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Principal Spillway Riser Tower and Reservoir at Bylin Dam – Walsh County, North Dakota

NORTH BRANCH FOREST RIVER DAM NO. 1 (BYLIN DAM)

Appendix D-1: Existing Conditions Assessment Report

Natural Resources Conservation Service

NORTH BRANCH FOREST RIVER DAM NO. 1 (BYLIN DAM)

APPENDIX D-1: EXISTING CONDITIONS ASSESSMENT REPORT

November 10, 2023

DRAFT

Walsh County Water Resource District

Houston Engineering, Inc.
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Phone # 701.237.5065

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am a duly Licensed Engineer under the laws of the State of North Dakota.

____
Zachary O. Herrmann, PE
PE-8405

____
Date

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EXECUTIVE SUMMARY

The purpose of this report is to document the data collected and analysis conducted for the existing condition of the North Branch Forest River Watershed Forest River Dam # 1, Bylin Dam. The data and analysis described in this report is being used to facilitate the completion of the overall Watershed Plan. Information on critical elevations, storage capacities, and surface areas for Bylin Dam are displayed in **Table D-1-1**.

Field survey data for the channel downstream of Bylin Dam, the dam embankment, spillways, and bathymetric survey data for the pool upstream of the dam was collected for this analysis. The survey data was used to determine the storage capacity of the dam, the topography of the embankment, and to develop accurate cross-sectional data for the North Branch Forest River channel downstream of the dam.

A site review and inspection of Bylin Dam was conducted by Houston Engineering Inc. (HEI) staff in September of 2020. The inspection showed that the principal spillway concrete inlet structure, conduit, and outlet structure had minor deficiencies and no immediate action to make repairs is recommended. The condition of the dam embankment and earthen auxiliary spillway were also determined to be adequate with only minor issues such as tree growth near the auxiliary spillway outlet and erosion that is occurring near the upstream portion of the auxiliary spillway.

A dam breach analysis was conducted, and a hazard classification was determined for Bylin Dam. The peak discharge criteria for the breach was determined based on guidance from *Technical Release 210-60: Earth Dams and Reservoirs* (NRCS, 2019). The peak discharge resulting from a dam breach was determined to be approximately 116,000 cubic feet per second. The breach was simulated through a hydraulic model and mapped to show at-risk structures and roads within the breach zone. After review of the results of the breach scenario, it was determined that Bylin Dam is best classified as a high hazard dam.

Hydrologic and hydraulic models of the of the North Branch Forest River Watershed were used to develop appropriate inflow hydrographs to the dam and to accurately route flows downstream of the dam. Spillway design hydrographs were developed based on criteria in *Technical Release 210-60: Earth Dams and Reservoirs* (NRCS, 2019). Principal spillway inflow hydrographs were developed for various rainfall and runoff scenarios. The probable maximum precipitation for the watershed was used to develop the freeboard and stability design hydrographs.

A geologic investigation was also conducted as part of this analysis. The investigation indicated that the current drain fill does not meet criteria for seepage control. The investigation also concluded that the slope stability associated with the embankment at Bylin Dam is adequate for the rapid drawdown and normal pool conditions but is not adequate for the flood surcharge condition as required in *Technical Release 210-60: Earth Dams and Reservoirs* (NRCS, 2019).

The adequacy of the principal and auxiliary spillways for Bylin Dam were determined by using the NRCS's SITES program. The principal spillway was determined to be inadequate based on criteria outlined in *Technical Release 210-60: Earth Dams and Reservoirs* (NRCS, 2019). Subsurface geologic data was used to determine the integrity of the auxiliary spillway for Bylin Dam. The auxiliary spillway was determined to be inadequate in terms of capacity and integrity when simulating the freeboard design hydrograph.

1 DAM SUMMARY DATA

***Table D-1-1**: Bylin Dam Summary Data*

General Data	
Year Designed	1959
Year Constructed	1964
Purpose	Flood Control and Recreation
Original Hazard Classification	Significant
Current Hazard Classification	High
Design Life	50 Years
Original Design Drainage Area	22.1 square miles
Revised Drainage Area (Direct)[1][2]	20.5 square miles
Dam Height	57.2 feet
Embankment Length	760 feet
Embankment Top Width	23 feet
Embankment Upstream Slope	3.5H:1V
Embankment Downstream Slope	2.5H:1V
Critical Elevations (NAVD88)[3]	
Principal Spillway Outlet Pool Invert (Approx.)	1461.8 feet
Principal Spillway Conduit Outlet Invert	1463.8 feet
Principal Spillway Orifice Inverts (First Stage Inlet)	1490.2 feet
Principal Spillway Riser Tower Crest (Second Stage Inlet)	1511.3 feet
Auxiliary Spillway Crest	1518.6 feet
Top of Dam	1523.8 feet
Storage Capacities[3]	
Principal Spillway Orifice Invert (First Stage Inlet)	524 acre-feet
Principal Spillway Riser Tower Crest (Second Stage Inlet)	2,790 acre-feet
Auxiliary Spillway Crest	4,223 acre-feet
Top of Dam	5,554 acre-feet
Pool Surface Areas	
Principal Spillway Orifice Inverts (First Stage Inlets) [3]	57 acres
Principal Spillway Riser Tower Crest (Second Stage Inlet)[1]	167 acres
Auxiliary Spillway Crest[1]	230 acres
Other Features	
Principal Spillway Orifice Sizes	1.5 feet by 2.5 feet orifice
Principal Spillway Conduit Size	2.5 feet diameter
Principal Spillway Conduit Length	304 feet (from as-builts)
Principal Spillway Riser Tower Crest Length	31 feet
Auxiliary Spillway Width	300 feet

[1] Revised using LiDAR data collected in 2008.
[2] Non-contributing drainage area excluded to account for hydrologically closed basins upstream of Bylin Dam

[3] Values based on survey data collected in 2020

2 FIELD SURVEY

Survey data obtained for this report was collected in the summer and fall of 2020. Survey data for the North Branch Forest River and other streams in the Forest River Watershed has been collected by HEI intermittently beginning in 2013. The data collected specifically for this report includes surveyed cross sections for the downstream channel, a topographic survey of the dam embankment and auxiliary spillway, a bathymetric survey in the reservoir upstream of the dam, and the collection of structure elevations throughout the breach zone downstream of Bylin Dam. Each of the survey processes is described in more detail in the following sub-sections.

