22833 TR 17	Delaware (Township of)	Hancock	Vernacular	Single Dwelling	Barn	1885	No
HAN0051518	17	282744	4523143	Fields Barn & Outbuildings		23058 TR 185	Delaware (Township of)	Hancock	Vernacular	Barn	Coop	1880	No
HAN0054818	17	280730	4524250	Gene Stuckey Barn		CR 183 N of US 30	Delaware (Township of)	Hancock	Vernacular	Barn		1900	No
HAN0055018	17	287578	4523236		Mary Kaufman House	SR 37 N of US 30	Delaware (Township of)	Hancock	Vernacular	Single Dwelling		1870	No
HAN0055118	17	287574	4523304		Mary Kaufman Barn	SR 37 N of US 30	Delaware (Township of)	Hancock	Vernacular	Barn	Coop	1870	No
HAN0060318	17	283343	4528894	Miller Farm	Josiah Elder Farm	16184 TR 270	Delaware (Township)	Hancock	Vernacular			ca. 1880	Yes - Blanchard River
HAN0060418	17	283231	4529641	Meyers House		16127 SR 103	Delaware (Township)	Hancock	Vernacular			ca. 1885	Yes - Blanchard River

Table B7
Blanchard River/Potato Run Study Area
Ohio Historic Inventory

OHI #	UTM Zone	Easting	Northing	Present Name	Other Name	Address	Place Name	County	Architectural Style	Primary Historic Function	Secondary Historic Function	Date	Within AOC?
HAN0060518	17	283404	4529687	Smith House		16323 SR 103	Delaware (Township)	Hancock	Vernacular			ca. 1925	Yes - Blanchard River
WYA0000105	17	289954	4525852	David D Beard Farm	John D Wickiser Farm	9184 TR 79	Richland (Township of)	Wyandot	Italianate	Single Dwelling	Food Procurement / Processing / Agriculture	1877	No
WYA0014005	17	292358	4526121	Wharton Fire House	Whartonsburg Township House	NWC W Sandusky & Railroad Sts	Wharton	Wyandot	Vernacular	Local Government Office		1879	No
WYA0030905	17	292421	4526138	Old Train Depot	Cinci, Sandusky, Cleve RR	off Cass St, along RR tracks	Wharton	Wyandot					No
WYA0031505	17	292376	4525970		WH Depew House	112 W Franklin St	Wharton	Wyandot					No
WYA0031605	17	292300	4525927	House		115 W Franklin St	Wharton	Wyandot					No
WYA0031705	17	292157	4525934	House		305 W Franklin St	Wharton	Wyandot					No
WYA0031805	17	292098	4525977	House		N side Franklin, 2nd hse E of Lee	Wharton	Wyandot					No
WYA0031905	17	292185	4526029	Wharton Cannery		W side Jackson, S of Sandusky	Wharton	Wyandot					No
WYA0034205	17	292439	4526059	The Village Bank		101 W Sandusky St	Wharton	Wyandot					No
WYA0034305	17	292434	4526100	Boden Hardware	Wharton IOOF #633	102-106 W Sandusky St	Wharton	Wyandot					No
WYA0034405	17	292421	4526059	House		103 W Sandusky St	Wharton	Wyandot					No
WYA0034505	17	292406	4526058	Barber Shop		105-107? W Sandusky St	Wharton	Wyandot					No
WYA0034605	17	292383	4526060	4 Commercial Bldgs		123-135? W Sandusky St	Wharton	Wyandot					No
WYA0034705	17	292364	4526060	House		139 W Sandusky St	Wharton	Wyandot					No
WYA0034905	17	292312	4526057	House		201 W Sandusky St	Wharton	Wyandot					No
WYA0035005	17	292319	4526097	House		202 W Sandusky St	Wharton	Wyandot					No
WYA0035105	17	292290	4526055	House		205 W Sandusky St	Wharton	Wyandot					No
WYA0035205	17	292247	4526052		Elizabeth Wood House	213 W Sandusky St	Wharton	Wyandot					No

Table B7
Blanchard River/Potato Run Study Area
Ohio Historic Inventory

OHI #	UTM Zone	Easting	Northing	Present Name	Other Name	Address	Place Name	County	Architectural Style	Primary Historic Function	Secondary Historic Function	Date	Within AOC?
WYA0035305	17	292268	4526099	House		212 W Sandusky St	Wharton	Wyandot					No
WYA0035405	17	292224	4526058		Wharton House Hotel	217 W Sandusky St	Wharton	Wyandot					No
WYA0035505	17	292224	4526104	House		224 W Sandusky St	Wharton	Wyandot					No
WYA0035605	17	292163	4526061		Peter Bangler House	305 W Sandusky St	Wharton	Wyandot					No
WYA0035705	17	292102	4526105	House		316 W Sandusky St	Wharton	Wyandot					No
WYA0035805	17	292100	4526063	House		317 W Sandusky St	Wharton	Wyandot					No
WYA0035905	17	292081	4526057	House		321 W Sandusky St	Wharton	Wyandot					No
WYA0036005	17	292049	4526104	House		324 W Sandusky St	Wharton	Wyandot					No
WYA0036105	17	292039	4526045	TJ Lee Farm		401 W Sandusky St	Wharton	Wyandot					No
WYA0036405	17	292336	4526202	House		W Wyandot St	Wharton	Wyandot					No
WYA0036505	17	292275	4526164	House		215 W Wyandot St	Wharton	Wyandot					No
WYA0036605	17	292254	4526165	House		217 W Wyandot St	Wharton	Wyandot					No
WYA0036705	17	292234	4526168	House		219 W Wyandot St	Wharton	Wyandot					No
WYA0066205	17	288721	4523823	Marvin Lamb House	Mary Lowrey House	10467 CR 78	Richland (Township of)	Wyandot					No
WYA0066305	17	288746	4524121	Fay Searfuss House	Shannon House	10271 CR 78	Richland (Township of)	Wyandot					No
WYA0066405	17	288726	4523584	James Farthing House	MM Williams House	10615 CR 78	Richland (Township of)	Wyandot					No
WYA0066505	17	289879	4524032	Doug Woods House	Anne Benjamin House	10284 TR 79	Richland (Township of)	Wyandot					No
WYA0066805	17	291228	4523961	Oral Clinger House		E side CR 81, N of US 30	Richland (Township of)	Wyandot					No
WYA0066905	17	291078	4523984	Bonnie Rinker House	S Katchty House	W side CR 81, N of US 30	Richland (Township of)	Wyandot					No

Table B8
Blanchard River/Potato Run Study Area
Historic Cemeteries

OGS ID #	UTM Zone	Easting	Northing	Cemetery Name	City / Twp	County	Twp / Range	Section	Burial Status	Burial Condition	Location Confidence	Within AOC?
4780	17	284729	4532101	Krout	Amanda	Hancock	T1S:R11E	SW corner of NW1/4 of S36		Highly Maintained	Yes	No
4797	17	287788	4527484	Adams	Delaware	Hancock	T2S:R12E	NE1/4 of S18	Inactive	Moderate Maintenance	Yes	Yes - Potato Run
4815	17	284650	4532112	Riverview	Jackson	Hancock	T1S:R11E	SE corner of NE1/4 of S35		Highly Maintained	Yes	No
4801	17	285329	4524015	Johnson / Johnston	Delaware	Hancock	T2S:R11E	SW1/4 of S25		Neglected	Yes	No
12982	17	290014	4525723	Spoon	Richland	Wyandot		NW1/4 of S21	Inactive	Highly Maintained	Yes	No
4798	17	280571	4529815	Caster / Castor	Delaware	Hancock	T2S:R11E	SW1/4 of S4		Neglected	Yes	No
4802	17	285009	4530981	Mount Blanchard	Delaware	Hancock	T2S:R11E	NE corner of S2		Highly Maintained	Yes	No
4779	17	288295	4532723	Five Points - Six Points	Amanda	Hancock	T1S:R12E	SW corner of S29		Neglected	Yes	No
4800	17	281885	4527341	Earlywine	Delaware	Hancock	T2S:R11E	NW central S15		Neglected	Yes	Yes - Blanchard River
4799	17	283964	4530640	Old Caster-Burson-Bunker Hill	Delaware	Hancock	T2S:R11E	SE1/4 of S2		Endangered	Yes	No

Table B9
Blanchard River/Potato Run Study Area
Ohio Archaeological Inventory

OAI #	UTM Zone	Easting	Northing	Quad Name	Temporal Affiliation	Cultural Affiliation	Site Function	County	Site Area (m2)	Setting	Within AOC?
33HK0277	17	281021	4524064	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0278	17	280848	4524099	Forest	Prehistoric	Unknown	Unknown	Hancock	600	Open	No
33HK0326	17	279718	4524252	Forest	Prehistoric	Late Archaic	Unknown	Hancock	1	Open	No
33HK0327	17	279876	4524212	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0328	17	279607	4523696	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0329	17	280750	4524103	Forest	Prehistoric	Unknown	Unknown	Hancock	20	Open	No
33HK0330	17	280194	4524212	Forest	Prehistoric	Unknown	Unknown	Hancock	150	Open	No
33HK0331	17	280401	4524145	Forest	Prehistoric	Unknown	Unknown	Hancock	5	Open	No
33HK0332	17	280403	4524197	Forest	Prehistoric	Late Archaic	Unknown	Hancock	1	Open	No
33HK0333	17	280776	4524444	Forest	Historic	Euro-American	Residential	Hancock	1000	Open	No
33HK0334	17	281386	4524103	Forest	Historic	Euro-American	Residential	Hancock	25	Open	No
33HK0335	17	282019	4524109	Forest	Prehistoric and Historic	Middle Woodland; Euro-American	Prehistoric - Unknown; Historic - Residential	Hancock	3040	Open	No
33HK0336	17	282372	4524064	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0337	17	282409	4524098	Forest	Prehistoric	Unknown	Unknown	Hancock	105	Open	No
33HK0338	17	282609	4524075	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0339	17	282742	4524143	Forest	Prehistoric	Unknown	Unknown	Hancock	5	Open	No
33HK0340	17	282264	4524004	Forest	Prehistoric	Early Woodland	Unknown	Hancock	160	Open	No
33HK0341	17	282115	4524001	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0342	17	282050	4524030	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0343	17	282008	4523849	Forest	Prehistoric	Unknown	Unknown	Hancock	5	Open	No
33HK0344	17	281970	4524050	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0345	17	282953	4524212	Forest	Prehistoric	Unknown	Unknown	Hancock	24	Open	No
33HK0346	17	283114	4524216	Forest	Prehistoric	Unknown	Unknown	Hancock	40	Open	No
33HK0347	17	283144	4524198	Forest	Prehistoric	Late Archaic	Unknown	Hancock	1	Open	No
33HK0348	17	283181	4524110	Forest	Prehistoric	Unknown	Unknown	Hancock	50	Open	No
33HK0349	17	283170	4523978	Forest	Prehistoric	Early Archaic	Unknown	Hancock	1	Open	No
33HK0350	17	282972	4524055	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0351	17	282840	4524390	Forest	Prehistoric	Early Archaic	Unknown	Hancock	1	Open	No
33HK0352	17	285529	4523749	Forest	Prehistoric	Unknown	Unknown	Hancock	65	Open	No

Table B9
Blanchard River/Potato Run Study Area
Ohio Archaeological Inventory

OAI #	UTM Zone	Easting	Northing	Quad Name	Temporal Affiliation	Cultural Affiliation	Site Function	County	Site Area (m2)	Setting	Within AOC?
33HK0353	17	285892	4523837	Forest	Prehistoric	Early Archaic	Unknown	Hancock	8	Open	No
33HK0354	17	285911	4523764	Forest	Prehistoric	Late Woodland	Unknown	Hancock	6	Open	No
33HK0355	17	286217	4523756	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0356	17	286475	4523759	Forest	Prehistoric	Paleoindian	Unknown	Hancock	2160	Open	No
33HK0357	17	286686	4523737	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0358	17	286216	4523806	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0359	17	287596	4523708	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0362	17	283701	4524159	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0363	17	283954	4524173	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0364	17	284261	4524083	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0365	17	283680	4523900	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0441	17	283536	4524213	Forest	Prehistoric	Unknown	Unknown	Hancock	1400	Open	No
33HK0442	17	283421	4524165	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0443	17	283565	4524161	Forest	Prehistoric	Early Archaic	Unknown	Hancock	40	Open	No
33HK0444	17	283339	4524195	Forest	Prehistoric	Unknown	Unknown	Hancock	800	Open	No
33HK0445	17	283232	4524149	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0459	17	287359	4523705	Forest	Prehistoric	Unknown	Unknown	Hancock	150	Open	No
33HK0460	17	281085	4524005	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0472	17	282780	4522925	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0475	17	283152	4523573	Forest	Prehistoric	Early, Middle and Late Archaic; Early and Late Woodland	Unknown	Hancock	18000	Open	No
33HK0496	17	279164	4524265	Forest	Historic	Euro-American	Residential	Hancock	1000	Open	No
33HK0497	17	283325	4523911	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0498	17	283487	4523903	Forest	Prehistoric	Unknown	Unknown	Hancock	200	Open	No
33HK0499	17	287877	4523483	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0500	17	287713	4523637	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0501	17	287498	4523212	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0521	17	279632	4524332	Forest	Historic	Euro-American	Unknown	Hancock	1800	Open	No
33HK0522	17	280181	4524244	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No

Table B9
Blanchard River/Potato Run Study Area
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OAI #	UTM Zone	Easting	Northing	Quad Name	Temporal Affiliation	Cultural Affiliation	Site Function	County	Site Area (m2)	Setting	Within AOC?
33HK0523	17	280500	4524245	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0524	17	280853	4524222	Forest	Historic	Euro-American	Residential	Hancock	5625	Open	No
33HK0525	17	284420	4523698	Forest	Prehistoric	Unknown	Unknown	Hancock	20	Open	No
33HK0526	17	285053	4523685	Forest	Prehistoric	Unknown	Unknown	Hancock	450	Open	No
33HK0527	17	284712	4523704	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0528	17	284640	4523720	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0529	17	285623	4523733	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0572	17	282752	4523036	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0573	17	282750	4523095	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0579	17	283923	4522876	Forest	Historic	Euro-American	Residential	Hancock	1000	Open	No
33HK0601	17	280563	4524230	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0602	17	280253	4524237	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0603	17	280547	4524120	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0604	17	280646	4524168	Forest	Prehistoric	Late Archaic; Late Woodland	Unknown	Hancock	3188	Open	No
33HK0623	17	282690	4524218	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0624	17	282242	4524318	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0626	17	282457	4524292	Forest	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0658	17	283690	4529600	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1	Open	Yes - Blanchard River
33HK0659	17	283682	4529432	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	2100	Open	Yes - Blanchard River
33HK0660	17	283690	4529243	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1	Open	Yes - Blanchard River
33HK0661	17	283756	4529256	Mt. Blanchard	Prehistoric	Middle Woodland	Unknown	Hancock	200	Open	Yes - Blanchard River
33HK0662	17	283750	4529610	Mt. Blanchard	Prehistoric	Early Archaic	Unknown	Hancock	1	Open	Yes - Blanchard River
33HK0663	17	283814	4529611	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	100	Open	Yes - Blanchard River

Table B9
Blanchard River/Potato Run Study Area
Ohio Archaeological Inventory

OAI #	UTM Zone	Easting	Northing	Quad Name	Temporal Affiliation	Cultural Affiliation	Site Function	County	Site Area (m2)	Setting	Within AOC?
33HK0664	17	283820	4529461	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1	Open	Yes - Blanchard River
33HK0665	17	283828	4529388	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1	Open	Yes - Blanchard River
33HK0666	17	283900	4529280	Mt. Blanchard	Prehistoric	Late Woodland; Late Prehistoric	Unknown	Hancock	1	Open	Yes - Blanchard River
33HK0667	17	283343	4529295	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1	Open	Yes - Blanchard River
33HK0668	17	283504	4529209	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1	Open	Yes - Blanchard River
33HK0669	17	283615	4529204	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1	Open	Yes - Blanchard River
33HK0670	17	283688	4529176	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1	Open	Yes - Blanchard River
33HK0671	17	283773	4529172	Mt. Blanchard	Prehistoric and Historic	Prehistoric - Unknown; Euro-American	Prehistoric - Unknown; Historic - Unknown	Hancock	6450	Open	Yes - Blanchard River
33HK0672	17	283540	4529130	Mt. Blanchard	Prehistoric	Early Archaic	Unknown	Hancock	1	Open	Yes - Blanchard River
33HK0673	17	283431	4529143	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	500	Open	Yes - Blanchard River
33HK0674	17	283466	4529022	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	100	Open	Yes - Blanchard River
33HK0675	17	283707	4529025	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1450	Open	Yes - Blanchard River
33HK0676	17	283319	4528911	Mt. Blanchard	Prehistoric and Historic	Prehistoric - Early Archaic; Euro-American	Prehistoric - Unknown; Historic - Farmstead	Hancock	16400	Open	Yes - Blanchard River
33HK0677	17	283528	4528894	Mt. Blanchard	Historic	Euro-American	Unknown	Hancock	2050	Open	Yes - Blanchard River

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Blanchard River/Potato Run Study Area
Ohio Archaeological Inventory

OAI #	UTM Zone	Easting	Northing	Quad Name	Temporal Affiliation	Cultural Affiliation	Site Function	County	Site Area (m2)	Setting	Within AOC?
33HK0678	17	283249	4528825	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1	Open	Yes - Blanchard River
33HK0679	17	283537	4528776	Mt. Blanchard	Prehistoric	Paleoindian	Unknown	Hancock	1	Open	Yes - Blanchard River
33HK0680	17	283888	4529665	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1	Open	Yes - Blanchard River
33HK0681	17	283270	4529690	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1	Open	Yes - Blanchard River
33HK0682	17	283599	4528700	Mt. Blanchard	Prehistoric and Historic	Prehistoric - Unknown; Euro-American	Prehistoric - Unknown; Historic - Unknown	Hancock	4050	Open	Yes - Blanchard River
33HK0683	17	283068	4530182	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0684	17	283148	4530375	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0685	17	283131	4530210	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0686	17	283197	4530134	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0699	17	283440	4530187	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1	Open	No
33HK0700	17	283031	4529701	Mt. Blanchard	Prehistoric	Unknown	Unknown	Hancock	1	Open	Yes - Blanchard River
33HK0701	17	283643	4530640	Mt. Blanchard	Historic	Euro-American	Transportation	Hancock	22186	Open	No
33WY0248	17	291585	4531920	Carey	Prehistoric	Early Archaic	Unknown	Wyandot	1	Open	No
33WY0267	17	288916	4523730	Forest	Historic	Euro-American	Unknown	Wyandot	3650	Open	No
33WY0268	17	289235	4523780	Wharton	Prehistoric	Unknown	Unknown	Wyandot	1	Open	No
33WY0269	17	289385	4523735	Wharton	Prehistoric	Unknown	Unknown	Wyandot	1	Open	No
33WY0270	17	288945	4523806	Forest	Prehistoric	Late Archaic	Unknown	Wyandot	56	Open	No
33WY0271	17	288394	4523770	Forest	Prehistoric	Early Archaic	Unknown	Wyandot	6300	Open	No
33WY0272	17	287929	4523693	Forest	Prehistoric and Historic	Prehistoric - Unknown; Euro-American	Prehistoric - Unknown; Historic - Farm	Wyandot	7975	Open	No
33WY0273	17	288171	4523710	Forest	Prehistoric	Unknown	Unknown	Wyandot	3	Open	No

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OAI #	UTM Zone	Easting	Northing	Quad Name	Temporal Affiliation	Cultural Affiliation	Site Function	County	Site Area (m2)	Setting	Within AOC?
33WY0274	17	288627	4523405	Forest	Prehistoric and Historic	Prehistoric - Unknown; Euro-American	Prehistoric - Unknown; Historic - Unknown	Wyandot	600	Open	No
33WY0275	17	289964	4523702	Wharton	Prehistoric	Unknown	Unknown	Wyandot	1	Open	No
33WY0276	17	290014	4523688	Wharton	Prehistoric	Unknown	Unknown	Wyandot	8	Open	No
33WY0277	17	290089	4523709	Wharton	Prehistoric	Unknown	Unknown	Wyandot	189	Open	No
33WY0278	17	290532	4523738	Wharton	Prehistoric	Late Archaic	Unknown	Wyandot	84	Open	No
33WY0279	17	290214	4523761	Wharton	Prehistoric	Unknown	Unknown	Wyandot	10	Open	No
33WY0280	17	289931	4523773	Wharton	Prehistoric and Historic	Prehistoric - Unknown; Euro-American	Prehistoric - Unknown; Historic - Residential	Wyandot	3750	Open	No
33WY0281	17	290598	4523711	Wharton	Historic	Euro-American	Transportation	Wyandot	13720	Open	No
33WY0285	17	291289	4523664	Wharton	Prehistoric	Unknown	Unknown	Wyandot	3	Open	No
33WY0286	17	291248	4523653	Wharton	Prehistoric	Early Archaic	Unknown	Wyandot	1	Open	No
33WY0377	17	289858	4523371	Wharton	Historic	Euro-American	Unknown	Wyandot	24	Open	No
33WY0380	17	288913	4523775	Forest	Prehistoric	Unknown	Unknown	Wyandot	10	Open	No
33WY0508	17	288227	4523565	Forest	Prehistoric	Unknown	Unknown	Wyandot	1	Open	No
33WY0509	17	288560	4523611	Forest	Prehistoric	Unknown	Unknown	Wyandot	15	Open	No
33WY0523	17	288842	4523682	Forest	Prehistoric	Unknown	Unknown	Wyandot	60	Open	No
33WY0524	17	289360	4523653	Wharton	Prehistoric	Unknown	Unknown	Wyandot	5	Open	No
33WY0525	17	289641	4523822	Wharton	Prehistoric	Unknown	Unknown	Wyandot	375	Open	No
33WY0526	17	289939	4524250	Wharton	Historic	Euro-American	Residential	Wyandot	50	Open	No
33WY0527	17	290645	4523813	Wharton	Historic	Euro-American	Residential	Wyandot	899	Open	No
33WY0528	17	290754	4523806	Wharton	Prehistoric	Unknown	Unknown	Wyandot	1	Open	No
33WY0529	17	290833	4523790	Wharton	Prehistoric	Unknown	Unknown	Wyandot	1	Open	No
33WY0530	17	291449	4523769	Wharton	Prehistoric	Paleoindian; Early Archaic	Unknown	Wyandot	1	Open	No
33WY0531	17	291570	4523776	Wharton	Prehistoric	Late Archaic	Unknown	Wyandot	100	Open	No
33WY1125	17	288471	4523478	Forest	Prehistoric	Middle Archaic	Unknown	Wyandot	1	Open	No
33WY1129	17	288842	4523566	Forest	Prehistoric	Unknown	Unknown	Wyandot	1	Open	No

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OAI #	UTM Zone	Easting	Northing	Quad Name	Temporal Affiliation	Cultural Affiliation	Site Function	County	Site Area (m2)	Setting	Within AOC?
33WY1227	17	292241	4525479	Wharton	Prehistoric	Paleoindian	Unknown	Wyandot	1	Open	No
33WY1229	17	292321	4527565	Wharton	Prehistoric	Early and Late Archaic; Middle Woodland	Unknown	Wyandot	10000	Open	No
33WY1268	17	291250	4530372	Carey	Prehistoric	Early Archaic	Unknown			Open	No
33WY1270	17	290684	4525685	Wharton	Prehistoric	Early Archaic	Unknown			Open	No
33WY1271	17	290856	4525542	Wharton	Prehistoric	Early Archaic	Unknown			Open	No
33WY1280	17	292189	4525493	Wharton	Prehistoric	Unknown	Unknown	Wyandot	1	Open	No
33WY1281	17	292036	4525335	Wharton	Prehistoric	Unknown	Unknown	Wyandot	8	Open	No

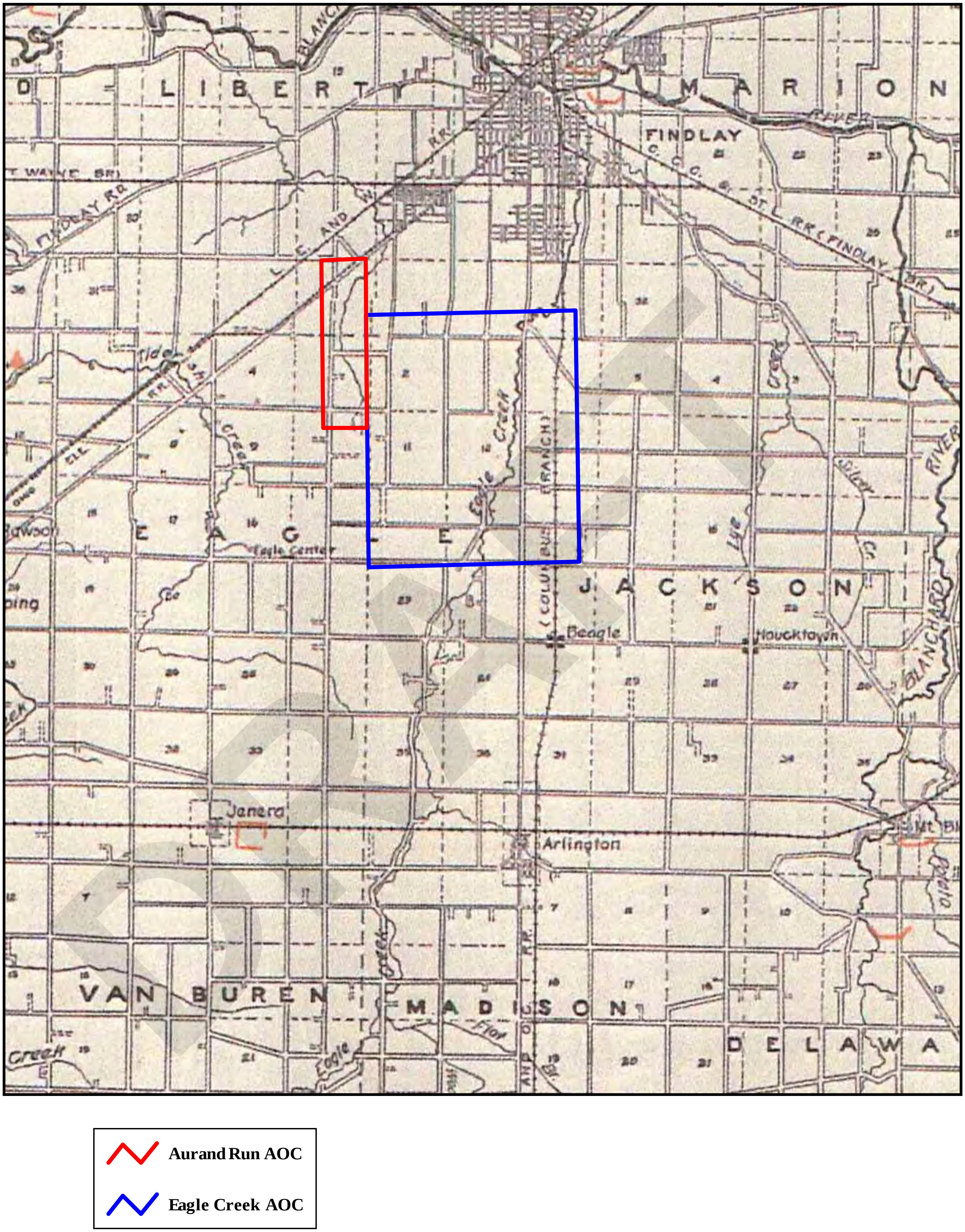
Table B10
Blanchard River/Potato Run Study Area
Previous Cultural Resources Investigations

NADB #	Phase	Title	Primary Author	Secondary Author(s)	Conducted by	County	Year	Acres
13040	1	Cultural Resources Survey of a Proposed 9.6 Mile Gas Pipeline Replacement, Handcock and Wyandot Counties, Ohio	Kreinbrink, Jeannine	David J. Rue	WAPORA, INC.	Hancock	1989	56.27
15194	1	Phase I Cultural Resource Management Survey of the Proposed 7.7 ha (19.1 a) Treatment Plant in Delaware Township, Hancock County, Ohio	Nye, Kevin A.	Craig S. Keener	Professional Archaeological Services Team	Hancock	2002	20.65
16107	1	A Cultural Resources Literature Review & Reconnaissance Survey of the Eastern Portion (CR 12, Orange Twp., HN Co. to TR 108, Salem Twp., WY Co.) of Segment II of the Prop. US 30 Relocation through AL, HN, & WY Cos., Ohio (PID 8360)	Grimes, Chris J.	Deborah Dobson-Brown, Luella Beth Hillen, William J. Hillen, III, and Dan Prosser	ASC Group, Inc.	Hancock	1992	3619.41
16110	1	Addendum To: A Cultural Resource Lit Review and Reconnaissance Survey of the Eastern Portion (C.R. 12/Orange Twp. HN Co. to T.R. 108, Salem Twp., WY Co.) - Segment II of the Proposed US 30 Relocation through Allen, Hancock, and Wayne Counties, Ohio	Mustain, Chuck	Deborah Dobson-Brown	ASC Group, Inc.	Hancock	1993	3937.19
16111	1	2nd Addendum To: A Cultural Resource Lit Review and Reconnaissance Survey of the Eastern Portion (C.R. 12, Orange Twp., HN Co. to T.R. 108, Salem Twp., WY Co.) of Segment II of the Proposed US 30 Relocation through Allen, Hancock, & Wayne Counties, Ohio	Mustain, Chuck	Lori O'Donnell, Deborah Dobson-Brown, and Keith Pruffer	ASC Group, Inc.	Hancock	1995	850.62
16154	1	Phase I Cultural Resource Management Survey of a Proposed 7.7 ha (19.1 a.) Treatment Plant in Delaware Township, Hancock County, Ohio	Keener, Craig S.		Professional Archaeological Services Team	Hancock	2003	9.20
16174	1	Phase I Cultural Resources Survey for HAN-TR 187/TR 270-1.57/0.04, the Township Road 187 Bridge Replacement Project in Delaware Township, Hancock County, Ohio (Short Report Format)	Mustain, Chuck	James A. Goodman, Alan Tonetti, and Lori O. Thursby	ASC Group, Inc.	Hancock	2002	169.87
17880	1	Blanchard Wireless Cellular Tower in Jackson Township, Hancock County, Ohio	Workman, Keith		EMH&T, Inc.	Hancock	2008	0.23

Table B10
Blanchard River/Potato Run Study Area
Previous Cultural Resources Investigations

NADB #	Phase	Title	Primary Author	Secondary Author(s)	Conducted by	County	Year	Acres
18229	1	Phase I Cultural Resource Management Survey of a Proposed 5.8 ha (14.5 a.) Wastewater Retention Lagoon and 411.5 m (1,350 ft.) of Sewer Lines in Richland Township, Wyandot County, Ohio.	Keener, Craig S.		Professional Archaeological Services Team	Wyandot	2009	13.43
16112	2	Phase II Assessment Survey of 18 Archaeological Sites Within Project II of Segment II of the U.S. Route 30 Relocation Project in Hancock and Wyandot Counties, Ohio	Mustain, Chuck	Brent Campagna, Lori Frye, Timothy Allen	ASC Group, Inc.	Hancock	1996	35.32
16113	2	Assessment Survey of 8 Prehistoric Site Clusters, 6 Prehistoric Sites, 8 Historic Sites, and 7 Architecture Locations to be Impacted by the Eastern Portion of Segment II of the Proposed US 30 Relocation (P.I.D. 8360) Hancock & Wayne Counties	Mustain, Chuck	Deborah Dobson-Brown, Joe Wakeman, Gary McDaniel, Flora Church, and Annette Ericksen	ASC Group, Inc.	Hancock	1995	102.29

ATTACHMENT C
HISTORIC MAPS



TECHNICAL SKILL. CREATIVE SPIRIT.

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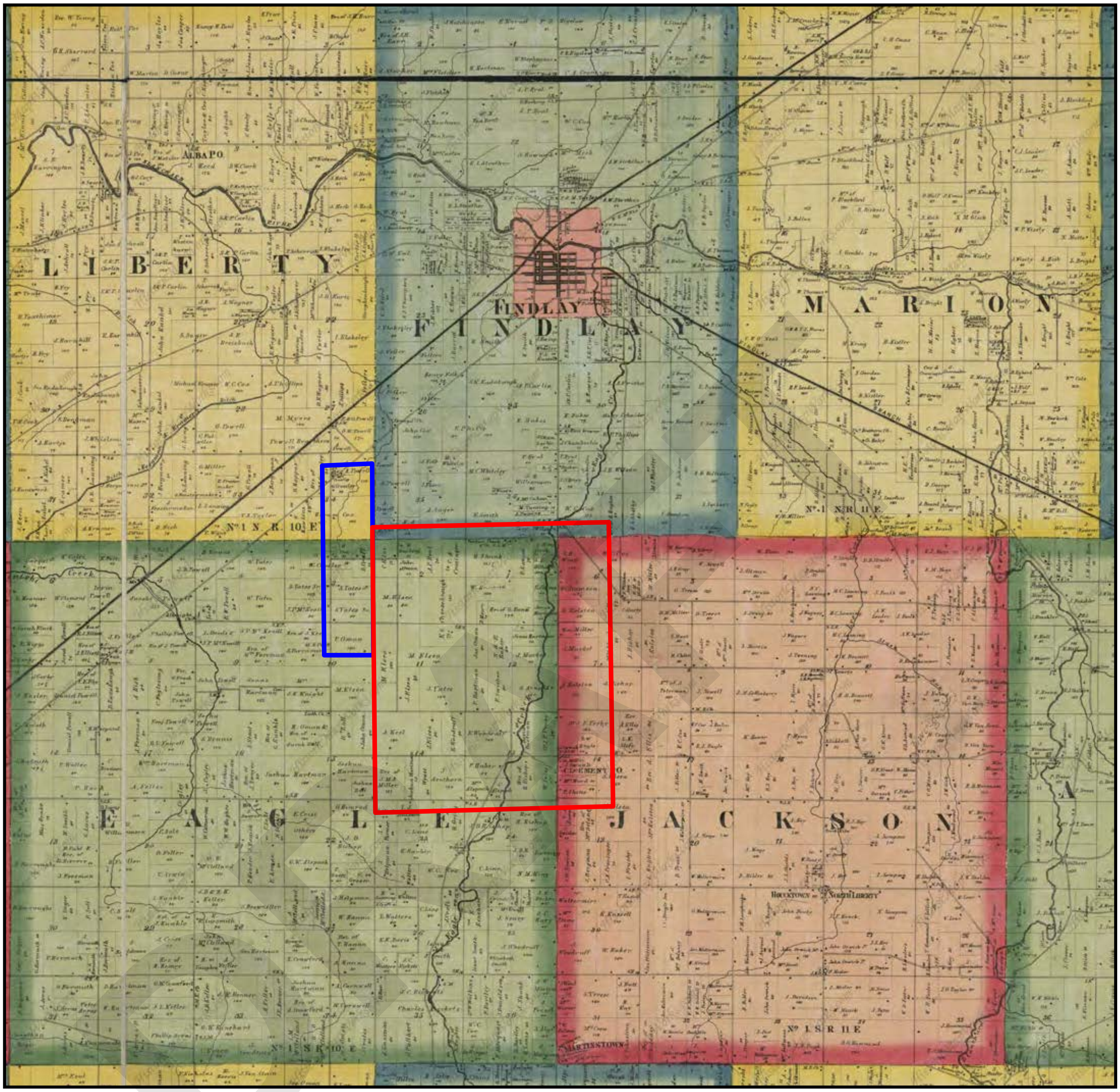
Figure C1
Archaeological Atlas of Ohio
Hancock County (Detail)
(Mills 1914)

N



Aurand Run AOC

Eagle Creek AOC

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CREATIVE SPIRIT.