2.1 DOWNSTREAM CHANNEL SURVEY

The channel survey conducted in the North Branch Forest River was completed in the spring of 2020. The extent of the survey spanned from the outlet of Bylin Dam to the confluence of the North Branch Forest River and the Middle Branch Forest River near the town of Fordville, ND. All downstream channel survey data is shown in **Figure D-1-1**. The survey consisted of river channel cross sections and river channel hydraulic structures along the North Branch Forest River.

2.1.1 METHODS

A spacing of 1,000 feet was used between surveyed channel cross sections. Data collected for the North Branch Forest River that also serves as Walsh County Drain No. 97 from North Dakota State Highway 32 to 57th Street NE included only the hydraulic structures and cross sections up and downstream of those structures. Cross sections along the entirety of Drain 97 were deemed unnecessary because of recent drain cleanouts that have occurred in Drain 97. The channel shape and grade line were assumed to be uniform and constant between surveyed hydraulic structures. Drain 97 is shown as the dashed black and blue line in **Figure D-1-1**.

Four permanent survey benchmarks were set for the downstream channel survey using GPS and MidStates Virtual Reference Station (VRS). The benchmarks used are shown in **Figure D-1-1.** The cross sections and profile of the downstream river channel were surveyed using real-time kinematic (RTK) global positioning system (GPS) equipment. Cross section data is supplemented with LiDAR collected in 2008 and 2009 (IWI, 2008-2009). The horizontal datum used throughout the downstream channel survey collect was NAD83 (Conus), GeoID12B, North Dakota State Planes, North. The vertical datum used was NAVD 1988.

2.2 BYLIN DAM TOPOGRAPHIC SURVEY

The topographic survey of Bylin Dam was conducted in the summer of 2020. Some of the elements of the dam that were surveyed include the dam centerline along 121st Ave NE, edge of gravel, spot points for the upstream dam face, and spot points for the downstream dam face. The principal spillway concrete riser structure was surveyed as well with data points collected for the second stage inlet elevation and orifice openings in the riser. The conduit invert elevation at the outlet of the structure into the North Branch Forest River was also collected. The auxiliary spillway was surveyed from the upstream side of the dam near the normal pool to downstream of the dam where the spillway enters in the North Branch Forest River channel. **Figure D-1-2** shows the topographic data collected at Bylin Dam. Maps provided in **Appendix C** (**Figure C-1** through **C-3**) show the topographic survey data collected at Bylin Dam. Supporting information on topographic survey data can be made available upon request from the North Dakota National Resources Conservation Service (NRCS).

In addition to topographic survey data collected at Bylin Dam, elevations along the centerline of the former dam known as Dougherty Dam were collected. Dougherty Dam is a dam that was built by the Civilian Conservation Corps in 1935 and is located approximately 1.2 miles west of the Bylin Dam embankment. The centerline of Dougherty Dam is shown in **Figure D-1-2**. Collecting additional survey data other than the dam centerline was unnecessary because the reservoir upstream of Bylin Dam rises above Dougherty Dam during a 10-year rainfall event. Refer to Section 5.1.3 for additional details on the hydrology and hydraulics associated with Dougherty Dam.

2.2.1 METHODS

A maximum spacing of 50 feet was used to collect cross sections across the dam. The maximum distance between profile shots for the top of dam and emergency spillway centerline was also 50 linear feet.

Three permanent survey benchmark control points were set for the topographic survey using GPS and MidStates VRS. A level circuit was run through all control points with a level to verify vertical accuracy and continuity. The control points used for the topographic survey of the dam are shown in **Figure D-1-2**. A robotic total station was used to survey the profile of the dam, profile of the spillway, and elements of the principal spillway structure. RTK GPS equipment was used to survey cross sections of the dam. The horizontal datum used throughout the topographic survey collect was NAD83 (Conus), GeoID12B, North Dakota State Planes, North. The vertical datum used was NAVD 1988.

2.2.2 CHANGES IN ELEVATION

The topographic survey was compared to key elevations shown on the as-built drawings presented in **Attachment D-1-1.** Elevations in the as-built drawings reference the NGVD 1929 vertical datum. Elevations at the dam site can be converted from NGVD 1929 to NAVD 1988 by adding approximately 1.24 feet based on the Vertical Datum Conversion Program (VERTCON) available through the National Geodetic Survey (NGS, 2018). For example, the principal spillway orifice inverts are at elevation 1489 feet in the as-built drawings (NGVD 1929), so the elevation of the principal spillway orifice inverts would be at 1490.24 feet in NAVD 1988. The elevation of the principal spillway orifice inverts that was surveyed is approximately 1490.2 feet (NAVD 1988). Therefore, the elevation of the principal spillway orifice inverts is approximately 0.04 feet lower than expected. Similarly, the principal spillway riser tower crest was 0.03 feet lower than expected. Because surveyed elevations were within 0.1 feet of elevations when using the vertical conversion factor, any elevations that were not able to be surveyed are assumed to be equal to the as-built elevation plus the vertical conversion factor of 1.24 feet. For example, invert elevations of the conduit running through Bylin Dam were not able to be collected due to the inability to enter the principal spillway structure, but the elevations associated with the conduit can be calculated by using the inverts in the as-built plans, plus 1.24 feet.

The elevation of the auxiliary spillway crest was approximately 0.4 feet higher than expected and the elevation of the top of the dam was approximately 0.4 feet higher than expected. Differences between these elevations can be attributed to construction methods used over 50 years ago and to the estimated settlement of the dam being slightly different than what was predicted.