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Figure C2
1863 Hancock County Atlas (Detail)
(Lake 1863)

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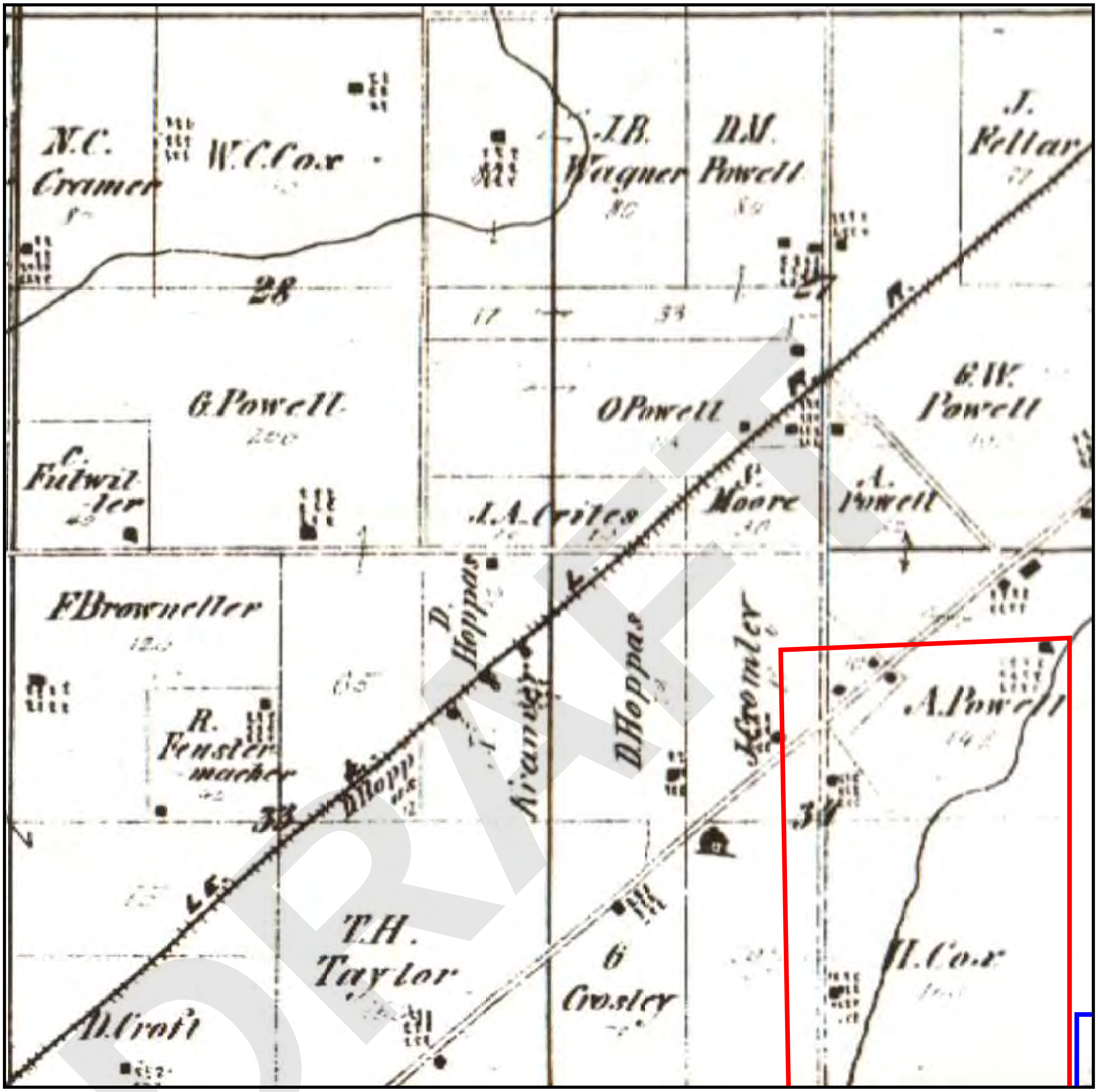

🟥 Aurand Run AOC

🟦 Eagle Creek AOC

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Figure C3
1875 Hancock County Atlas
Liberty Township
(Hardesty 1875)

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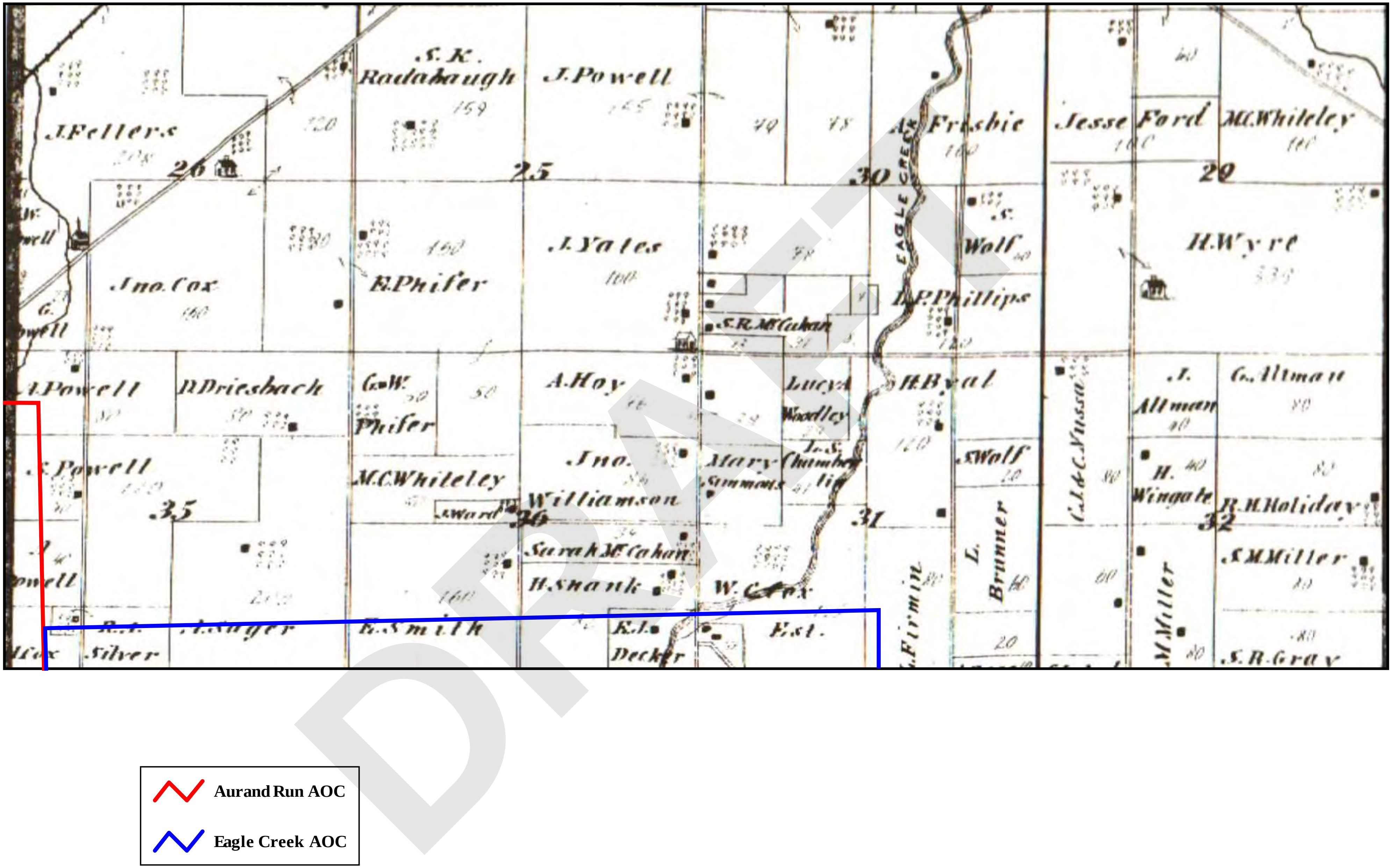

Figure C4
1875 Hancock County Atlas
Findlay Township
(Hardesty 1875)

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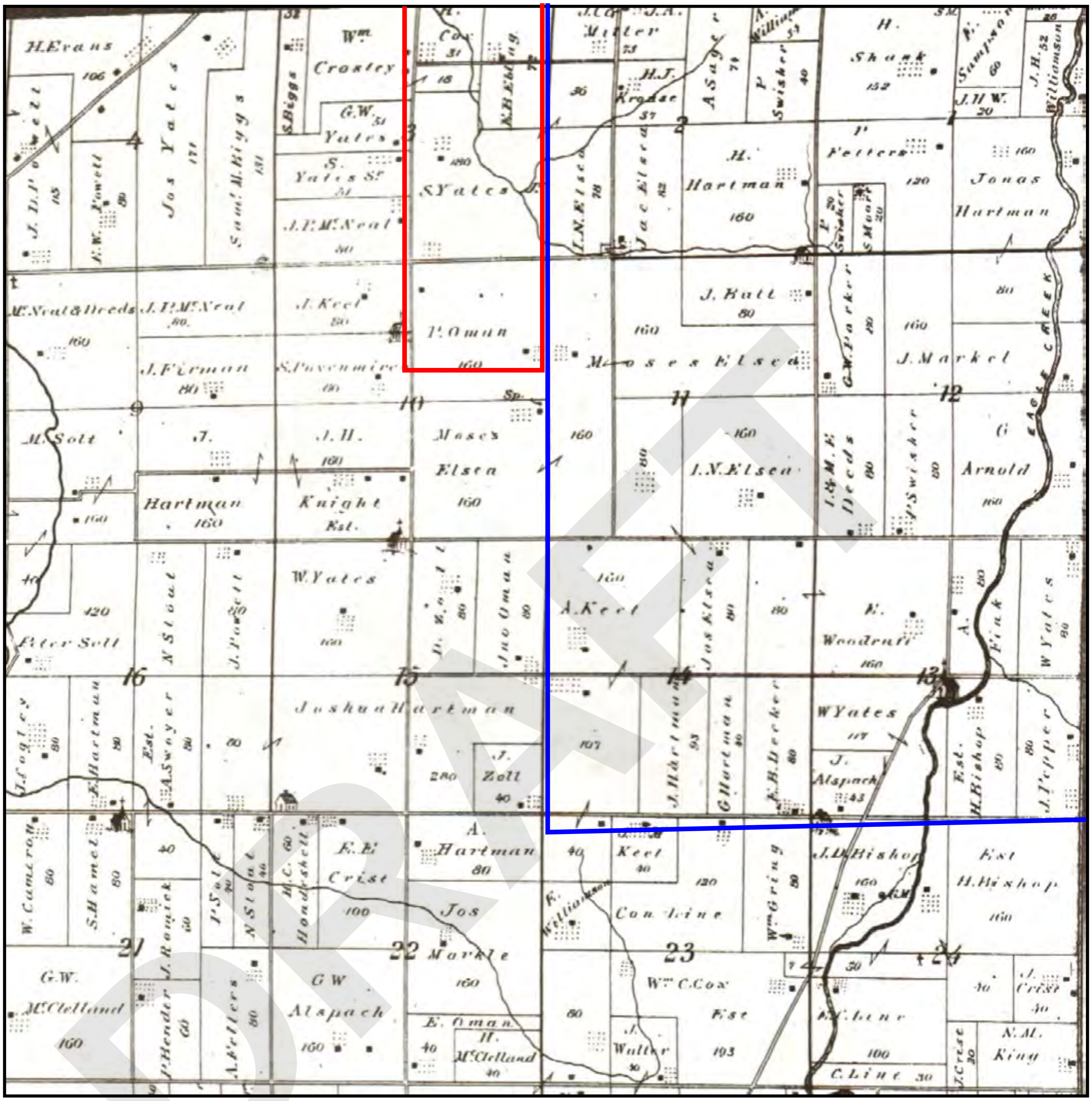

🟥 Aurand Run AOC

🟦 Eagle Creek AOC

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CREATIVE SPIRIT.

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Figure C5
1875 Hancock County Atlas
Eagle Township
(Hardesty 1875)

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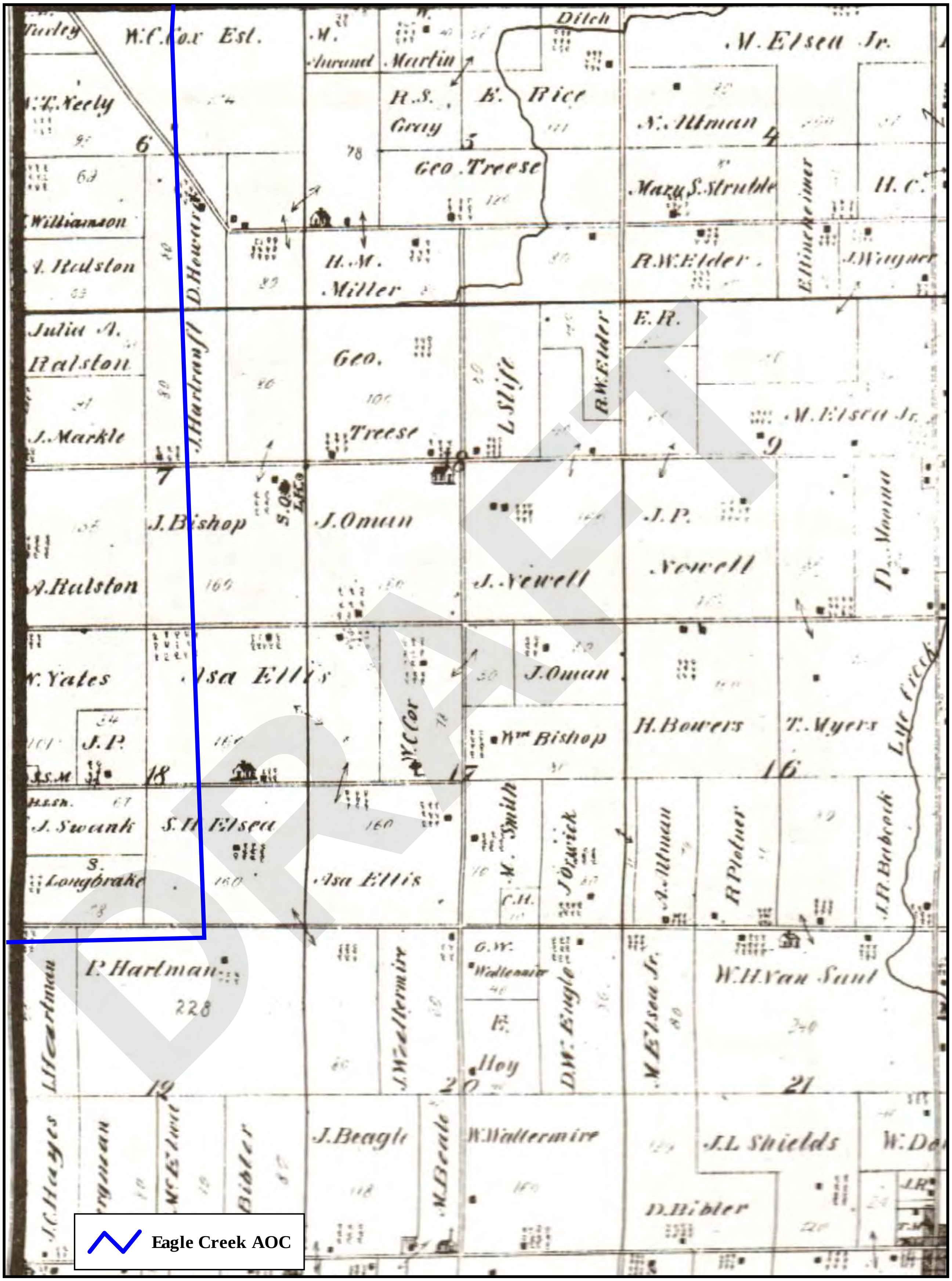

Figure C6
1875 Hancock County Atlas
Jackson Township
(Hardesty 1875)

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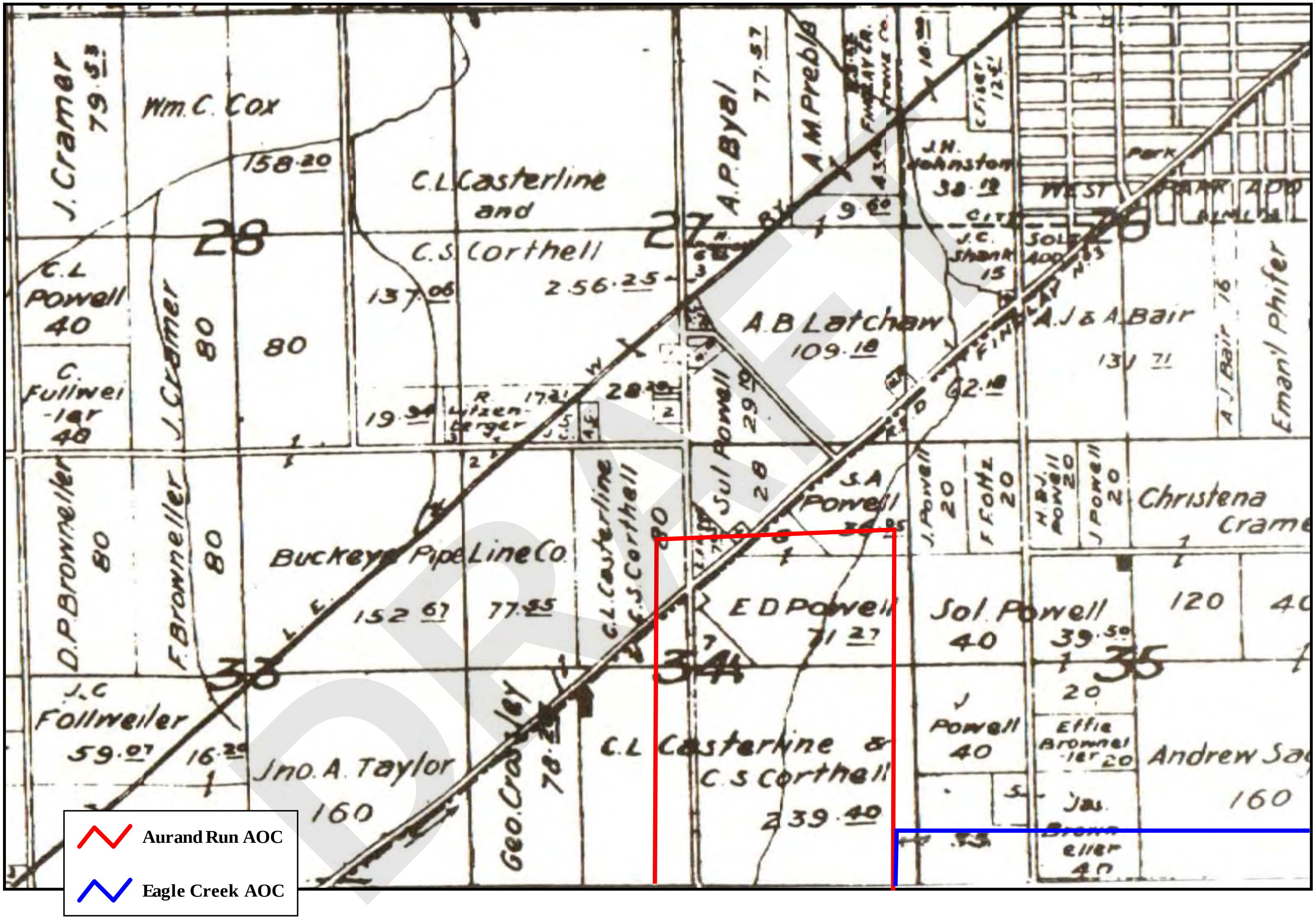

TECHNICAL SKILL. CREATIVE SPIRIT.

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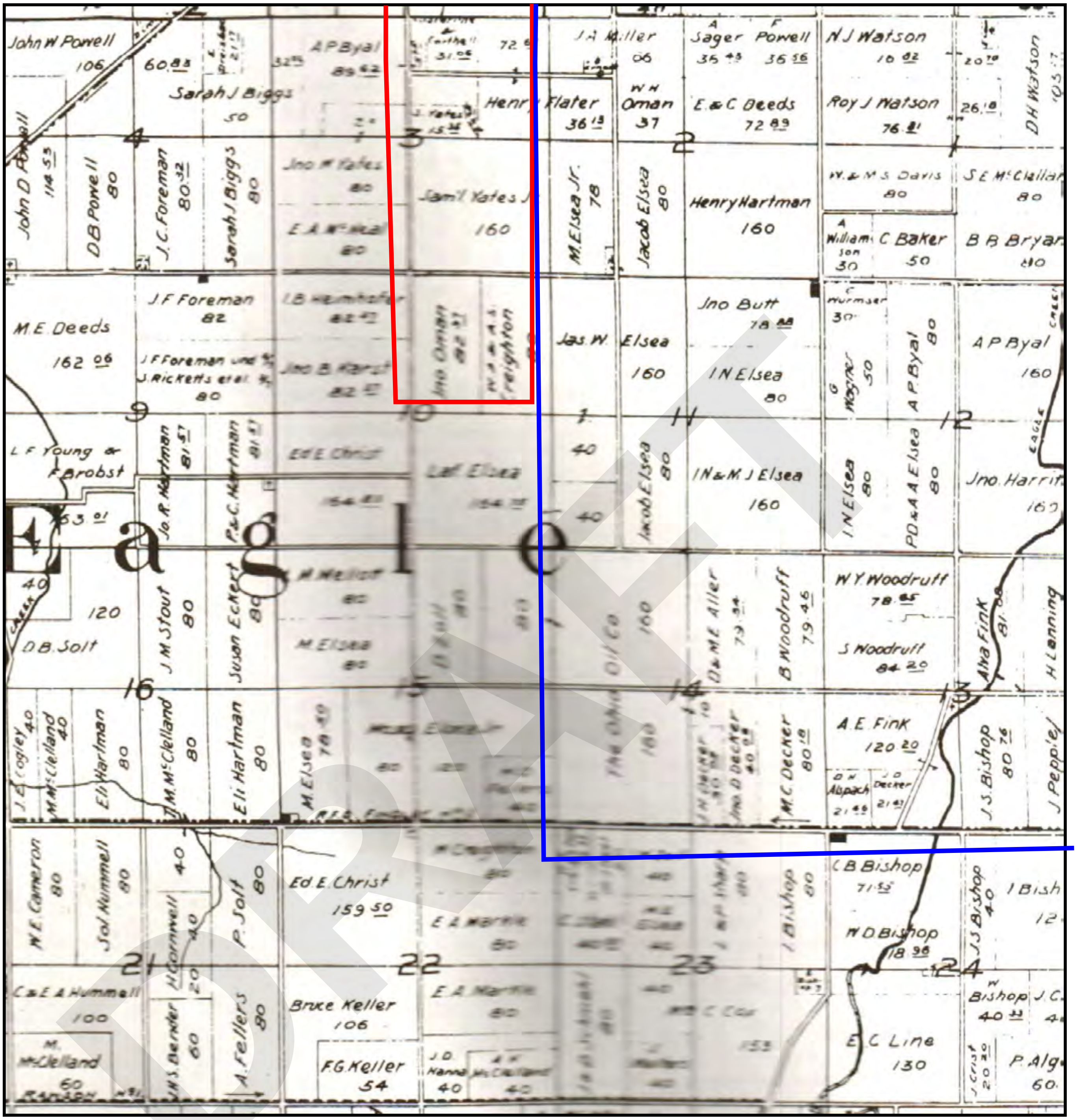
Figure C7
1902 Hancock County Atlas
Liberty Township
(The Republican Company 1902)

N



Aurand Run AOC

Eagle Creek AOC

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Figure C8
1902 Hancock County Atlas
Eagle Township
(The Republican Company 1902)

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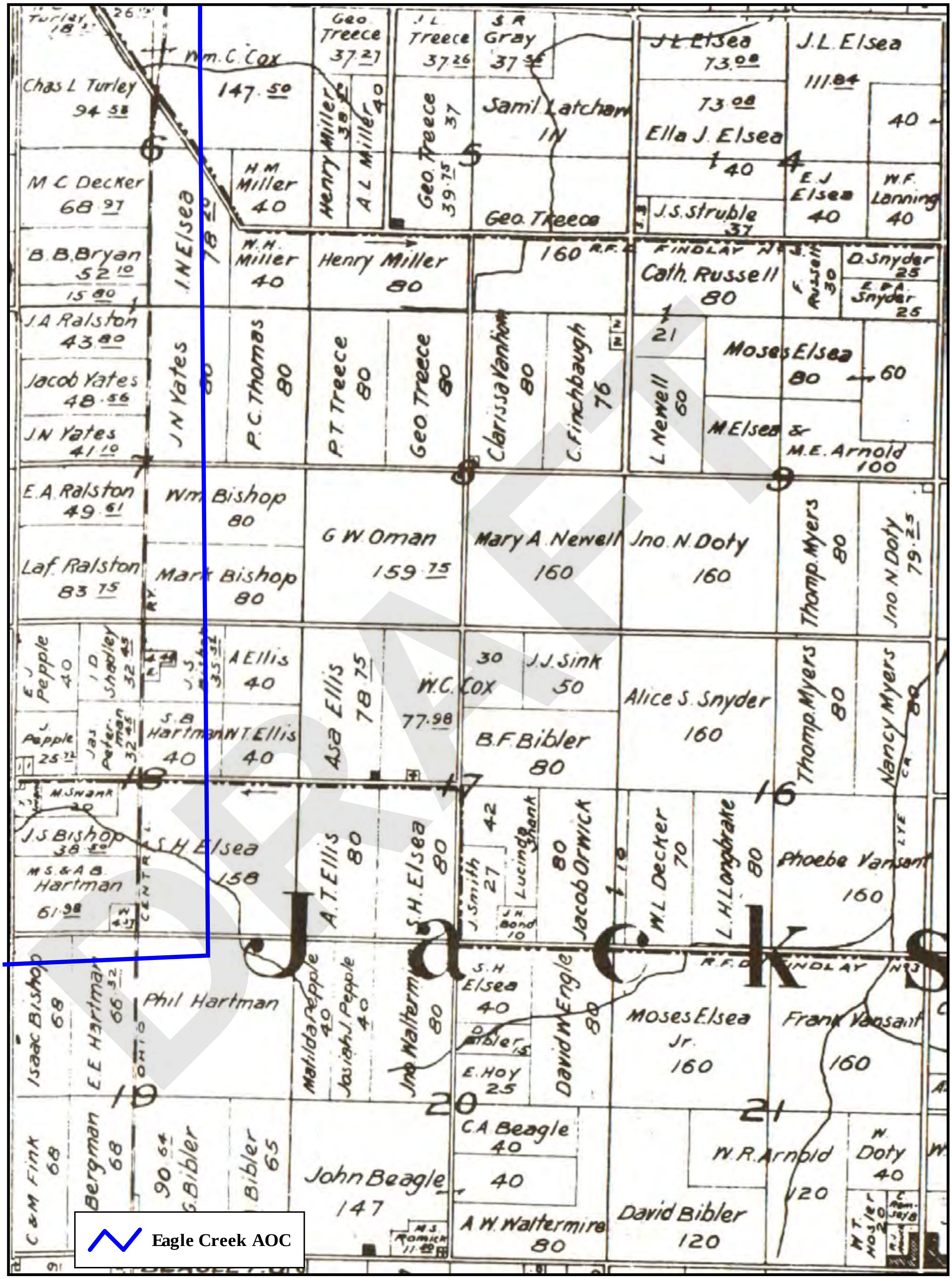

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Figure C9
1902 Hancock County Atlas
Jackson Township
(The Republican Company 1902)

N

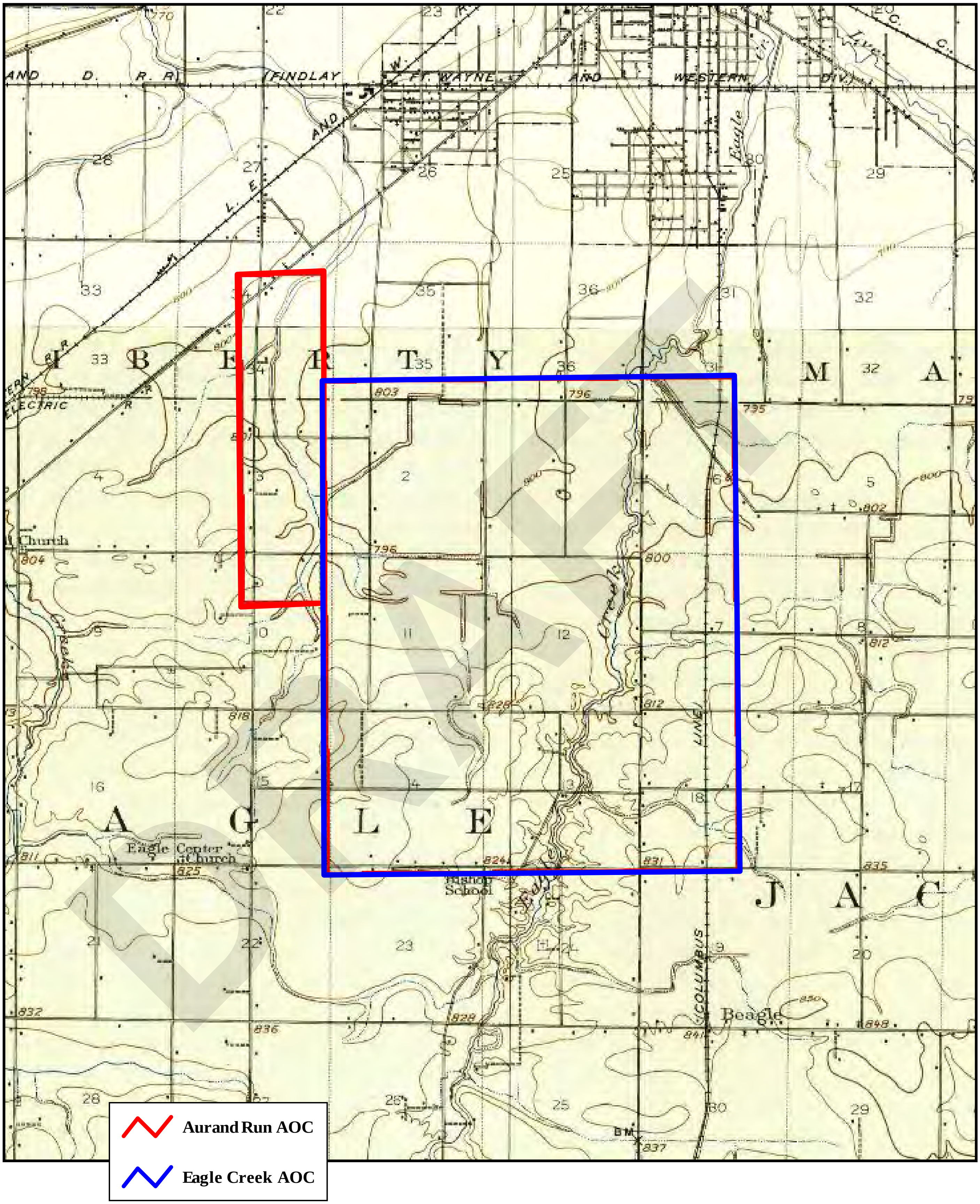

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Figure C10
15' Topographical Map
1907 Arlington, OH Quadrangle
1903 Findlay, OH Quadrangle
(USGS 2018a, 2018b)

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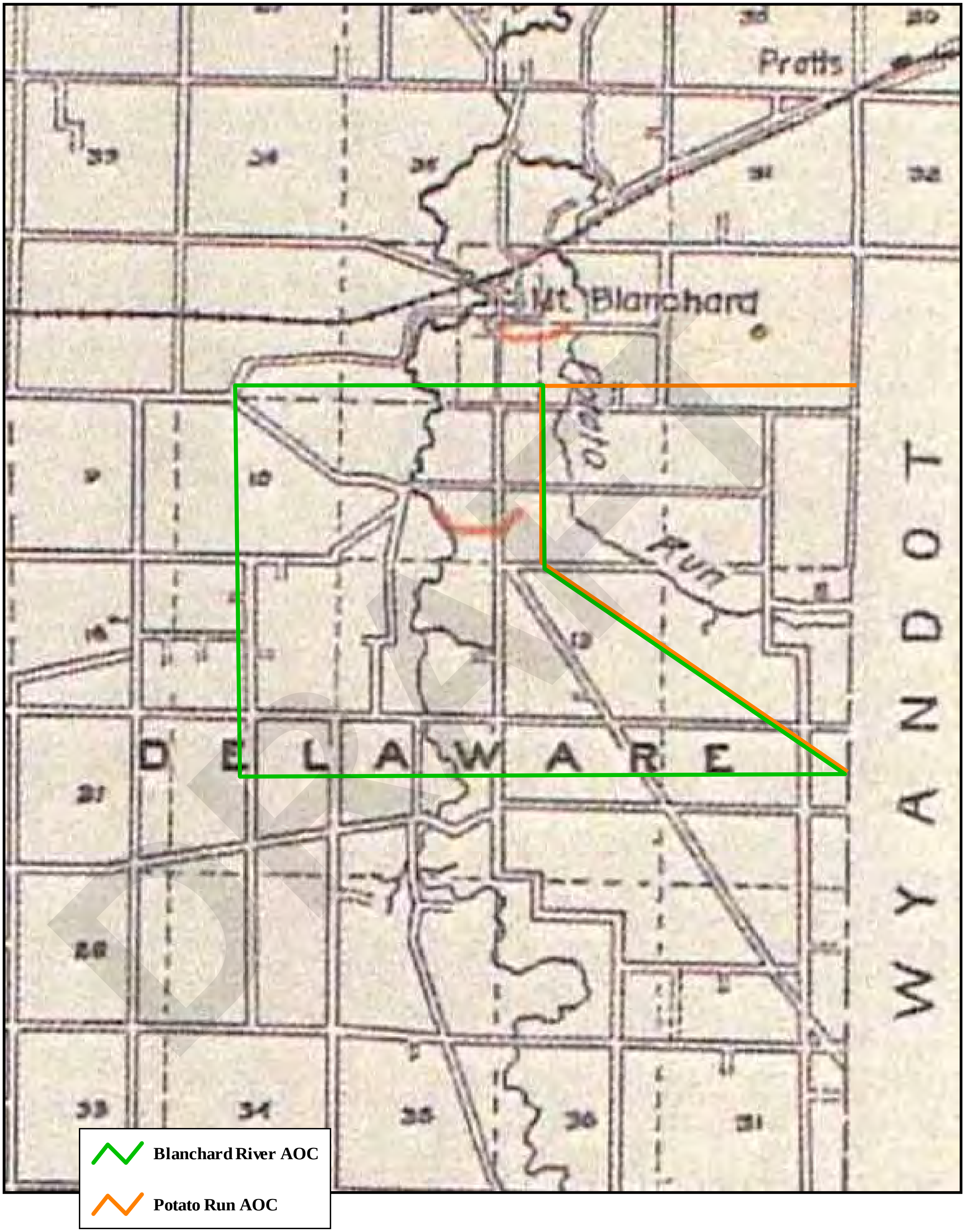

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Figure C11
Archaeological Atlas of Ohio
Hancock County (Detail)
(Mills 1914)

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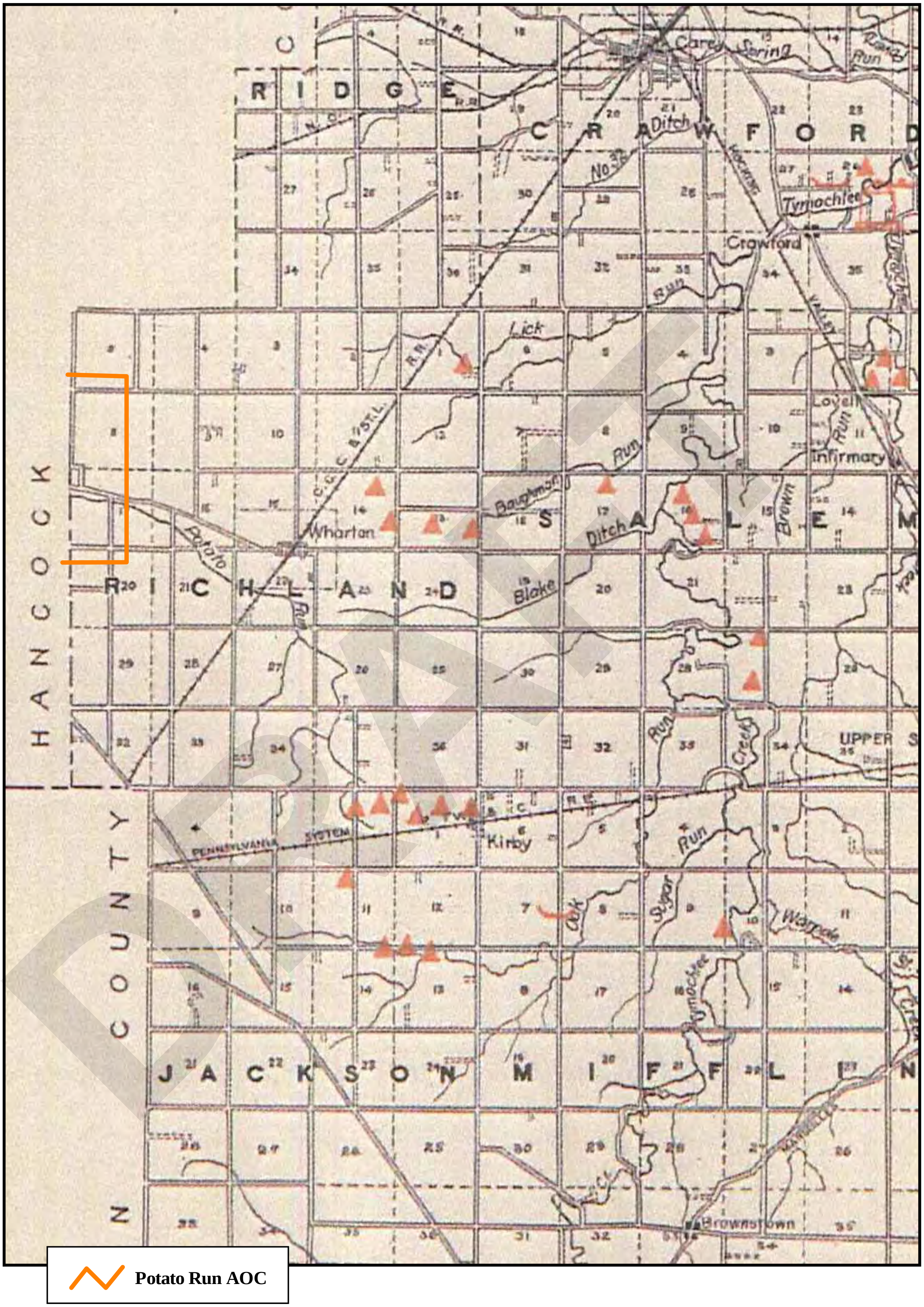

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Figure C12
Archaeological Atlas of Ohio
Wyandot County (Detail)
(Mills 1914)

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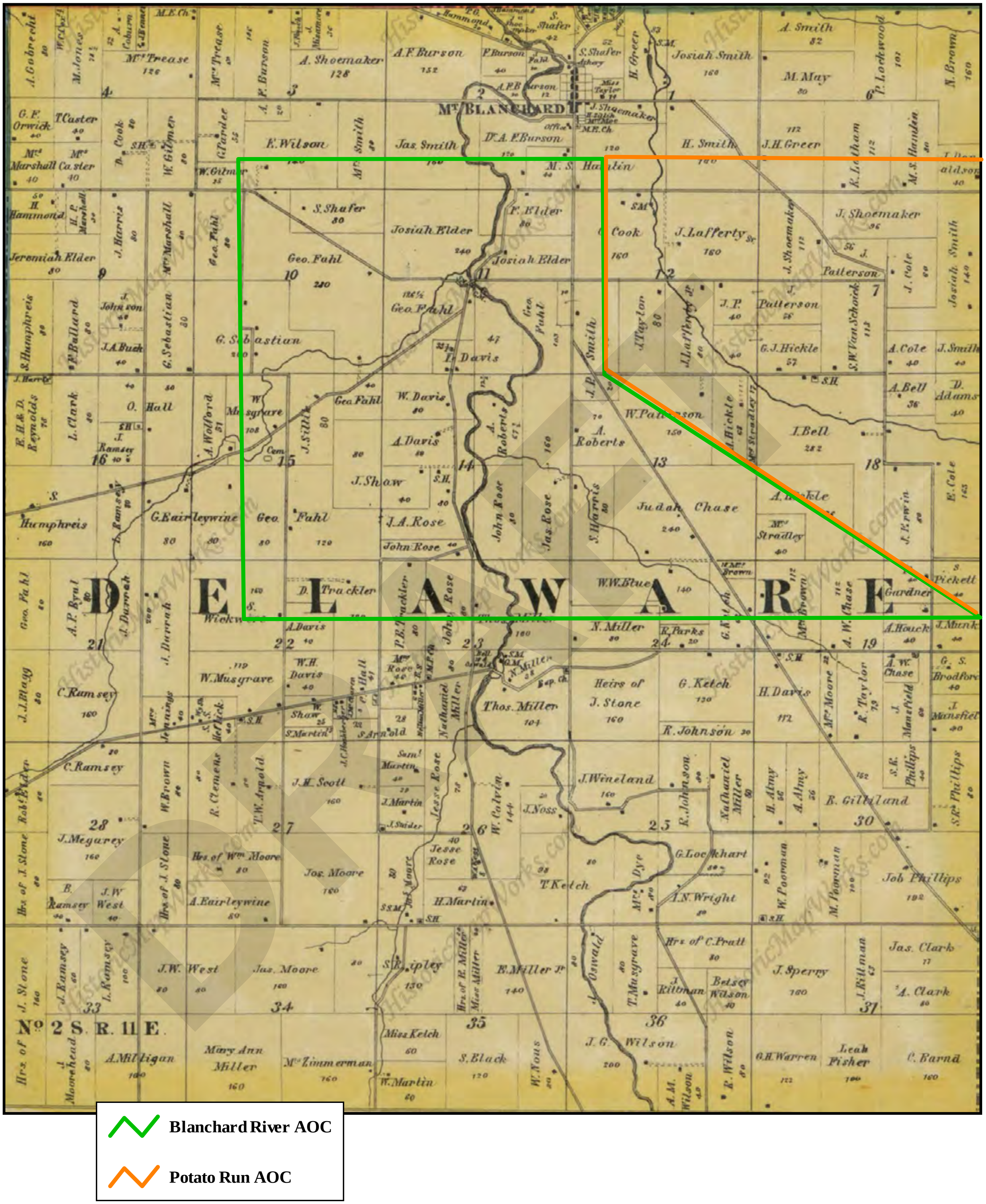

Figure C13
1863 Hancock County Atlas (Detail)
(Lake 1863)

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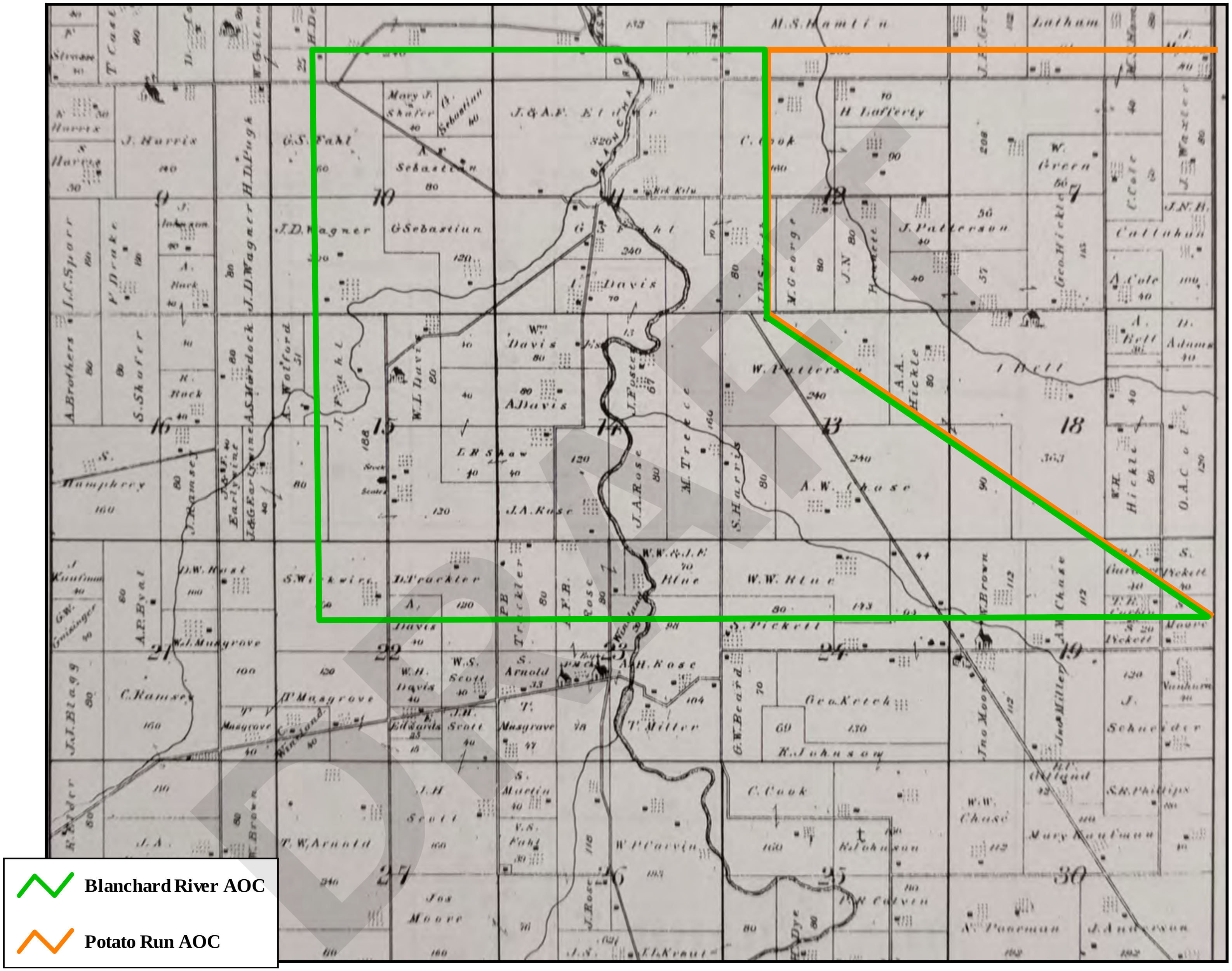

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Figure C14
1875 Hancock County Atlas
Delaware Township
(Hardesty 1875)

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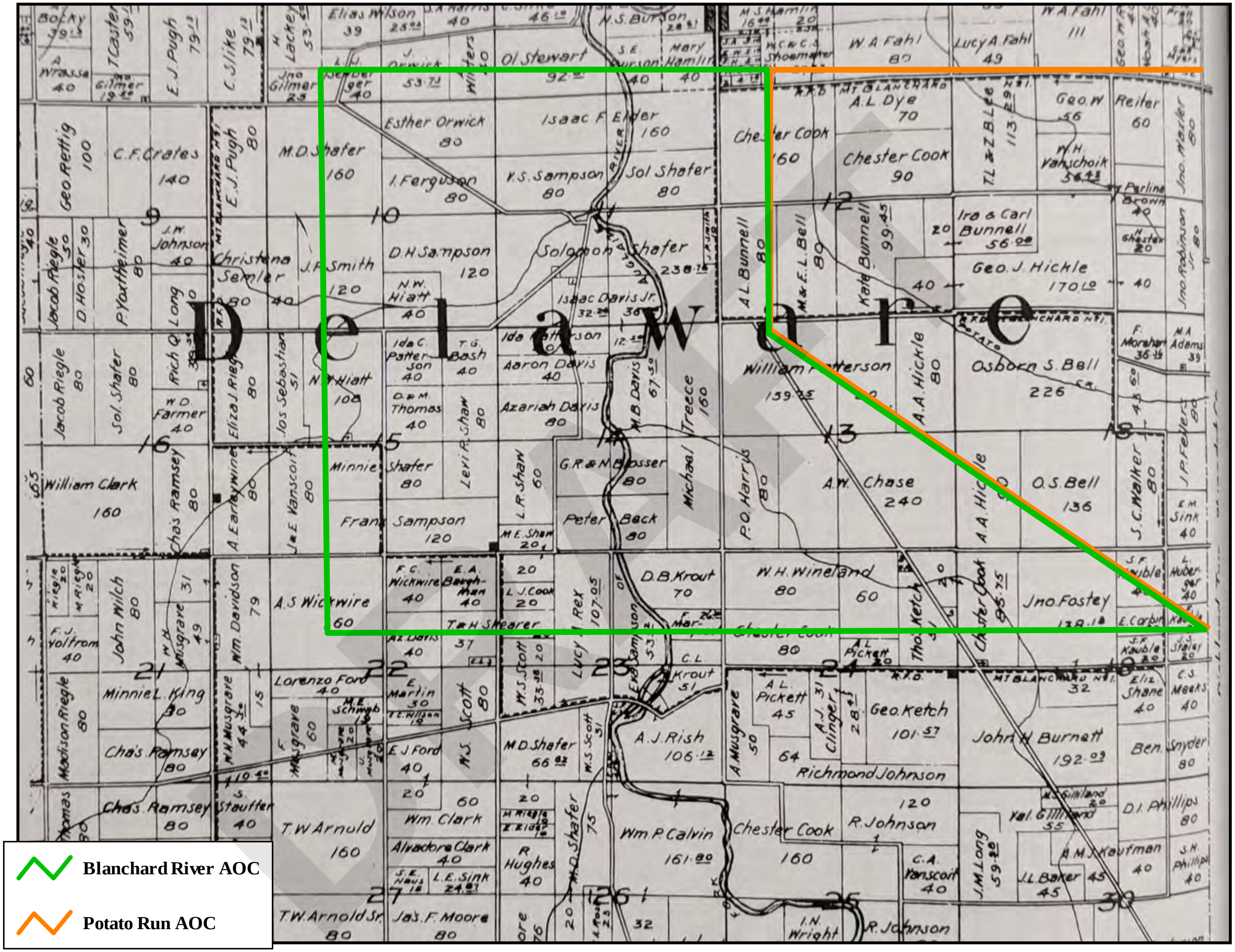

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Figure C15
1902 Hancock County Atlas
Delaware Township
(The Republican Company 1902)

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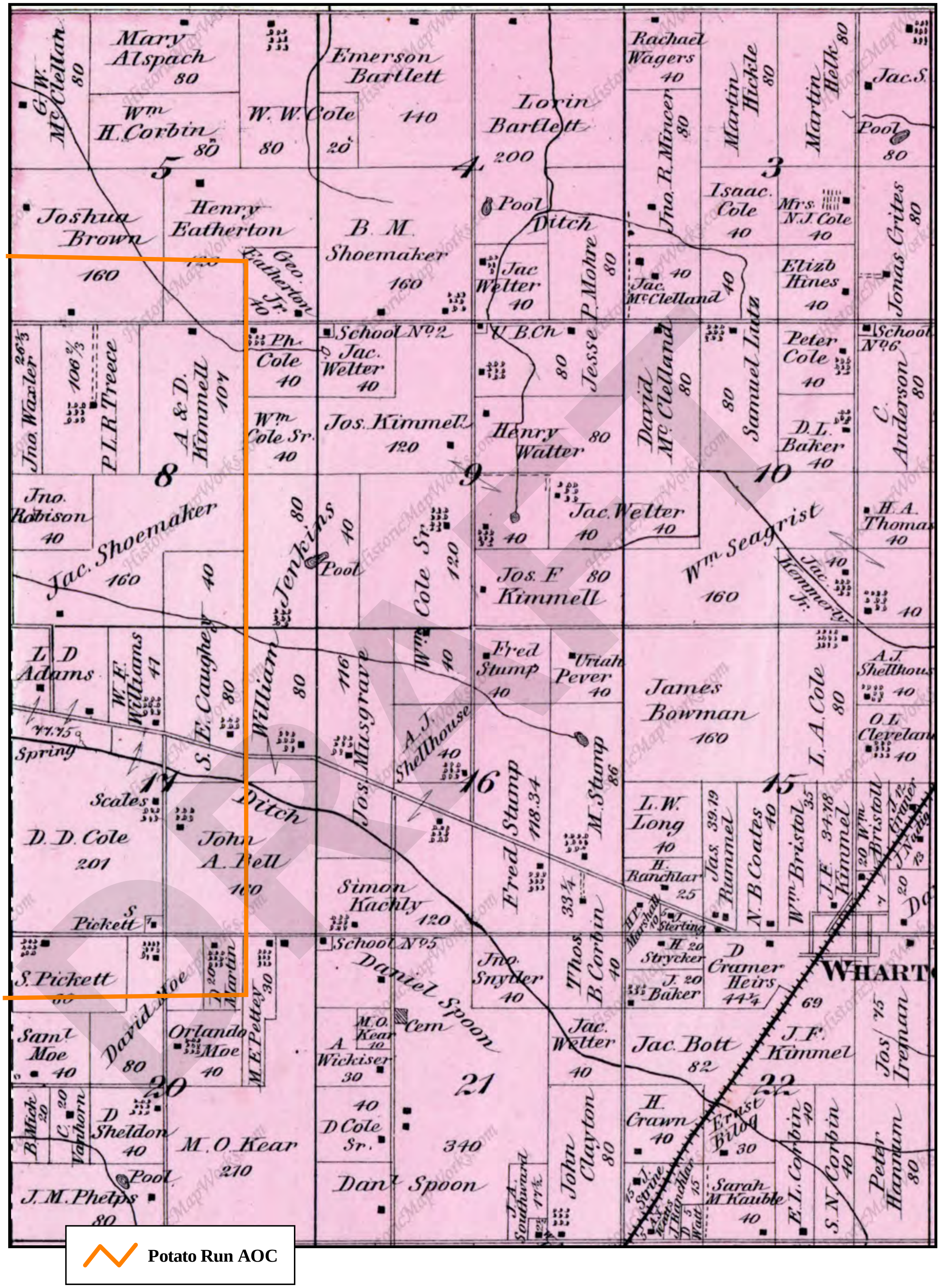

Figure C16
1879 Wyandot County Atlas
Richland Township
(Harrison & Hare 1879)

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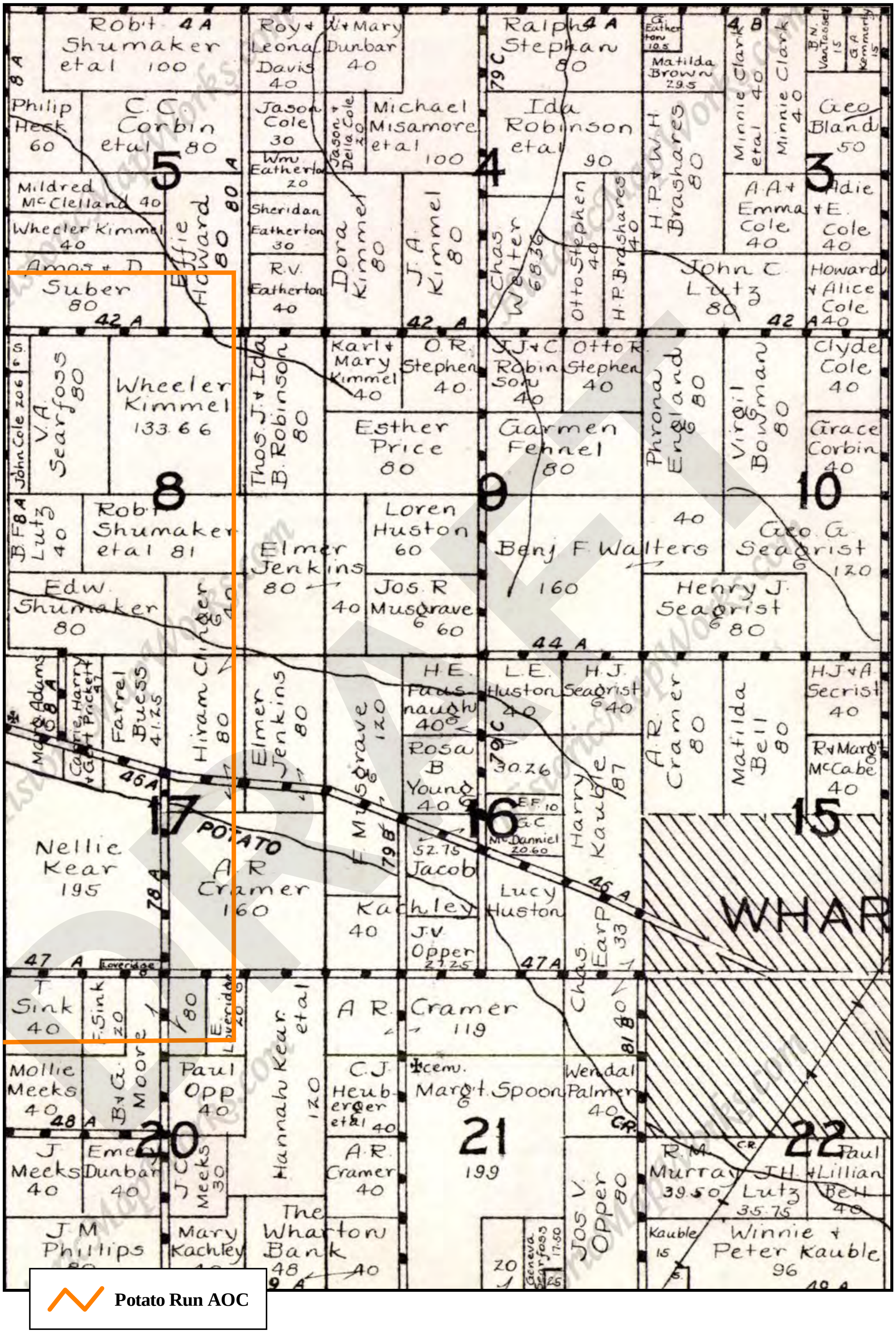

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Figure C17
1939 Wyandot County Atlas
Richland Township
(W.W. Hixson & Company, Inc. 1939)

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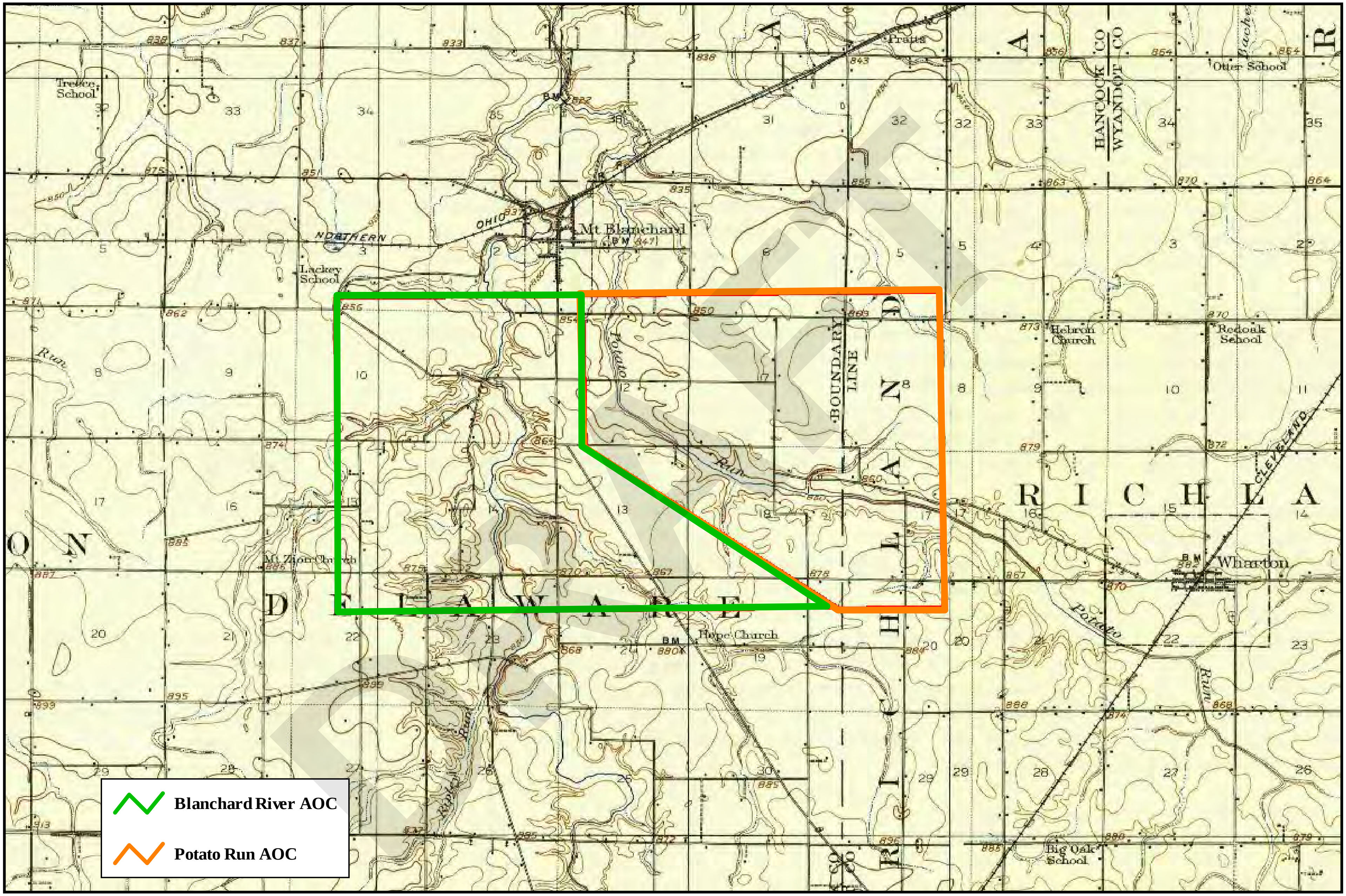

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Figure C18

15' Topographical Map

1907 Arlington, OH Quadrangle

1907 Upper Sandusky, OH Quadrangle

(USGS 2018b, 2018c)

N

Appendix E – UPDATED BENEFIT-TO-COST ANALYSIS

Hancock County Flood Risk Reduction Program:
Updated Benefit Cost Analysis

(STANTEC Project # 174316204)

Prepared for:

Stantec

Submitted by:

Economics
Public Policy
Planning
Jack Faucett Associates
Since 1963

Point of Contact:
Michael F. Lawrence, JFA President
4915 Saint Elmo Avenue, Suite 205
Bethesda, Maryland 20814
Phone: (301) 961-8835 Fax: (301) 469-3001
lawrence@jfaucett.com

DRAFT FINAL REPORT

June 2018

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Table of Contents

List of Exhibits

List of Appendices

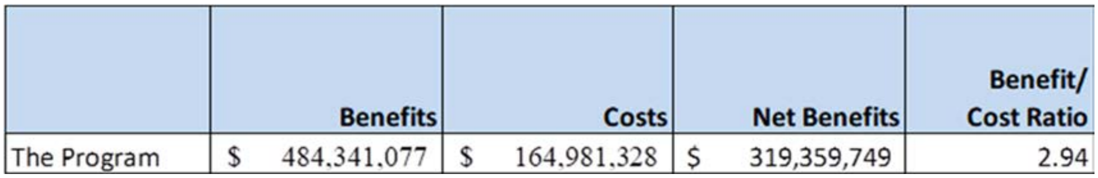
Executive Summary

The Maumee Watershed Conservancy District (MWCD) engaged the services of Stantec Consulting Services Inc. (Stantec) to analyze the feasibility of alternative structural and non-structural flood control approaches in their watershed and to provide an update to the previously submitted *Hancock County Flood Risk Reduction Program Final Report: Data Review, Gap Analysis, USACE Plan and Alternatives Review, and Program Recommendation*. Following the completion of the 2017 Hancock County Flood Risk Reduction Program report, MWCD and Stantec reviewed feedback from the community, processed additional survey data, and finalized the hydrologic analysis to help refine the study. The additional data collected verified the residual risk of the Program components and allowed the team to update the benefits and impacts of the considered alternatives.

Jack Faucett Associates (JFA) supported Stantec by revising the benefit-cost analysis (BCA) associated with the refinement of the Hancock County Flood Risk Reduction Program. The revised Program and its expected reduction of flood risk and subsequent damages is the subject of this updated BCA report. The BCA presented in this report represents an update and refinement of the previous BCA published March 2017. The project team expended a substantial effort to update and refine the estimates in this report, as well as conduct a complete quality assurance/quality control (QA/QC) analysis of each of the components of the BCA. The BCA addresses the data improvements, changes to the methodology, costs and benefits, and QA/QC efforts that resulted.

The summary of costs and benefits are provided in Exhibit ES- 1. The net present value for The Program with maintenance costs equals **$164.98 million**. The anticipated annual Program costs and benefits are included in Appendix A.

Exhibit ES- 1: Net Present Value of Benefits and Costs of the Hancock County Flood Risk Reduction Program, 2018 Dollars



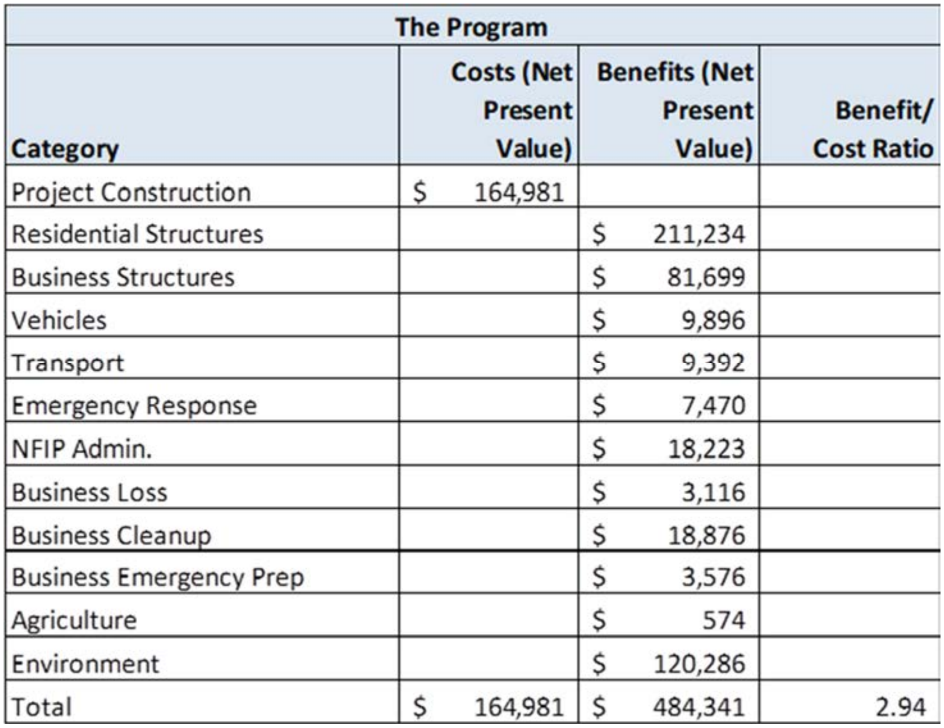
	Benefits	Costs	Net Benefits	Benefit/ Cost Ratio
The Program	$ 484,341,077	$ 164,981,328	$ 319,359,749	2.94

The individual benefit categories described in the report and in Exhibit ES- 2 provide the present value of each of the individual benefit categories, over the expected 50-year program analysis period.

Exhibit ES- 2 provides the benefits from The Program. Summing all of the present values of these benefits, the total benefits attributable to the Program are approximately **$484.3 million**, achieving a Benefit-Cost Ratio of **2.94**.

Exhibit ES- 2: Present Value Benefits from The Program,

Thousands of 2018 Dollars



The Program			
Category	**Costs (Net Present Value)**	**Benefits (Net Present Value)**	**Benefit/ Cost Ratio**
Project Construction	$ 164,981		
Residential Structures		$ 211,234	
Business Structures		$ 81,699	
Vehicles		$ 9,896	
Transport		$ 9,392	
Emergency Response		$ 7,470	
NFIP Admin.		$ 18,223	
Business Loss		$ 3,116	
Business Cleanup		$ 18,876	
Business Emergency Prep		$ 3,576	
Agriculture		$ 574	
Environment		$ 120,286	
Total	$ 164,981	$ 484,341	2.94

Respectfully Submitted,

Michael F. Lawrence, President

Chapter 1 Introduction

The Maumee Watershed Conservancy District (MWCD) engaged the services of Stantec Consulting Services Inc. (Stantec) to analyze the feasibility of alternative structural and non-structural flood control approaches in their watershed and to provide an update to the previously submitted *Hancock County Flood Risk Reduction Program Final Report: Data Review, Gap Analysis, USACE Plan and Alternatives Review, and Program Recommendation*. The U.S. Army Corps of Engineers (USACE), Buffalo District, previously published a report in November 2015 entitled, "The Blanchard River Flood Risk Management Feasibility Study Appendix B – Economics (DRAFT)." Jack Faucett Associates (JFA) supported Stantec by conducting a review of the USACE economics report (*Phase 1 Memorandum: Review and Assessment of the "Blanchard River Management Feasibility Study Appendix B – Economics (Draft)"* – December 2016). In 2017 JFA conducted a benefit-cost analysis (BCA) of the Hydraulic Improvements component of the Hancock County Flood Risk Reduction Program as well as the Final Program recommended by Stantec. This BCA effort is described in detail in a report entitled, "*Hancock County Flood Risk Reduction Program: Benefit Cost Analysis*" (March 2017). Following the completion of the 2017 Hancock County Flood Risk Reduction Program report, MWCD and Stantec reviewed feedback from the community, processed additional survey data, and finalized the hydrologic analysis to help refine the study. The additional data collected verified the residual risk of the Program components and allowed to the team to update the benefits and impacts of the considered alternatives. Stantec revised the hydrologic and hydraulic models for the Hancock County Flood Risk Reduction Program (The Program), generated revised water surface profiles, provided a refined opinion of probable cost for each Program component, and updated the elevations of the structure inventory based on the processed LiDAR data. The revised Program and its expected reduction of flood risk and subsequent damages is the subject of this updated benefit cost analysis report.

1.1 Organization of the Report

This report contains 12 chapters. Chapter 1, the introductory chapter, describes the project background along with a brief history of the areas typically impacted by flooding, impacts of the 2007 flood event and progress on flood mitigation efforts to date. It also provides an overview of the study effort, report organization and project rationale. Chapter 2 describes the methodology used to evaluate the economic efficiency of the proposed Program. It provides an overview of benefit-cost analysis (BCA) and describes the types of benefits included. Chapter 3 describes the Program's opinion of probable costs for the flood mitigation efforts and a projected Program schedule. Chapter 4 reviews the benefit of reduced structural and content damages to residences and businesses as a result of the proposed program alternatives. Chapter 5 covers reduced damages to motor vehicles. Chapter 6 reports the benefits of reduced road closures and transportation impacts. Chapter 7 provides the benefits of reduced costs related to emergency response and debris removal. Chapter 8 looks at the benefit of avoiding administrative costs for the National Flood Insurance Program. Chapter 9 reviews the estimated value of mitigating reduced business sales and wage losses. Chapter 10 reports agricultural losses that the program may mitigate. Chapter 11 outlines increased environmental and land use benefits. Chapter 12 summarizes the key results of the BCA.

1.2 Background and Flood History

The Blanchard River Watershed, a portion of the Maumee River Watershed, is located within the counties of Allen, Hancock, Hardin, Putnam, Seneca, and Wyandot in northwest Ohio. The Blanchard River has a history of flooding with records dating back to January 1846, causing significant damages in the City of Findlay, Hancock County, and the Villages of Ottawa and Glandorf during the 2007 and 2008 floods. According to the stream gage located at Findlay[1] maintained by the U.S. Geological Survey (USGS), the Blanchard River has reached flood stage at least once in 15 of the past 20 years. Between December 2006 and March 2008, Findlay flooded four times with events considered larger than the 10-percent annual chance exceedance (ACE) event flood. Two of the four flooding events are within the top six floods ever recorded in the City.[2]

Three types of flooding occur most often in the Blanchard River Basin – river flooding, flash flooding and urban flooding. Flooding takes place in the urban areas of Findlay and throughout the agricultural land adjacent to the major streams, particularly in the spring when the snows melt and rainfall increases.[3] In the City of Findlay and the Villages of Ottawa and Glandorf, tens of millions of dollars in damage resulted from flooding in 2007 and 2008. Based upon available information, the estimated value of the properties in the potential floodplain within the areas influenced by the recommended Flood Risk Reduction Program exceeds $1 billion. Both businesses and residences experience substantial damage during flood events. Flooding often persists for days during major events, resulting in significant cleanup and restoration expenses to the local, state and federal governments.[4]

In addition to the flood damage to residences and small businesses, flooding damages disrupt the local road and rail systems, as well as regional manufacturing businesses that rely on those facilities. During the periods of major flooding, extensive road closures and delays are typical.

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[1] USGS stream gage located in Blanchard River near Findlay, Ohio (04189000)

[2] National Weather Service. https://water.weather.gov/ahps2/hydrograph.php?wfo=cle&gage=fdyo1

[3] USACE, Blanchard River Flood Risk Management Feasibility Study Appendix B – Economics (DRAFT), November 2015

[4] Ibid.

1.3 Benefit-Cost Analysis

The application of a benefit-cost analysis (BCA) has a long-standing history in the region to augment community information and inform local decision-making. Historically, the Ohio Conservancy Law (ORC Chapter 6101), passed in 1914, gave the state authority to establish watershed districts to raise funds for improvements through various funding mechanisms.[5] In the early 20th century, the Miami Conservancy District project brought this approach to fruition with the use of complex simulation and optimization modeling, a detailed cost–benefit analysis, and linking of economics, engineering, science, and law into a far-reaching solution to a complex water resources problem.[6] The Miami Conservancy District is a river management agency operating in Southwest Ohio to control flooding of the Great Miami River and its tributaries. Similarly, the Maumee Watershed Conservancy District, or MWCD, established in December of 1948, provided similar solutions to 15 counties tributary to the Maumee River and western basin of Lake Erie.[7] The upper reaches of the Blanchard River examined within this report are included within the Maumee River watershed.

The benefit-cost ratio (BCR) is determined by dividing the present value of total estimated economic benefits by the present value of estimated costs of the recommended improvements. The BCR indicates which project alternatives produce the most benefits for each dollar of cost. Projects with high BCRs produce the most efficiency per dollar invested. The ratio of benefits to costs must exceed 1.0 for consideration of advancement under Ohio Conservancy Law.

In this BCA study, the research team identified the estimated costs avoided by reducing flooding in and around the City of Findlay and Hancock County. Stantec developed the Hancock County Flood Risk Reduction Program to mitigate the risk of flooding and to increase protection for the community and their assets from periodic flooding events. Stantec provided JFA with Water Surface Profiles (WSP) for the Blanchard River, Eagle Creek, and Lye Creek for eight different return frequencies. By combining the WSP and the floodplain structure inventory, the team determined the expected flood damages avoided over the life of the Program.

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[5] http://www.ohiohistorycentral.org/w/Ohio_Conservancy_Law

[6] Holmes, K. & Wolman, M. Early Development of Systems Analysis in Natural Resources Management from *Man and Nature* to the Miami Conservancy District. Environmental Management (2001) 27: 177

[7] https://www.leagle.com/decision/1960579112ohioapp4671501

1.4 Project Description and Rationale

Representing 15 counties in northwest Ohio and the second largest conservancy district in the state, MWCD is a political subdivision of the State of Ohio that oversees water management, including flood risk reduction, as established under Ohio Revised Code Chapter 6101. The District has the experience assessing these issues and the authority to deal with drainage in the watershed.

In 2016, MWCD contracted Stantec to complete a "Proof of Concept" by reviewing the recommended USACE plan for technically feasible optimizations while at the same time taking a step back to see if there were other feasible and cost-effective solutions that were implementable within the watershed.

After project refinements, Stantec, in March 2017, recommended additional alternative solutions to the base project including dry storage basins on Eagle Creek, the Blanchard River, and Potato Run, removing inline structures on the Blanchard River, and widening the floodplain bench as the Blanchard River flows through the City. Stantec's recommended Final Program increases the level of flood reduction reduces the flooding stage for the 1-percent annual change event by an estimated 3.6 feet below the existing flood elevation on the Blanchard River near Main Street.

JFA evaluated benefits for both the Hydraulic Improvements along the Blanchard River in downtown Findlay and the Final Program. JFA produced a benefit-cost analysis for both the Final Program, as well as the initial Hydraulic Improvements project. That BCA produced a BCR (4.64 – Hydraulic Improvements, 1.60 – Final Program) that demonstrated to the community that the Program benefits outweighed the costs and warranted additional support for moving forward. The BCA demonstrates that the project is highly beneficial to Hancock County community and its residents.

With the additional survey data that was processed, and the finalized hydrologic analysis in hand, Stantec revisited the Final Program at the request of MWCD to refine the study. Stantec verified alternatives that were viable and confirmed the solutions that were not economical based on the enhanced data from the LiDAR survey and projected cost estimates. Stantec completed multiple hydraulic simulations to produce revised WSPs for JFA to utilize in a revised BCA. The following report describes the methodology used in the updated BCA, opinion of probable Program costs and anticipated benefits of the updated Hancock County Flood Risk Reduction Program compared to the existing conditions.

The benefit-cost analysis (BCA) presented in this report represents an update and refinement of the previous BCA published March 2017. The project team expended a substantial effort to update and refine all of the estimates in this report, as well as conduct a complete quality assurance/quality control (QA/QC) analysis of each of the components of the BCA. The last section of Chapter 12, Benefit Cost Analysis Results, highlights major data improvements, changes to the methodology, levels of costs and benefits, and QA/QC efforts.

Chapter 2 Methodology

Chapter 2 describes the methodology used to evaluate the economic efficiency of the proposed *Hancock County Flood Risk Reduction Program: Updated Benefit-Cost Analysis*. It provides background information on conducting a benefit-cost analysis (BCA), explains the construct of "base case" or "no action" condition, expands upon the types of benefits measured and explains the concepts of net present value and of discounting in this type of project.

2.1 Fundamentals of Benefit Cost Analysis

This section provides a brief overview of the essentials of benefit-cost analysis (BCA). Benefit-cost analysis is an economic technique to evaluate what is achieved (benefits) compared to what is invested (costs).[8] BCA analyzes whether the value of benefits exceeds the value of the costs. This allows decision makers to allocate resources in an efficient manner.

BCA can assist decision makers select the best alternative by monetizing both benefits and costs. The first comparison in BCA is to calculate the net benefits by subtracting economic costs from total economic benefits. This allows the analysis to scale a range of alternatives for comparison. The second comparison is to calculate the benefit-cost ratio (BCR) by dividing the present value of total economic benefits by the present value of total economic costs. The ratio of these two values (total benefits/total costs) allows for ranking or comparing different projects by informing which alternative produces the most benefits for every dollar of cost. A BCR of one (1) indicates the total benefits equal the total costs. Therefore, for each dollar of cost, a dollar of benefit accrues. If the ratio of total benefits to total costs is less than one (1), the total costs exceed the total benefits. This indicates a poor investment of resources.

For projects such as flood risk management, decision makers can compare and prioritize projects from across the nation and regionally. Projects with higher BCRs are preferred and the BCR becomes a factor to authorize projects to move from conceptual planning to detailed design and implementation. In an earlier phase of this project, the prior USACE plan used a BCA to compare a range of flood mitigation alternatives from a national perspective. Under the most recent preceding phase of this program, with efforts led by the Maumee Watershed Conservancy District (MWCD), the Program Team utilized a BCA to examine the costs and benefits of the recommended Flood Risk Reduction Program from a regional perspective. This current project is similar in scope. The JFA Team is updating the BCA with new model and cost estimate information provided by Stantec. Exhibit 2-1 provides some useful applications of BCA.

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[8] USACE & Institute for Water Resources. Economics Primer. IWR Report 09-R-3, June 2009.

Exhibit 2-1: Useful Applications of Benefit Cost Analyses

Useful Applications of Benefit Cost Analyses (BCAs)

A BCA considers the changes in benefits and costs that a project would produce by a potential improvement to the status quo protection. In flood mitigation, decision makers may use BCA to help determine the following:

- ***Whether or not a project should be undertaken at all*** - (i.e., whether the project's life-cycle benefits will exceed its costs).
- ***When a project should be undertaken -*** A BCA may reveal that the project does not pass economic muster now, but would be worth pursuing 10 years from now due to projected regional growth. If so, it may be prudent to take steps now to preserve the future project's footprint.
- ***Which among many competing alternatives and projects should be funded given a limited budget -*** A BCA can be used to select from among design alternatives that yield different benefits.
- ***After project implementation -*** BCA can evaluate current project performance or evaluate implemented projects to verify BCA ratios for future project performance measurement.

The comparison of benefits to costs over the life of a project is not a simple task of adding up the benefits. The reason is the value of a dollar changes with time. A dollar an entity spends or earns in the future is usually worth less than it is today. To compare multiyear projects, one must account for this changing value of the dollar. Two factors account for the diminishing value of the dollar over time. The two factors are 1) inflation, and 2) the time value of resources. BCA compares projects in real or base year dollars, eliminating the effects of inflation. The process measures the time value of resources by the annual percentage factor known as the discount rate. Through discounting, decision makers can objectively compare different investment alternatives based on their respective current values.

The USACE developed a series of manuals describing how to evaluate urban benefits of water resources implementation projects. The general guidance within these manuals is applicable for both national and regional analyses. JFA followed the guidance of these manuals in reviewing the earlier BCA and, as described below, used these USACE-derived procedures to estimate

Regional Economic Development (RED) benefits and costs of the recommended water resource projects.[9] [10] Exhibit 2-2 provides the major steps in the BCA process.

The objective of the following sections is to discuss in greater detail several methodological issues and procedures applied in this review. These areas include defining the base case condition, project alternatives, Regional Economic Development (RED) benefits, and analysis methodology.

2.2 Base Case Condition ("Without Project Alternative")

An important aspect of benefit-cost analysis is the selection of a base case (i.e. a "without-project condition" or "no action condition") and its comparison with the recommended Flood Risk Reduction Program. According to the USACE's Planning Guidance Notebook, the without-project condition is defined as, *"… the most likely condition expected to exist in the future in the absence of a proposed water resources project. Proper definition and forecast of the future without-project condition are critical to the success of the planning process. The future without-project condition constitutes the benchmark against which plans are evaluated."*[11]

Exhibit 2-2: Major Steps in the Benefit Cost Analysis Process

1. Establish objectives
2. Identify constraints and specify assumptions
3. Define the base case and identify alternatives
4. Set the analysis period
5. Define the level of effort for screening alternatives
6. Develop base case damage estimate
7. Estimate benefits and costs relative to base case
8. Evaluate risks
9. Compare net benefits and rank alternatives
10. Make recommendations

2.3 Definition of NED and RED Benefits

The USACE defines National Economic Development (NED) benefits as benefits that accrue to the nation as a whole: *"Beneficial effects in the NED account are increases in the economic value of the national output of goods and services from a plan."*[12] The methodology employed by the USACE recognizes NED benefits as only those impacts that would be lost to the nation in the absence of the project.

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[9] USACE, Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies, 1983

[10] Planning Guidance Notebook" (Engineering Record No. 1105-2-100), 2000.

[11] USACE. 2000. "Planning Guidance Notebook." (Engineering Record No. 1105-2-100, Section 2-4.b.(1)). http://www.usace.army.mil/publications/eng-regs/er1105-2-100/

[12] USACE. 1983. "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies." p.8, Section 1.7.1.(b).

In addition, USACE recognizes improvements in efficiency, such as reductions in the nation's overall flood protection bill as NED benefits.

The USACE defines Regional Economic Development (RED) benefits as benefits that accrue at the regional level. According to the USACE Principles and Guidelines, *"The RED account registers changes in the distribution of regional economic activity that result from each alternative plan."* [13]

2.4 Definition of the RED Area

According to the USACE Principles and Guidelines, *"The regions used for RED analysis are those regions with in which the plan will have particularly significant income and employment effects."* [14] For this study, Hancock County is the core of the RED area.

2.5 Benefit-Cost and Net Present Value Analysis

To determine whether an investment is justifiable, the project sponsor performs a Benefit-Cost Analysis (BCA) that quantifies the benefits and costs. The analysis can analyze benefit and cost quantities in many ways, such as total benefits minus total costs (i.e. net present value analysis) or benefits divided by costs (i.e. benefit-cost ratio). In the previous case, the net present value of the costs were based upon estimated costs provided by Stantec for the proposed Hydraulic Improvements components and The Program within the Blanchard River, Eagle Creek and Lye Creek floodplain in and near Findlay, Ohio. The current project again relies on estimated costs updated and provided by Stantec for the Program. However, in order to be meaningful, a BCA must not only express all benefits and costs in monetary terms, it must also account for the change in the value of the dollar over time.