2.3 NORMAL POOL BATHYMETRIC AND SEDIMENTATION SURVEY

The normal pool bathymetric and sediment surveys were done simultaneously in June of 2020. A survey of the pool upstream of Bylin Dam and downstream of the former Dougherty Dam was completed along with a survey of the pool upstream of the former Dougherty Dam. The elevation of the pool upstream of Bylin Dam was 1490.59 feet (NAVD 1988) and the elevation of the pool upstream of Dougherty Dam was 1500.44 feet (NAVD 1988) at the time of the survey.

2.3.1 METHODS

Bathymetry data for both pools upstream of Bylin Dam was collected using a GPS linked, multi-frequency sonar or, more specifically, Specialty Device Inc.'s BSS+ Sediment Profiling System. Core samples were collected to calibrate the sonar returns from the BSS+ System using a vibrating head core sampler. The grid spacing during the bathymetric survey did not exceed 250 feet in any direction. The survey data points collected are shown on **Figure D-1-3**. The survey provided existing sediment elevation and the elevation of the original ground before construction of the dam. The existing sediment elevations are shown on **Figure D-1-4**.

2.3.2 RESULTS

A cumulative sediment volume in the reservoirs upstream of Bylin Dam was estimated based on the multi-frequency sonar data that was collected in the summer of 2020. The estimated volume of sediment that accumulated in the reservoirs since the construction of the dam in 1964 is 179 acre-feet. This equates to a sedimentation rate of 0.16 acre-feet per year per square mile of uncontrolled drainage area. The distribution of the sediment covers the length of both pools at varying depths. The sediment depth in each pool is shown in **Figure D-1-5**.

A Supplemental Watershed Work Plan for Bylin Dam (Grand Forks, Nelson, and Walsh Counties, 1970) indicates that the sedimentation rate predicted was 0.15 acre-feet per year per square mile, and the total sediment storage available for Bylin Dam (based on the Watershed Work Plan) was estimated to be 141 acre-feet.

A stage-storage relationship for Bylin Dam was developed based on the bathymetric survey data collected in the summer of 2020 and LiDAR data (IWI, 2008-2009). Stage-storage curves were developed for both the existing condition of the reservoir (top of sediment) and the original reservoir condition when the dam was built (bottom of sediment). **Figure D-1-6** shows the computed elevation-storage relationship for existing and original conditions, as well as the as-built elevation-storage curve for the dam. The as-built curve is similar to the bottom of sediment curve developed from the bathymetric survey. At a specific elevation, the difference between the storage of the bottom of sediment curve and top of sediment curve is the volume of sediment at that elevation. For example, at the low-level drawdown elevation of 1477.24 feet (NAVD88) the volume for the top of sediment curve is 60 acre-feet and the volume for the bottom of sediment curve is 131 acre-feet. The difference of those two volumes is 71 acre-feet which would be the volume of sediment below the low-level drawdown elevation.

2.4 STRUCTURE FOUNDATION ELEVATIONS

Foundation elevations of structures downstream of Bylin Dam were collected in November of 2020 to verify the hydraulic depth associated with the structures during breach conditions and other synthetic events simulated. In total, there were approximately 165 structures surveyed within the North Branch Forest River Watershed downstream of Bylin Dam.

2.4.1 METHODS

The permanent survey benchmarks that were set for the downstream channel survey discussed in Section 2.1.1 were also used to collect elevations at the structures. Finished floor elevations of structures identified as being within the designated breach zone or being impacted by a 500-year rainfall event were surveyed using real-time kinematic (RTK) global positioning system (GPS) equipment. The horizontal datum used throughout the downstream channel survey collect was NAD83 (Conus), GeoID12B, North Dakota State Planes, North. The vertical datum used was NAVD 1988.

3 REVIEW AND INSPECTION OF STRUCTURE

Site inspections for Bylin Dam were conducted by Houston Engineering Inc. in September of 2020. The objective of the inspections was to assess the condition of all elements of the dam including the embankment, slope protection, concrete inlet structure, principal spillway conduit, auxiliary spillway, and all related miscellaneous elements. A dam inspection checklist was used to record findings and can be made available upon request from the North Dakota NRCS. Photographs were also taken during all inspection visits. Photographs of the dam site as well as photographs of any noted deficiencies during the site inspections are presented in **Attachment D-1-2**. Previous inspection reports were reviewed to verify existing conditions and to evaluate deteriorating conditions. The reported conditions are based on observations of field conditions at the time of inspection, and it is important to note that the condition of the various elements of the dam depend on numerous and constantly changing internal and external factors. Continued care, maintenance, and inspections are necessary to detect unsafe conditions.

3.1 PRINCIPAL SPILLWAY CONCRETE INLET STRUCTURE

All visible sections of the principal spillway concrete inlet structure exterior were inspected for potential damage or movement. Due to site conditions and geometric constrictions, the interior portion of the concrete inlet structure was not able to be inspected during the initial site visit. A supplemental inspection was conducted in April of 2021 to collect images of the interior of the concrete inlet structure. It has been noted on previous inspection reports that the concrete of the inlet structure is in good overall condition. Upon closer inspection of the interior walls of the concrete inlet structure, some minor concrete spalling primarily at normal water elevations was noted. Several areas of the exposed exterior concrete walls were also noted to have minor spalled concrete areas. These areas are noted and can be seen in the photographs in **Attachment D-1-2.**

The reservoir level at the time of inspections was just below the first stage inlet orifice of the principal spillway structure. The anti-vortex baffle on top of the structure is in good condition. A low-level draw down exists on the front side of the inlet structure consisting of a 12-inch diameter welded steel pipe and valve assembly; however, it has been noted from previous inspection reports to not be functional and the valve-well has been covered with a steel plate and bolted shut. There were no signs of significant debris/trash accumulation around the weir openings and all trash racks appeared to be in good condition with minor surface corrosion. Fine-meshed screens exist on the front face of the trash racks but were noted to have been removed on each side of the trash rack. Overall, all visible portions of the concrete inlet structure appear to be in good condition and appear to be structurally sound. No external evidence of any settlement or movement of the structure was observed.