The value of a dollar changes not only with inflation, but also because today's dollar is worth more than a dollar available years from now. For example, a single dollar available today would be worth more than one single dollar in five years because it could be invested and earn interest for five years. An economic concept called "net present value," accounts for the impact of time on the value of money and discounts the future value of a dollar. The analyst selects an appropriate discount rate to calculate the "present value" of any sum of resources or money to be spent or received in the future. The discount rate for costs and benefits applied here is from the annual US Office of Management and Budget (OMB) publication, ***Discount Rates for Cost-Effectiveness, Lease Purchase, and Related Analyses*** which applies to long lived infrastructure investments. The application of the discount rate to future sums to calculate their present value is known as "discounting." Through discounting, different investment alternatives can be objectively compared based on their respective present values, even though

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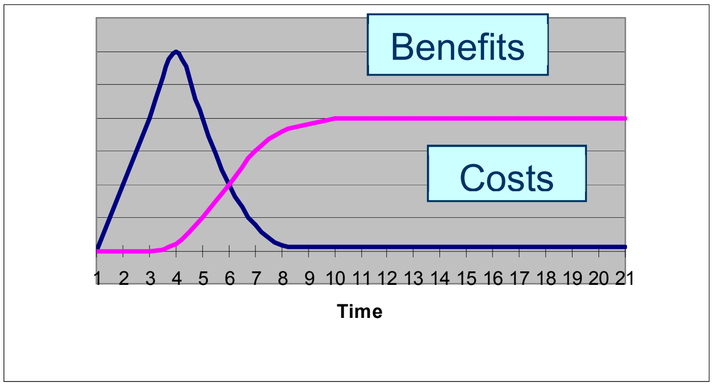
[13] Ibid., p. 11, Section 1.7.4.(a)(1).

[14] USACE. 1983. "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies." p. 11, 1.7.4.(a)(2).

each has a different stream of future benefits and costs. This concept of net present value is important because the timing of costs and benefits of a flood risk reduction program are often different.

A frequent observation in public infrastructure projects is that costs accrue both immediately and over time, while benefits accrue over time after the majority of costs accrue. Exhibit 2-3 provides a sample of typical project benefit and cost flows. Costs, as considered by an engineer for example, inflate over time to reflect generally accepted increases in the costs for goods and services. This provides an estimate of the cash that is going to be necessary to complete a project. However, benefits, as considered in economics, are discounted as they move into the future. Net present value provides the common ground against which the analysis considers costs and benefits.

Exhibit 2-3: Sample Project Costs and Benefit Streams



Most major infrastructure projects use a period of analysis of 50 to 100 years.[15] However there is no specific criterion for selecting a period of analysis. For the purposes of developing this BCA, a period of 50 years has been utilized.

A Benefit-Cost Ratio (BCR) greater than one indicates the anticipated net present value of benefits derived because of the proposed improvements will exceed the estimated net present value of costs and that the investment is anticipated to provide positive value to the community. A ratio of less than one indicates that the anticipated benefits are less than the estimated costs and would require further study or innovative strategies to justify the project.

2.6 Economic Analysis Methodology

There are several steps undertaken to develop a flood risk reduction program BCA. Estimating the program costs and benefits is the initial step in the economic analysis methodology. Once

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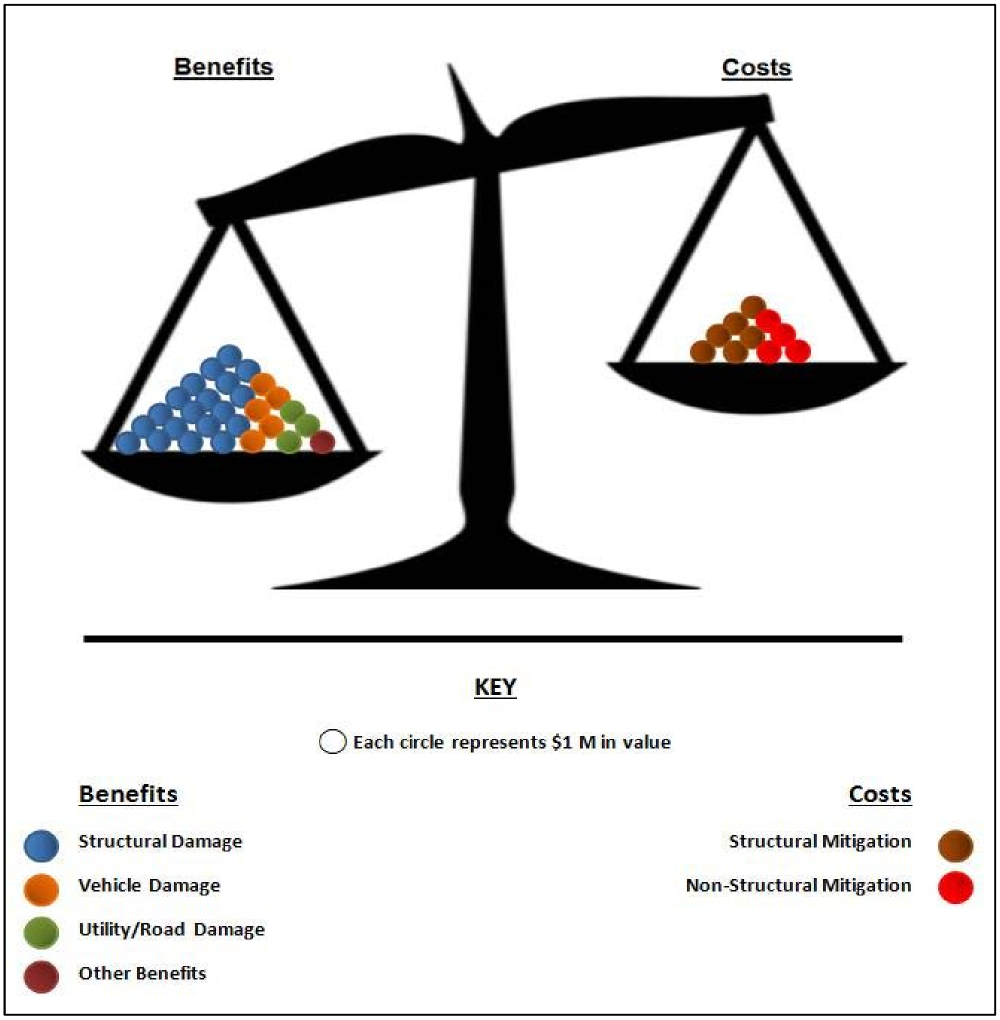
[15] USACE, National Economic Development Procedures Manual, Urban Flood Damage. IWR Report 88-R-2. March 1988

the engineers have analyzed the causes of flooding and developed alternative mitigation strategies, a cost to implement the strategy or strategies is developed. This will include both construction costs and the expenses for on-going maintenance of the program.

Program benefits are changes in value to the output of goods and services expressed in monetary units. Economic benefits are those that accrue in the planning area and the rest of the nation from the selected program. Benefits typically include flood damage reduction avoided in commercial and residential buildings, vehicles, transportation, utilities, equipment, roads, bridges, crops and others. Exhibit 2-4 provides an example of how the BCA weighs benefits and costs against each other.

Flood damages to property, injury and the loss of human life has identified flood risk as the largest single category of loss from natural disasters. Many of these losses can be reduced or prevented with proper planning and engineered solutions. A flood damage reduction plan includes one or more of the measures identified by the engineers. Each one of these measures has some effect on one or more of the three input relationships to the hydro-economic model used to estimate expected annual damages (EAD). The effects of damage reduction measures on the various EAD relationships are what provide the monetized benefits of flood risk reduction.

Exhibit 2-4: Example of Benefits Versus Costs in Flood Mitigation BCA



A stage-damage function (i.e., depth-damage or damage function) shows the relationship between the depth of water and the amount of damages sustained at that depth. Damages may be separated by contents, structure, business loss, transportation losses and other categories of physical and economic damage. The effectiveness of any plan in reducing these various categories of damages will vary from measure-to-measure and plan-to-plan. It is generally the economist's job to estimate a damage function without and with a plan in place and then to estimate a new damage function for every plan that may alter the damage function.

A stage-discharge function (i.e., the rating curve) shows the relationship between the amount of water (discharge or flow) and the stage or depth it reaches in the floodplain reach. Some flood damage reduction measures will alter the stage-discharge relationship. A levee or floodwall, for example, may actually cause a given amount of water to attain a greater depth, causing the rating curve or a part of it to shift upward.

The discharge-exceedance frequency function (i.e., the flow-frequency or frequency curve) shows the relationship between a flow of water (discharge) and the frequency with which a flow of that amount or a greater amount will occur in any given year. Some flood damage measures alter this relationship. Ordinarily, a given flow or discharge will become less frequent, thereby reducing damages. It is generally the engineer's job to estimate discharge-exceedance frequency relationships without a plan in place and then to estimate new functions for every plan that may alter the discharge-exceedance frequency function.

Channel modifications can affect the discharge-exceedance frequency function as well as the rating curve. In many cases, the modifications will increase velocity in the improved section but downstream, where no improvements have been made, there may be a greater discharge and an increase in its frequency. For more detailed discussion of these relationships, refer to Stantec's *Hancock County Flood Risk Reduction Program Final Report*.

The analysis proceeds with an inventory of all structures and land use within the identified floodplain. Structural damage costs for the without program and with the program were estimated using the USACE Hydrologic Engineering Center Flood Damage Analysis (HEC-FDA) Economic model, Version 1.4.2 (July 2017). The analysis follows the framework and methodology as directed by the *HEC-FDA Flood Damage Reduction Analysis User's Manual (*April 2016*).* The content damage, including motor vehicles, is also estimated by applying the HEC-FDA model to the structure inventory and the water surface profiles without The Program and with The Program implemented. The difference between the without and with program damages are the damages avoided for the major categories of benefits. Other benefit categories included in this report include:

- Transportation
- Emergency Response
- NFIP Administrative Cost
- Business Losses (Income)
- Business Losses (Cleanup)
- Business Losses (Emergency-Plan)
- Agricultural
- Environmental & Land Use

For each of these benefit categories the study team utilized existing data and tools or developed new data and tools to estimate the EAD as was done with the HEC-FDA model. The team conducted surveys and interviews with key leaders of the local business, agricultural, and educational communities. Information was collected on how their organizations were impacted by the 2007 flood or other flooding events to determine how a reduction in the flood water depths would reduce flooding damages and disruptions. Each chapter of this report discusses these loss reductions and how they were estimated.

The team employed data and tools from Federal Emergency Management Agency (FEMA), USACE, the IMPLAN Group, Inc. and the Office of Management and Budget (OMB). From FEMA, we utilized the portion of the HAZUS-Flood model dealing with motor vehicle damages. FEMA databases also provided estimates of the annual environmental benefits from the conversion of land use to reduced flood damage risk. Data acquired by the USACE in the original efforts related to Hancock County and Blanchard River provided a detailed crop damage model that was calibrated to Hancock County. The OMB provided a discount rate for long lived infrastructure projects. IMPLAN is a supplier of detailed economic models designed to measure how the Hancock County economy would be impacted due to the loss of business activity during and after the flood event. The various data sources are cited in the individual chapters of this report.

Chapter 3 Project Costs and Schedule

This chapter presents the estimates for both one-time capital and ongoing maintenance costs associated with the *Hancock County Flood Risk Reduction Program: Updated Benefit-Cost Analysis*. The first section describes what project costs are used in a Benefit Cost Analysis. The next section provides the details on 1) one-time construction, planning, engineering and design costs 2) maintenance and associated costs, and 3) program timeline of costs and the start of benefit accrual. The third and final section of this chapter presents the discounted value of the costs.

3.1 Definition of Project Costs

All of the expenditures required for implementation of the project define the costs of the program. The benefit-cost analysis (BCA) weighs the costs of the project against the project benefits. In this program, the cost includes preparatory work, engineering, construction and other elements described below, plus operations and maintenance (O&M) costs to maintain performance of the proposed improvements program. Costs are based on professional judgement based upon past experience, prior bid prices received from previous analogous projects, estimated material costs and other anecdotal information provided by the local communities. Contingencies and administrative expenses factor into project cost estimates. For this Program, project costs are based on costs local to the City of Findlay and Hancock County.

3.2 Hancock County Flood Risk Reduction Program Cost Estimates

This BCA estimates the anticipated costs and benefits of the proposed Flood Risk Reduction Program against a baseline (also called the “base case” or “no build” case). The baseline represents an assessment of the way the world would look if this project is not undertaken. This section covers the estimated construction and maintenance costs.

3.2.1 Construction Costs

Stantec developed estimates for the opinion of probable costs for The Program reported in the revised Final Report (*Hancock County Flood Risk Reduction Program – Final Report Update*). Exhibit 3-1 to Exhibit 3-5 summarize the opinion of probable costs for various phases and elements of The Program. Each exhibit lists the description of each of ten areas of work tasks. These elements include:

- Mobilization, Demobilization and Preparatory Work
- Lands and Damages
- Relocations
- Fish and Wildlife

- Road, Railroads & Bridges
- Channels and Canals
- Floodway Control & Diversion
- Cultural Resources
- Engineering & Design
- Construction Management

The remaining four columns of Exhibits 3-2 to 3-5 detail the anticipated direct cost, contingency percent (25.0% or 30.0% depending on the case), contingency amount, and the total cost. The work phases shown in the five exhibits are:

- Exhibit 3-1: Hydraulic Improvements – Phase 1
- Exhibit 3-2: Hydraulic Improvements – Phase 2: Railroad Bridge Modifications
- Exhibit 3-3: Eagle Creek Dry Storage Basin (Option EC-2C)
- Exhibit 3-4: Potato Run Dry Storage Basin (Option PR-1)
- Exhibit 3-5: Blanchard River Dry Storage Basin (Option BR-3)

Exhibit 3-1 and Exhibit 3-2 together represent the opinion of probable cost for Phase 1 and Phase 2 Hydraulic Improvements component of the Program. Phase 1 total costs are rounded to the nearest thousand dollars. Phase 2 of the Hydraulic Improvements cover the Blanchard River Railroad Bridge Modifications. The Program includes the costs of the Hydraulic Improvements (Phase 1 and Phase 2), plus the costs of the recommended dry storage basins shown in Exhibits 3-3, 3-4 and 3-5.

Exhibit 3-1: Hydraulic Improvements - Phase 1: Opinion of Probable Costs

Description	Amount
Construction Costs	
In-Stream Improvements	$1,638,000
Floodplain Bench Widening Improvements	$7,099,200
Utility and Bike Path Improvements	$1,347,900
Utility Coordination	$768,800
Construction Subtotal	$10,853,900
Contingency (10%)	$1,085,390
Construction Total	$11,939,290
Other Costs	
Tree Removal (Including Debris Removal)	$105,000
Stream Wetland and T&E Mitigation	$77,250
Construction Administration	$675,000
Other Subtotal	**$857,250**
Total Project Costs	**$ 12,797,000**

Exhibit 3-2: Hydraulic Improvements – Phase 2: Railroad Bridge Modifications

Description	Amount	Contingency %	Contingency $	Total
Mob., Demob., & Preparatory Work	$100,000	30.0%	$30,000	$130,000
01 - Lands and Damages	$6,000	30.0%	$1,800	$7,800
02 - Relocations	$0	30.0%	$0	$0
06 - Fish and Wildlife	$0	30.0%	$0	$0
08 - Road, Railroads & Bridges	$2,500,000	30.0%	$750,000	$3,250,000
09 - Channels and Canals	$5,000	30.0%	$1,500	$6,500
15 - Floodway Control & Diversion	$3,000	30.0%	$900	$3,900
18 - Cultural Resources	$16,000	30.0%	$4,800	$20,800
30 - Engineering & Design	$400,000	30.0%	$120,000	$520,000
31 - Construction Management	$400,000	30.0%	$120,000	$520,000
Total	**$3,430,000**		**$1,029,000**	**$4,459,000**

Exhibit 3-3: Eagle Creek Dry Storage Basin (EC-2C)

Description	Amount	Contingency %	Contingency $	Total
Mob., Demob., & Preparatory Work	$1,400,000	25.0%	$350,000	$1,750,000
01 - Lands and Damages	$13,800,000	25.0%	$3,450,000	$17,250,000
02 - Relocations	$100,000	25.0%	$25,000	$125,000
06 - Fish and Wildlife	$500,000	25.0%	$125,000	$625,000
08 - Road, Railroads & Bridges	$2,100,000	25.0%	$525,000	$2,625,000
09 - Channels and Canals	$12,700,000	25.0%	$3,175,000	$15,875,000
15 - Floodway Control & Diversion	$11,900,000	25.0%	$2,975,000	$14,875,000
18 - Cultural Resources	$300,000	25.0%	$75,000	$375,000
30 - Engineering & Design	$6,400,000	25.0%	$1,600,000	$8,000,000
31 - Construction Management	$3,100,000	25.0%	$775,000	$3,875,000
Total	**$52,300,000**		**$13,075,000**	**$65,375,000**

Exhibit 3-4: Potato Run Dry Storage Basin (PR-1)

Description	Amount	Contingency %	Contingency $	Total
Mob., Demob., & Preparatory Work	$500,000	25.0%	$125,000	$625,000
01 - Lands and Damages	$9,000,000	25.0%	$2,250,000	$11,250,000
02 - Relocations	$0	25.0%	$0	$0
06 - Fish and Wildlife	$200,000	25.0%	$50,000	$250,000
08 - Road, Railroads & Bridges	$1,400,000	25.0%	$350,000	$1,750,000
09 - Channels and Canals	$2,200,000	25.0%	$550,000	$2,750,000
15 - Floodway Control & Diversion	$4,500,000	25.0%	$1,125,000	$5,625,000
18 - Cultural Resources	$100,000	25.0%	$25,000	$125,000
30 - Engineering & Design	$2,700,000	25.0%	$675,000	$3,375,000
31 - Construction Management	$1,300,000	25.0%	$325,000	$1,625,000
Total	**$21,900,000**		**$5,475,000**	**$27,375,000**

Exhibit 3-5: Blanchard River Dry Storage Basin (BR-3)

Description	Amount	Contingency %	Contingency $	Total
Mob., Demob., & Preparatory Work	$900,000	25.0%	$225,000	$1,125,000
01 - Lands and Damages	$9,600,000	25.0%	$2,400,000	$12,000,000
02 - Relocations	$100,000	25.0%	$25,000	$125,000
06 - Fish and Wildlife	$2,500,000	25.0%	$625,000	$3,125,000
08 - Road, Railroads & Bridges	$1,600,000	25.0%	$400,000	$2,000,000
09 - Channels and Canals	$3,300,000	25.0%	$825,000	$4,125,000
15 - Floodway Control & Diversion	$11,100,000	25.0%	$2,775,000	$13,875,000
18 - Cultural Resources	$200,000	25.0%	$50,000	$250,000
30 - Engineering & Design	$4,400,000	25.0%	$1,100,000	$5,500,000
31 - Construction Management	$2,100,000	25.0%	$525,000	$2,625,000
Total	**$35,800,000**		**$8,950,000**	**$44,750,000**

The costs for the Hydraulic Improvements in Phase 1 include construction costs for in-stream improvements, floodplain bench widening, utility and bike path improvements, utility coordination, and other costs for tree and debris removal, stream, wetland and threatened and endangered species (T&E) mitigation, and construction administration. Phase 2 Hydraulic Improvements are for Blanchard River Railroad Bridge Modifications (Exhibit 3-2). The Program costs include the Hydraulic Improvements plus the costs of the remaining three phases including the Eagle Creek Dry Storage Basin, Blanchard River Dry Storage Basin and the Potato Run Dry Storage Basin. The estimated total Program costs are $154,756,000.

3.2.2 Maintenance Costs

This section outlines the maintenance costs of the program. Stantec provided estimated values of the Operations, Maintenance and Replacement (OM&R) costs for the project.

Operations and maintenance for the benching area in the Hydraulic Improvements component are estimated at $17,700 annually for mowing and occasional debris removal following flooding events. No additional OM&R costs are applied. The following calculations inform the costs:

- Mowing: 8 hours/mowing x ($25/hour (fully loaded labor rate) + $25/hour mower cost) x 1 mowing/week x 36 weeks/year = $14,400.00
- Debris Removal: 2 staff x $25/hour x 8 hours x 2 times/year + $1,000 per day for equipment x 2 days + $500 disposal = $3,300.00
- Mowing plus Debris Removal = $14,400 + $3,300 = $17,700.00

The Norfolk Southern railroad bridge OM&R costs assume annual inspections and replacement in approximately 75 years. However, the bridge is owned and maintained by the railroad with yearly inspections and minor upkeep in the range of $10,000 to $12,000 annually. The cost analysis assumes inspections and replacement will occur regardless of this Program and thus are not factored into these calculations.

The total annual OM&R costs are $172,700 for the Program starting in 2029, based upon the $17,700 for the Hydraulic Improvements component above, plus the sum of the estimated O&M for the recommended dry storage basins, as follows:

- $75,000 for Eagle Creek Storage Basin
- $40,000 for Blanchard River Storage Basin
- $40,000 for Potato Run Storage Basin

Exhibit 3.8 provides the annual schedule of all construction and OM&R costs.

3.3 Timeline of Costs and Benefits

This section provides the timeline of costs and benefits for the phases of The Program. The analysis assumes costs are divided equally over the span of the timeline for each phase. Benefits occur incrementally after the early stages of The Program are completed. The benefits of The Program occur at terminus of construction. Exhibit 3-6 provides the starting and ending years for costs incurred at each phase of The Program. Construction for Phase 1 of the Hydraulic Improvements project is anticipated to begin in the summer of 2018 pending the permitting process. Initial benefits derived from the completion of the Hydraulic Improvement are expected to begin at the end of 2018.

Exhibit 3-6: Program Schedule by Phase of Project

Project	Phase 1 - Hydraulic Improvements	Phase 2 - Hydraulic Improvements	Phase 3 - Eagle Creek Dry Storage Basin	Phase 4a - Potato Run Dry Storage Basin	Phase 4b - Blanchard River Dry Storage Basin
Timeline (year)	**2018-2019**	**2020-2021**	**2020-2025**	**2022-2029**	**2023-2029**

Exhibit 3-7 shows the timeline when the percentage of annual Program benefits start to accrue as The Program implementation progresses. The left column shows when benefits associated with the improvements would commence. The right column shows the percent of benefits provided through that year.

Exhibit 3-7: Percent of Program Benefits Provided by Year

Year	Benefits (%)
2018	10
2019	25
2020	25
2021	33
2022	33
2023	33
2024	33
2025	67
2026	67
2027	67
2028	67
2029	100
2030	100

3.4 Present Value of Program Construction and OM&R Cost

This section and Exhibit 3-8 provide the total construction costs, including OM&R and present value of total costs by year, for The Program. Costs for Phase 1 and Phase 2 of the Hydraulic Improvements span the first four construction years, from 2018 to 2021 and are shown in column three of Exhibit 3-8. Maintenance costs of $17,700 per year commence following construction and are shown in the fourth column of the exhibit. Construction costs for the Hydraulic Improvements total $17,256,000 for the life of the Project. Maintenance costs total $867,300 over the life of the Project.

The next three columns of Exhibit 3-8 show the construction costs for the three storage basins: Eagle Creek, Potato Run and the Blanchard River. Construction of the Eagle Creek storage basin is estimated to take six years at a cost of $10,896,000 per year. Construction of the storage basin for Potato Run was estimated to cost $3,422,000 per year for eight years. The storage basin for the Blanchard River is estimated to cost $6,393,000 per year for seven years. Total costs for each of the three storage basins are Eagle Creek $65,375,000; Potato Run $27,375,000; Blanchard River $44,750,000.

Maintenance costs for each storage basin begins in the year following its construction. Maintenance costs for the Eagle Creek storage basin begin in 2026 when its construction concludes. As shown above, it is estimated at $75,000 per annum shown in column eight. Maintenance costs for the Potato Run and Blanchard River storage basins begin following their construction in 2030. Those costs, as shown above, are estimated at $40,000 per year for each. These maintenance costs are added to the Eagle Creek maintenance costs beginning in 2030 ($75,000 + $40,000 + $40,000 = $155,000). The costs are assumed constant for the remaining life of The Program.

The final two columns of Exhibit 3-8 show the total costs per year and the net present value of the costs per year. The column showing total costs are the sum of all construction and maintenance costs by year for The Program. Total Program costs are $171,961,000.

Net present value accounts for the time value of money. Economists assume that a dollar earned today is worth more than that dollar in the future, due to inflation. Future sums must be reduced to account for this delay. All future costs are converted to their present values (or discounted values) by using a discount rate. This BCA used a discount rate of 0.6 percent. It allows for comparison of the buying power of one future dollar to the purchasing power of one dollar today. The net present value of the costs each year is shown in the final column of the exhibit. The total net present value of The Program is $164,981,000. The total costs and net present value total costs serve as denominators in the subsequent BCR calculations presented within this report.

Exhibit 3-8: Discounted Construction Project Costs by Year (Present Value, Thousand $)

	Hydraulic Improvements Phases I and 2		Storage Basins				Program	
Year	**Construct**	**Maint.**	**Construct: Eagle Creek**	**Construct: Potato Run**	**Construct: Blanchard River**	**Maint.**	**Total Costs in 2018 Dollars**	**Net Present Value**
2018	6,399						6,399	6,399
2019	6,399						6,399	6,360
2020	6,254	17.7	10,896				17,167	16,963
2021	6,254	17.7	10,896				17,167	16,862
2022		17.7	10,896	3,422			14,335	13,996
2023		17.7	10,896	3,422	6,393		20,728	20,117
2024		17.7	10,896	3,422	6,393		20,728	19,997
2025		17.7	10,896	3,422	6,393		20,728	19,878
2026		17.7		3,422	6,393	75	9,907	9,444
2027		17.7		3,422	6,393	75	9,907	9,388
2028		17.7		3,422	6,393	75	9,907	9,332
2029		17.7		3,422	6,393	75	9,907	9,276
2030		17.7				155	173	161
2031		17.7				155	173	160
2032		17.7				155	173	159
2033		17.7				155	173	158
2034		17.7				155	173	157
2035		17.7				155	173	156
2036		17.7				155	173	155
2037		17.7				155	173	154
2038		17.7				155	173	153
2039		17.7				155	173	152
2040		17.7				155	173	151
2041		17.7				155	173	151
2042		17.7				155	173	150
2043		17.7				155	173	149
2044		17.7				155	173	148
2045		17.7				155	173	147
2046		17.7				155	173	146
2047		17.7				155	173	145
2048		17.7				155	173	144
2049		17.7				155	173	143
2050		17.7				155	173	143
2051		17.7				155	173	142
2052		17.7				155	173	141
2053		17.7				155	173	140
2054		17.7				155	173	139
2055		17.7				155	173	138
2056		17.7				155	173	138
2057		17.7				155	173	137
2058		17.7				155	173	136
2059		17.7				155	173	135
2060		17.7				155	173	134
2061		17.7				155	173	134
2062		17.7				155	173	133
2063		17.7				155	173	132
2064		17.7				155	173	131
2065		17.7				155	173	130
2066		17.7				155	173	130
2067		17.7				155	173	129
2068		17.7				155	173	128
2069		17.7				155	173	127
2070		17.7				155	173	127
2071		17.7				155	173	126
2072		17.7				155	173	125
2073		17.7				155	173	124
2074		17.7				155	173	124
2075		17.7				155	173	123
2076		17.7				155	173	122
2077		17.7				155	173	121
2078		17.7				155	173	121
2079		17.7				155	173	120
Total	**25,304**	**1,062**	**65,375**	**27,375**	**44,750**	**8,050**	**171,916**	**164,981**

Chapter 4 Structure/Content Damages

Damages to structure, contents, and automobiles account for the majority of damages that result from a flood event. These categories provide the foundation for the economic evaluation of the alternatives. Flood risk reduction projects are developed with these damages in mind; the goal of plan formulation is to minimize these flood impacts in a way that is consistent with protecting the environment and quality of life in our communities. The USACE Hydrologic Engineering Center's Flood Damage Analysis (HEC-FDA) software was used in this BCA to estimate damages to structures, contents, and automobiles for without-project and with-project alternatives of the updated Hancock County Flood Risk Reduction Program.

The structure inventory developed for the HEC-FDA analysis comprises all residential and nonresidential structures within the planning model's 0.2% Annual Chance Exceedance (ACE) (500-year) event floodplain and additional structures located in areas that could potentially experience induced flooding identified by project engineers. The structure inventory used for this May 2018 analysis was updated based on the 2015 inventory with modifications as described in the following sections.

4.1 Rationale and Justification for Inclusion

Among the physical damage categories identified by the USACE are the savings of structure and contents from flood damage. According to the Corps, most benefits from flood damage reduction projects come from the reduction of inundation damages.[16] The loss of contents may include furnishings and equipment, decorations, raw materials, processed material, among others. The damages are calculated individually for residential, commercial, industrial and public properties. Outside property damage can also be significant, including sheds, garages and other small buildings – structures that may be particularly vulnerable to collapse or being washed away in a flood. Guidance from the Corps states that the value of electrical or mechanical equipment in residential garages damaged by flooding should also be recorded. Damages play a significant role in studies designed for flood mitigation decisions. Regardless of the scope of the study at hand, the Corps states:

> "..accurate estimates of damages to residential and commercial structures and their contents are essential in establishing the feasibility and optimal choice of engineering plans designed to alleviate the effects of flooding. The relationship between the depth of flooding and the severity of damage to structures and their

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[16] Institute for Water Resource, USACE. National Economic Development Procedures Manual – Urban Flood Damage. IWR Report 88-R-2, March 1988.

> contents is an integral part of the methodology used to estimate the economic benefits associated with floodplain modifications."[17]

This project follows the guidance stated by the Corps in determining benefits derived by removing structures from the floodplain. These benefits are then used in the benefit-cost analysis according to accepted Corps practice. Modern depth damage curves such as those incorporated in the CORP HEC/FDA model include in a single curve the structure and content damage based on the level of inundation.

4.2 Structure Inventory Overview

The structure inventory developed and refined for the analysis contains 4,483 structures: 3,891 residential (86.8%), 453 commercial (10.1%), 129 public (2.9%) and 10 industrial (0.2%). Exhibit 4-1 shows this structure breakdown.

Exhibit 4-1: Hancock County Structure Inventory

Structure Type	Damage Category	Structure Count	Percent of Total
Residential	RES	3,891	86.8
Commercial	COM	453	10.1
Public/Other	P&O	129	2.9
Industrial	IND	10	0.2
Total		**4,483**	**100.0**

Residential structures comprise a majority of the structures in the inventory. Exhibit 4-2 provides a summary of the type of residential structures which exist in the study area. Of the 3,893 residential structures included in the analysis: 1,800 are one-story without basements (46.3%), 886 are one-story with basements (22.8%), 793 are two-plus stories with basements (20.4%), 309 are two-plus stories without basements (7.9%), 56 are split levels without basements (1.4%), and 46 are split levels (1.2%) with basements.

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[17] USACE. Final Report: Depth-Damage Relationships For Structures, Contents, And Vehicles And Content-To-Structure Value Ratios (CSVR) In Support Of The Donaldsonville To The Gulf, Louisiana, Feasibility Study. March 2006.

Exhibit 4-2: Residential Structures by Type

Residence Type	Number	Percent of Total
1ST-NB	1,800	46.3
1ST-B	886	22.8
2ST-B	793	20.4
2ST-NB	309	7.9
SL-NB	56	1.4
SL-B	46	1.2
Total	**3,893**	**100.0**

The structure inventory includes specific building attributes for each structure, including a unique structure name, parcel ID, latitude/longitude, structure type, structure/content value, stream and bank side on which the structure is located, approximate stream station location, depth damage function (DDF), first floor elevation (FFE), ground elevation and begin damage elevation.

Following the 2007 flood event, Hancock County purchased multiple structures for flood mitigation via grants funded by the City of Findlay, Hancock County, and Northwest Ohio Flood Mitigation Partnership. Hancock County provided a list of 166 structures that the County purchased inside the 1% ACE floodplain. Six additional structures have been removed since the 2017 study. These 172 structures were removed from the inventory used in the analysis since they no longer exist in the floodplain.

4.3 Structure Location

Project engineers determined structure locations using Geographic Information System (GIS) dwelling footprint and address shapefiles. Each structure with an address was represented by a point file generally at the lowest point of the dwelling footprint. If a dwelling footprint was not available, an address point file generally near the mailbox of the structure was used. This location was assumed to be generally representative of the location of the structure. Structures within the planning model's 0.2% ACE floodplain were selected for analysis. The shapefiles were joined to their respective parcel shapefile obtained from Hancock County tax assessor. This file contained parcel boundaries and parcel numbers that could be cross referenced with the Hancock County tax assessor information.

Project engineers assigned structures to a stream based on their location in the study area. The stream that was adjacent to the structure was typically assigned. In cases where it was not clear which stream to assign (e.g., structure located at the confluence of two streams), professional judgment was used to assign the stream based on which stream was most representative of the flood characteristics for that structure. The structures in Hancock County were assigned to one of three streams: Blanchard River, Eagle Creek, or Lye Creek.

Stream stations which correspond to those used in the hydraulic model were imported into ArcGIS software and used to match each structure to a stream station. The assigned station was the closest point where the structure was perpendicular to the stream.

4.4 Structure Elevation

Project engineers determined the First Floor Elevation (FFE) for each structure by using a Digital Elevation Model (DEM) created by Kucera International with the data obtain from the aerial survey. The DEM was derived from Light Detection and Ranging (LiDAR) collected in 2016 by Kucera.

Based on the structure locations (denoted as points), the DEM was used to extract an elevation of the adjacent grade to the structure point file (ground elevation). Since the study area is very flat, the analysis assumes the ground elevation surrounding a structure was a consistent height. Therefore, grade at each structure was used to represent the adjacent ground elevation. The ground elevation was then adjusted and increased by 1.0 feet to estimate the height of the first floor relative to the ground (FFE).

Since most structures in the study area are damaged by overland flooding, the begin damage point for each structure was assumed to be the elevation of the adjacent grade. HEC-FDA uses the begin damage point to estimate the water elevation that could start to impact a structure. If the begin damage point is not entered, HEC-FDA would begin to estimate damages beginning from the bottom of the depth-damage function assigned to a structure. For overland flooding, flood water would not be anticipated to impact a structure until water reached the structure.

For structures with basements, it would be anticipated that floodwater would enter the structure and fill the basement through a window or other low-level opening. Therefore, the begin damage point was set at the adjacent grade to avoid overestimating damages, especially to structures with basements.

4.5 Depreciated Replacement Value

Hancock County tax assessors provided value data for residential and non-residential structures in the study area. The tax assessor data listed multiple valuation components (e.g., land, improvement) for each parcel that could be used to represent the value of structures in the study area. To ensure compliance with USACE guidance requiring the use of depreciated replacement values for structures, a random sample of the structures were valued using

RSMeans[18], a commercially available valuation method for comparison to the tax assessor valuations.

A field inventory of 10% of the structures in the study area was conducted to collect characteristics of the structures, such as size, condition, quality, roofing material, etc. The characteristics are input variables used to estimate the replacement value using RSMeans. The replacement values were adjusted for depreciation using ratios developed by the Institute for Water Resources (IWR). The depreciated replacement values calculated for the sample of inventoried structures were compared to tax assessor values to determine if a relationship between the data sets could be identified. However, there was great variance between the data sets and a relationship could not be identified. Because of the impact that nonresidential structures can have on the results of a flood risk management study and because there were relatively few nonresidential structures in the study area, a second field inventory was conducted to inventory the remaining nonresidential structures. The remaining nonresidential structures were also valued using RSMeans and depreciated. These values were used for the economic analysis of nonresidential structures.

The 2015 USACE inventory further refined structure value using a random sample of records in the inventory. From the random sample, an average dollar per square foot value was estimated based on the structure type (e.g., one-story, two-story). The average dollar per square foot value was then applied to each residential structure in the study area based on the size and characteristics from the tax assessor database. While individual structures may not be as accurate using this method, USACE determined it should provide a reasonable overall estimate of the study area.

The 2015 USACE inventory developed depreciated replacement values from October 2012 prices. These values were updated to November 2014 prices for the current analysis using the Civil Works Construction Cost Index System (CWCCIS – EM 111-2-1304) composite index. The 2015 USACE inventory yielded a 4% increase in structure inventory values. These values were indexed using a 1.0267 percent to account for property value increases to the base year of 2018.

Besides the structures identified by the USACE in 2015, project engineers identified an additional 992 structures located in the 0.2% ACE (500-year) floodplain for the May 2018 analysis. The values used for these structures were based on the Hancock County tax assessor records. The remaining 3,491 records kept the beginning damage depths, structure values and structure types developed by the USACE in 2015.

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[18] Replacement costs were estimated using the model approach provided in the RSMeans Square Foot Costs book (2012). The replacement values were adjusted for depreciation using ratios developed for the USACE Institute for Water Resources.

4.6 Depth-Damage Functions

Each structure was assigned a Depth Damage Function (DDF) that estimates an economic loss as a percentage of the value of the structure or contents based on the depth of flooding. The DDFs used in the May 2018 analysis were based on the USACE analysis completed in 2015. The 2015 analysis used four sources: Economic Guidance Memorandum (EGM) 04-01 Generic Depth-Damage Relationships for Residential Structures, EGM 09-04 Generic Depth-Damage Relationships for Vehicles, building specific commercial damage surveys and generic curves obtained from USACE Galveston District.

4.6.1 Residential Structures

All structure and content DDFs assigned to residential structures were developed by IWR as referenced in EGM 04-01. These DDFs are considered generic and are appropriate for use throughout the United States. The DDFs are divided into multiple categories based on the type of structure (e.g., one-story, two-story, foundation type), with separate DDFs to represent damages to the structure and the contents. The DDFs were assigned to each structure based on information contained in the tax assessor databases (e.g., number of floors, presence of basement). A content-to-structural value (CSVR) of 55 percent was used for residential structures.

4.6.2 Non-Residential Structures

All structure DDFs assigned to non-residential structures were obtained from the 2015 USACE analysis (based on the USACE Galveston District values). These DDFs were selected for use because structures in both locations are built using similar techniques and materials, and they represent fresh water flood damages. The appropriate DDFs were selected from available USACE Galveston District based on the type and the use of the structure. A portion of the DDFs assigned to nonresidential structures were developed based on personal interviews with business owners and operators.

4.6.3 Residential and Non-Residential Structure

In cases where multiple structures were located on a single parcel, the data on the individual structures from the interviews (completed by the USACE in 2015) were combined to form a single DDF. Therefore, each entry in the structural inventory is representative of the damages that would occur for that parcel - not necessarily each structure on the parcel. The content-to-structure-value ratios (CSVRs) for all of the structures were incorporated into the analysis based on the assigned DDF and interview data.

4.7 HEC-FDA Methodology

Structural damage costs were estimated using the USACE Hydrologic Engineering Center Flood Damage Analysis (HEC-FDA) Economic model. The analysis follows the framework and methodology as directed by the *HEC-FDA Flood Damage Reduction Analysis User's Manual*

(April 2016). Project analysts used Revision 1.4.2 of the HEC-FDA model to assess floodplain damage and develop Equivalent Annual Damage (EAD) estimates for the base case ("without") and program scenario:

- Without Scenario (Base Case). The Without scenario evaluated damage to structures in the base case and none of the proposed improvements were constructed.
- Program Scenario. The Program scenario estimated structural damage for assuming all the proposed improvements are constructed.

The time value of resources is measured by an annual percentage factor known as the discount rate. An appropriate discount rate can be used to calculate the "present value" of any sum of resources or money to be spent or received in the future. The analysis used a discount rate of 0.6 percent for the present value calculation. This discount rate was obtained from the annual Office of Management and Budget publication, *Discount Rates for Cost-Effectiveness, Lease Purchase, and Related Analyses*[19] which applies to long-lived infrastructure investments. The application of the discount rate to future sums to calculate their present value is known as "discounting." Through discounting, different investment alternatives can be objectively compared based on their respective present values, even though each has a different stream of future benefits and costs.