For the purposes of the rehabilitation effort at Bylin Dam, the minor cracking and spalling noted on the principal spillway tower will be patched if the existing structure is to remain in place. Replacement of the trash rack would also be warranted due to the corrosion noted. The low-level drawdown gate would either need replacement or would need to be repaired as part of this rehabilitation effort if the existing principal spillway riser tower were to remain in place. With these modifications, the principal spillway inlet structure appears to be adequate to last through the expected dam rehabilitation design life of 50 years.

3.2 PRINCIPAL SPILLWAY CONDUIT AND OUTLET

Due to the size, the interior of the 30-inch reinforced concrete pipe (RCP) principal spillway conduit was inspected for potential damages and movement using a remotely operated vehicle. Video footage of the inside of the spillway conduit while the remotely operated vehicle traveled through it showed no significant signs of deterioration, movement, or separation of joints. The principal spillway conduit joints were numbered to refence the locations of the observations made and are provided in the dam cross section view provided in **Appendix C-3**. Two areas near joint number 4 and joint number 11 were noted to have minor cracking of the pipe sections. Photographs of the interior of the principal spillway conduit are provided in **Attachment D-1-2**. Concrete loss was noted on the bottom of the exterior of the concrete pipe at the outlet of the principal spillway conduit. The 30-inch RCP discharges into a rock-lined plunge pool at the toe of the dam. Toe drains are located adjacent to the 30-inch RCP outlet and discharge into the plunge pool. It was noted that an animal guard was present on the south drain but has been removed on the north drain. Both drains were discharging water at the time of inspection.

For the purposes of the rehabilitation effort at Bylin Dam, the outlet end of the principal spillway conduit would need replacement or repair work if the conduit were to stay in place. Additionally, a new animal guard on the outlet of the north toe drain would be added. With these improvements, the principal spillway conduit appears to be adequate to last through the expected dam rehabilitation design life of 50 years. All structural elements should continue to be monitored on a regular basis. Observations from the inspection associated with the principal spillway concrete inlet structure, conduit, and outlet are provided in **Table D-1-2**.

Table D-1-2: Bylin Dam Structural Deficiency Summary

Deficiency Location	Description
Concrete Inlet Structure	▪ Minor spalled areas near the normal water elevations ▪ Minor spalled areas on exterior of concrete inlet structure most likely caused by debris or ice loading. ▪ Minor surface corrosion noted on trash rack ▪ Fine mesh screens on sides of trash rack panels removed. ▪ Low level drawdown gate and operator is inoperable and has been bolted shut.
30" RCP Principal Spillway Conduit Near J11	▪ Concrete pipe crack around majority of pipe noted near J11 (Roughly 122' from outlet).
30" RCP Principal Spillway Conduit Near J4	▪ Concrete pipe crack near pipe connection at J4 (Roughly 250' from outlet).
30" RCP Principal Spillway Conduit - Outlet	▪ Concrete loss was noted on the bottom of the exterior of the concrete pipe at the discharge end.
Toe Drains	▪ North toe drain animal guard has been removed.

3.3 EMBANKMENT AND AUXILIARY SPILLWAY

Overall, the dam embankment and auxiliary spillway were found to be in good condition. The vegetative cover of the upstream and downstream slopes was in good condition with no bare areas. There are some vehicle tracks and animal trails that are of no major concern. There are some scattered small trees and woody vegetation. The most significant area that contains tree growth is a 0.1-acre area on the right side (northeast) of the downstream side of the auxiliary spillway. The auxiliary spillway ends at the steep bank near the outlet of the auxiliary spillway channel and no erosion control is in place.

In addition to the embankment and auxiliary spillway inspection, it was noted that a section of the access road to the beach and boat ramp has eroded over a length of approximately 170 feet along with portions of the beach area. All deficiencies associated with the dam embankment and auxiliary spillway are noted in a Dam Inspection Form which can be made available upon request. **Attachment D-1-2** contains photographs of the embankment and auxiliary spillway of Bylin Dam.

4 DAM BREACH ANALYSIS AND HAZARD CLASSIFICATION

The breach analysis and hazard classification of Bylin Dam were evaluated based on guidelines established in *TR 210-60* (NRCS, 2019). The sub-sections that follow describe how the breach analysis was conducted, the results from the dam breach scenario, and the resulting hazard classification associated with Bylin Dam.

4.1 PEAK BREACH DISCHARGE CRITERIA

The peak discharge criteria for the dam breach were developed using equations found in Chapter 1 of *Technical Release 210-60 Earth Dams and Reservoirs* (NRCS, 2019). Based on *TR 210-60*, the failure or breach of the dam is to be evaluated with the water surface elevation of the reservoir at the dam crest or the peak reservoir stage resulting from the probable maximum flood (PMF). The PMF occurs as a result of the runoff from a PMP event. Equations in Part I of *TR 210-60* were used to compute the peak breach discharge for Bylin Dam. The peak breach discharge calculated for the dam was approximately 103,000 cubic feet per second. Peak breach discharge calculations and data are provided in **Attachment D-1-3**.

The downstream water surface profiles for the dam breach were developed using the HEC-RAS modeling program (U.S. Army Corps of Engineers, 2018). The extent of the model and elements used in the model are shown in **Figure D-1-15** (details on the development of the HEC-RAS model are explained in Section 5.2.1). Tools within the HEC-RAS framework were utilized to develop the dam breach simulation. To meet the peak breach discharge, the elevation of the reservoir was set to the top of dam elevation, and the breach formation time within the hydraulic model was altered to yield a peak flow of 103,000 cubic feet per second. The progression of the breach occurred in at a linear rate. The breach formation characteristics such as breach width, side slopes, and temporal characteristics were based on the Froehlich Equations (Froehlich, 2008). The resulting outflow hydrograph from the breach simulation is shown in **Figure D-1-7**.

4.2 BREACH RESULTS

The inundation produced from the simulated breach based on *TR 210-60* criteria is shown through the breach zone on **Figure D-1-8**. **Figure D-1-9** through **Figure D-1-12** show more detailed views of the inundation mapping along with structures affected and roads overtopped throughout the breach zone. The breach zone was developed based on the requirements outlined in item B.1 under the Expected Accomplishments and Deliverables section in the Cooperative Agreement between the NRCS and the Walsh County Water Resource District. The extent of the breach zone is established at the point where the breach scenario water surface profile converges with the 100-year synthetic rainfall event water surface profile. For Bylin Dam, the breach zone begins at Bylin Dam and extends downstream to a location where the water surface profiles for the breach scenario and the 100-year synthetic rainfall event are within half of a foot on the mainstem of the North Branch Forest River.

All residential structures that were potentially impacted by the dam breach are summarized in **Table D-1-3** and are labeled in **Figure D-1-8** as well as **Figures D-1-9** through **Figure D-1-12**. Structures were identified within the HEC-RAS modeling extents via imagery made available through the National Agriculture Imagery Program (NAIP) (United States Department of Agriculture, 2019). **Table D-1-3** provides data on the finished floor elevation of each structure, maximum inundation depth of the structure, maximum velocity of flow at the structure location, and the amount of time it would take for the breach discharge to reach the structure. Structures without flood depths or velocities listed are not impacted by inundation during the breach event. In addition to the residential structures impacted by the breach, an estimated 159 non-residential structures would be impacted. The additional structures consist mostly of agricultural storage facilities, grain bins, and other buildings used for agricultural production.

There are various instances of roads being overtopped during the breach scenario. For this analysis, only roads with an average annual daily traffic (AADT) value greater than 400 are considered. This AADT value was chosen based on recommendations that were provided to the North Dakota State Water Commission for hazard classification of dams in North Dakota by Gannett Fleming Inc. in July of 2017 (Gannett Fleming Inc., 2017). Smaller roads, such as township roads, are less likely to have vehicles on them during a breach. The only road in the breach zone with an AADT value in excess of 400 is North Dakota State Highway 32, which overtops in three different locations. The road overtopping locations are shown in **Figure D-1-10** and **Figure D-1-11**. Information about the three overtopping locations on North Dakota State Highway 32 is provided in **Table D-1-4**. **Table D-1-4** provides data on maximum inundation depth where the road overtops, maximum velocity over the road, and the amount of time it would take for the breach discharge to first overtop the road.

Table D-1-3: *Residential Structures Potentially Impacted by a Breach of Bylin Dam*

Structure ID	Finished Floor Elevation (ft, NAVD88)	Depth (ft)	Velocity (ft/s)	Arrival Time[2] (hours)
S1	1475.2	7.3	1.3	1
S2	1456.2	18.1	3.5	1
S3	1447.9	22.4	4.4	1
S4	1438.3	22.5	6.8	1
S5	1440.2	13.5	2.8	1
S6	1383.1[1]	28.0	5.5	2
S7	1232.4	-	-	3
S8	1228.7	-	-	4
S9	1193.4	0.1	0.3	6
S10	1180.4	0.5	0.7	4
S11	1178.6	1.0	1.8	4
S12	1179.0[1]	-	-	7
S13	1178.5	0.4	0.4	8
S14	1175.7	0.2	1.2	8
S15	1173.0	-	-	8
S16	1168.0	1.1	1.5	6
S17	1164.0[1]	-	-	17
S18	1163.4[1]	-	-	0
S19	1161.3[1]	-	-	11

[1] Surveyed finished floor elevation was unable to be obtained. Floor elevation estimated from available LiDAR data

[2] Breach arrival time is relative to the initiation of the dam breach

Table D-1-4: *Road Overtopping Data for ND Highway 32 During a Breach of Bylin Dam*

Road ID[1]	Depth (ft)	Velocity (ft/s)	Arrival Time[2] (hours)
R1	1.21	3.62	4
R2	0.37	1.60	7
R3	0.33	2.13	8

[1] See **Figure D-1-10** and **Figure D-1-11** for road overtopping locations
[2] Breach arrival time is relative to the initiation of the dam breach

The structures and roadways listed in **Table D-1-3** and **Table D-1-4** were analyzed further to determine if there is the potential for loss of life during a breach of the magnitude described. Depth and velocity flood danger level relationships established in *Downstream Hazard Classification Guidelines* (U.S. Bureau of Reclamation, 1988) were used to determine which structures and roads have a high danger potential during a breach at Bylin Dam.

The chart from *Downstream Hazard Classification Guidelines* that shows the depth-velocity flood danger level relationship for homes built on foundations is shown on **Figure D-1-13**. The structures corresponding to **Table D-1-3** are also plotted on **Figure D-1-13**. Structures plotted in the red fall in the category of high danger level, indicating that loss of life is likely. Structures in the yellow fall into what is called the judgement zone where some level of engineering judgement should be used to determine if the structure has a high or low danger potential. Structures plotted in the green area have a low danger level, and loss of life is not likely. **Figure D-1-13** shows that there are six structures in the high danger (red) zone and no structures in the judgment (yellow) zone. Therefore, a total of six out of the nineteen total residential structures have a high danger potential for loss of life if Bylin Dam were to breach with the magnitude described in Section 4.1. The six structures that have a high danger potential are shown as red triangles in **Figure D-1-8** through **Figure D-1-12**. The remaining structures that are in the low danger potential category are shown as green triangles in those same figures.

The hazard potential for habitable structures was also reviewed based on guidance in the National Engineering Manual (NRCS, 2017), which indicates that products of four or greater that result from depth (in feet) and velocity (in feet per second) combinations could result in loss of life. The six structures identified as high danger potential all have depth and velocity products greater than four and structures in the low danger potential category have depth and velocity combinations that result in a product of less than four. Therefore, the methods used to identify habitable structures within the breach zone that may experience loss of life during a breach were verified by criteria in the National Engineering Manual.