Costs and benefits are expressed in 2018 prices and for each phase of the project a 50-year benefit period is assumed for each phase of the project, beginning in the year after that phase of the project construction is completed. No uncertainty factors were used to develop the analysis nor were Monte Carlo simulations employed to evaluate risk and uncertainty in the analysis. The analyses of without-project and with-project damages include damages or costs incurred from a range of categories. Categories considered in the economic analysis are: damages to structures and contents, damages to automobiles, increased emergency response expenditures, evacuation and subsistence expenditures, reoccupation costs, and costs for commercial cleanup and restoration. These categories are intended to capture a substantial portion of the financial burden incurred by a flood event; however, they are not comprehensive enough to capture every cost or damage that could result from flooding in the area.

Generally, flood damages increase as flood frequency decreases; they are typically higher for the 0.01% Annual Chance Exceedance (ACE) flood compared to the 50% ACE flood. Damages by flood frequency are paramount from the economic perspective since flood damages are reduced to annualized averages based upon the annual chance probability of flood occurrence.

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[19] https://www.federalregister.gov/documents/2018/02/08/2018-02520/discount-rates-for-cost-effectiveness-analysis-of-federal-programs

To estimate expected annual damages (EADs) from flooding, eight flooding event frequencies were modeled, representing a range of recurrence probabilities from a 50% ACE (2-year) flood event to 0.2% ACE (500-year) flood event.

4.8 Hydrologic and Hydraulic Modeling

Refer to Stantec's Hancock County Flood Risk Reduction Program Revised Final Report for additional details.

4.8.1 Damage Reaches

The streams in the study area were divided into reaches based on existing features (e.g., bridges) and the extent of proposed alternatives. Dividing the streams into reaches provided the ability to more accurately assess the impacts of proposed alternatives and to focus the analysis on specific areas.

Project engineers assigned reach index locations as a point of reference in development of the stream profiles. The project engineers assigned index locations to locations that were considered to be most closely representative of the actual field conditions when compared to the model results. Exhibit 4-3 summarizes the streams, reaches, and index locations for this HEC-FDA study.

Using HEC-RAS, project engineers developed water surface profiles for each stream and damage reach in the Without and With-Program scenarios. These water surface profiles are read into the HEC-FDA model in order to estimate damage for the eight return frequencies.

Exhibit 4-3: Findlay Streams, Reaches, and Index Locations

Stream Name	Reach Name	Beginning Station	Ending Station	Index Station
Blanchard	Above Potato	394284.7	439732.5	394284.7
	Above Findlay	299534	393578.9	299534
	Eagle-Lye	298205	298802	298205
	Findlay	291423	297726	291423
	Below Findlay	268028	290955	268028
	Gilboa	118486.4	265870	118486.4
Eagle Creek	Full Length	207	49960	207
Lye Creek	Full Length	21515.59	63760	21515.59
	y	72	15758.7	72

4.8.2 Flood Stage Damage Estimation

HEC-FDA uses modeled flooding events to estimate damages to affected structures based on data associated with each structure. HEC-FDA was used to estimate the damages for structures, contents, and automobiles. The HEC-FDA program compiles data generated from the hydraulic analyses, as well as the structure inventory and associated data described above. The hydraulic components used in this analysis included the water surface profiles for every stream for each of the eight analyzed exceedance probability flood events: 50% (2-year), 20% (5-year), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) and 0.2% (500-year) ACE flood events.

These compiled data are a series of probabilistic curves defining relationships between flood stage and frequency of occurrence, and flood stage and damages. These relationships are used to generate a curve relating probability of occurrence and total damages; the integration of which provides the EAD.

With-project and without-project damages are estimated for both the initial baseline conditions and future conditions, which account for any growth in development and runoff in the study area. As the hydrologic condition of the study area is not anticipated to increase over the period of analysis, the HEC-FDA model was run only for the initial baseline condition, with the resulting annual damages expected to prevail over the 50-year period of analysis.

4.8.3 Damage Categories

Project analysts assigned each structure or vehicle record to one of five damage categories defined for the analysis consistent with USACE guidance:

- **RES.** Residential structure damage category which includes one story, two story homes with and without basements
- **COM.** Commercial structure damage category which includes activities such as offices and restaurants.
- **IND.** Industrial structures damage category which includes activities such as warehouses.
- **P&O.** Public and other structure damage category which includes municipal buildings, public schools, colleges/universities and hospitals.
- **AUTO.** Vehicle damage category including private automobiles, light trucks and heavy trucks.

These damage categories were used to calculate the stage-damage functions and to calculate the Equivalent Annual Damage (EAD) described in the next section.

4.9 Results: Equivalent Annual Damage (EAD)

The results of the HEC-FDA analysis are expressed as an Equivalent Annual Damage (EAD) for each scenario. The USACE defines EAD as the damage value associated with the without- or with-project condition over the analysis period (project life) considering changes in hydrology, hydraulics, and flood damage conditions over the life of the project. HEC-FDA calculates expected annual damage for each analysis year and discounts the value to present worth, then annualizes it to obtain the EAD. Rather than compute the expected annual damage for each year, HEC-FDA computes EAD for the base year and most likely future years and interpolates it for subsequent years. The expected annual damage for years beyond the most likely future conditions year is assumed equal to that year.

Expected annual damage represents the mean amount of damage that would occur in **any given year**, if **that year** were repeated infinitely many times over. The mean value is based on the frequency of recurrence for each flood event, as well as the uncertainties in stage-damage, stage flow, and flow-frequency relationships.

EAD can vary by year, depending on changes in hydraulic, hydrologic, and economic conditions. Throughout the period of analysis, EAD can vary if there are changes in hydraulic, hydrologic, or economic conditions. If each year is taken in sequence from the beginning of the period of analysis to the end, the result is a series or “stream” of EAD values.

Calculated EAD for each scenario, stream and damage category is presented in Exhibit 4-4 and Exhibit 4-5. These values are reported in 2017 dollars.

Exhibit 4-4: Equivalent Annual Damage by Stream, Scenario and Damage Category ($1,000s)

	Without (Base Case)	Program
Blanchard		
AUTO	195.28	30.55
RES	2352.1	482.81
COM	1288.38	119.78
IND	6.95	0.37
P&O	535.89	74.41
Subtotal	**4378.6**	**707.92**
Lye		
AUTO	7.63	1.55
RES	354.82	92.57
COM	10.48	2.73
IND	0	0
P&O	8.07	0.69
Subtotal	**381.0**	**97.54**
Eagle		
AUTO	63.99	4.03
RES	3029.57	235.15
COM	254.12	18.97
IND	1.77	0.08
P&O	19.53	2.95
Subtotal	**3368.98**	**261.18**
Total	**8128.58**	**1066.64**

Exhibit 4-5: Equivalent Annual Damage by Damage Category ($1,000s)

	Without (Base Case)	Program
AUTO	266.9	36.13
RES	5736.49	810.53
COM	1552.98	141.48
IND	8.72	0.45
P&O	563.49	78.05
Total	**8,128.58**	**1066.64**

Chapter 5 Motor Vehicles

Damages to structure, contents, and automobiles account for the majority of damages that result from a flood event. These categories provide the foundation for the economic evaluation of the alternatives. This chapter presents the benefits that the project provides by reducing the risk of damages to motor vehicles related to flood events. It includes the rationale and justification for including these benefits and the methodology the study team used to calculate the benefits.

5.1 Rationale and Justification for Inclusion

This section provides the rationale and justification for inclusion of the benefit of reduced flooding of motor vehicles in the BCA. The USACE notes that for many cases, a major share of flood damage occurs to vehicles. Vehicle damage often occurs when warning lead times for flooding events are relatively short. Other factors that may influence the amount of damage to vehicles include the availability of individuals to move vehicles out of the floodplain and the degree of congestion expected on evacuation routes. Relatively low levels of flooding can nonetheless result in significant damage to vehicles. The USACE includes depth damage to vehicles among the four relationships necessary to estimate flood damages (along with depth-damage for structures, depth-damage for contents, and content-to-structure value ratio (CSVR)). [20]

Vehicle flood damage is among of the most frequent varieties of flood damage. Cars are the most often damaged, though they are also the first and most prone item for owners to relocate to safety. If owners are unaware of impending flooding, they may not move their vehicles from locations near a flooding river in time to avert damage. Drivers sometimes get themselves ensnared on flooding roads while attempting to escape flooding areas. Many motorists are largely uninformed of the water depths that will disable a vehicle and may attempt to drive through flooded areas only to become breakdown victims. Relatively shallow bodies of water can cause significant damage to vehicles. The ability to move vehicles makes it difficult for researchers to gauge damage sustained, which is dependent on the day and time of day of flooding and when the flood warning was provided.[21]

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[20] US Army Corps of Engineers, New Orleans District, Final Report: Depth-damage relationships for structures, contents and vehicles and content-to-structure value ratios (CSVR) in support of the Donaldsonville to the Gulf, Louisiana, Feasibility Study. March 2006.

[21] Richardson, et. al, 2005. Interview with David Richardson, Kevin Andrews from DEFRA and Bill Watts from Environmental Agency in London, March 17, 2005. Cited in: Volker Meyer and Frank Messner, UFZ-Discussion Papers, National Flood-Damage Evaluation Methods: A Review of Applied Methods In England, the Netherlands, the Czech Republic and Germany.

Flood damage to vehicles falls into the direct damage category. These damages occur because of physical contact with floodwaters. The damage is also tangible, which means the damages are assessable in monetary terms.[22]

This project follows the guidance stated by the Corps in determining benefits derived by removing vehicles from the floodplain. The benefit-cost analysis counts these benefits in according to accepted Corps practice.

5.2 Estimation Methodology

This section describes the methodology used to estimate the benefit of reduced flooding of motor vehicles. There are no primary data on the number of vehicles subject to flood damage during individual flood events. As a result, the analysis combined data on:

- The value of individual vehicle types
- The number of vehicles typically owned by households or parked at commercial structures
- The percent of vehicles typically evacuated during flooding events
- Depth-damage curves that predict the percent damage to vehicles caused by different water depths
- The water depths resulting from floods of varying probabilities

The following sections describe the estimation of each of these values. The final section provides the results of the calculations and discusses those results.

5.2.1 Vehicle Values

The project team estimated the average vehicle value by vehicle type by dividing data on the total value of vehicles by the number of vehicles. The Federal Highway Administration provides data on the number of vehicles in the publication Highway Statistics. The Bureau of Economic Analysis (BEA) provides data on the value of all vehicles in U.S. Economic Accounts, Fixed Assets Tables.

The Bureau of Economic Analysis (BEA) provides data on the value of all consumer and business vehicles. The BEA provides 2016 data for Consumer Durable Goods and Private Fixed Assets Nonresidential Equipment. The data represent yearend estimates of current-cost net stock and BEA updated them on August 23, 2017. BEA provides separate data for business and consumer automobiles, light trucks, and heavy trucks. The analysis assumes that the value of consumer owned heavy trucks is 50 percent of the BEA value of Recreational Vehicles (RVs). The BEA did not have data on the value of the vehicles stocks held by governments.

The Federal Highway Administration's (FHWA) "Highway Statistics," provides data on the number of vehicles. FHWA provides the data for 2016 in two tables. State Motor-Vehicle

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[22] Smith, K. and Ward, R.: Floods: Physical processes and human impacts. John Wiley & Sons, Chichester, 1998.

Registrations (Table MV-1) provides the number of private and commercial automobiles, buses, trucks, and motorcycles. Truck and Truck -Tractor Registrations (Table MV-9) has a set of columns that provide a Classification of Private and Commercial Trucks Registered. These columns provide data for truck tractors, pickups, vans, sport utilities, and other light trucks. Table MV-1 was the direct source of the number of automobiles. The number of light trucks is a sum of Table MV-9 data on the number of pickups, vans, sport utilities, and other light trucks. The number of heavy trucks is calculated based on the Table MV-1 data on the number of trucks, less the sum of the Table MV-9 figures of the number of pickups, vans, sport utilities, and other light trucks.

Using these sources, the average automobile was valued at $6,984, the average light truck was valued at $10,279, and average heavy truck was valued at $20,455. The analysis then updated the data from 2016 values to 2018 values using the U.S. Bureau of Labor Statistics (BLS) Consumer Price Index (CPI) Inflation Calculator. [23] The CPI inflation calculator uses the All Urban Consumers (CPI-U) U.S. city average series for all items, not seasonally adjusted. This data represents changes in the prices of all goods and services purchased for consumption by urban households. The analysis used the CPI change from February 2016 to February 2018 of 5.01 percent. After accounting for inflation, the average automobile was valued at $7,334, the average light truck was valued at $10,794, and the average heavy truck was valued at $21,480. Exhibit 5-1 provides the above calculation and final average values of vehicles by vehicle type.

Exhibit 5-1: Average Value of Vehicles by Vehicle Type

Vehicle Type	Number of Private and Commercial Vehicles (2016)	Highway Statistics Table Number	Consumer Durable Goods Current Cost ($, 2016, Million)	Non-Residential Fixed Assets Current Cost Net Stocks ($, 2016, Million)	Total Vehicle Value ($, 2016, Million)	Value per Vehicle ($, 2016)	CPI (Feburary 2018/ February 2016)	Value per Vehicle ($, 2018)
Automobiles	111,490,611	TABLE MV-1						
Buses	567,573	TABLE MV-1						
Trucks	143,913,338	TABLE MV-1						
Motorcycles	8,649,613	TABLE MV-1						
Truck Tractor	2,582,751	TABLE MV-9						
Pickups	46,941,851	TABLE MV-9						
Vans	16,577,778	TABLE MV-9						
Sport Utilities	69,112,824	TABLE MV-9						
Other Light	83,218	TABLE MV-9						
Automobiles	111,490,611		568,242	210,400	778,642	6,984	1.0501	7,334
Light Trucks	132,715,671		972,292	391,900	1,364,192	10,279	1.0501	10,794
Heavy Trucks	11,197,667		7,748	221,300	229,048	20,455	1.0501	21,480

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[23] U.S. Bureau of Labor Statistics, https://www.bls.gov/data/inflation_calculator.htm

5.2.2 Vehicle Inventory

Project analysts used the structure inventory and Hancock County tax assessor records to determine the location and value of vehicles in the study area. For residential structures, the analysis used data on the average number of vehicles owned by households. For commercial, industrial, and public/exempt structures, project analysts used estimates of vehicles per square foot by structure type and data on the square footage of each structure.

Two sources provided estimates of the number of vehicles per household. The Department of Transportation (2009) estimated an average of 1.9 vehicles per household for the United States. The American Factfinder (U.S. Census Bureau, 2014) estimated 1.8 vehicles per household for Hancock County, and 2.1 vehicles per household for Putnam County. Based on the findings, this study used an estimate of two vehicles per residential household. According to the Southeast Louisiana Evacuation Behavioral Report (2006) following Hurricanes Katrina and Rita, residents used approximately 70 percent of privately owned vehicles for evacuation during storm events. Residents left the remaining 30 percent of vehicles parked at residences and were subject to flooding. This study assumed a similar evacuation pattern for Findlay, with 30 percent of the automobiles remaining at households. Local officials confirmed this estimate as a reasonable approximation. One auto and one light truck record was generated for each structure record. The value was set equal to 30 percent of the value of an average auto or light truck.

In order to estimate flood damage of motor vehicles for non-residential structures, project analysts conducted an estimation procedure using the following steps:

1. Identification of square footage and structure use for each structure
2. Identification of vehicles per square foot based on structure use
3. Multiply square footage by vehicles per square foot, vehicle values and the evacuation factor

Project analysts obtained the square footage for each structure record using Hancock County tax assessment data.

The analysis used square footage conversion factors to estimate the total number of automobiles, light trucks and heavy trucks at each non-residential structure. A report in support of the Federal Emergency Management Agency (FEMA) HAZUS model contains these conversion factors.[24] Exhibit 5-2 provides the conversion factors.

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[24] HAZUS Vehicle Flood Damage Data and Analysis, Prepared For ABS Consulting by Jack Faucett Associates, June, 2008.

Exhibit 5-2: HAZUS Conversion Factors

HAZUS ID	HAZUS Building Code	HAZUS Building Category	Automobiles per 1,000 Sq. Feet	Light Trucks per 1,000 Sq. Feet	Heavy Trucks per 1,000 Sq. Feet
1	RES1	Single Family Dwelling	0.433963581	0.318221882	0.012114262
2	RES2	Mobile Home	0.995114383	0.729712148	0.012114262
3	RES3A	Multi Family Dwelling (2)	0.371494481	0.272413472	0.012114262
4	RES3B	Multi Family Dwelling (3-4)	0.637763410	0.467667709	0.012114262
5	RES3C	Multi Family Dwelling (5-9)	0.864554076	0.633972651	0.012114262
6	RES3D	Multi Family Dwelling (10-19)	0.864554076	0.633972651	0.012114262
7	RES3E	Multi Family Dwelling (20-49)	0.864554076	0.633972651	0.012114262
8	RES3F	Multi Family Dwelling (50+)	0.988022505	0.724511694	0.012114262
9	RES4	Temporary Lodging	1.705562886	1.251201290	0.012114262
10	RES5	Institutional Dormitory	0.376217121	0.276167215	0.012114262
11	RES6	Nursing Home	0.376217121	0.276167215	0.012114262
12	COM1	Retail Trade	1.261496553	0.926023763	0.308363031
13	COM2	Wholesale Trade	0.099306308	0.072925726	0.148675033
14	COM3	Personal and Repair Services	1.275829259	0.936660392	0.022025931
15	COM4	Professional/Technical Services	0.808172817	0.593623900	0.022025931
16	COM5	Banks	0.963020482	0.707189087	0.022025931
17	COM6	Hospital	1.152703116	0.846410007	0.022025931
18	COM7	Medical Office/Clinic	1.360449937	0.999090593	0.022025931
19	COM8	Entertainment & Recreation	3.588709699	2.634551062	0.022025931
20	COM9	Theaters	1.075357971	0.789343319	0.022025931
21	COM10	Parking			
22	IND1	Heavy	0.318307367	0.233768977	0.249994314
23	IND2	Light	0.195878311	0.143885211	0.249994314
24	IND3	Food/Drugs/Chemicals	0.318307367	0.233768977	0.249994314
25	IND4	Metals/Minerals Processing	0.318307367	0.233768977	0.249994314
26	IND5	High Technology	0.431667604	0.316994686	0.249994314
27	IND6	Construction	0.431667604	0.316994686	0.249994314
28	AGR	Agriculture	0.431667604	0.316994686	0.249994314
29	REL	Church/Non Profit	0.578117035	0.424301047	0.022025931
30	GOV1	General Services	1.182910329	0.868840761	0.022025931
31	GOV2	Emergency Services	1.476090593	1.083956859	0.022025931
32	EDU1	Schools/Libraries	0.600851617	0.441152292	0.022025931
33	EDU2	Colleges/Universities	0.390941783	0.287079052	0.022025931
Dollar Value			**$6,932.22**	**$9,841.89**	**$16,625.21**

The HAZUS conversion factor report relied upon a number of data sources. The primary source for automobiles and light trucks was the International Transportation Engineers (ITE) report, Parking Generation. [25] The primary data source for heavy trucks was a report from the National

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[25] International Transportation Engineers, Parking Generation, 3rd Edition, 2004.

Cooperative Highway Research Program.[26] The analysis to develop the data from these reports into conversion factors was extensive. The authors assigned building types from both reports to the HAZUS categories, estimated missing hourly data, converted hourly estimates to daytime and nighttime rates, converted data reported on a basis other than square footage, and scaled results to reflect nationwide vehicle inventories.

5.2.3 Vehicle Evacuation Factor

No primary data are available on the extent to which Findlay area residents successfully evacuate their vehicles during flood events. As a result, this study relies on secondary data from other locations. According to the Southeast Louisiana Evacuation Behavioral Report (2006) following Hurricanes Katrina and Rita, residents reported using approximately 70 percent of privately owned vehicles for evacuation during storm events. Residents left the remaining 30 percent of the vehicles parked at residences and subject to flooding. The study assumed that a similar evacuation pattern would be applicable for Findlay, with 30 percent of the automobiles remaining at the household when evacuating.

5.2.4 Depth-Damage Functions

Project analysts developed estimates of the value of flood damage to vehicles using data from an unpublished U.S. Army Corps of Engineers (USACE) document entitled, "Estimating Flood Damage to Vehicles" by Stuart A. Davis, Institute for Water Resources. The USACE document used data from a survey of 640 vehicles. The USACE analysis employed statistical regression to estimate the percent of damage sustained by various vehicles types relative to the depth of flooding. These USACE estimates represent a significant improvement in data quality compared to previous estimates. Data in the earlier version of the HAZUS provided data for only three general levels of waters and utilized rough estimates of damages collected from industry experts.

The USACE vehicle types included sedans, pickups, SUVs, sports cars, and minivans. Exhibit 5-3 provides the percent damage to vehicles by floodwater depth. Project staff assigned sedans and sport cars as proxies for automobiles. The analysis calculates auto damage by depth by weighting sedans at 90 percent and sports cars at 10 percent. These weights use the numbers of these vehicles surveyed in the Institute for Water Resources draft, where there were 37 sports cars and 369 sedans.

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[26] National Cooperative Highway Research Program, NCHRP SYNTHESIS 298, Truck Trip Generation Data: A Synthesis of Highway Practice, Michael J. Fischer Cambridge Systematics, Inc. and Myong Han Jack Faucett Associates, Transportation Research Board — National Research Council, National Academy Press,

Washington, D.C., 2001.

Exhibit 5-3: Percent Damage to Vehicles by Water Depth and Vehicle Type

Depth Above Ground	Survey Data*					Calculated Data**		
	Sedans	Pickups	SUVs	Sports	Mini Vans	Autos	Light Trucks	Heavy Trucks
0.5	7.6%	5.2%	0.0%	1.4%	0.0%	7.0%	1.8%	0.0%
1	28.0%	20.3%	13.8%	29.2%	17.8%	28.1%	16.6%	0.0%
2	46.2%	34.4%	30.6%	52.8%	38.3%	46.9%	32.9%	1.8%
3	62.2%	47.5%	45.8%	72.2%	56.8%	63.2%	47.8%	16.6%
4	76.0%	59.6%	59.4%	87.4%	73.3%	77.1%	61.2%	32.9%
5	87.6%	70.7%	71.4%	98.4%	87.8%	88.7%	73.2%	47.8%
6	97.0%	80.8%	81.8%	100.0%	100.0%	97.3%	83.7%	61.2%
7	100.0%	89.9%	90.6%	100.0%	100.0%	100.0%	91.5%	73.2%
8	100.0%	98.0%	97.8%	100.0%	100.0%	100.0%	98.1%	83.7%
9	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	91.5%
10	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	98.1%
11	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Project staff assigned pickups, SUVs, and minivans as proxies for light trucks. The analysis uses the relative number of these vehicles to derive an average damage for each depth of flooding. The number of vehicles of each type in 2016 is reported in Table MV-9 from the Federal Highway Administration's Highway Statistics. The table reports 46,941,851 pickups, 69,112,824 sport utilities and 16,577,778 vans. Heavy truck damage percentages were estimated assuming that these vehicles have an additional two feet of clearance relative to light trucks based on data from the previous HAZUS model. Therefore, heavy trucks sustain the same degree of damage as light trucks, but at higher levels of flooding.

The study assumed that the elevation of the vehicles was equal to be the elevation of each structure's adjacent grade, which the study estimated using digital elevation models and GIS.

5.2.5 Water Depths by Return Frequency

Project analysts derived vehicle location from the location of the associated structure and its assignment to the stream, stream bank, and damage reach used for the analysis in a similar manner as the structure inventory.

Project engineers assigned structures to a stream based on their location in the study area, typically assigning the stream that was adjacent to the structure. In cases where it was not clear which stream to assign (e.g., structure located at the confluence of two streams), professional judgment was used to assign the stream based on which stream was most representative of the flood characteristics for that structure. The analysis assigned the structures in Hancock County to one of three streams: Blanchard River, Eagle Creek, or Lye Creek.

The analysis imported stream stations, which correspond to those used in hydraulic model, into ArcGIS software to match each structure to a stream station. The assigned station was the closest point where the structure was perpendicular to the stream.

5.3 Results

The values of vehicles present at each structure along with the depth-damage curves for vehicles are an input into the HEC-FDA model. The model then processes the data in the same manner as for structures. The HEC-FDA model expresses results in terms of an Equivalent Annual Damage (EAD) for each scenario. The US Army Corps of Engineers defines EAD as the damage value associated with the without-or-with project condition over the analysis period (project life) considering changes in hydrology, hydraulics, and flood damage conditions that may occur over the useful life of the program. HEC-FDA calculates expected annual damage for each analysis year and discounts the value to present worth, then annualizes it to obtain the EAD. Rather than compute the expected annual damage for each year, HEC-FDA computes EAD for the base year and most likely future years and interpolates it for subsequent years. The expected annual damage for years beyond the most likely future conditions year is equal to that year.

The EAD represents the mean amount of damage that may occur in any given year, if that year repeated infinitely many times over. The mean value assumes the frequency of recurrence for each flood event, as well as the uncertainties in stage-damage, stage-flow, and flow-frequency relationships.

EAD can vary by year, depending on changes in hydraulic, hydrologic, and economic conditions. Throughout the period of analysis, EAD can vary if there are changes in hydraulic, hydrologic, or economic conditions. If each year occurs in sequence from the beginning of the period of analysis to the end, the result is a series or "stream" of EAD values.

Exhibit 5-4 presents the calculated EAD for each scenario, stream and damage category. The exhibit reports these values in 2018 dollars.

Exhibit 5-4: Equivalent Annual Damages for Motor Vehicles ($1,000s)

Reach	Without The Program (Base Case)	With The Program	Reduction in Damages
Blanchard	213.94	33.14	180.80
Lye	7.64	1.52	6.12
Eagle	69.48	4.06	65.42
Total	**291.06**	**38.72**	**252.34**

Chapter 6 Transportation Benefits

A flood event can have significant impacts on a regional transportation network. These impacts include road closures, and impediment to traffic flow between the origin and destination both resulting in increased travel times due to detours. This chapter presents the benefits provided by reducing the risk of potential impacts related to flood events. It includes the rationale and justification for including these benefits and the methodology the study team used to calculate the benefits.

6.1 Rationale and Justification for Inclusion

This section provides the rationale and justification for inclusion of transportation benefits in the BCA. The analysis of the benefits of flood mitigation projects commonly assess the benefits of reduced flooding on the transportation network. For example, the USACE National Economic Development Procedures Manual for Urban Flood Damage (NED Manual) states:

> *"Flooding can temporarily impede traffic by covering roads and bridges. Even the threat of flooding and concern for public safety may make it necessary to close roads and detour traffic. Bridge and road damage may cause detours for several months until repairs can be made. The costs of traffic disruption include 1) the additional operating cost for each vehicle, including depreciation, maintenance, and gasoline per mile of detour; and, 2) the traffic delay costs per passenger."*[27]

In the November 2015 USACE Economics Report (Blanchard River Flood Risk Management Feasibility Study Appendix B – Economics (DRAFT), the authors acknowledge the consequence of road flooding noting that:

> *"The Blanchard River Watershed is located in the center of an extensive transportation network of road and rail systems. The level of accessibility afforded by this network has contributed significantly to both local and regional economic growth. Although Hancock County is largely rural, it is also home to many businesses, (including Cooper Tire, Hearthside Foods, Marathon Petroleum, and Whirlpool Corporation) that are able to quickly and easily export manufactured goods using the area's many convenient State routes and interstates.*
>
> *During flood events, transportation infrastructure in the study area (including, but not limited to, I-75) is significantly impacted. Closure times range from short to relatively long to account for inundation, debris clearance, and safety assessments which vary by storm and particular*

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[27] U.S. Army Corps of Engineers, National Economic Development Procedures Manual - Urban Flood Damage. IWR Report 88-R-2, March 1988. pp. VII-6 – VII-11.

> *transportation route. During major flood events, a majority of the Blanchard River crossings are closed. Major flooding has also resulted in the closure of several Blanchard River rail crossings."*[28]

6.2 Estimation Methodology

This section describes the methodology used to estimate the transportation related benefits. The USACE describes in its NED Manual the recommended method for estimating the costs of rerouting traffic. The costs of traffic disruption include:

- The additional operating cost for each vehicle, including depreciation, maintenance, and gasoline per mile of detour
- The traffic delay costs per passenger

The USACE NED Manual notes, "To determine traffic operating cost, it is first necessary to determine the frequency, depth, and duration of flooding along major stretches of road that are subject to flooding. In order to concentrate on areas where the most significant benefits might occur, it is necessary to focus on portions of roads where there would be considerable traffic rerouting for long periods of time."

The manual notes that beyond the inundation mapping, there are several tasks necessary to determine the operating costs of traffic rerouting:[29]

Step 1: Determine the amount of time that particular stretches of road would be impassable.

Step 2: Determine the number of miles for the original route.

Step 3: Determine the number of miles for the best alternative route.

Step 4: Determine the additional miles per vehicle.

Step 5: Determine the total additional mileage by multiplying the additional miles per vehicle by the average daily travel and period that the roads are impassable.

Step 6: Estimate the average vehicle operating expense.

Step 7: Multiply average operating cost by total mileage to obtain additional operating cost.

The second portion of traffic rerouting is traffic delay costs. This cost accounts for the additional time spent by individuals forced to take the detours due to road closures. Since time is usually more valuable than the average vehicle operating costs in the same period, traffic delay costs are often higher than traffic operating costs. The procedures for calculating traffic delay costs are as follows:

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[28] Ibid, Section 1.3, p. 2.

[29] The steps described roughly parallel those that USACE provides in the National Economic Development Procedures Manual for Urban Flood Damage. However, the discussion both edited the steps to simplify the descriptions and enhanced them to include steps that the manual did not specifically discuss.

Step 1: Determine the amount of time that particular stretches of road would be impassable.

Step 2: Determine the number of miles for the original route.

Step 3: Determine the number of miles for the best alternative route.

Step 4: Determine the additional miles per vehicle.

Step 5: Determine the amount of time required on the original route.

Step 6: Determine the amount of time required on the alternative route.

Step 7: Subtract the original from the rerouted travel time to compute additional travel time.

Step 8: Determine the approximate average number of passengers per vehicle.

Step 9: Determine the total additional time by multiplying the additional time per vehicle by the number of passengers per vehicle and the average daily travel and the period that the roads are impassable.

Step 10: Determine the value-of-time for passengers using area wage rates.

Step 11: Multiply the additional travel time by the value-of-time.

During the 2007 floods, numerous routes became impassable. Based upon that anecdotal information from local records and interviews, the methodology calculates the results for each route separately and sums the results. In addition, the number of route closures has a significant impact on travel delays. According to local officials, traffic during the 2007 flood caused significant traffic delays on the alternative routes. As a result, the analysis assumes that the travel times on the alternate routes would be double the travel times with no delay.

The following sections detail the calculations that the analysis study team undertook to calculate the transportation benefits of reduced flooding that the proposed program alternatives would provide.

6.3 Inundated Routes

Steve Wilson, the former Hancock County Engineer and current Project Manager for the MWCD, provided a list of road closures and the estimated duration of those closures during the 2007 flood event. Exhibit 6-1 lists those road closures, along with the Average Daily Travel (ADT) traffic volume on sample segments for each of the roads. The exhibit also provides the estimates of closure durations during the 2007 event and an approximated detour, or in one case, alternative detours. The Ohio Department of Transportation (ODOT) was the source of ADT traffic volumes.

Exhibit 6-1: Inundated Travel Routes, Average Daily Travel and Detours

Name	Average Daily Travel	Duration of Closure During 2007 Event	Approximated Detour
US 224 - CR 140 to I-75	11,000	24	Local Traffic Westbound on 224 -- (West on Trenton Ave. (US 224), Turn right on Northridge Rd., Turn left on TR 94, Turn Left CR140) Non-Local Traffic Wanting to travel West -- (North on I-75, West on State Route 613, South on Local Road and destination)
Main St - Center St to Sandusky St	18,000	72	Southbound Main Street at Center Street -- Travel North to Trenton Ave. (224), turn left to I-75, travel south to SR 12 (exit 157), turn left to head east on Main Cross St. to Western Ave., to Hardin Street.
Main St - Olive Street to SR 15	8,000	48	Southbound Main Street -- Turn right at Orchard Lane, Right on Western Avenue to Lima Avenue, Left on Lima Avenue to CR 9, Left (south on CR 9 to CR 37) to US 68.
Main Cross St - Western Ave To Bright Rd 5 (West St)	12,000	72	Eastbound on SR 12 (Main Cross St.) -- Get onto northbound I-75, Take exit 159 to East 224, Travel east onto 224 back to the City.
Main Cross St - Western Ave To Bright Rd 4 (East St)	12,000	72	
Main Cross St - Western Ave To Bright Rd 3 (Blanchard St)	12,000	72	
Main Cross St - Western Ave To Bright Rd 2 (Warrington)	12,000	72	
Main Cross St - Western Ave To Bright Rd 1 (West of Bright)	12,000	72	
SR 37 - Main St to TR 205	5,000	72	Eastbound on SR 37 at Main St and Lincoln --Travel South on Main Street to Lima Avenue to CR 9, travel South on CR 9 to CR 37, continue on CR 37 to SR 37 south of SR 15.
SR 37 - CR 8 to TR 234	4,000	48	Southeast bound on SR 37 -- South on TR 180 to SR 15 to SR 37
Sandusky St (SR568) - Main St to TR 237 (TR 236)	12,000	72	Regionally closed to TR 245 - West on 568 from Main Street, Backtrack to I-75, go north to 224, follow 224 east to CR 330 (4 miles east of Findlay) follow CR 330 south to 568.
Sandusky St (SR568) - Main St to TR 237 (Lye Creek Bridge)	12,000	72	
Sandusky St (SR568) - Main St to TR 237 (Blanchard St)	12,000	72	
Sandusky St (SR568) - Main St to TR 237 (RR)	12,000	72	
SR 568 - TR 237 to TR 245 (twp hwy 241)	6,000	48	
SR 568 - TR 237 to TR 245 (TR 245)	6,000	48	
US 68 / SR 15 @ Eagle Creek (SR 15)	20,000	48	Westbound on SR 15, go south to Village of Vanlue SR 330. Get off at interchange, turn left through village, changes into CR 330. Follow north to US 224, West to I-75. Southbound on SR 15 from I-75, backtrack toward I-75 to Lima Avenue. Lima Ave west to CR 9, south on CR 9 to CR 37, east on CR 37 to SR 37, back north to SR 15.
US 68 / SR 15 @ Eagle Creek (US 68)	20,000	48	From South to North, (to west side of Findlay) get off of US 68 at CR 37 to CR 9 to Lima Ave into Findlay. From South to North, (to east side of Findlay) TWP 168 to Twp Rd 180. turn left on 180 to SR 15. East on SR 15 to Village of Vanlue and SR 330.

6.4 Time and Distance Values

The research team selected ten road segments and their expected detour routes for analysis. Exhibit 6-2 lists each of the road segments, the ADT, the change in distance in miles due to detour, the change in time in minutes due to detour, the mileage rate the analysis used, and the value of time in dollars per minute that the analysis used. The analysis calculated distances and times using standard travel route mapping software. The Internal Revenue Service was the source for the mileage rate for 2018 of $0.545.[30] The value of time per vehicle per minute of $0.322 is a weighted average of personal and commercial wage rates multiplied by average vehicle occupancy. The weighting, 95.4 percent for personal purposes and 4.6 percent for business, is from the US DOT. The US Bureau of Labor Statistics, State Occupational Employment and Wage Estimates, was the source of the 2015 mean hourly wage rate for Ohio of $22.08. The assumption was that the personal value of time was half the wage rate. The source of the vehicle occupancy rate of 1.67 was the 2017 National Household Travel Survey, which is the latest version of that survey.

Exhibit 6-2: Time, Distance, and Rate Variables:

Name	ADT	Est. Duration Closed 1% ACE	Change in Distance (miles)	Change in Time (minutes)	Mileage Rate ($)	Value of Time ($/minute)
US 224 - CR 140 to I-75	11,000	24	1.1	9	0.545	$ 0.322
Main St - Center St to Sandusky St	18,000	72	4.2	23	0.545	$ 0.322
Main St - Olive Street to SR 15	8,000	48	7.8	28	0.545	$ 0.322
Main Cross St - Western Ave To Bright Rd 3	12,000	72	3.1	26	0.545	$ 0.322
SR 37 - Main St to TR 205	5,000	72	5.5	34	0.545	$ 0.322
SR 37 - CR 8 to TR 234	4,000	48	1.9	11	0.545	$ 0.322
Sandusky St (SR568) - Main St to TR 237	12,000	72	15.8	58	0.545	$ 0.322
SR 568 - TR 237 to TR 245 (TR 245)	6,000	48	15.8	58	0.545	$ 0.322
US 68 / SR 15 @ Eagle Creek (SR 15)	20,000	48	8.2	38	0.545	$ 0.322
US 68 / SR 15 @ Eagle Creek (US 68)	20,000	48	2.7	20	0.545	$ 0.322

6.5 Road Closure Durations

The research team estimated durations of road closures using water surface profiles and time-varied inundation mapping from the planning level hydraulic modeling. Stantec calculated the closure durations using HEC-RAS for each scenario and eight flood frequencies. Stantec assumed that for roads with inundation depths less than 0.5 feet the segment did not close. If the inundation depth was between 0.5 and 0.9 feet, Stantec assumed the closure was a

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[30] https://www.irs.gov/newsroom/standard-mileage-rates-for-2018-up-from-rates-for-2017

minimum of 12 hours, or longer in 2-hour increments if the inundation was greater than 12 hours. If the inundation depth was greater than 1.0 foot, Stantec assumed the closure was a minimum of 24 hours, or longer in 2-hour increments if the inundation was greater than 24 hours. The ADTs from Exhibit 6-2 were used for this analysis. Exhibit 6-3 provides road closure durations for the without project conditions, for The Program and the difference between the two conditions.

Exhibit 6-3: Road Closure Durations for Without and With Program Conditions

	Existing Conditions - Road Closed (Flooding > 6 inches (Hours))							
Name	2-Yr (50%)	5-Yr (20%)	10-Yr (10%)	25-Yr (4%)	50-Yr (2%)	100-Yr (1%)	200-Yr (.5%)	500-Yr (.2%)
US 224 - CR 140 to I-75	0	0	0	24	34	42	48	54
Main St - Center St to Sandusky St	0	0	24	40	46	52	56	62
Main St - Olive Street to SR 15	0	0	0	12	16	24	24	28
Main Cross St - Western Ave To Bright Rd 3 (Blanchard St)	62	70	76	80	86	90	94	108
SR 37 - Main St to TR 205	0	0	24	24	38	44	48	54
SR 37 - CR 8 to TR 234	0	0	0	0	0	0	0	12
Sandusky St (SR568) - Main St to TR 237 (Lye Creek Bridge)	0	26	40	50	54	60	64	72
SR 568 - TR 237 to TR 245 (TR 245)	0	0	0	16	24	32	38	46
US 68 / SR 15 @ Eagle Creek (SR 15)	0	0	0	0	0	12	24	24
US 68 / SR 15 @ Eagle Creek (US 68)	0	0	0	12	24	24	24	26

	Program Road Closed (Flooding > 6 inches (Hours))							
Name	2-Yr (50%)	5-Yr (20%)	10-Yr (10%)	25-Yr (4%)	50-Yr (2%)	100-Yr (1%)	200-Yr (.5%)	500-Yr (.2%)
US 224 - CR 140 to I-75	0	0	0	0	0	34	44	54
Main St - Center St to Sandusky St	0	0	0	0	0	34	46	52
Main St - Olive Street to SR 15	0	0	0	0	0	0	0	12
Main Cross St - Western Ave To Bright Rd 3	48	60	66	74	80	84	88	94
SR 37 - Main St to TR 205	0	0	0	0	0	0	24	40
SR 37 - CR 8 to TR 234	0	0	0	0	0	0	0	0
Sandusky St (SR568) - Main St to TR 237	0	0	0	36	48	56	60	64
SR 568 - TR 237 to TR 245 (TR 245)	0	0	0	0	0	0	38	46
US 68 / SR 15 @ Eagle Creek (SR 15)	0	0	0	0	0	0	0	0
US 68 / SR 15 @ Eagle Creek (US 68)	0	0	0	0	0	0	0	24

	Difference in Duration of Road Closure (Hours)							
Name	**2-Yr (50%)**	**5-Yr (20%)**	**10-Yr (10%)**	**25-Yr (4%)**	**50-Yr (2%)**	**100-Yr (1%)**	**200-Yr (.5%)**	**500-Yr (.2%)**
US 224 - CR 140 to I-75	0	0	0	24	34	8	4	0
Main St - Center St to Sandusky St	0	0	24	40	46	18	10	10
Main St - Olive Street to SR 15	0	0	0	12	16	24	24	16
Main Cross St - Western Ave To Bright Rd 3	14	10	10	6	6	6	6	14
SR 37 - Main St to TR 205	0	0	24	24	38	44	24	14
SR 37 - CR 8 to TR 234	0	0	0	0	0	0	0	12
Sandusky St (SR568) - Main St to TR 237	0	26	40	14	6	4	4	8
SR 568 - TR 237 to TR 245 (TR 245)	0	0	0	16	24	32	0	0
US 68 / SR 15 @ Eagle Creek (SR 15)	0	0	0	0	0	12	24	24
US 68 / SR 15 @ Eagle Creek (US 68)	0	0	0	12	24	24	24	2

6.6 Change in Distance Traveled

Exhibit 6-4 estimates the number of vehicles impacted and changes in distance traveled due to detours. The exhibit calculates the number of vehicles impacted by multiplying the ADT by the duration of flooding in hours and dividing the result by 24 hours per day. It also displays the calculated changes in distance traveled. These values were developed by multiplying the number of vehicles impacted by the change in distance caused by the detour. Exhibit 6-4 provides results by flood frequency and road segment.

Exhibit 6-4: Number of Vehicles Impacted and Change in Distance Traveled

	Number of Vehicles Impacted							
Name	**2-Yr (50%)**	**5-Yr (20%)**	**10-Yr (10%)**	**25-Yr (4%)**	**50-Yr (2%)**	**100-Yr (1%)**	**200-Yr (.5%)**	**500-Yr (.2%)**
US 224 - CR 140 to I-75	-	-	-	11,000	15,583	3,667	1,833	-
Main St - Center St to Sandusky St	-	-	18,000	30,000	34,500	13,500	7,500	7,500
Main St - Olive Street to SR 15	-	-	-	4,000	5,333	8,000	8,000	5,333
Main Cross St - Western Ave To Bright Rd 3	7,000	5,000	5,000	3,000	3,000	3,000	3,000	7,000
SR 37 - Main St to TR 205	-	-	5,000	5,000	7,917	9,167	5,000	2,917
SR 37 - CR 8 to TR 234	-	-	-	-	-	-	-	2,000
Sandusky St (SR568) - Main St to TR 237	-	13,000	20,000	7,000	3,000	2,000	2,000	4,000
SR 568 - TR 237 to TR 245 (TR 245)	-	-	-	4,000	6,000	8,000	-	-
US 68 / SR 15 @ Eagle Creek (SR 15)	-	-	-	-	-	10,000	20,000	20,000
US 68 / SR 15 @ Eagle Creek (US 68)	-	-	-	10,000	20,000	20,000	20,000	1,667

	Change in Distance Traveled (miles)							
Name	**2-Yr (50%)**	**5-Yr (20%)**	**10-Yr (10%)**	**25-Yr (4%)**	**50-Yr (2%)**	**100-Yr (1%)**	**200-Yr (.5%)**	**500-Yr (.2%)**
US 224 - CR 140 to I-75	-	-	-	12,100	17,142	4,033	2,017	-
Main St - Center St to Sandusky St	-	-	75,600	126,000	144,900	56,700	31,500	31,500
Main St - Olive Street to SR 15	-	-	-	31,200	41,600	62,400	62,400	41,600
Main Cross St - Western Ave To Bright Rd 3	21,700	15,500	15,500	9,300	9,300	9,300	9,300	21,700
SR 37 - Main St to TR 205	-	-	27,500	27,500	43,542	50,417	27,500	16,042
SR 37 - CR 8 to TR 234	-	-	-	-	-	-	-	3,800
Sandusky St (SR568) - Main St to TR 237	-	205,400	316,000	110,600	47,400	31,600	31,600	63,200
SR 568 - TR 237 to TR 245 (TR 245)	-	-	-	63,200	94,800	126,400	-	-
US 68 / SR 15 @ Eagle Creek (SR 15)	-	-	-	-	-	82,000	164,000	164,000
US 68 / SR 15 @ Eagle Creek (US 68)	-	-	-	27,000	54,000	54,000	54,000	4,500

6.7 Change in Vehicle Operating Cost

Exhibit 6-5 estimates the change in vehicle operating cost. The exhibit calculates change in vehicle operating cost by multiplying the changes in distance traveled by the IRS mileage rate. The exhibit provides results by flood frequency and road segment.

Exhibit 6-5: Change in Vehicle Operating Cost

	Change in Vehicle Operating Cost ($)							
Name	**2-Yr (50%)**	**5-Yr (20%)**	**10-Yr (10%)**	**25-Yr (4%)**	**50-Yr (2%)**	**100-Yr (1%)**	**200-Yr (.5%)**	**500-Yr (.2%)**
US 224 - CR 140 to I-75	-	-	-	6,474	9,171	2,158	1,079	-
Main St - Center St to Sandusky St	-	-	40,446	67,410	77,522	30,335	16,853	16,853
Main St - Olive Street to SR 15	-	-	-	16,692	22,256	33,384	33,384	22,256
Main Cross St - Western Ave To Bright Rd 3	11,610	8,293	8,293	4,976	4,976	4,976	4,976	11,610
SR 37 - Main St to TR 205	-	-	14,713	14,713	23,295	26,973	14,713	8,582
SR 37 - CR 8 to TR 234	-	-	-	-	-	-	-	2,033
Sandusky St (SR568) - Main St to TR 237	-	109,889	169,060	59,171	25,359	16,906	16,906	33,812
SR 568 - TR 237 to TR 245 (TR 245)	-	-	-	33,812	50,718	67,624	-	-
US 68 / SR 15 @ Eagle Creek (SR 15)	-	-	-	-	-	43,870	87,740	87,740
US 68 / SR 15 @ Eagle Creek (US 68)	-	-	-	14,445	28,890	28,890	28,890	2,408

6.8 Change in Time Traveled and Value of Time

Exhibit 6-6 estimates the change in time traveled due to detour and change in value of time. The exhibit shows the calculated change in time traveled. These values were developed by multiplying the number of vehicles impacted by the change in time the detour causes. The exhibit also shows the changes in value of time calculated by multiplying the change in time traveled by the value of time per hour. The exhibit provides results by flood frequency and road segment.

Exhibit 6-6: Change in Time Traveled

	Change in Time Traveled (minutes)							
Name	**2-Yr (50%)**	**5-Yr (20%)**	**10-Yr (10%)**	**25-Yr (4%)**	**50-Yr (2%)**	**100-Yr (1%)**	**200-Yr (.5%)**	**500-Yr (.2%)**
US 224 - CR 140 to I-75	-	-	-	99,000	140,250	33,000	16,500	-
Main St - Center St to Sandusky St	-	-	414,000	690,000	793,500	310,500	172,500	172,500
Main St - Olive Street to SR 15	-	-	-	112,000	149,333	224,000	224,000	149,333
Main Cross St - Western Ave To Bright Rd 3	182,000	130,000	130,000	78,000	78,000	78,000	78,000	182,000
SR 37 - Main St to TR 205	-	-	170,000	170,000	269,167	311,667	170,000	99,167
SR 37 - CR 8 to TR 234	-	-	-	-	-	-	-	22,000
Sandusky St (SR568) - Main St to TR 237	-	754,000	1,160,000	406,000	174,000	116,000	116,000	232,000
SR 568 - TR 237 to TR 245 (TR 245)	-	-	-	232,000	348,000	464,000	-	-
US 68 / SR 15 @ Eagle Creek (SR 15)	-	-	-	-	-	380,000	760,000	760,000
US 68 / SR 15 @ Eagle Creek (US 68)	-	-	-	200,000	400,000	400,000	400,000	33,333

Exhibit 6-7: Change in Value of Time

	Change in Value of Time ($)							
Name	**2-Yr (50%)**	**5-Yr (20%)**	**10-Yr (10%)**	**25-Yr (4%)**	**50-Yr (2%)**	**100-Yr (1%)**	**200-Yr (.5%)**	**500-Yr (.2%)**
US 224 - CR 140 to I-75	-	-	-	31,850	45,122	10,617	5,308	-
Main St - Center St to Sandusky St	-	-	133,193	221,988	255,287	99,895	55,497	55,497
Main St - Olive Street to SR 15	-	-	-	36,033	48,044	72,066	72,066	48,044
Main Cross St - Western Ave To Bright Rd 3	58,553	41,824	41,824	25,094	25,094	25,094	25,094	58,553
SR 37 - Main St to TR 205	-	-	54,693	54,693	86,597	100,270	54,693	31,904
SR 37 - CR 8 to TR 234	-	-	-	-	-	-	-	7,078
Sandusky St (SR568) - Main St to TR 237	-	242,579	373,198	130,619	55,980	37,320	37,320	74,640
SR 568 - TR 237 to TR 245 (TR 245)	-	-	-	74,640	111,959	149,279	-	-
US 68 / SR 15 @ Eagle Creek (SR 15)	-	-	-	-	-	122,254	244,509	244,509
US 68 / SR 15 @ Eagle Creek (US 68)	-	-	-	64,344	128,689	128,689	128,689	10,724

6.9 Change in Transportation Cost

Exhibit 6-7 estimates the change in transportation cost. The exhibit shows the change in transportation cost calculated by summing the change in vehicle operating cost and the change in value of time. The exhibit provides results by flood frequency and road segment.

Exhibit 6-7: Change in Transportation Cost

	Change in Transportation Cost ($)							
Name	**2-Yr (50%)**	**5-Yr (20%)**	**10-Yr (10%)**	**25-Yr (4%)**	**50-Yr (2%)**	**100-Yr (1%)**	**200-Yr (.5%)**	**500-Yr (.2%)**
US 224 - CR 140 to I-75	-	-	-	38,324	54,292	12,775	6,387	-
Main St - Center St to Sandusky St	-	-	173,639	289,398	332,808	130,229	72,350	72,350
Main St - Olive Street to SR 15	-	-	-	52,725	70,300	105,450	105,450	70,300
Main Cross St - Western Ave To Bright Rd 3	70,163	50,116	50,116	30,070	30,070	30,070	30,070	70,163
SR 37 - Main St to TR 205	-	-	69,405	69,405	109,892	127,243	69,405	40,486
SR 37 - CR 8 to TR 234	-	-	-	-	-	-	-	9,111
Sandusky St (SR568) - Main St to TR 237	-	352,468	542,258	189,790	81,339	54,226	54,226	108,452
SR 568 - TR 237 to TR 245 (TR 245)	-	-	-	108,452	162,677	216,903	-	-
US 68 / SR 15 @ Eagle Creek (SR 15)	-	-	-	-	-	166,124	332,249	332,249
US 68 / SR 15 @ Eagle Creek (US 68)	-	-	-	78,789	157,579	157,579	157,579	13,132

6.10 Results

Exhibit 6-8 estimates the average annual benefit (the change in transportation cost). The first column of the exhibit lists the flood frequencies. The second column lists the sum of the change in transportation costs from Exhibit 6-8. The final stage of the analysis (columns three through six) involves constructing a frequency-damage curve from the results of the change in transportation cost for each frequency. This involves the calculation of the average change in transportation cost, the probability of occurrence, the incremental occurrence and the average annual change in transportation cost. The sum of the average annual change over the eight frequencies provides the incremental average annual change in transportation cost, which is the estimate of the benefit. The annual average benefit of reducing flood related transportation detours is $219,027.

Exhibit 6-8: Average Annual Transportation Benefits

Flood Event	Total Damage	Average Damage	Probability of Occurrence	Incremental Occurrence	Average Annual Change
500	$ 716,242		0.002		
		$ 771,978		0.003	$ 2,316
200	$ 827,715		0.005		
		$ 914,157		0.005	$ 4,571
100	$ 1,000,599		0.01		
		$ 999,778		0.01	$ 9,998
50	$ 998,957		0.02		
		$ 927,955		0.02	$ 18,559
25	$ 856,953		0.04		
		$ 846,186		0.06	$ 50,771
10	$ 835,418		0.1		
		$ 619,001		0.1	$ 61,900
5	$ 402,584		0.2		
		$ 236,373		0.3	$ 70,912
2	$ 70,163		0.5		
Total average annual change:					**$ 219,027**

Chapter 7 Debris Removal, Relocations & Emergency Response

This chapter presents the rationale, methodology and results of the economic benefit resulting from reduction of Emergency Response expenses. These reductions occur when emergency responders from Hancock County, various Townships and the City of Findlay are able to avoid the expenses brought about by responses and rescues related to significant flood events. The flood damage expenses avoided may include water and flood-related rescues, utility damages, debris removal, costs associated with emergency shelters and temporary relocations for residents, government agencies and businesses, and other disaster related costs. The savings in emergency response expenditures constitutes a benefit of the Hancock County Flood Risk Reduction Program.

7.1 Rationale and Justification for Inclusion

The US Army Corps of Engineers (USACE) classifies emergency costs as nonphysical flood losses.[31] Emergency response costs are incurred by Federal, State, and local government agencies that provide emergency services and debris removal during a flood. Benefits accrue when the community avoids expenses for emergency services brought on by flooding. These may include, for example, costs of rescue, flood fighting and cleanup along with the costs of debris removal, resident evacuation and temporary housing, and first responders including police and fire. As noted by the USACE,

> *"Emergency costs include those expenses resulting from a flood that would not otherwise be incurred. For example, the costs of evacuation and reoccupation, flood fighting, and administrative costs of disaster relief; increased costs of normal operations during the flood; and increased costs of police, fire, or military patrol. Emergency costs should be determined by specific survey or research and should not be estimated by applying arbitrary percentages to the physical damage estimates."*[32]

The agency's Flood Risk Management report elaborates:

> *"Clean up and recovery costs include the cost of all labor and materials associated with cleaning up flood debris and damage, repairing damages, replacing evacuated and moved*

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[31] Flood Risk Management. Institute for Water Resources Report 2013-R-05, Department of the Army, U.S. Army Corps of Engineers, Washington, DC, June 2013.

[32] Economic and Environmental Principles for Water and Related Land Resources Implementation Studies, Planning Guidance Notebook, ER 1105-2-100, Department of the Army, U.S. Army Corps of Engineers, Washington, DC, 22 April 2000.

> *property, providing emergency food, water, shelter and medical expenses, policing and securing damaged areas, clearing roads, disposing of debris and other similar expenses."*[33]

7.2 Estimation Methodology

This section describes the methodology used to estimate the economic benefit from reduced emergency expenses. The research team received a summary of Disaster Assistance funds distributed by FEMA for the 2007 flood in Findlay (not including Flood Insurance payments to businesses) from the Maumee Watershed Conservancy District Project Manager. The Ohio Emergency Management Agency (EMA) provided the information. [34] There are two sets of data, one covering loans and one covering public assistance.

7.2.1 Loans

Exhibit 7-1 provides the Hancock County loan funding that came from two sources, the Individuals and Households Program (IHP) and the Small Business Administration (SBA). The IHP provides financial help or direct services to those who have necessary expenses and serious needs if they are unable to meet those needs through other means. [35] The SBA provides federal disaster loan assistance to businesses, homeowners, nonprofits and renters.[36] The total loans issued in response to the 2007 flooding event summed to just under $20 million. The IHP funding represented 2,743 registrations of which 1,748 were approved for $7,234,176. The SBA funds covered 211 Home/Personal Property Loans totaling $6,798,400 and 69 Business Loans totaling $5,768,700.

Exhibit 7-1: Hancock County Loan Funding

				Small Business Administration (SBA)			
	Individuals and Households Program (IHP)			Home/Personal Property Loans		Business Loans	
County	Registrations	Approved	Amount				
Hancock	2,743	1,748	$7,234,176	211	$6,798,400	69	$5,768,700

Since the funds were loans and used primarily for structure and content damage, according to the Project Manager for the MWCD, these funds are not included in this part of the analysis. The simulations of the HEC-FDA model produce values for individual and household losses.

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[33] Flood Risk Management. Institute for Water Resources Report 2013-R-05, Department of the Army, U.S. Army Corps of Engineers, Washington, DC, June 2013.

[34] http://www.ema.ohio.gov/

[35] https://www.fema.gov/media-library/assets/documents/24945

[36] https://disasterloan.sba.gov/ela/Declarations

7.2.2 Public Assistance

The second funding source, representing $7,652,947.58 in public assistance, provided detail for Hancock County grant awards in response to the 2007 flood event. The data included the fund recipients, such as Blanchard Valley Health System and Findlay City Schools, and the breakdown by funding source, such as Federal, Administrative (federal) State or Local share.

The first column in Exhibit 7-2 provides the total public assistance for each entity. First, the research team assigned these expenses to one of four expense categories. The categories were debris removal and roadway and bridge impacts, emergency services, structure or content damage, and outside of the Flood Risk Reduction Program zone of influence.

Exhibit 7-2: Hancock County Grant Recipients by Jurisdiction and Damage Category

Jurisdiction	Total Grant Award	Debris Removal and Roadway and Bridge Impacts	Emergency Services	Structure and Content Damage	Outside of Program Influence
Amanda Township	$45,051	$45,051	$0	$0	$0
Blanchard Township	$5,471	$5,471	$0	$0	$0
Blanchard Valley Health System	$50,416	$0	$50,416	$0	$0
City of Findlay	$1,592,447	$1,592,447	$0	$0	$0
Delaware Township	$7,342	$7,342	$0	$0	$0
Findlay City Schools	$2,457,104	$0	$0	$2,457,104	$0
Findlay-Hancock Co. Public Library	$2,220,342	$0	$0	$2,220,342	$0
Hancock County Agency on Aging	$6,496	$0	$6,496	$0	$0
Hancock County Board of Elections	$130,431	$0	$0	$130,431	$0
Hancock County Board of MR/DD	$3,566	$0	$0	$3,566	$0
Hancock County Commissioners	$656,513	$0	$0	$656,513	$0
Hancock County Engineer	$195,774	$195,774	$0	$0	$0
Hancock County Fairgrounds	$19,787	$4,947	$0	$14,840	$0
Hancock County Health Dept.	$19,118	$0	$0	$19,118	$0
Hancock County Sheriff	$28,385	$0	$0	$28,385	$0
Hancock Park District	$14,995	$0	$0	$14,995	$0
Liberty Township	$13,590	$13,590	$0	$0	$0
Madison Township	$4,047	$0	$0	$0	$4,047
Marion Township	$18,375	$18,375	$0	$0	$0
Pioneer Club	$7,279	$0	$0	$7,279	$0
The Arts Partnership of Greater Hancock	$26,697	$0	$0	$26,697	$0
Village of Arlington	$78,236	$0	$0	$0	$78,236
Village of Jenera	$3,813	$0	$0	$0	$3,813
Village of Mt. Blanchard	$47,671	$0	$0	$0	$47,671
HANCOCK COUNTY TOTALS	**$7,652,948**	**$1,882,997**	**$56,912**	**$5,579,270**	**$133,768**

Second, the research team determined which of the entities were outside the area of influence of the Flood Risk Reduction Program based on geographic location. As shown in the rightmost column of Exhibit 7-2, expenses expended to jurisdictions outside of The Program influence totaled $133,768.

Third, to assign the remaining funds to the remaining three categories of Debris Removal and Bridge Impacts, Emergency Services and Structure and Content Damage, the research team collected FEMA damage applications as available from the Hancock County Historical Society and reviewed them to determine what the actual funding request was for.

The final total of emergency response costs from 2007 is $1,939,909, the sum of debris removal and emergency services in Exhibit 7-2. The analysis then updated the data from 2007 values to 2018 values using the U.S. Bureau of Labor Statistics (BLS) Consumer Price Index (CPI) Inflation Calculator. [37] The CPI inflation calculator uses the All Urban Consumers (CPI-U) U.S. city average series for all items, not seasonally adjusted. This data represents changes in the prices of all goods and services purchased for consumption by urban households. The analysis used the CPI change from February 2007 to February 2018. After accounting for inflation, the 2018 cost of emergency response is $2,373,574.

7.3 Results

This section provides the results related to the emergency response component of the BCA. In order to estimate the benefits, the research team made several assumptions. First, the research team removed funding for structure and contents damage to avoid double counting. Second, the research team assumed that the estimates included within the funding applications submitted in response to the 2007 flood event approximated these costs during a 1% ACE event. Third, a method was required to scale these estimates to other flood frequencies. Duration of road closures provides a reasonable proxy for debris removal and the research team chose to use hours of road closures as the proxy. Thus, the impacts were scaled to the other flood frequencies using the number of hours of road closures. Exhibit 7-3 provides the results of emergency response avoidance benefits under the existing and program scenarios.

The water surface elevation (WSE) reductions related to the Flood Risk Reduction Program were compared to the existing 1% ACE flood event. The Program improvements scenario saves $174,208 ($387,448 - $213,241) in incremental annual damages.

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[37] U.S. Bureau of Labor Statistics, https://www.bls.gov/data/inflation_calculator.htm

Exhibit 7-3: Benefits of Avoidance of Emergency Response Expenses

Flood Event	Duration of Road Closures (hours)	Total Damage	Average Damage	Probability of Occurrence	Incremental Occurrence	Average Annual Damage	Incremental Annual Damage
Existing Conditions							
500	486	$ 3,035,676		0.002			
			$ 2,829,550		0.003	$ 8,489	
200	420	$ 2,623,424		0.005			
			$ 2,498,499		0.005	$ 12,492	
100	380	$ 2,373,574		0.01			
			$ 2,192,433		0.01	$ 21,924	
50	322	$ 2,011,292		0.02			
			$ 1,811,412		0.02	$ 36,228	
25	258	$ 1,611,532		0.04			
			$ 1,317,958		0.06	$ 79,077	
10	164	$ 1,024,385		0.1			
			$ 812,012		0.1	$ 81,201	
5	96	$ 599,640		0.2			
			$ 493,454		0.3	$ 148,036	
2	62	$ 387,267		0.5			
Total average annual damage:						$ 387,448	
Program							
500	386	$ 2,411,051		0.002			
			$ 2,142,463		0.003	$ 6,427	
200	300	$ 1,873,874		0.005			
			$ 1,586,547		0.005	$ 7,933	
100	208	$ 1,299,219		0.01			
			$ 1,049,370		0.01	$ 10,494	
50	128	$ 799,520		0.02			
			$ 743,303		0.02	$ 14,866	
25	110	$ 687,087		0.04			
			$ 549,670		0.06	$ 32,980	
10	66	$ 412,252		0.1			
			$ 393,514		0.1	$ 39,351	
5	60	$ 374,775		0.2			
			$ 337,297		0.3	$ 101,189	
2	48	$ 299,820		0.5			
Total average annual damage:						$ 213,241	**$ 174,208**

Chapter 8 Reduced NFIP Administrative Costs

This chapter presents the rationale, methodology and results of the economic benefit resulting from reduction of National Flood Insurance Program (NFIP) administrative costs. These reductions occur when structure owners are no longer required to purchase flood insurance or experience fewer flood events. The savings in administrative costs is a benefit of the flood mitigation program.

8.1 Rationale and Justification for Inclusion

The NFIP is a Federal program created by Congress in 1968 to mitigate future flood losses nationwide through sound, community-enforced building and zoning ordinances and to provide access to affordable, federally backed primary flood insurance protection for property owners. The NFIP provides an insurance alternative to disaster assistance to meet the escalating costs of repairing damage to buildings and their contents caused by floods.[38] One purpose is to reduce flood risk through the adoption of floodplain management standards.[39]

This section provides the rationale and justification for inclusion of savings in administrative costs for policies in the national flood insurance program. Owners of structures within the 1% Annual Chance Exceedance (ACE) (100-year) floodplain are required to purchase NFIP flood insurance. As with any insurance, the owners pay yearly premiums for the insurance policies regardless of whether they file claims. The NFIP program returns the majority of these premiums to the owners in the form of payments for claims. However, the program includes administrative costs that owners never recover. In essence, these administrative costs are "lost" each year.

The proposed Flood Risk Reduction Program will result in the removal of some of the structures from the 1% ACE (100-year) floodplain. The owners of these parcels will no longer be required to purchase NFIP insurance and therefore would not pay for certain administrative costs such as insurance agent's commissions and general overhead costs. The proposed Flood Risk Reduction Program also reduces the frequency that individual structures are flooded. This

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[38] U.S. Department of Homeland Security. FEMA. National Flood Insurance Program. Answers to Questions about the NFIP. FEMA F-084. March 2011.

[39] Congressional Research Service. Introduction to FEMA's National Flood Insurance Program (NFIP). August 16, 2016.

reduces other administrative costs such as the cost of claim adjustment. Flood mitigation projects that eliminate the requirement to carry a flood insurance policy or reduce the claim administration burden provide benefits in the form of reduced NFIP administrative costs.

8.2 Estimation Methodology

This section describes the methodology used to estimate the benefit from reduced NFIP administrative costs. This methodology uses data on NFIP administrative costs and data on flooding of structures.

8.2.1 NFIP Administrative Costs

The USACE publishes guidance on NFIP administrative costs for flood projects.[40] The current updated operating cost per policy is $192. However, USACE has not updated the guidance memorandum since 2006. The research team was able to identify newer data from an actuarial rate review that the Federal Insurance and Mitigation Administration (FIMA) conducted.[41] In addition, recently an analyst at the National Water Management Center (NWMC) calculated the average administrative cost per policy in second quarter 2015 dollar terms.[42] This included the calculation of the 2005-2009 arithmetic mean, of price updated administrative costs, for each year. The NWMC price updated the FEMA data using Implicit Price Deflators for Gross Domestic Product published by the US Bureau of Economic Analysis. Using the same source, the research team further updated the table to fourth quarter 2017 dollar terms. [43]

Exhibit 8-1 provides the estimated cost of national flood insurance based on 2011 actuarial analysis. The top part of the exhibit provides the data that the NWMC extracted from the FEMA Actuarial report, the middle part of the exhibit provides the data the authors used to calculate the average administrative cost per policy, and the lower part of the exhibit provides the conversion to current dollars. Average administrative cost per policy in fourth quarter 2017 dollar terms is $321.69.

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[40] USACE, National Flood Insurance Program Operating Costs, Fiscal Year 2006, Memorandum For Planning Community Of Practice, Economic Guidance Memorandum 06-04, CECW-CP April 6, 2006.

[41] Actuarial Rate Review In Support of the Recommended October 1, 2011, Rate and Rule Changes; Thomas L. Hayes, ACAS, MAAA Actuary and D. Andrew Neal, FSA Actuary Federal Insurance and Mitigation Administration (FIMA).

[42] George Townsley, National Water Management Center, Personal Communication. April 19, 2016.

[43] Table 1.1.9. Implicit Price Deflators for Gross Domestic Product. 2017 Q4. Last revised on April 27, 2018. https://bea.gov/iTable/iTable.cfm?reqid=19&step=3&isuri=1&1921=survey&1903=13#reqid=19&step=3&isuri=1&1921=survey&1903=13

Exhibit 8-1: Estimated Cost of National Flood Insurance based on 2011 Actuarial Analysis

Item	2005	2006	2007	2008	2009	Mean: 2005-09
Actuarial Data						
1) Average Amount of Insurance per Policy	$170,683	$185,090	$196,009	$205,768	$213,659	$194,242
2) Earned Premium (A)	$1,967,567,898	$2,246,009,756	$2,538,508,566	$2,781,296,850	$2,975,306,740	$2,501,737,962
3) Losses Cost Incurred (B)	$17,574,729,866	$632,729,059	$605,120,360	$3,362,868,736	$727,585,902	$4,580,606,785
4A) Allocated Loss Adjustment Expense (ALAE)	$456,472,905	$28,755,619	$27,540,260	$129,548,476	$38,051,385	$136,073,729
4B) Special All. Loss Adjustment Expense (SALAE)	$41,507,953	$3,189,318	$2,935,928	$10,201,394	$1,948,928	$11,956,704
4C) Unallocated Loss Adjustment Expense (ULAE)	$558,464,178	$17,804,122	$16,757,316	$104,041,398	$19,172,477	$143,247,898
5) Loss Cost & LAE per Policy	$18,631,174,902	$682,478,119	$652,353,863	$3,606,660,004	$786,758,692	$4,871,885,116
6) Loss & LAE Ratio	9.469	0.304	0.257	1.297	0.264	$2
7A) Direct Agent Commission	$13,358,493	$13,404,745	$13,949,376	$14,608,696	$14,850,458	$14,034,354
7B) WYO Agent Commission Allowance	$281,776,692	$323,496,719	$366,826,909	$402,585,831	$431,445,553	$361,226,341
8A) Direct & Bureau General Expense	$54,800,000	$58,320,000	$68,753,000	$72,501,000	$81,315,000	$67,137,800
8B) Interest on 2005 Borrowing	$5,232,217	$523,535,548	$730,185,164	$811,515,698	$214,368,255	$456,967,376
8C) WYO Operating Allowance (w/o ULAE)	$326,860,963	$378,491,161	$406,566,491	$407,953,642	$437,198,160	$391,414,083
9) Earned Exposure (C)	4,657,365	5,132,786	5,463,375	5,587,482	5,616,311	$5,291,464
10) Average Premium	$422.46	$437.58	$464.64	$497.77	$529.76	$470
11) Average Operating Expense Other than Agent Commission & Loss Adjustment Expense	$83.07	$187.10	$220.65	$231.23	$130.49	$171
12) Average Agent Commission	$63.37	$65.64	$69.70	$74.67	$79.46	$71
13) Average Loss Cost & LAE per Policy	$4,000.37	$132.96	$119.40	$645.49	$140.08	$1,008
14) Underwriting Profit/(Deficit) per Policy	($3,724.34)	$51.88	$54.89	($453.61)	$179.72	$778
Calculation of Average Administrative Cost Per Policy						
Million Exposures	4.66	5.13	5.46	5.59	5.62	5.29
4) Allocated Loss Adjustment Expenses (ALAE)	$497,980,858	$31,944,937	$30,476,188	$139,749,870	$40,000,313	$148,030,433
4) Allocated Loss Adjustment Expenses (ALAE)/Exposures	$106.92	$6.22	$5.58	$25.01	$7.12	$30.17
10) Average Operating Other than Agent Commission & Loss Adjustsment Expense	$83.07	$187.10	$220.65	$231.23	$130.49	$170.51
11) Average Insurance Agents' Commission	$63.37	$65.64	$69.70	$74.67	$79.46	$70.57
Average Administrative Cost Per Policy	$253.36	$258.96	$295.93	$330.91	$217.07	$271.25
Conversion to Current Dollars						
GDP-IPD	91.543	94.587	97.194	98.995	99.895	114.352
Average Administrative Cost Per Policy (2017 QIV Dollar Terms)	$316.49	$313.08	$348.17	$382.25	$248.49	$321.69

For the period 2005 to 2009, the administrative cost consists of three major expenses:

- Loss Adjustment Expenses (ALAE)/Exposures ($30.17)
- Operating Expense ($170.51)
- Insurance Agents' Commission ($70.57)

Note that only the smallest category depends on whether a structure is flooded, while the bulk of administrative costs depends on whether there is a policy in place. If the structure is out of the 1% ACE (100-year) floodplain, the owner saves the administrative costs of the insurance policy. Therefore, the methodology derives the estimate of benefits by multiplying the number of structures removed from the 1% ACE (100-year) floodplain in each alternative by the NFIP administrative cost. The number of structures includes residences and businesses as stated in guidance provided by FEMA:

> "Flood insurance is available to homeowners for dwellings and contents, to businesses for buildings and contents, and to renters for contents."[44]

8.2.2 Number of Structures

The research team determined the number of structures currently within the 1% ACE (100-year) floodplain "Without Project" base case and the number protected from flooding in The Program case. Exhibit 8-2 provides the number of structures with total damage greater than zero for the 1% ACE (100-year) flood in the base case and Program scenarios. The earlier chapter on structures provides a detailed description of the development of these estimates.

Exhibit 8-2: Number of Structures with Total Damage Greater Than Zero for the 1% ACE Flood Event

Area	Base Case	The Program
Eagle Creek	504	50
Lye Creek	74	8
Blanchard River	947	146
TOTAL	**1,525**	**204**

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[44] Now that you know, what are you going to do? FEMA Press Release: 1709-114. November 8, 2009. https://www.fema.gov/news-release/2007/11/08/now-you-know-what-are-you-going-do#. Accessed May 10, 2018.

8.3 Results

Exhibit 8-3 provides the calculation of the annual benefit for each alternative. The methodology multiplies tallies of residential structures no longer flooded in the 1% ACE (100-year) flood event by the average NFIP administrative cost. The average annual benefit for The Program is $424,952.

Exhibit 8-3: Benefits of Reduced NFIP Administrative Costs

Alternative	Structures Flooded in 100-Year Event	Reduced Number of Structures	NFIP Administrative Cost per Structure	Yearly Savings (Benefit)
Without project	1,525			
The Program	204	1,321	$321.69	$424,952

The reduction in average annual damages this chapter describes will occur as the community implements the flood reduction program. The reduction in average annual damages will then continue throughout the 50-year life of the program. The Results chapter at the end of this report describes and provides the calculation of the net present value of that stream of benefits.

Chapter 9 Business Losses

This chapter presents the rationale, methodology and results of the economic benefit resulting from reduction of business losses due to the implementation of flood protection measures contained in the *Hancock County Flood Risk Reduction Program*. These reductions occur when business structure owners are no longer impaired by recurring flooding events and do not have to close their businesses for an extended or temporary period of time. The reduction in business losses generated from flood protection measures is a benefit of the flood mitigation program.

9.1 Rationale and Justification for Inclusion

The USACE report quotes its own guidance informing how lost wages should be included over and above physical flood damages. The guidance goes on to explain the method to derive those estimates. However, lost income or lost wages do not appear to be included in "The Blanchard River Flood Risk Management Feasibility Study Appendix B – Economics (DRAFT)" results. The National Economic Development (NED) Manual classifies income loss under non-physical damage.[45] The manual defines it as *"the loss of wages or net profits to businesses over and above physical flood damages. It results from a disruption of normal activities that cannot be recouped from other businesses or from the same business at another time. Prevention of income loss can be counted as a national benefit only to the extent that such loss cannot be offset by postponement of an activity or transfer of the activity to other establishments."*[46]

Under some conditions, income loss is an NED benefit. The NED Manual states *"Income losses are reductions in the national income when flooding or the threat of flooding halts production or delivery of goods and services. National losses occur 1) when the production or delivery of these goods and services are not recuperated by postponing the activity or transferring it to another location, or, 2) when there are additional costs caused by delay or transfer of the activity. Income losses are incurred by businesses and labor as a result of flood induced shut-down in the production and delivery of goods and services. These losses can occur at any time during three periods: 1) flood warning, when business operations shut down and effort concentrates on damage prevention and evacuation; 2) flood inundation, when flood fighting and evacuation continues; and, 3) cleanup and restoration, when there may be a phasing in of normal activity. Even the threat of flooding can cause shut down of business operations for extended periods along large river basins. Inundation can vary from several hours to over a week, depending on the sources of flooding. Income losses may occur directly to the business or institution being*

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[45] USACE. National Economic Development Procedures Manual – Urban Flood Damage. 1988 Section VII-2.

[46] Ibid.

flooded. Losses may occur indirectly when roads are closed and public utilities are cut off. Business losses can also occur from the spoilage of perishable commodities and when their processing or distribution are [sic] interrupted by flooding. Income losses also include any additional transportation or production costs that occur from transferring production from one area to another.”[47]

9.2 Estimation Methodology

This section describes the methodology used to estimate the benefit from reduced business losses in Hancock County generated by the Hancock County Flood Risk Reduction Program. It is structured in three main parts: Business Loss Categories, Business Loss Recovery Rate and Final Methodology.

9.2.1 Business Loss Categories

The U.S. Army Corps of Engineers (USACE), Buffalo District, previously published a report in November 2015 entitled “The Blanchard River Flood Risk Management Feasibility Study Appendix B – Economics (DRAFT).” The business loss benefit category and methodology uses data on business losses and flooding of business structures captured in a survey called “Commercial and Industrial Flood Damage Survey Findlay, OH”, (Survey), which was part of the aforementioned report.[48] The Survey included 431 businesses responses, which the study team used to estimate the business losses for this BCA. In order to generate the business loss results, the research team extracted the following three response categories from the Survey:

1. Loss of Net Income
2. Cost of Cleanup
3. Cost of Emergency Plan

Please note that all the above categories and the respective values represent estimates made by the business owners who responded to the Survey. Furthermore, the research team made several assumptions in order to provide for a conservative estimate of business losses. First, the team considered losses of net income as losses in sales, which is a more conservative approach. This is because sales are much larger than net income, including taxes, fees, cost of goods sold, and other business expenses such as labor and rent. The project team made this assumption because it appeared that some respondents may have reported sales rather than net income. Second, the study team assumed that the responses the Survey collected represent the entirety of all business activities in Hancock County. Since the Survey included 431 responses and there

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[47] Ibid.

[48] Office of Budget and Management (OMB), Commercial and Industrial Flood Damage Survey Findlay, OH, OMB Control Number 0710-0001

are over 1,500 businesses in Hancock County, this approach neglects possible additional business losses that may occur in the case of a flooding event or have occurred during flooding events in the past. Therefore, this approach is more conservative than an extrapolation of business losses to the total of 1,500 businesses. Exhibit 9-1 shows an illustration of the types of responses that were posted on the Survey.[49] It includes the following columns: *Has the facility flooded in the past? (Y/N)*, *Loss of Net Income*, *Cost of Cleanup* and *Estimated Cost of Emergency Plan*.

Exhibit 9-1: Extract of Business Loss Category Questions

Has the Facility flooded in the past? (Y/N)	Loss of Net Income	Cost of Cleanup	Estimated cost of emergency plan
Y	-	$ -	$ 1,000
Y	-	$ -	$ 200
Y	-	$ 7,000	$ 1,000
No	-	-	-
Y	$ 300,000	$ 30,000	-
Y	-	$ 1,000	$ 5,000
Y	-	$ 5,000	$ 75
Y	-	$ -	$ 200
Y	$ 3,000	$ 4,000	$ 6,000
Y	$ 7,000	$ 4,000	$ 1,000
Y	-	$ -	$ 200
Y	-	$ -	$ 3,000
Y	$ 200,000	$ 300,000	$ 500
Y	-	$ 200	$ 7,000
No	-	-	-
Y	-	$ 500,000	-
Y	-	$ 2,500	-
Y	$ 400	$ 300	$ 30
No	-	-	-
Y	-	$ 22,000	$ 400
Y	$ 35,000	$ 500	$ 500
Y	$ 25,000	$ 15,000	$ 1,010
Y	-	$ 500	$ 50

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[49] For illustrative purposes only. Not exact responses from the USACE Survey.

9.2.2 Business Loss Recovery Rate

It is common that businesses are able to recover temporary business losses caused by flooding later on. Therefore, the research team generated an average business loss recovery rate and applied it to the estimated business losses in order to provide for meaningful benefit results in this category.

For this purpose, the team used most recent data from a new on-line business survey that the Program Team conducted in Hancock County to estimate the business loss recovery rate for this benefit category. Based on the current business survey, the JFA team created the following formula to estimate the average business loss recovery rate:

$$Business\ Loss\ Recovery\ Rate = \frac{\left(\left(\frac{100+91}{2}\right)*21\right)+\left(\left(\frac{90+75}{2}\right)*5\right)+\left(\left(\frac{0+74}{2}\right)*16\right)}{42}$$

The numbers highlighted in yellow represent the number of businesses that estimated their business loss recovery rate in one of the following three brackets:

1. 91-100% (21 responses)
2. 75-90% (5 responses)
3. 0-74% (16 responses)

The number that is highlighted in green represents the total amount of responses for business loss recovery rates included in the recent business survey. JFA used these responses because they represent the most recent data on business loss recovery in Hancock County.

This formula results in an average business loss recovery rate of 71.67%. The JFA team used this average in the *Final Methodology* section to generate the final benefit results for this benefit category.