Another chart in *Downstream Hazard Classification Guidelines* (U.S. Bureau of Reclamation, 1988) shows the depth-velocity flood danger level relationship for passenger vehicles. That chart can be seen on **Figure D-1-14**. The three road overtopping locations along North Dakota State Highway 32 (listed in **Table D-1-4** and shown on **Figure D-1-10** and **Figure D-1-11**) are plotted on **Figure D-1-14** as well. **Figure D-1-14** shows that all three overtopping locations fall in the low danger category and loss of life due to flooding over the road is not likely.

4.3 HAZARD CLASSIFICATION

Title 210, National Engineering Manual, Part 520 Subpart C "Dams" (NRCS, 2017) describes the hazard potential resulting from failure of dams. According to this guidance, a high hazard potential is "Dams where failure may cause loss of life or serious damage to homes, industrial or commercial buildings, important public utilities, main highways, or railroads."

A similar definition is outlined in Article 89-08 of the North Dakota Century Code (ND SWC, 2015) where a high hazard dam is defined as, "A dam located upstream of developed or urban areas where failure may cause serious damage to homes, industrial and commercial buildings, and major public utilities. There is potential for the loss of more than a few lives if the dam fails."

Based on the data presented in Section 4.2, the high hazard designation for Bylin Dam was confirmed.

5 HYDROLOGIC AND HYDRAULIC MODELING

5.1 HYDROLOGY MODEL

Several hydrologic modeling efforts have been completed or are currently underway for other projects in the Forest River Watershed. In 2011, the United States Army Corps of Engineers (USACE) along with local sponsors began work on the development of hydrologic models from Halstad, MN, to the international border (including the Forest River Watershed) using HEC-HMS (U.S. Army Corps of Engineers, 2017) as part of the *Red River of the North Hydrologic Modeling – Phase 2* report (USACE, 2013). Methods developed as part of the Phase 2 study were aimed at developing a consistent method to analyze hydrology within the Red River Basin while still accounting for unique characteristics within each subwatershed.

Further development of the hydrologic model was done through the *Forest River Watershed Comprehensive Detention Plan* (Red River Joint Water Resource District, 2013). This effort focused on the development of potential storage sites in the watershed. Through the study, detail was added to the hydrologic model and input parameters were refined through calibration efforts beyond the Phase 2 report.

Recently, ongoing efforts toward a Watershed Plan through the Regional Cooperation Partnership Program (RCPP) have enabled further refinement of the hydrologic model for the Forest River Watershed. As part of the RCPP, an *Existing Conditions Hydrology and Hydraulics Report* for the Forest River Watershed was completed by Houston Engineering Inc. (2019). The hydrologic model detailed in that report was used for this assessment with some minor modifications. Changes to the model and other important elements associated with the hydrology of Bylin Dam are described in the following sub-sections.

5.1.1 SUBBASIN BOUNDARIES

Subbasins developed through previous modeling efforts incorporated non-contributing drainage areas which were developed to evaluate potential for hydrologically closed basins within the watershed. Areas within the subbasins that have the potential to store runoff produced during the 100-year event shown in Figure 21-2 in Chapter 21 of Part 630 within the National Engineering Handbook (NRCS, 2019) were considered non-contributing areas. Those areas were removed from the drainage area for the Principal Spillway Inflow Hydrograph simulation described in Section 5.5.1.

For the larger inflow hydrographs, including the stability design hydrograph (SDH) and freeboard hydrograph (FBH), all drainage area in the watershed upstream of Bylin Dam was assumed to contribute runoff. For the drainage area to Bylin Dam, non-contributing areas associated with the 100-year runoff based on Figure 21-2 in Chapter 21 (Part 630 of the National Engineering Handbook) accounted for approximately 0.34 square miles of the total 20.86 square mile drainage area. In the current HEC-HMS model, the entire drainage area to Bylin Dam is simulated as one subbasin. The subbasins used in the HEC-HMS model for the entire Forest River Watershed can be seen in the *Existing Conditions Hydrology and Hydraulics Report* (Houston Engineering Inc., 2019) for the Forest River Watershed.

5.1.2 SUBBASIN PARAMETERS

Subbasin parameters were originally developed as part of the *Red River of the North Hydrologic Modeling – Phase 2* report (USACE, 2013) mentioned previously. Additional details on the various input parameters used in the hydrologic model are provided in the following sections. The time of concentration and storage coefficient values were modified through the calibration process described in Section 5.3.

5.1.2.1 CURVE NUMBERS

For the development of the *Red River of the North Hydrologic Modeling – Phase 2* report, National Land Cover Database (NLCD) (Homer, et al., 2015) data and Hydrologic Soil classifications from the Soil Survey Geographic Database (SSURGO) (NRCS, 2001) were combined to develop Red River Basin-wide 24-hour AMC II Curve Number (CN) data. Guidance from TR-55 Urban Hydrology for Small Watersheds (NRCS, 1986) and Minnesota Hydrology Guide (USDA, SCS, 1976) was used to develop a conversion table to determine an appropriate 24-hour CN for a given hydrologic soil group and an NLCD land use combination. This information was applied in GIS to create a Red River Basin 24-hour AMC II CN gridded dataset. More detailed information is available in the *Red River of the North Hydrologic Modeling – Phase 2* report.

5.1.2.2 TIME OF CONCENTRATION

Travel time grids were created for each tributary subwatershed within the Red River basin as part of the Phase 2 study. Grids were created using a travel time routine developed by the Minnesota Department of Natural Resources (MnDNR). The routine is implemented within a GIS environment using LiDAR topographic data, National Land Cover Data (NLCD) (Homer, et al., 2015), and various derivative GIS datasets. The routine assigns a Manning's N-value based on the accumulated flow and land use. Slope is then used to estimate velocity, and subsequently travel time using Manning's equation. Procedures utilized within the travel time tool follow guidance for developing time of concentration values with the Velocity Method described in Chapter 15 of Part 630 within the National Engineering Handbook in (NRCS, 2010). The longest travel time per subbasin can then be derived in a consistent method across the modeling extents. The longest travel time derived from the MnDNR Travel Time Routine served as an initial time of concentration (Tc) estimate for each subbasin, with further refinements through calibration to historic flood events.