9.2.3 Final Methodology

This section brings together the Business Loss Categories and Business Loss Recovery Rate sections to provide a concise overview of the final methodology the research team utilized to generate the benefits for this category. In order to generate the business loss results, the research team extracted the following three business loss categories from the Survey:

1. Loss of Net Income
2. Cost of Cleanup
3. Cost of Emergency Plan

This section is structured based on these three business loss categories. The *Cost of Cleanup* and *Cost of Emergency Plan* are direct expenses that the respective businesses would not have to incur if there was no flooding event. Therefore, they can be summed up as direct benefits, since they represent a reduction of business expenses. This section describes the methodology for business loss category 2 (Cost of Cleanup) and 3 (Cost of Emergency Plan) first. Exhibit 9-2 shows the totals for both of these business loss categories. Please note that these figures were extracted directly from the Survey and reflect 2007 dollar values. This approach provides a conservative estimate, since the figures would be higher in 2018 dollars.

Exhibit 9-2: Total Costs of Cleanup and Emergency Plan in 2007 Dollars

Data Point	Total
Total Cost of Cleanup	$ 7,316,873
Estimated Cost of Emergency Plan	$ 1,386,061

The team did not apply the Business Loss Recovery Rate to these *Costs of Cleanup and Emergency Plan* since the businesses that incurred expenses for these two categories cannot recoup these expenses through regular business activities.

Next, the project team calculated the Loss Value Added, a measure similar to gross national product (GNP) but at the local level. Exhibit 9-3 shows the total dollar amount for Loss of Sales Income based on the USACE Survey. Since this research effort is only interested in the economic value that was lost due to the flooding event in 2007, the total amount of Loss of Sales requires several adjustments.

Exhibit 9-3: Total Loss of Sales

Data Point	Total
Total Loss of Sales	$ 6,393,892

The first set of adjustments was to run the sales data through the IMPLAN model to calculate changes in the value added that would result from the direct, indirect and induced economic activity generated by those sales. For this purpose, the research team assigned each Loss of Net Income response collected in the survey to an IMPLAN code. IMPLAN is an economic model that estimates the final amount of Value Added for the Business Losses Category "Loss of Net Income." Exhibit 9-4 shows an example extract of the single survey responses with the according IMPLAN code, business description and Loss of Net Income dollar amount.

Exhibit 9-4: Example Extract of Loss of Net Income Responses Coded to IMPLAN Sectors

All Assigned IMPLAN Codes	IMPLAN Description	Loss of Net Income
399	Retail - Building material and garden equipment and supplies stores	$ 60,000
400	Retail - Food and beverage stores	$ 10,000
509	Personal care services	$ 20,000
509	Personal care services	$ 1,500
509	Personal care services	$ 2,000
499	Hotels and motels, including casino hotels	$ 50,000
406	Retail - Miscellaneous store retailers	$ 400

Finally, the team summed up the dollar amount for each IMPLAN sector and ran it through the IMPLAN Model. Exhibit 9-5 provides an example extract of the records for final IMPLAN concordance.

Exhibit 9-3: Extract of Final IMPLAN Concordance

All Assigned IMPLAN Codes	Sales By IMPLAN Sector
56	$ 10,000
58	$ 20,000
59	$ 10,000
166	$ 60,000
394	$ 3,300
395	$ 4,000
396	$ 76,000
398	$ 10,000
399	$ 138,750
400	$ 185,600
401	$ 47,000
403	$ 14,000
404	$ 10,000
406	$ 164,900
416	$ 55,750

As a last step, the research team applied the business loss recovery rate of 100%-76.67%=28.33% to the IMPLAN results.

9.3 Results

This section provides the benefits or costs avoided from the program improvements. In order to estimate the benefits the research team made several assumptions. First, the research team assumed that the 2007 estimates approximated these costs during a 1% annual chance event (ACE). Second, a method was required to scale these estimates to other flood return frequencies. Duration of road closures provides a reasonable proxy for Loss of Net Income as it measures the inability of customers and employees to travel and conduct commerce. For the other two categories, Costs of Cleanup and Costs of Emergency Plan, the research team utilized the number of flooded commercial and industrial buildings for each return frequency.

Exhibit 9-6 provides the results of avoided business loss benefits (Average Annual Damages – AAD) under The Program scenario for Business Loss Category 1, Loss of Net Income.

Exhibit 9-4: Results for Business Loss Category 1, Loss of Sales

Flood Event	Duration of Road Closures (hours)	Total Damage	Average Damage	Probability of Occurrence	Incremental Occurrence	Average Annual Damage	Incremental Average Annual Damage
Existing Conditions							
500	486	$ 1,266,224		0.002			
			$ 1,180,246		0.003	$ 3,541	
200	420	$ 1,094,268		0.005			
			$ 1,042,160		0.005	$ 5,211	
100	380	$ 990,052		0.01			
			$ 914,495		0.01	$ 9,145	
50	322	$ 838,939		0.02			
			$ 755,566		0.02	$ 15,111	
25	258	$ 672,193		0.04			
			$ 549,739		0.06	$ 32,984	
10	164	$ 427,286		0.1			
			$ 338,702		0.1	$ 33,870	
5	96	$ 250,118		0.2			
			$ 205,827		0.3	$ 61,748	
2	62	$ 161,535		0.5			
Total average annual damage:						$ 161,610	
The Program							
500	386	$ 1,005,684		0.002			
			$ 893,652		0.003	$ 2,681	
200	300	$ 781,620		0.005			
			$ 661,772		0.005	$ 3,309	
100	208	$ 541,923		0.01			
			$ 437,707		0.01	$ 4,377	
50	128	$ 333,491		0.02			
			$ 310,043		0.02	$ 6,201	
25	110	$ 286,594		0.04			
			$ 229,275		0.06	$ 13,757	
10	66	$ 171,956		0.1			
			$ 164,140		0.1	$ 16,414	
5	60	$ 156,324		0.2			
			$ 140,692		0.3	$ 42,207	
2	48	$ 125,059		0.5			
Total average annual damage:						$ 88,946	**$ 72,665**

Exhibit 9-7 provides the results of avoided business loss benefits under The Program scenario for Business Loss Category 2, Costs of Cleanup.

Exhibit 9-5: Results for Business Loss Category 2, Costs of Cleanup

Flood Event	of Commercial and Industrial Buildings	Total Damage	Average Damage	Probability of Occurrence	Incremental Occurrence	Average Annual Damage	Incremental Average Annual Damage
Existing Conditions							
500	333	$ 15,421,004		0.002			
			$ 13,267,621		0.003	$ 39,803	
200	240	$ 11,114,237		0.005			
			$ 9,215,555		0.005	$ 46,078	
100	158	$ 7,316,873		0.01			
			$ 5,904,439		0.01	$ 59,044	
50	97	$ 4,492,004		0.02			
			$ 3,450,045		0.02	$ 69,001	
25	52	$ 2,408,085		0.04			
			$ 1,875,528		0.06	$ 112,532	
10	29	$ 1,342,970		0.1			
			$ 926,186		0.1	$ 92,619	
5	11	$ 509,403		0.2			
			$ 324,165		0.3	$ 97,250	
2	3	$ 138,928		0.5			
Total average annual damage:						$ 516,326	
The Program							
500	111	$ 5,140,335		0.002			
			$ 3,727,900		0.003	$ 11,184	
200	50	$ 2,315,466		0.005			
			$ 1,736,600		0.005	$ 8,683	
100	25	$ 1,157,733		0.01			
			$ 856,722		0.01	$ 8,567	
50	12	$ 555,712		0.02			
			$ 463,093		0.02	$ 9,262	
25	8	$ 370,475		0.04			
			$ 254,701		0.06	$ 15,282	
10	3	$ 138,928		0.1			
			$ 92,619		0.1	$ 9,262	
5	1	$ 46,309		0.2			
			$ 46,309		0.3	$ 13,893	
2	1	$ 46,309		0.5			
Total average annual damage:						$ 76,133	**$ 440,193**

Exhibit 9-8 provides the results of avoided business loss benefits under The Program scenario for Business Loss Category 3, Costs of Emergency Plan.

Exhibit 9-6: Results for Business Loss Category 3, Costs of Emergency Plan

Flood Event	of Commercial and Industrial Buildings (Flood	Total Damage	Average Damage	Probability of Occurrence	Incremental Occurrence	Average Annual Damage	Incremental Average Annual Damage
Existing Conditions							
500	333	$ 2,921,255		0.002			
			$ 2,513,332		0.003	$ 7,540	
200	240	$ 2,105,409		0.005			
			$ 1,745,735		0.005	$ 8,729	
100	158	$ 1,386,061		0.01			
			$ 1,118,499		0.01	$ 11,185	
50	97	$ 850,936		0.02			
			$ 653,554		0.02	$ 13,071	
25	52	$ 456,172		0.04			
			$ 355,288		0.06	$ 21,317	
10	29	$ 254,404		0.1			
			$ 175,451		0.1	$ 17,545	
5	11	$ 96,498		0.2			
			$ 61,408		0.3	$ 18,422	
2	3	$ 26,318		0.5			
Total average annual damage:						$ 97,809	
The Program							
500	111	$ 973,752		0.002			
			$ 706,189		0.003	$ 2,119	
200	50	$ 438,627		0.005			
			$ 328,970		0.005	$ 1,645	
100	25	$ 219,313		0.01			
			$ 162,292		0.01	$ 1,623	
50	12	$ 105,270		0.02			
			$ 87,725		0.02	$ 1,755	
25	8	$ 70,180		0.04			
			$ 48,249		0.06	$ 2,895	
10	3	$ 26,318		0.1			
			$ 17,545		0.1	$ 1,755	
5	1	$ 8,773		0.2			
			$ 8,773		0.3	$ 2,632	
2	1	$ 8,773		0.5			
Total average annual damage:						$ 14,422	**$ 83,387**

Finally, Exhibit 9-9 summarizes the AAD and incremental AAD avoided which represent the benefits of the three Business Loss Categories. Please note that the table contains standard dollar values, as opposed to other tables in this report. The Program improvements scenario reduces annual damages by $596,245 over existing conditions. This is called the incremental annual damages avoided shown in the column labeled IAAD in Exhibit 9-9.

Exhibit 9-7: Business Losses Final Results: AAD and IADA Avoided

Average and Incremental Annual Damages Avoided			
	AAD		IAAD
Category and Scenario	Existing Conditions	The Program	
Loss of Net Income	$ 161,610	$ 88,946	$ 72,665
Cost of Cleanup	$ 516,326	$ 76,133	$ 440,193
Cost of Emergency Plan	$ 97,809	$ 14,422	$ 83,387
Total	**$ 775,745**	**$ 179,501**	**$ 596,245**

In each case, the AAD avoided is the basis for the Net Present Value of damages or costs avoided over the 50-year analysis period of the Hancock County Flood Risk Reduction Program.

Chapter 10 Agricultural Damages Avoided

This chapter presents the agricultural damages avoided by the Hancock County Flood Risk Reduction Program. The first section describes the rationale and justification for inclusion of agricultural damages in a benefit cost analysis. The second section explains the methodology used to calculate the costs and benefits.[50] The third section presents the results of the benefit cost analysis.

10.1 Rationale and Justification for Inclusion

Ponding and flooding can damage crops, but the extent of the damage depends on the type of plant, growth stage, air temperature, and the duration of the flooding.[51] In general:

- Plants with some growth above the water level are more likely to survive.
- A warmer mid-summer flood increases the rate of damage and death to submerged plants, whereas plants can survive longer under water during a colder spring flood.
- Plants that encounter flash-flooding, where the water rises and recedes quickly, are more likely to survive than longer-duration flooding.

The agricultural analysis focuses on Hancock County, where the primary crops grown are soybeans, corn, and wheat.

Soybeans can generally survive for 2 to 4 days when completely submersed. The actual time frame depends on air temperature, cloud cover, soil moisture conditions prior to flooding, and rate of soil drainage. Cool air temperatures and cloudy days increase the survival of a flooded soybean crop; whereas in temperatures of 80 degrees Fahrenheit or above, soybean plants may only survive a few days. Increased soil moisture conditions prior to flooding and a decreased rate of soil drainage contribute to the buildup of toxins and carbon dioxide, which is more damaging to plants than lack of oxygen.

The plant stage of development when ponding occurs, the duration of ponding, and the air temperature determine the extent to which flooding damages corn crops. Prior to the 6-leaf collar stage or when the growing plant is at or below the soil surface, corn can usually survive only 2 to 4 days of flooded conditions. If the air temperature is greater than 77 degrees Fahrenheit during ponding, corn plants may not survive 24 hours, but cooler air temperatures

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[50] The research team received detailed spreadsheets, modeling program and a draft write-up of this chapter from the USACE. The research team relied extensively on these materials.

[51] Exhibit 10-2 and the discussion of that exhibit provide the sources this study used to estimate potential reduction in yield from flooding by crop.

(mid-60s or cooler) can prolong survival up to about 4 days. Also, once the growing point is above the water level, the likelihood for survival improves greatly.

The most significant factor affecting wheat during a flooding event is air temperature. During summer conditions, 2 to 3 days of flooding can impact plant growth. If the air temperature is above 65 degrees Fahrenheit and the plants are below water for more than 5 to 7 days, the wheat crops will not survive. There is limited information on the effect of flooding on wheat when temperatures are below 40 degrees Fahrenheit. Under cooler temperatures, the negative effects of flooding take longer to impact plant tissues, so winter wheat can tolerate flooding beyond the limits described above for summer conditions.

10.2 Methodology

Resources published by the USDA National Water Management Center describe the methodology applied to evaluate flood damages to crops. The resources are available online.[52] The agricultural damages estimation used the following basic data:

- The U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS) data sources provided land use, average crop production (bushels per acre), and crop progress and condition by month in Hancock and Putnam Counties.
- The Agricultural Resource Management Survey (ARMS) provided costs of farm operation per acre (crop production costs). ARMS is jointly sponsored by USDA's Economic Research Service (ERS) and the National Agricultural Statistics Service (NASS),
- The USDA Economic Research Service provided the 2016 normalized value of production per acre by county and crop (based on 5-year lagged averages of actual market prices).
- Weather Spark provided air temperature ranges and probabilities by month.
- Floodwater damage percentages indicate the average loss of yield by month compared to flood-free conditions. The percentages vary according to the depth and the duration of the flood event. The Hancock County Soil and Water Conservation District vetted these estimates with USACE.
- The Stantec team estimated the number of acres flooded for the with- and without-project conditions for each of the return frequencies.

The method for calculating agricultural benefits began with the identification of land use and cropping patterns. The study focused on the three primary crops grown in the study area:

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[52] USDA, Natural Resources Conservation Service, National Water Management Center. Flood Damage Assessment Tools. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/nwmc/partners/?&cid=nrcs143_009725

soybeans, corn, and wheat. The analysis assumed that the crop distribution remained constant over the period of analysis for each alternative. The analysis used the following crop distribution for Hancock County:

- 54 percent soybeans
- 36 percent corn
- 8 percent wheat

These data come from the 2012 Census of Agriculture.[53]

Stantec provided data sourced from hydraulic modeling in conjunction with GIS to provide the number of acres flooded. The research team distributed the damage by duration (less than one day, 1 to 2 days, 2 to 3 days, and more than 3 days) for each flood recurrence interval using data from the previous USACE study. The research team calculated the areas flooded under exiting conditions and under The Program. Exhibit 10-1 shows, for each flood stage, the area flooded under existing conditions and The Program, as well as the acres removed from flooding.

Exhibit 10-1: Acres Flooded and Protected by Flood Stage

Flood Stage (yr)	Area Flooded (Acres)		
	Existing Conditions	The Program	Reduction in Area Flooded
2	3,116	2,525	591
5	4,090	3,104	986
10	5,015	3,608	1,407
25	6,165	4,252	1,914
50	7,025	4,760	2,265
100	7,906	5,312	2,594
200	8,691	6,408	2,283
500	9,854	7,560	2,294

The analysis identified the acres as soybean, corn or wheat crops according the crop distribution. The damages were valued by analyzing the production function of farm land under the with- and without-project alternatives. Assuming the cropping pattern did not change; the

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[53] U.S. Department of Agriculture, 2012 Census Volume 1, Chapter 2: County Level Data (Ohio). Accessed at: http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_County_Level/Ohio/

benefit was determined by using the applicable farm budget and the likelihood of a yield loss and/or need for replanting according to each month of the year.

The reduction in crop yield as a result of flooding was estimated from publications and work on other studies (Butzen, 2010; Elmore and Abendroth, 2008; Nielsen, 2011; Pedersen, 2008; Ransom, 2009; Thomison, 2012), but primarily from the USDA Natural Resources Conservation Service study, *Final Supplementation Watershed Plan No. 1 and Environmental Assessment for Big Slough Watershed.* Exhibit 10-2 presents the anticipated reduction in yield, which accounts for the impacts of air temperature, crop progress by month, and whether there is an opportunity to replant the crop. Flooding durations less than the amount described above would have minimal impacts on the yield.

Exhibit 10-2: Potential Reduction in Yield from Flooding

Month	Soybeans	Winter Wheat	Corn
January	No loss	100% yield loss	No loss
February	No loss	100% yield loss	No loss
March	No loss	100% yield loss	No loss
April	Replanting	100% yield loss	Replanting
May	Replanting	100% yield loss	Replanting & 25% yield loss
June	Replanting & 25% yield loss	10–65% yield loss	50–75% yield loss
July	50–100% yield loss	0% loss	100% yield loss
August	100% yield loss	0% loss	100% yield loss
September	65–100% yield loss	Replanting	60–85% yield loss
October	10–65% yield loss	Replanting	25–50% yield loss
November	0–5% yield loss	25% yield loss	10–30% yield loss
December	No loss	40–100% yield loss	No loss

Exhibit 10-3 provides production values, operating costs, replanting costs and overhead for corn, soybean and wheat production per planted acre in for 2017. Soybeans were the most profitable crop followed by corn and wheat, as valued by calculating production less operating costs. The data are from the U.S. Department of Agriculture, Commodity Costs and Returns.[54]

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[54] Commodity Costs and Returns, U.S. Department of Agriculture, Economic Research Service, accessed at: https://www.ers.usda.gov/data-products/commodity-costs-and-returns/

Exhibit 10-3: 2017 Production Values and Returns in the Program Area

Item	Corn	Soybeans	Wheat
Gross value of production			
Primary product	651.24	492.37	345.19
Secondary product	0.84		5.96
Total, gross value of production	652.08	492.37	351.15
Operating costs:			
Seed	103.48	57.22	27.08
Fertilizer	119.64	25.28	72.16
Chemicals	36.12	27.15	9.56
Custom operations	23.33	9.52	12.23
Fuel, lube, and electricity	24.62	11.24	9.40
Repairs	31.22	19.89	15.72
Purchased irrigation water	0.00	0.00	0.52
Interest on operating capital	1.78	0.79	0.77
Total, operating costs	340.19	151.09	147.44
Replanting Cost	282.72	129.25	130.19
Allocated overhead:			
Hired labor	3.21	1.95	1.84
Opportunity cost of unpaid labor	20.27	17.65	19.55
Capital recovery of machinery and equipment	120.25	84.01	73.65
Opportunity cost of land (rental rate)	195.75	177.60	136.88
Taxes and insurance	11.56	11.09	7.73
General farm overhead	17.17	18.74	14.24
Total, allocated overhead	368.21	311.04	253.89
Total, costs listed	708.40	462.13	401.33
Value of production less total costs listed	-56.32	30.24	-50.18
Value of production less operating costs	311.89	341.28	203.71
Supporting information:			
Yield (bushels per planted acre)	201.00	53.00	68.90
Price (dollars per bushel at harvest)	3.24	9.29	5.01
Enterprise size (planted acres)	307.00	268.00	101.00

The analysis calculated replanting costs by summing costs per seed, fertilizer, chemicals, hired labor and opportunity cost of unpaid labor.

The analysis calculated full damages (complete loss of crop) for each month by multiplying the average value of the crop per acre and adding the replanting cost (Exhibit 10-3), if necessary, by the percentage yield loss. The analysis assumes damages would occur in two scenarios, in the case where there was 2 to 3 days of flooding, or in the case where there was more than 3 days of flooding.

To estimate the damages for each of these scenarios and each flood event, the analysis multiplies the full damages for each month by the corresponding probability that each flood event would occur in that particular month. The probability that a flood event would occur in a particular month uses data from the U.S. Geological Survey (USGS). Project analysts obtained gage data (maximum per day) for USGS site 04189000 (Blanchard River near Findlay OH) for 1924 to 2016. The analysts sorted the data and found when flow was higher than 3,000 cfs for unique years. Exhibit 10-4 provides the frequency of occurrence of maximum yearly peak discharge by month for period 1923 to 2011.

Exhibit 10-4: Frequency of Occurrence of Maximum Yearly Peak Discharge by Month 1924-2016

Month	Number of Maximum Events	Percent of Total
January	14	12.8%
February	12	11.0%
March	15	13.8%
April	13	11.9%
May	10	9.2%
June	10	9.2%
July	8	7.3%
August	1	0.9%
September	6	5.5%
October	1	0.9%
November	5	4.6%
December	14	12.8%
Total	**109**	**100.0%**

The analysis then multiplies the damages for each scenario by the corresponding number of acres damaged for each crop and for each flood event. The NED benefit is the net increase in yield attributable to a with-project alternative.

10.3 Results

This section presents the results of the benefit cost analysis in the base case (no action alternative) and the Final Program cases. Exhibit 10-4 shows the average annual damage in the Base Case and The Program scenarios for each modeled ACE flooding event. The average annual damage in the no project or base case was $63,133. With the Final Program in place, the average annual damage fell to $49,758. The incremental average annual damage avoided would then be $13,375, representing the difference between the two averages.

Exhibit 10-5: Flood Damage by Event in Base Case and Full Program Scenarios

Flood Event	Total Damage	Average Damage	Probability of Occurrence	Incremental Occurrence	Average Annual Damage
Without Project					
500	$ 1,228,058		0.002		
		$ 1,040,292		0.003	$ 3,121
200	$ 852,527		0.005		
		$ 739,032		0.005	$ 3,695
100	$ 625,538		0.01		
		$ 564,827		0.01	$ 5,648
50	$ 504,116		0.02		
		$ 469,373		0.02	$ 9,387
25	$ 434,629		0.04		
		$ 347,014		0.06	$ 20,821
10	$ 259,398		0.1		
		$ 144,122		0.1	$ 14,412
5	$ 28,846		0.2		
		$ 20,161		0.3	$ 6,048
2	$ 11,476		0.5		
Total Average Annual Damage:					**$ 63,133**
The Program					
500	$ 948,656		0.002		
		$ 791,335		0.003	$ 2,374
200	$ 634,014		0.005		
		$ 549,340		0.005	$ 2,747
100	$ 464,666		0.01		
		$ 423,895		0.01	$ 4,239
50	$ 383,124		0.02		
		$ 354,769		0.02	$ 7,095
25	$ 326,414		0.04		
		$ 265,577		0.06	$ 15,935
10	$ 204,740		0.1		
		$ 115,497		0.1	$ 11,550
5	$ 26,254		0.2		
		$ 19,396		0.3	$ 5,819
2	$ 12,539		0.5		
Total Average Annual Damage:					**$ 49,758**
Incremental Average Annual Damage Avoided:					**$ 13,375**

Chapter 11 Environmental and Land Use Benefits

This chapter presents the environmental benefits of changes in land use resulting from the purchase and conversion of land and properties to facilitate the implementation of the Flood Risk Reduction Program. It includes the rationale and justification for including these benefits and the methodology used to calculate the economic benefits resulting from the purchases.

11.1 Rationale and Justification for Inclusion

This section provides the rationale and justification for inclusion of environmental land use benefits in the BCA. Environmental benefits are an important component of flood protection benefits. FEMA guidance contends specified types of environmental benefits may be realized when land is returned to open space uses. The purchase of land is a significant cost attributed to the Hancock County Flood Risk Reduction Program. However, new uses of the purchased properties provide economic benefits.

FEMA allows consideration of Environmental Benefits in the Evaluation of Acquisition Projects under its Hazard Mitigation Assistance (HMA) Programs.[55] Therefore, this project, in accordance with the FEMA guidance, includes environmental benefits in the benefit cost analysis (BCA). The objective is to determine the benefits and costs under The Program.

11.2 Estimation Methodology

This section describes the methodology used to estimate the environmental land use benefits from the flood mitigation project. The City of Findlay and Hancock County purchased approximately 150 properties damaged in prior flooding. In addition, the proposed project will include the purchase, use, and conversion of lands among various land use types. Each of these land acquisitions and conversions may provide environmental benefit beyond the avoidance of structure damage. Changes in land value are benefits of newly protected lands from the base case to The Program.

The estimation methodology relies upon environmental values of different land use classes that FEMA developed. The analysis couples these values with data Stantec provided the research

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[55] U.S. Department of Homeland Security, “Consideration of Environmental Benefits in the Evaluation of Acquisition Projects under the Hazard Mitigation Assistance (HMA) Programs,” FEMA Mitigation Policy – FP-108-024-01, June 18, 2013.

team on the acreage of the converted lands for four types of land use classifications. The four pre-flood and post-flood mitigation land classifications are:

- **Riparian Areas** - Similar to Green Open Space but the lot is located along a water feature such as the stream, creek, or river. These areas serve as a buffer to improve water quality entering the stream, as well as reducing erosion potential
- **Green Open Space** - Defined as land allowed to revert to a natural state or be converted into park-like settings
- **Agricultural Land** - The third type of post-mitigation land use assumes a portion of the acquired land remains agricultural and is either leased or sold back for agricultural purposes
- **Woods/Shrubs -** The projects converts some areas from woods and shrubs to other land use, while leaving some areas in that state. This analysis classifies this land in the forest category.

11.2.1 Environmental Land Values

Land values were required for the four types of land affected by this project. The source for land values in this study was FEMA. FEMA guidance provides values for two of the types of land analyzed in the project. The report states:

> "FEMA has identified and quantified environmental benefits for mitigation activities. Incorporating environmental benefits into the overall quantification of benefits for acquisition-related activities supports the Flood Insurance and Mitigation Administration's (FIMA's) mission of risk reduction, environmental compliance, and preservation of the natural and beneficial functions of the floodplain."[56]

In addition, FEMA has developed an excel-based "Environmental Benefits Calculator for Acquisition Projects," and developed a policy statement on the consideration of environmental benefits.[57] Finally, a more detailed report provides detailed environmental benefits for many land use types along with the methodology and data used to estimate the values.[58] Exhibit 11-1 provides these values in monetized benefits per acre per year.

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[56] FEMA, Hazard Mitigation Assistance Guidance, Hazard Mitigation Grant Program, Pre-Disaster Mitigation Program, and Flood Mitigation Assistance Program, Federal Emergency Management Agency Department of Homeland Security, Washington, DC, February 27, 2015.

[57] U.S. Department of Homeland Security, "Consideration of Environmental Benefits in the Evaluation of Acquisition Projects under the Hazard Mitigation Assistance (HMA) Programs," FEMA Mitigation Policy – FP-108-024-01, June 18, 2013.

[58] Final Sustainability Benefits Methodology Report, Federal Emergency Management Agency, Department of Homeland Security, Developed under Contract HSFEHQ-10-D-0806, Task Order HSFEHQ-11-J-1408, Washington, D.C., August 23, 2012

Exhibit 11-1: Monetized Environmental Benefits by Type of Land Use and Type of Benefit

Environmental Benefit	**Monetary Benefit per Acre per Year ($, 2011)**				
	Riparian Area	**Wetland**	**Green Space**	**Agricultural Lands**	**Forests**
Aesthetic Value	$ 580.87	$ 1,720.99	$ 1,623.00	$ 51.87	
Air Quality	$ 215.06		$ 204.47		$ 225.65
Biological Control	$ 163.68			$ 14.29	
Biodiversity		$ 113.12			
Climate Regulation	$ 204.21	$ 214.48	$ 13.19		$ 395.23
Erosion Control	$ 11,447.30		$ 64.88		$ 62.22
Flood Hazard Reduction	$ 4,007.01				
Hurricane Storm Hazard Risk Reduction		$ 3,982.70			
Water Supply		$ 218.57			
Fiber/Raw Materials		$ 560.72			
Food Provisioning	$ 609.44	$ 1,338.96			
Habitat	$ 835.41	$ 164.07			
Pollination			$ 290.08	$ 900.85	
Recreation/ Tourism	$ 15,178.07	$ 483.57	$ 5,365.26		
Storm Water Retention		$ 5,335.30	$ 293.02		
Nutrient Cycling		$ 527.65			
Water Filtration	$ 4,251.89	$ 731.21			
Soil Erosion				$ 127.14	
Carbon Storage				$ 51.48	
Soil Formation				$ 109.47	
Total	**$ 37,492.94**	**$ 15,391.34**	**$ 7,853.90**	**$ 1,255.10**	**$ 683.10**

The project team adjusted these values for use in this project. First, the analysis updated the data from 2011 values to 2018 values using the U.S. Bureau of Labor Statistics (BLS) Consumer Price Index (CPI) Inflation Calculator. [59] The CPI inflation calculator uses the for All Urban Consumers (CPI-U) U.S. city average series for all items, not seasonally adjusted. This data represents changes in the prices of all goods and services purchased for consumption by urban households. The analysis used the CPI change from February 2011 to February 2018. Next, the analysis eliminated the benefits of Erosion Control and Flood Hazard Reduction from the post-project land use categories Riparian Areas and Green Space. The project team did this to eliminate double counting, as the analysis already accounts the benefits of these items in

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[59] U.S. Bureau of Labor Statistics, https://www.bls.gov/data/inflation_calculator.htm

categories such as structural benefits. The project team also eliminated the Recreation/Tourism benefit for the post-project land use categories Riparian Areas and Green Space, as these rural former farmland areas do not provide these types of benefits. The exception is the downtown Riparian Areas, as the project is converting these to park type lands with walkways, benches, and plantings. In addition, the analysis eliminated the wetlands land use classification as none of the lands the project affected fit this land use. Exhibit 11-2 provides the revised monetized environmental benefits by type of land use and type of benefit

Exhibit 11-2: Revised Monetized Environmental Benefits

	Monetary Benefit per Acre per Year ($, 2018)				
Environmental Benefit	**Downtown Riparian Area**	**Riparian Area**	**Green Space**	**Agricultural Lands**	**Forests**
Aesthetic Value	$ 656.38	$ 656.38	$ 1,833.99	$ 58.61	
Air Quality	$ 243.02	$ 243.02	$ 231.05		$ 254.98
Biological Control	$ 184.96	$ 184.96		$ 16.15	
Biodiversity					
Climate Regulation	$ 230.76	$ 230.76	$ 14.90		$ 446.61
Erosion Control					$ 70.31
Flood Hazard Reduction					
Hurricane Storm Hazard Risk Reduction					
Water Supply					
Fiber/Raw Materials					
Food Provisioning	$ 688.67	$ 688.67			
Habitat	$ 944.01	$ 944.01			
Pollination			$ 327.79	$ 1,017.96	
Recreation/ Tourism	$ 17,151.22				
Storm Water Retention					
Nutrient Cycling					
Water Filtration	$ 4,804.64	$ 4,804.64			
Soil Erosion				$ 143.67	
Carbon Storage				$ 58.17	
Soil Formation				$ 123.70	
Total	**$ 24,903.65**	**$ 7,752.43**	**$ 2,407.74**	**$ 1,418.26**	**$ 771.90**

11.2.2 Land Acreages

Stantec provided aerial photos containing the approximate acreage for each type of land use area both before and after The Program. Exhibit 11-3 (Blanchard River Hydraulic Improvements), Exhibit 11-4 (Eagle Creek Dry Storage), and Exhibit 11-5 (Potato Run & Blanchard River Dry Storage) provide these photographic images depicting the changes in land uses and associated acreages.

Exhibit 11-3: Locations of Pre-Project Land Uses and Acreages for the Blanchard River Hydraulic Improvements

Exhibit 11-3: Locations of Post-Project Land Uses and Acreages for the Blanchard River Hydraulic Improvements

Exhibit 11-4: Locations of Pre-Project Land Uses and Acreages for the Eagle Creek Dry Storage

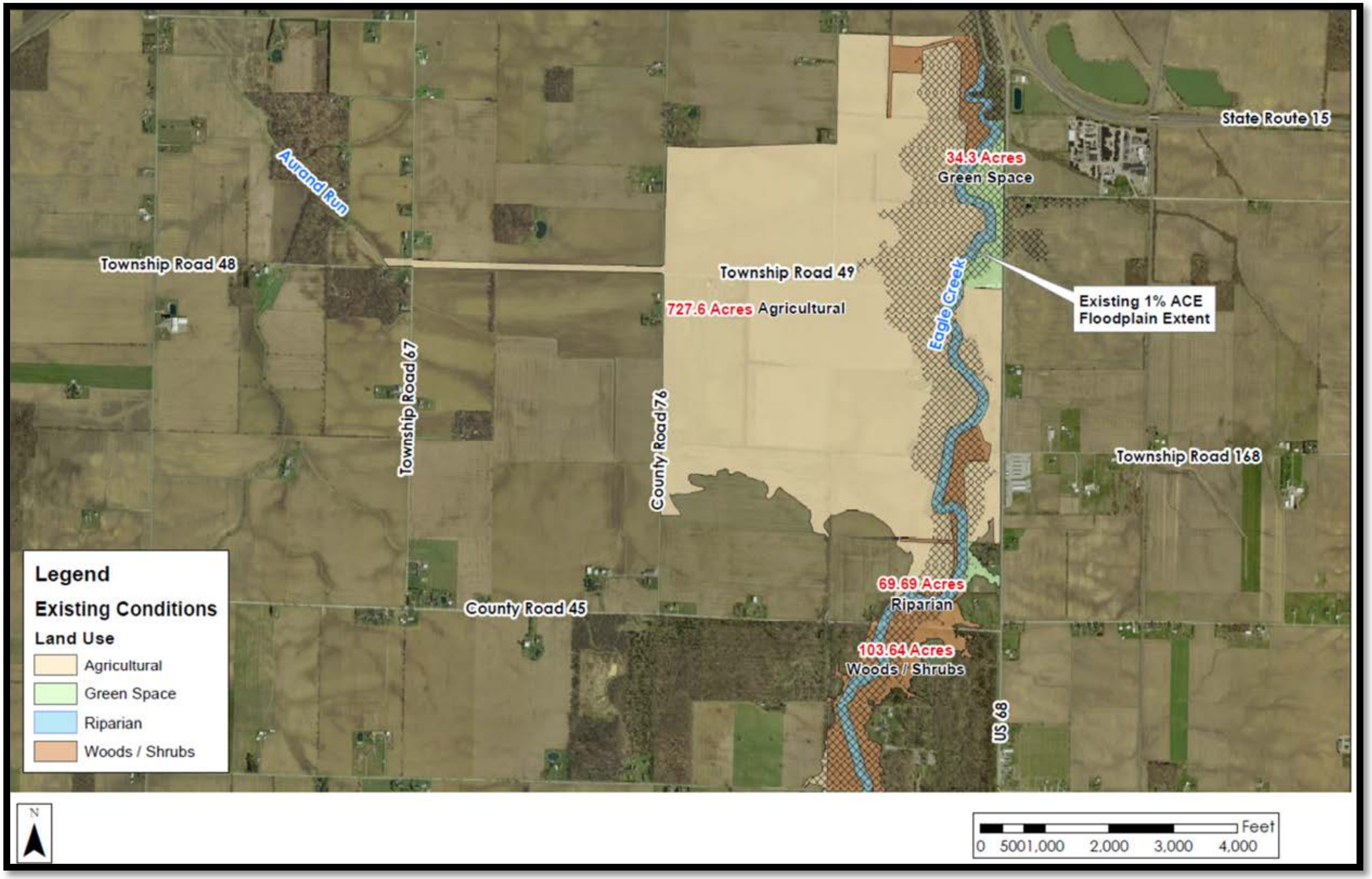


Exhibit 11-4: Locations of Post-Project Land Uses and Acreages for the Eagle Creek Dry Storage

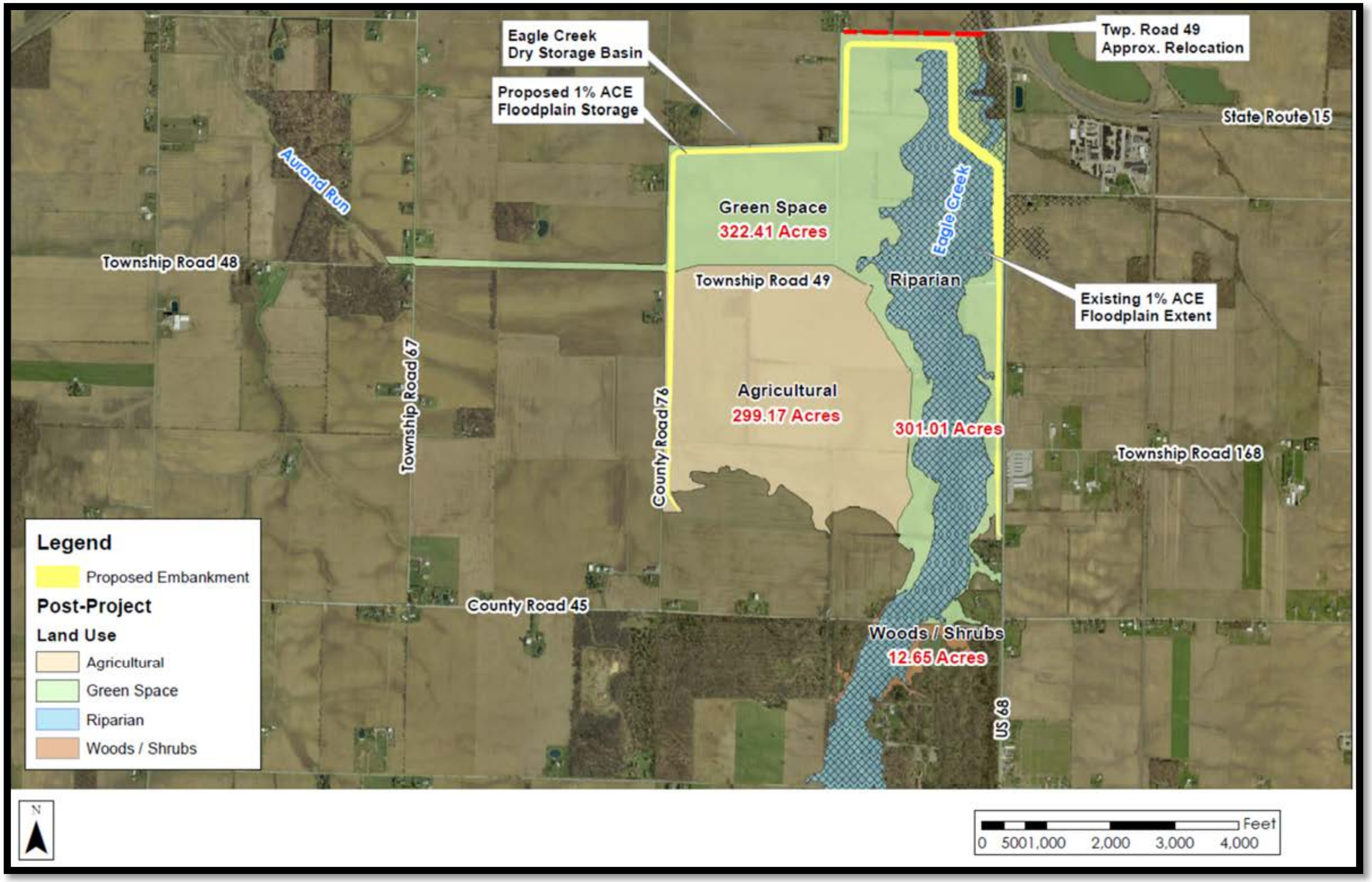


Exhibit 11-5: Locations of Pre-Project Land Uses and Acreages for the Potato Run and Blanchard River Storage

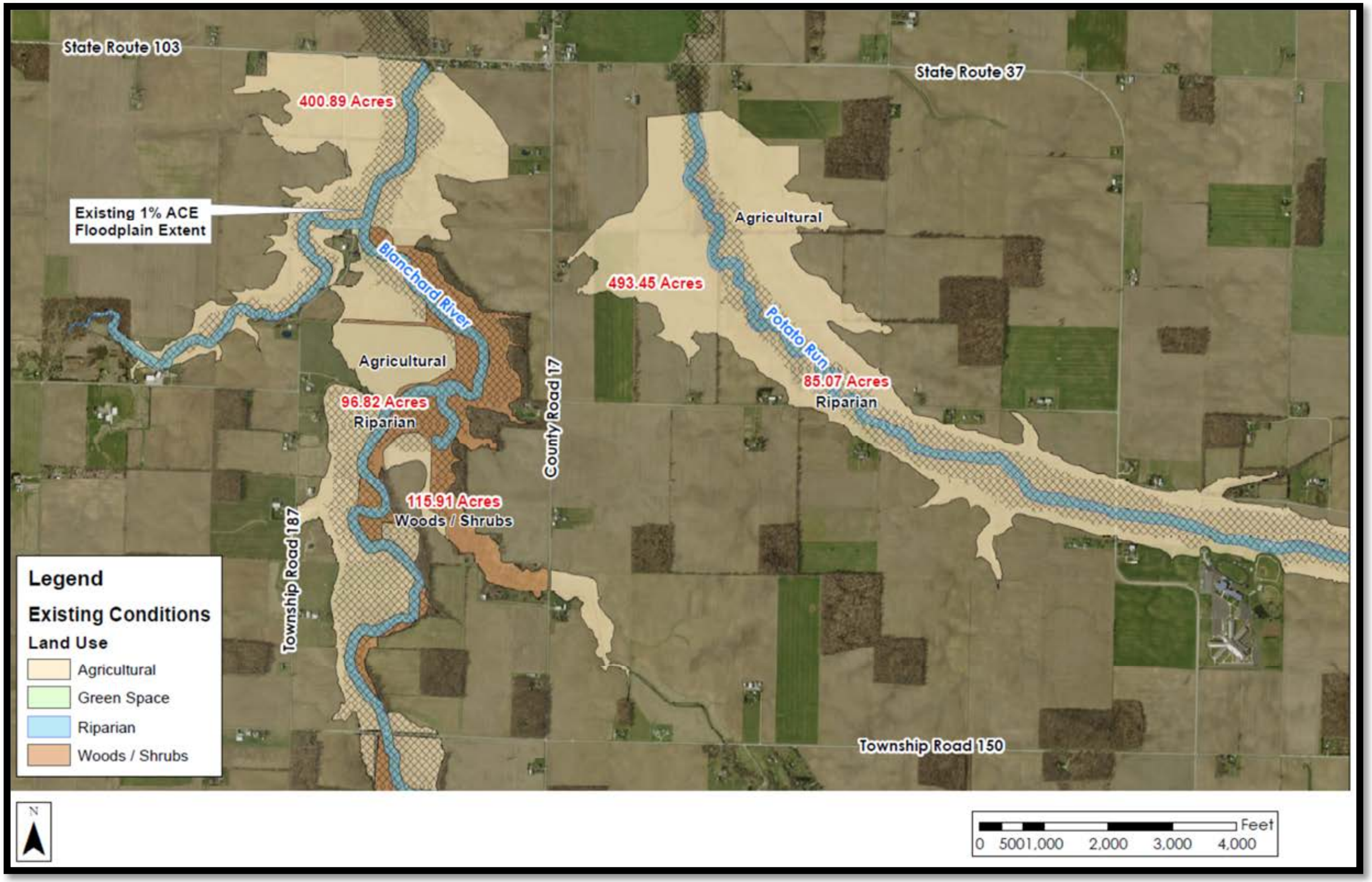
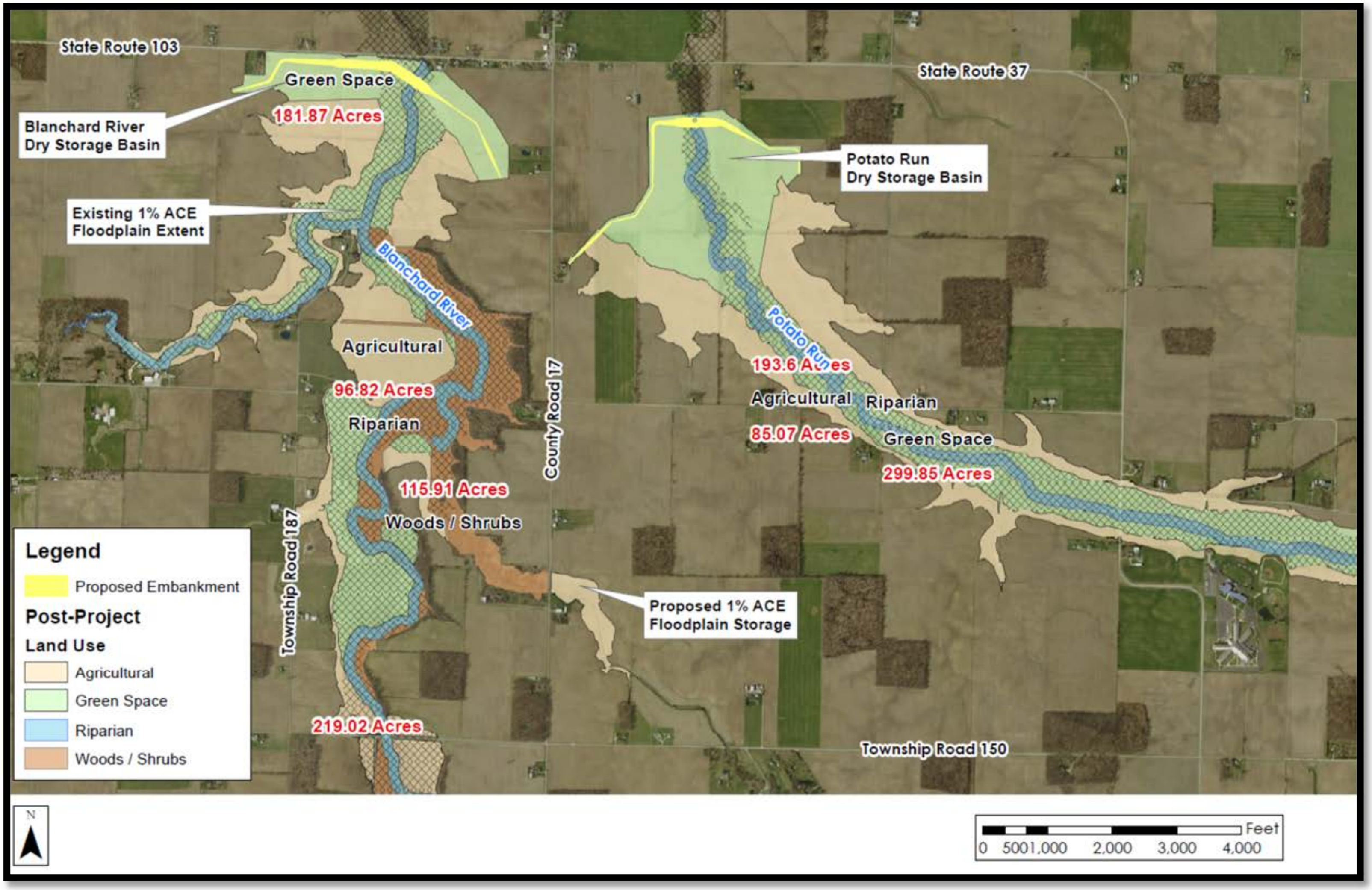


Exhibit 11-5: Locations of Post-Project Land Uses and Acreages for the Potato Run and Blanchard River Storage



11.3 Results

Exhibit 11-6 calculates the environmental benefit value for land use changes. The research team used the property acreages and classifications from the photographic images. The first part of the exhibit provides the existing acres by land use and area, while the second provides the after project acres by land use and area. The third section of the exhibit summaries the annual environmental benefits per acre by land use and area. The forth section calculates the environmental benefits of the current land uses by multiplying the existing acres by the benefits per acre. The fifth section calculates the environmental benefits after the project by multiplying the acres by land use after the project by the benefits per acre. The sixth and final section, subtracts the existing condition benefits from the post program benefits to calculate the increase in environmental benefits, which the methodology estimates at $2,805,050 per year.

Exhibit 11-6: Annual Environmental Benefit of Land Use Changes

Land Use	Hydraulic Improvements	Eagle Creek	Blanchard River	Potato Run	Total
Existing Conditions (Acres)					
Agriculture	-	727.6	400.9	493.4	1,621.9
Green Space	6.2	34.3	-	-	40.5
Riparian	10.4	69.7	96.8	85.1	262.0
Woods / Shrubs	18.4	103.6	115.9	-	237.9
Total	34.9	935.2	613.6	578.5	2,162.3
The Program (Acres)					
Agriculture	-	299.2	219.0	193.6	711.8
Green Space	2.8	322.4	181.9	299.9	806.9
Riparian	32.1	301.0	96.8	85.1	515.0
Woods / Shrubs	-	12.6	115.9	-	128.6
Total	34.9	935.2	613.6	578.5	2,162.3
Benefits (Per Acre)					
Agriculture	$ 1,418.26	$ 1,418.26	$ 1,418.26	$ 1,418.26	
Green Space	$ 2,407.74	$ 2,407.74	$ 2,407.74	$ 2,407.74	
Riparian	$ 24,903.65	$ 7,752.43	$ 7,752.43	$ 7,752.43	
Woods / Shrubs	$ 771.90	$ 771.90	$ 771.90	$ 771.90	
Existing Conditions (Benefits)					
Agriculture	$ -	$ 1,031,923	$ 568,567	$ 699,840	$ 2,300,330
Green Space	$ 14,848	$ 82,595	$ -	$ -	$ 97,443
Riparian	$ 258,011	$ 540,301	$ 750,617	$ 659,524	$ 2,208,453
Woods / Shrubs	$ 14,195	$ 79,999	$ 89,473	$ -	$ 183,668
Total	$ 287,055	$ 1,734,819	$ 1,408,657	$ 1,359,364	$ 4,789,895
The Program (Benefits)					
Agriculture	$ -	$ 424,297	$ 310,627	$ 274,569	$ 1,009,494
Green Space	$ 6,765	$ 776,271	$ 437,903	$ 721,968	$ 1,942,906
Riparian	$ 799,607	$ 2,333,559	$ 750,617	$ 659,524	$ 4,543,306
Woods / Shrubs	$ -	$ 9,765	$ 89,473	$ -	$ 99,237
Total	$ 806,371	$ 3,543,892	$ 1,588,620	$ 1,656,061	$ 7,594,944
Change in Environmental Benefits					
Agriculture	$ -	$ (607,626)	$ (257,940)	$ (425,271)	$ (1,290,836)
Green Space	$ (8,084)	$ 693,676	$ 437,903	$ 721,968	$ 1,845,463
Riparian	$ 541,595	$ 1,793,258	$ -	$ -	$ 2,334,853
Woods / Shrubs	$ (14,195)	$ (70,235)	$ -	$ -	$ (84,430)
Total	$ 519,316	$ 1,809,074	$ 179,963	$ 296,697	$ 2,805,050

Chapter 12 Benefit Cost Analysis Results

This section summarizes and compares the data on benefits and costs developed in the previous sections of this report. The section begins with an overview of Conservancy Court Law, summarizes costs, summarizes benefits, compares costs to benefits, and then concludes with the presentation of benefit-cost ratios.

For the Conservancy Court to approve a reappraisal of benefits, it must determine that the benefits exceed the cost. In Muskingum Watershed Conservancy District vs. Clow, 57 Ohio App. 132 (Fifth District 1937) the syllabus of the court discussed section 6828-33 of the General Code (now R.C. **§**6101.34) and stated that it was essential "that it be determined as a matter of fact that the estimated cost of the improvement is less than the benefit appraised." The Court also noted that the term "cost," as used in this section means the cost to the District and does not include contribution by the Federal Government, or by the State of Ohio.

The primary purpose of this report is to evaluate the benefits and costs of the Hancock County Flood Risk Reduction Program, including the proposed activities in the Program Plan. From a legal perspective, it is important to consider the benefits and costs of the entire program from its inception. The timing of the construction activities and costs, maintenance, and the period where partial and full benefits begin to accrue for the community determine the present value of benefits and costs. The analysis assumes the stream of project costs and benefits continues for 50 years after the completion of all phases of the project.

Exhibit 12-1 provides a summary of costs and benefits. The net present value of costs of The Program with maintenance equals **$164.98 million**. Appendix A provides the anticipated annual program costs by component and year, both undiscounted and discounted. The net present value of benefits of The Program with maintenance equals **$484.3 million**. Appendix A also includes benefits by component and year, both undiscounted and discounted.

Exhibit 12-1: Costs of the Hancock County Flood Risk Reduction Program (2018$, Millions)

	Benefits	Costs
The Program	$484.3	$ 164.98

Exhibit 12-2 summarizes the individual benefits described in the previous chapters and provides the present values of each of the individual benefits over the expected 50-year program analysis period. Benefits from the reduced flooding of structures constitute the largest share of benefits, followed by environmental benefits. Overall, the project achieves a Benefit-Cost Ratio of 2.94.

Exhibit 12-2: Present Value Benefits and Costs for The Program (2018$, Thousands)

The Program			
Category	**Costs (Net Present Value)**	**Benefits (Net Present Value)**	**Benefit/ Cost Ratio**
Project Construction	$ 164,981		
Residential Structures		$ 211,234	
Business Structures		$ 81,699	
Vehicles		$ 9,896	
Transport		$ 9,392	
Emergency Response		$ 7,470	
NFIP Admin.		$ 18,223	
Business Loss		$ 3,116	
Business Cleanup		$ 18,876	
Business Emergency Prep		$ 3,576	
Agriculture		$ 574	
Environment		$ 120,286	
Total	$ 164,981	$ 484,341	2.94

Exhibit 12-3 summarizes the individual benefits described in graphical form. Benefits from the reduced flooding of residential structures constitute the largest share of benefits, followed by environmental benefits and reduced flooding of business and government structures.

Exhibit 12-3: Present Value Benefits for The Program (2018$, Thousands)

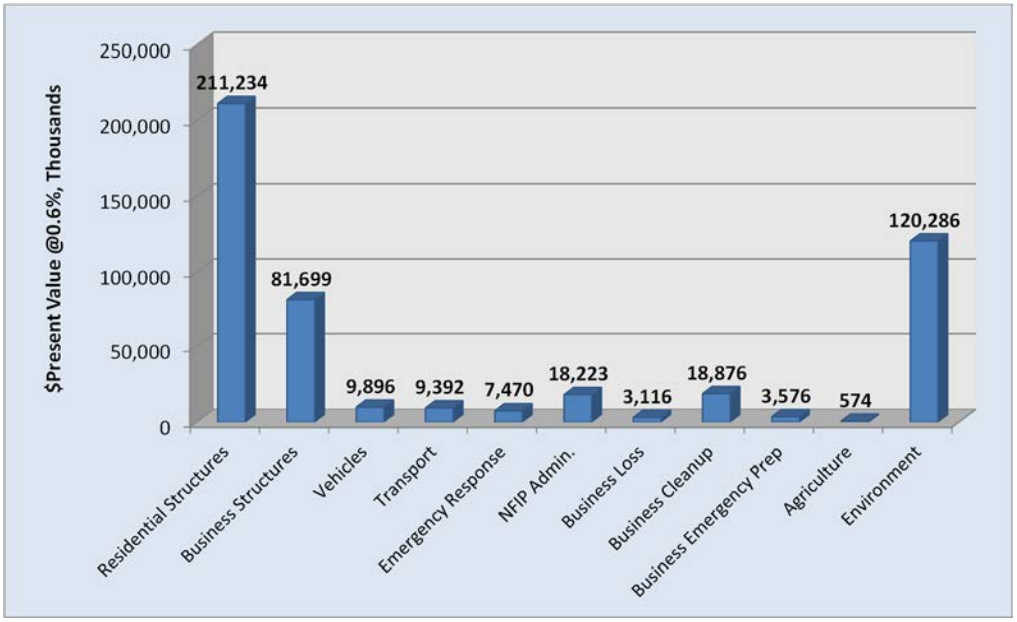
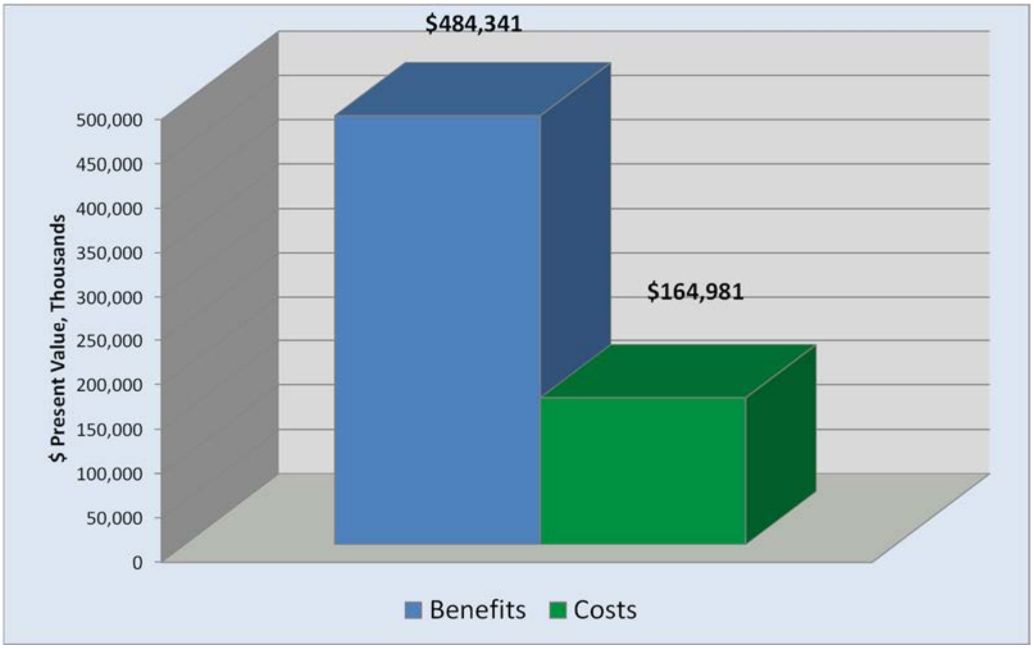


Exhibit 12-4 compares the benefits and costs of The Program graphically for a side-by-side comparison. The exhibit shows that the estimated benefits of the Hancock County Flood Risk Reduction Program are larger than the opinion of probable cost by a large margin.

Exhibit 12-4: Summary of Hancock County Flood Risk Reduction Program (2018$, Thousands)



Economists typically compare the present values of benefits and costs in two ways. One is to calculate the difference between the benefits and the costs. Economists referred to this as the net present value (NPV). If this value is larger than zero, benefits exceed costs and the project is economically justified. The second method is to calculate the ratio of benefits to costs. In this case, if the benefit-cost ratio (B/C Ratio) exceeds one, the project is economically justified.[60] Exhibit 12-5 presents the results of the benefit cost analysis, in terms of both net present value and benefit-cost ratio.

12-5: Summary of Results of the Benefit Cost Analysis, NPV and B/C Ratio

	Benefits	Costs	Net Benefits	Benefit/ Cost Ratio
The Program	$ 484,341,077	$ 164,981,328	$ 319,359,749	2.94

This Benefit Cost Analysis of the Hancock County Flood Risk Reduction Program demonstrates that the recommended Flood Risk Reduction Program is cost effective. The Net Present Value

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[60] These two methods are mathematically equivalent. Consider the following illustration:

A > B is equivalent to A – B > 0 (subtract B from both sides) and A/B > 1 (divide B from both sides).

of $319.4 million substantially exceeds the cost, indicating that it is an efficient infrastructure investment. In addition, the Benefit Cost Ratios of 2.94 reveals a substantial benefit margin over costs. This indicates that for each dollar of investment in The Program, the communities will receive $2.94 in estimated benefits.

Enhancements and Quality Assurance and Control

The Benefit-Cost Ratio increased from 1.6 in 2017 to 2.9 in the current study, due the many modifications made to methods and procedures which are discussed for each benefit category below. The benefit-cost analysis (BCA) presented in this report represents an update and refinement of the previous BCA published March 2017. The project team expended a substantial effort to update and refine all of the estimates in this report, as well as conduct a complete quality assurance/quality control (QA/QC) analysis of each of the components of the BCA. The following paragraphs highlight some of the major data improvements, changes to the methodology, levels of costs and benefits, and QA/QC efforts that resulted.

On the cost side, the project team incorporated new cost estimates and a revised project schedule. This included a revised time schedule that affected the level of both benefits and costs. In addition, a 50-year benefit period specific to each phase of the project now follows each of the five main phases of the project (hydraulic improvements, railroad bridge modifications, Eagle Creek storage basin, Potato Run storage basin, and Blanchard River storage basin). This change affects the present value of both benefits and costs, but increases benefits more than costs, as they are larger in the out years of the project.

In addition, the analysis uses an updated discount rate.[61] The White House Office of Management and Budget publishes an annual update of "A forecast of real interest rates from which the inflation premium has been removed and based on the economic assumptions from the 2018 Budget… These real rates are to be used for discounting constant-dollar flows, as is often required in cost-effectiveness analysis." This study uses the 30-Year rate of 0.6 percent, which is down from the previous rate of 0.7 percent. Note that the circular states "Programs with durations longer than 30 years may use the 30-year interest rate." This updated discount rate increases benefits and the BCA ratio as future benefits have relatively higher value.

Structure benefits have also undergone changes. The project team has used new aerial laser LIDAR imaging to improve the accuracy of structure elevations. The project team also revised the water surface profiles (WSP) using the last National Oceanic and Atmospheric Administration (NOAA) data. The team also reduced first floor elevations by a half foot relative to the ground elevation to provide a more accurate reflection of actual conditions. In addition, the project team is now employing the recently released and improved U.S. Army Corps of Engineers (USACE) Hydraulic Engineering Center (HEC) Flood Damage Reduction Analysis (FDA)

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[61] OMB Circular No. A–94, Appendix C, Discount Rates for Cost-Effectiveness, Lease Purchase, and Related Analyses. Office of Management and Budget, Revised November 2017. Accessed at https://www.whitehouse.gov/wp-content/uploads/2017/1 l/Appendix-C.pdf.

software version 1.4.2. The overall effect of these changes is an increase in the benefits associated with reductions in structure damages. The project team conducted detailed QA/QC of the HEC-FDA model runs including processing the previous and current elevations and WSPs through both the current and previous versions of HEC-FDA. The team performed these runs with both current and previous assumptions on first floor elevations and structure inventories. Finally, the team compared results for high damage structures between the various runs. This process verified that the new model was functioning correctly and verified that changes in damages accurately reflected changes in input data and assumptions.

Estimates of damages to motor vehicles have also changed. For this update, the project team fully deployed an improved methodology that the Federal Emergency Management Agency (FEMA) uses in their HAZUS model. The previous USACE methodology valued vehicles using new car prices and assumed that vehicles were only located at residences with no vehicles located at non-residential structures. The enhanced methodology uses data from the Bureau of Economic Analysis on the value of vehicle stocks by vehicle type, Federal Highway Administration data on the number of vehicles by type, International Transportation Engineers (ITE) data on parking generation by type of vehicle and structure, and USACE data on depth-damage curves by vehicle type. The overall effect of these changes is an increase in the benefits associated with reductions in vehicle damages.

The methodologies for transportation, emergency response, NFIP administrative costs, and business losses are largely unchanged. Transportation benefits have increased slightly due to increase in IRS mileage rates, increases in local wage rates, changes in flood depths, and slightly longer benefit horizons. Emergency response benefits increased as the project team enhanced the methodology to update 2007 costs using a Consumer Price Index (CPI) inflator and slightly longer benefit horizons. The benefit of reduced NFIP administrative costs increased primarily due to slightly longer benefit horizons. While the methodology for the three business loss categories was largely unchanged, the estimates for business cleanup costs and business emergency preparation both increased due to QA/QC enhancements while business sales losses remained virtually unchanged.

Estimates or reductions in agricultural losses changed, albeit from a small base. This change resulted from updates in crop production and replanting costs, as well as incorporation of new U.S. Geological Survey (USGS) data on flood history by month, which expanded estimates of flood likelihood during the peak growing season.

Environmental benefits also expanded. This is the result of major improvements in the methodology. In the previous BCA, the project team was working from Federal Emergency Management Agency (FEMA) summary guidance on environmental benefits. However, for this update, the project team was able to work back to the detailed research that underpinned the FEMA summary guidance. Using this detailed source data, the team was able to update the benefit period and discount rate to make them more compatible with this study, incorporate better data on the environmental benefits of agricultural and forested lands, and include estimates of the recreational value of the riparian waterfront parks and trails.

Appendix A:

50 Year Calculation of the Benefits and Costs of the Hancock County Flood Risk Reduction Program

A-1: Hancock County Flood Risk Reduction Program Costs, Present Value ($2018, Thousands)

	Hydraulic Improvements Phases I and 2		Storage Basins				Program	
Year	Construct	Maint.	Construct: Eagle Creek	Construct: Potato Run	Construct: Blanchard River	Maint.	Total Costs in 2018 Dollars	Net Present Value
2018	6,399						6,399	6,399
2019	6,399						6,399	6,360
2020	6,254	17.7	10,896				17,167	16,963
2021	6,254	17.7	10,896				17,167	16,862
2022		17.7	10,896	3,422			14,335	13,996
2023		17.7	10,896	3,422	6,393		20,728	20,117
2024		17.7	10,896	3,422	6,393		20,728	19,997
2025		17.7	10,896	3,422	6,393		20,728	19,878
2026		17.7		3,422	6,393	75	9,907	9,444
2027		17.7		3,422	6,393	75	9,907	9,388
2028		17.7		3,422	6,393	75	9,907	9,332
2029		17.7		3,422	6,393	75	9,907	9,276
2030		17.7				155	173	161
2031		17.7				155	173	160
2032		17.7				155	173	159
2033		17.7				155	173	158
2034		17.7				155	173	157
2035		17.7				155	173	156
2036		17.7				155	173	155
2037		17.7				155	173	154
2038		17.7				155	173	153
2039		17.7				155	173	152
2040		17.7				155	173	151
2041		17.7				155	173	151
2042		17.7				155	173	150
2043		17.7				155	173	149
2044		17.7				155	173	148
2045		17.7				155	173	147
2046		17.7				155	173	146
2047		17.7				155	173	145
2048		17.7				155	173	144
2049		17.7				155	173	143
2050		17.7				155	173	143
2051		17.7				155	173	142
2052		17.7				155	173	141
2053		17.7				155	173	140
2054		17.7				155	173	139
2055		17.7				155	173	138
2056		17.7				155	173	138
2057		17.7				155	173	137
2058		17.7				155	173	136
2059		17.7				155	173	135
2060		17.7				155	173	134
2061		17.7				155	173	134
2062		17.7				155	173	133
2063		17.7				155	173	132
2064		17.7				155	173	131
2065		17.7				155	173	130
2066		17.7				155	173	130
2067		17.7				155	173	129
2068		17.7				155	173	128
2069		17.7				155	173	127
2070		17.7				155	173	127
2071		17.7				155	173	126
2072		17.7				155	173	125
2073		17.7				155	173	124
2074		17.7				155	173	124
2075		17.7				155	173	123
2076		17.7				155	173	122
2077		17.7				155	173	121
2078		17.7				155	173	121
2079		17.7				155	173	120
Total	**25,304**	**1,062**	**65,375**	**27,375**	**44,750**	**8,050**	**171,916**	**164,981**

A-2: Hancock County Flood Risk Reduction Program Anticipated Benefits, ($2018, Thousands)

Year	Residential Structures	Business Structures	Vehicles	Transport	Emergency Response	NFIP Admin.	Business Loss	Business Cleanup	Business Emergency Prep	Agriculture	Environment	Total
2017	492.6	190.5	23.1	21.9	17.4	42.5	7.3	44.0	8.3	1.3	280.5	1,129.5
2018	1,231.5	476.3	57.7	54.8	43.6	106.2	18.2	110.0	20.8	3.3	701.3	2,823.7
2019	1,231.5	476.3	57.7	54.8	43.6	106.2	18.2	110.0	20.8	3.3	701.3	2,823.7
2020	1,625.6	628.7	76.2	72.3	57.5	140.2	24.0	145.3	27.5	4.4	925.7	3,727.3
2021	1,625.6	628.7	76.2	72.3	57.5	140.2	24.0	145.3	27.5	4.4	925.7	3,727.3
2022	1,625.6	628.7	76.2	72.3	57.5	140.2	24.0	145.3	27.5	4.4	925.7	3,727.3
2023	1,625.6	628.7	76.2	72.3	57.5	140.2	24.0	145.3	27.5	4.4	925.7	3,727.3
2024	3,300.4	1,276.5	154.6	146.7	116.7	284.7	48.7	294.9	55.9	9.0	1,879.4	7,567.5
2025	3,300.4	1,276.5	154.6	146.7	116.7	284.7	48.7	294.9	55.9	9.0	1,879.4	7,567.5
2026	3,300.4	1,276.5	154.6	146.7	116.7	284.7	48.7	294.9	55.9	9.0	1,879.4	7,567.5
2027	3,300.4	1,276.5	154.6	146.7	116.7	284.7	48.7	294.9	55.9	9.0	1,879.4	7,567.5
2028	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2029	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2030	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2031	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2032	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2033	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2034	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2035	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2036	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2037	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2038	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2039	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2040	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2041	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2042	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2043	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2044	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2045	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2046	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2047	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2048	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2049	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2050	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2051	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2052	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2053	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2054	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2055	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2056	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2057	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2058	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2059	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2060	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2061	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2062	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2063	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2064	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2065	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2066	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2067	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2068	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2069	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2070	4,926.0	1,905.2	230.8	219.0	174.2	425.0	72.7	440.2	83.4	13.4	2,805.1	11,294.8
2071	3,300.4	1,276.5	154.6	146.7	116.7	284.7	48.7	294.9	55.9	9.0	1,879.4	7,567.5
2072	3,300.4	1,276.5	154.6	146.7	116.7	284.7	48.7	294.9	55.9	9.0	1,879.4	7,567.5
2073	3,300.4	1,276.5	154.6	146.7	116.7	284.7	48.7	294.9	55.9	9.0	1,879.4	7,567.5
2074	3,300.4	1,276.5	154.6	146.7	116.7	284.7	48.7	294.9	55.9	9.0	1,879.4	7,567.5
2075	1,625.6	628.7	76.2	72.3	57.5	140.2	24.0	145.3	27.5	4.4	925.7	3,727.3
2076	1,625.6	628.7	76.2	72.3	57.5	140.2	24.0	145.3	27.5	4.4	925.7	3,727.3
2077	1,625.6	628.7	76.2	72.3	57.5	140.2	24.0	145.3	27.5	4.4	925.7	3,727.3
2078	1,625.6	628.7	76.2	72.3	57.5	140.2	24.0	145.3	27.5	4.4	925.7	3,727.3
	254,179.5	**98,308.8**	**11,907.7**	**11,301.8**	**8,989.1**	**21,927.5**	**3,749.5**	**22,714.0**	**4,302.8**	**690.2**	**144,740.6**	**582,811.5**

A-3: Hancock County Flood Risk Reduction Program Anticipated Benefits Present Value ($2018, Thousands)

Year	ResidentialStructures	Business Structures	Vehicles	Transport	Emergency Response	NFIP Admin.	Business Loss	Business Cleanup	Business Emergency Prep	Agriculture	Environ-mental	Total
2017	492.6	190.5	23.1	21.9	17.4	42.5	7.3	44.0	8.3	1.3	280.5	1,129.5
2018	1,224.1	473.5	57.3	54.4	43.3	105.6	18.1	109.4	20.7	3.3	697.1	2,806.9
2019	1,216.8	470.6	57.0	54.1	43.0	105.0	18.0	108.7	20.6	3.3	692.9	2,790.1
2020	1,596.7	617.5	74.8	71.0	56.5	137.7	23.6	142.7	27.0	4.3	909.2	3,661.0
2021	1,587.1	613.9	74.4	70.6	56.1	136.9	23.4	141.8	26.9	4.3	903.8	3,639.2
2022	1,577.7	610.2	73.9	70.1	55.8	136.1	23.3	141.0	26.7	4.3	898.4	3,617.4
2023	1,568.3	606.6	73.5	69.7	55.5	135.3	23.1	140.1	26.5	4.3	893.0	3,595.9
2024	3,165.0	1,224.1	148.3	140.7	111.9	273.0	46.7	282.8	53.6	8.6	1,802.3	7,257.2
2025	3,146.2	1,216.8	147.4	139.9	111.3	271.4	46.4	281.1	53.3	8.5	1,791.6	7,213.9
2026	3,127.4	1,209.6	146.5	139.1	110.6	269.8	46.1	279.5	52.9	8.5	1,780.9	7,170.9
2027	3,108.8	1,202.4	145.6	138.2	109.9	268.2	45.9	277.8	52.6	8.4	1,770.3	7,128.1
2028	4,612.3	1,783.9	216.1	205.1	163.1	397.9	68.0	412.2	78.1	12.5	2,626.4	10,575.5
2029	4,584.7	1,773.2	214.8	203.9	162.1	395.5	67.6	409.7	77.6	12.4	2,610.7	10,512.4
2030	4,557.4	1,762.7	213.5	202.6	161.2	393.2	67.2	407.3	77.1	12.4	2,595.2	10,449.7
2031	4,530.2	1,752.1	212.2	201.4	160.2	390.8	66.8	404.8	76.7	12.3	2,579.7	10,387.4
2032	4,503.2	1,741.7	211.0	200.2	159.3	388.5	66.4	402.4	76.2	12.2	2,564.3	10,325.4
2033	4,476.3	1,731.3	209.7	199.0	158.3	386.2	66.0	400.0	75.8	12.2	2,549.0	10,263.9
2034	4,449.6	1,721.0	208.5	197.8	157.4	383.9	65.6	397.6	75.3	12.1	2,533.8	10,202.6
2035	4,423.1	1,710.7	207.2	196.7	156.4	381.6	65.2	395.3	74.9	12.0	2,518.7	10,141.8
2036	4,396.7	1,700.5	206.0	195.5	155.5	379.3	64.9	392.9	74.4	11.9	2,503.7	10,081.3
2037	4,370.5	1,690.4	204.7	194.3	154.6	377.0	64.5	390.6	74.0	11.9	2,488.7	10,021.2
2038	4,344.4	1,680.3	203.5	193.2	153.6	374.8	64.1	388.2	73.5	11.8	2,473.9	9,961.4
2039	4,318.5	1,670.3	202.3	192.0	152.7	372.5	63.7	385.9	73.1	11.7	2,459.2	9,902.0
2040	4,292.8	1,660.3	201.1	190.9	151.8	370.3	63.3	383.6	72.7	11.7	2,444.5	9,842.9
2041	4,267.2	1,650.4	199.9	189.7	150.9	368.1	62.9	381.3	72.2	11.6	2,429.9	9,784.2
2042	4,241.7	1,640.6	198.7	188.6	150.0	365.9	62.6	379.0	71.8	11.5	2,415.4	9,725.9
2043	4,216.4	1,630.8	197.5	187.5	149.1	363.7	62.2	376.8	71.4	11.4	2,401.0	9,667.9
2044	4,191.3	1,621.1	196.4	186.4	148.2	361.6	61.8	374.5	71.0	11.4	2,386.7	9,610.2
2045	4,166.3	1,611.4	195.2	185.2	147.3	359.4	61.5	372.3	70.5	11.3	2,372.5	9,552.9
2046	4,141.4	1,601.8	194.0	184.1	146.5	357.3	61.1	370.1	70.1	11.2	2,358.3	9,495.9
2047	4,116.7	1,592.2	192.9	183.0	145.6	355.1	60.7	367.9	69.7	11.2	2,344.2	9,439.3
2048	4,092.2	1,582.7	191.7	182.0	144.7	353.0	60.4	365.7	69.3	11.1	2,330.3	9,383.0
2049	4,067.8	1,573.3	190.6	180.9	143.9	350.9	60.0	363.5	68.9	11.0	2,316.4	9,327.0
2050	4,043.5	1,563.9	189.4	179.8	143.0	348.8	59.6	361.3	68.4	11.0	2,302.5	9,271.4
2051	4,019.4	1,554.6	188.3	178.7	142.1	346.7	59.3	359.2	68.0	10.9	2,288.8	9,216.1
2052	3,995.4	1,545.3	187.2	177.7	141.3	344.7	58.9	357.0	67.6	10.8	2,275.2	9,161.1
2053	3,971.6	1,536.1	186.1	176.6	140.5	342.6	58.6	354.9	67.2	10.8	2,261.6	9,106.5
2054	3,947.9	1,526.9	184.9	175.5	139.6	340.6	58.2	352.8	66.8	10.7	2,248.1	9,052.2
2055	3,924.3	1,517.8	183.8	174.5	138.8	338.5	57.9	350.7	66.4	10.7	2,234.7	8,998.2
2056	3,900.9	1,508.8	182.8	173.5	138.0	336.5	57.5	348.6	66.0	10.6	2,221.4	8,944.5
2057	3,877.7	1,499.8	181.7	172.4	137.1	334.5	57.2	346.5	65.6	10.5	2,208.1	8,891.2
2058	3,854.5	1,490.8	180.6	171.4	136.3	332.5	56.9	344.4	65.3	10.5	2,194.9	8,838.1
2059	3,831.6	1,481.9	179.5	170.4	135.5	330.5	56.5	342.4	64.9	10.4	2,181.9	8,785.4
2060	3,808.7	1,473.1	178.4	169.3	134.7	328.6	56.2	340.4	64.5	10.3	2,168.8	8,733.0
2061	3,786.0	1,464.3	177.4	168.3	133.9	326.6	55.8	338.3	64.1	10.3	2,155.9	8,681.0
2062	3,763.4	1,455.6	176.3	167.3	133.1	324.7	55.5	336.3	63.7	10.2	2,143.0	8,629.2
2063	3,741.0	1,446.9	175.3	166.3	132.3	322.7	55.2	334.3	63.3	10.2	2,130.3	8,577.7
2064	3,718.7	1,438.3	174.2	165.3	131.5	320.8	54.9	332.3	62.9	10.1	2,117.6	8,526.5
2065	3,696.5	1,429.7	173.2	164.4	130.7	318.9	54.5	330.3	62.6	10.0	2,104.9	8,475.7
2066	3,674.4	1,421.2	172.1	163.4	129.9	317.0	54.2	328.4	62.2	10.0	2,092.4	8,425.1
2067	3,652.5	1,412.7	171.1	162.4	129.2	315.1	53.9	326.4	61.8	9.9	2,079.9	8,374.9
2068	3,630.7	1,404.3	170.1	161.4	128.4	313.2	53.6	324.4	61.5	9.9	2,067.5	8,324.9
2069	3,609.1	1,395.9	169.1	160.5	127.6	311.3	53.2	322.5	61.1	9.8	2,055.2	8,275.3
2070	3,587.5	1,387.6	168.1	159.5	126.9	309.5	52.9	320.6	60.7	9.7	2,042.9	8,225.9
2071	2,389.3	924.1	111.9	106.2	84.5	206.1	35.2	213.5	40.4	6.5	1,360.6	5,478.5
2072	2,375.1	918.6	111.3	105.6	84.0	204.9	35.0	212.2	40.2	6.4	1,352.5	5,445.8
2073	2,360.9	913.1	110.6	105.0	83.5	203.7	34.8	211.0	40.0	6.4	1,344.4	5,413.4
2074	2,346.8	907.7	109.9	104.3	83.0	202.5	34.6	209.7	39.7	6.4	1,336.4	5,381.1
2075	1,149.0	444.4	53.8	51.1	40.6	99.1	16.9	102.7	19.5	3.1	654.3	2,634.6
2076	1,142.2	441.7	53.5	50.8	40.4	98.5	16.8	102.1	19.3	3.1	650.4	2,618.9
2077	1,135.3	439.1	53.2	50.5	40.2	97.9	16.7	101.5	19.2	3.1	646.5	2,603.2
2078	1,128.6	436.5	52.9	50.2	39.9	97.4	16.6	100.9	19.1	3.1	642.7	2,587.7
Total	**211,234.0**	**81,698.8**	**9,895.8**	**9,392.3**	**7,470.4**	**18,222.7**	**3,116.0**	**18,876.3**	**3,575.8**	**573.5**	**120,285.6**	**484,341.1**