5.1.2.3 CLARK'S STORAGE COEFFICIENT

A regional regression analysis was conducted during the Phase 2 model development to develop a consistent method for the initial estimate of the Clark's Storage Coefficient (R). The analysis considered parameters for the watersheds above gaging locations such as stream length, drainage area, percent slope, NWI wetlands and lakes, and watershed slope. This analysis resulted in a relationship between the time of concentration and the Clark's Storage Coefficient that was spatially dependent. The relationship was applied in GIS to allow the relationship to be applied to each subbasin used in the HEC-HMS model. Similar to the time of concentration, Clark's Storage Coefficients derived with this analysis served as an initial estimate for each subbasin, with further refinements through calibration to historic flood events.

5.1.3 DOUGHERTY DAM

Dougherty Dam is a dam that was built by the Civilian Conservation Corps in 1935 and is located approximately 1.2 miles west of the Bylin Dam embankment. During large rainfall or runoff events, the reservoir for Bylin Dam will rise to a level that will cause the embankment of Dougherty Dam to be fully immersed under water. The spillway for Dougherty Dam is a 50-foot-wide concrete weir section. It is assumed that the weir would cause very little attenuation of floodwaters upstream of the dam. Due to the weir spillway on Dougherty Dam causing the flow into the reservoir to be approximately equal to the flow leaving the dam, and the fact that the dam is inundated during large rainfall/runoff events, the dam was not included in the HEC-HMS model simulations.

A breach of Dougherty Dam was not considered for this analysis because it would not result in a cascading failure of Bylin Dam due to the amount of flood storage available upstream of Bylin that far exceeds the floodwater storage capacity of Dougherty Dam. As a slightly conservative assumption, all of the volume upstream of Dougherty Dam was assumed to be routed through the breach of Bylin Dam, even though this structure may still be intact during a breach of Bylin Dam.

5.2 HYDRAULIC (HEC-RAS) MODEL

An unsteady HEC-RAS (v.5.0.7) model was developed and used to generate water surface profiles by hydraulically routing runoff hydrographs generated by the HEC-HMS model. The HEC-RAS model is used to verify the hazard classification of Bylin Dam by routing breach hydrographs through the downstream channel and to develop inundation extents for synthetic events to assist with the various scenarios to be evaluated for the Watershed Plan. The HEC-RAS model consists of channel cross sections, 1-dimensional storage areas, and 2-dimensional storage areas. The channel cross sections route flows in the North Branch Forest River and Drain 97. Cross sections on the North Branch Forest River span from Bylin Dam to the confluence of the North Branch Forest River with the Middle Branch Forest River. 1-dimensional storage areas were used to represent the elevation-storage relationship in the Bylin Dam reservoir. 2-dimensional storage areas are located adjacent to the North Branch Forest River mainstem to route overland or breakout flows. Channel cross sections, 1-dimensional storage areas, and 2-dimensional storage areas in the HEC-RAS model schematic are shown on **Figure D-1-15.**

5.2.1 STORAGE ROUTING

Storage routing is used to account for floodplain storage adjacent to the North Branch Forest River mainstem. Due to the complex routing of overland flooding, 2-dimensional storage areas are used for the North Branch Forest River Watershed. 2-dimensional storage areas allow the model to account for floodplain storage available for out of bank flows and are used to convey flows through the floodplain. Storage areas are connected to cross sections and other storage areas to hydraulically route flows through the floodplain. Internal storage connections are used to represent township roads that contain culverts or bridges to simulate flow through the roadways.

Bylin Dam is modeled with a 1-dimensional storage area and the elevation-storage data was derived from LiDAR data. Flood storage in the model for Bylin Dam only includes LiDAR data and does not include the bathymetric data. This is not seen as a concern because the LiDAR data represents the flood storage above the normal pool elevation and any data below the normal pool is not relevant for the hydraulic simulations.

5.2.2 CHANNEL BATHYMETRY AND HYDRAULIC STRUCTURES

The channel shape and bathymetry of the North Branch Forest River was developed based on the survey data described in Section 2.1. Bridges and culvert crossings along the North Branch Forest River were also modeled using survey data. Channel data for Walsh County Drain 97 from North Dakota State Highway 32 to 57th Street NE was interpolated based on surveyed hydraulic structures along Drain 97. The channel for Drain 97 in between hydraulic structures was assumed to be uniform and at a constant grade because of recent drain cleanouts that have occurred in this region of the drain.

5.2.3 MANNING'S N-VALUES

Manning's n-values are set within the HEC-RAS cross sections to account for channel roughness. NLCD land use GIS grids were used to generate a Manning's n-value grid. The NLCD land cover categories were aggregated into five land use types; channels, agricultural or cropland, wetlands, forested, and developed. Due to the cell size of the NLCD GIS grids (30 meters x 30 meters), portions of the river channels can be omitted from the NLCD grids. The NLCD grid was modified by generating a channel boundary and merging the channel with the NLCD grid. The NLCD grid was also used for flow routing computations in 2-dimensional areas. Manning's n-values were set through calibration and verification of the Forest River Watershed HEC-RAS and HEC-HMS models as described in Section 5.3. The calibrated Manning's n-values in the existing conditions hydraulic model are shown in **Table D-1-5** along with a normal range for the Manning's n-values.

Table D-1-5: *Manning's n-Values by Land Use*

Land Use	Manning's n-Value	Normal Range
Channel	0.05	0.04 – 0.055
Agricultural / Cropland	0.06	0.035 – 0.06
Wetlands	0.05	0.035 – 0.07
Forested	0.11	0.08 – 0.12
Developed / Barren	0.08	0.025 – 0.10

5.2.4 INFLOWS

Hydrographs generated from the HEC-HMS model were applied to the HEC-RAS model. HEC-HMS junction hydrographs were applied at the upstream extents to cross sections or 1-dimensional storage areas within the HEC-RAS model. Further downstream, HEC-HMS subbasin hydrographs were applied to the cross sections in the HEC-RAS model.

5.2.5 TAILWATER

For synthetic event modeling in the Forest River Watershed, the tailwater boundary condition for the North Branch Forest River was estimated by entering a stage hydrograph for the Middle Branch Forest River downstream of the North Branch Forest River. When the stage in the downstream channel was not known, a friction slope was entered for the tailwater boundary condition. The slope was estimated from survey data collected previously along the Middle Branch Forest River.

5.3 CALIBRATION AND VERIFICATION

Two historic rainfall events were used for calibration and verification of the HEC-HMS and HEC-RAS models for the North Branch Forest River Watershed. A rainfall event in mid-June of 2016 was used to estimate model parameters in the Forest River hydrologic and hydraulic models. An event in May of 2010 was used to verify the parameters used in the models.

5.3.1 JUNE 2016 CALIBRATION EVENT

The hydrologic and hydraulic models were calibrated based on a rainfall event that occurred in the summer of 2016. Rainfall depths in the Forest River Watershed upstream of Lake Ardoch during the event ranged from 1.3 to 3.8 inches. The average total rainfall depth upstream of Lake Ardoch was approximately 2.7 inches. The majority of the rainfall that was modeled in the simulation occurred on June 17th from about 5 a.m. to 11 a.m. where an average of 2.2 inches of precipitation occurred. The remaining precipitation that was simulated occurred on June 19th from 3 a.m. to 7 a.m. Total rainfall depths throughout the Forest River Watershed during the event are shown on **Figure D-1-16**.

Documented historic data that was used for calibration of the models included: observed rainfall depths at gaging stations, NEXRAD rainfall data, and discharge measurements at the Forest River USGS Streamgage 05084000 near Fordville, ND. The observed discharge hydrograph was used to derive daily flow volumes at the USGS Streamgage near Fordville, ND. Discharge measurements for Forest River USGS Streamgage 05085000 at Minto, ND were not relied upon for the calibration of the hydrologic and hydraulic models associated with the North Branch Forest River Watershed because the entire watershed is upstream of the USGS streamgage near Fordville, ND and any modifications made to calibrate to the USGS streamgage at Minto, ND are not relevant for this analysis.

Runoff curve numbers for a 24-hour storm duration were initially applied for the calibration event. Curve numbers were adjusted to match the observed discharge volume through the USGS gage site near Fordville, ND. The final curve numbers used in the simulation were just slightly higher than an AMC II condition. This antecedent moisture condition was reviewed based on guidance from the *National Engineering Handbook (NEH)* (NRCS, 2004), and is valid based on a small rainfall event occurring in the a few days prior to the event.

During the simulation of the historic rainfall event, pool elevations for all dams in the watershed were set to the normal pool elevation. The small rainfall event that occurred prior to the historic rainfall event subsided approximately two days before the simulated event began. This would allow enough time to draw pool elevations down to, or near the normal pool elevation. Baseflow was added to the HEC-RAS model to match discharge at both USGS gages before the rainfall event.

Initial unit hydrograph parameters that were estimated in previous modeling efforts (Section 5.1) were further adjusted with the June 2016 rainfall event. Modifications were made to the storage coefficient (R) and time of concentration (Tc) values used in the Clark Unit Hydrograph transform during calibration. Final R/Tc ratios from calibration are shown on **Figure D-1-17**. Within the North Branch Forest River Watershed, both the time of concentration and Clark's storage coefficient values were reduced substantially to calibrate the hydraulic and hydrologic models to the historic events analyzed. A similar procedure was followed when the models were calibrated for the *Existing Conditions Hydrology and Hydraulics Report* for the Forest River Watershed (Houston Engineering Inc., 2019).

Hydrographs in the hydraulic model were compared to the recorded discharge at the Forest River USGS Streamgage near Fordville, ND. The observed discharge hydrograph for the Streamgage near Fordville and simulated HEC-RAS model discharge hydrograph are shown on **Figure D-1-18**. The simulated HEC-

RAS peak flow rate and volume are consistent with observed flow rates and volumes at the gage during the event.

Table D-1-6 summarizes the peak flow rates and timing, as well as the 1-day through 3-day volumes centered on the peak flow rate (i.e. the 1-day through 3-day volumes were computed by finding the area under the hydrograph centered on the peak ±0.5 days, ±1.0 days, etc.). Observed volumes at the gaging site beyond 3 days was not considered because of a second rainfall event that came through the watershed on June 19th. The hydrologic model uses the curve number runoff method. This runoff method does not account for initial abstraction that would occur during a second rainfall event in the hydrologic simulation. Therefore, the model results show a larger secondary peak from the second rainfall that occurred within the watershed.

Table D-1-6: *Peak Flow and Volume Comparison at USGS Gage near Fordville, ND in June 2016*

Source	Peak Flow (cfs)	Peak Flow Time	Volume (Ac-Ft)		
			1-Day	2-Day	3-Day
USGS Gage 05084000 at Fordville, ND	1,860	6/18/2016 3:00	2,610	3,681	4,394
HEC RAS Model	1,817	6/18/2016 4:00	2,587	3,570	4,281
%Difference	-2.3%	1 hour	-0.9%	-3.0%	-2.6%

Parameters in the HEC-RAS model were also established during calibration. These parameters include Manning's n-values, overbank reach lengths, and storage area connection coefficients. Initial values were set based on guidance from the *HEC-RAS User's Manual* (USACE, 2016) and *HEC-RAS Technical Reference Manual* (USACE, 2016). Manning's n-values were generally assumed to be a crop covered condition (crop development and mature crop). A sensitivity analysis on Manning's n-values was completed in the *Existing Conditions Hydrology and Hydraulics Report* for the Forest River Watershed (Houston Engineering Inc., 2019). Overbank reach lengths were digitized utilizing GIS and the resultant HEC-RAS model floodplain. Storage area connection coefficients were generally set based on Table D-1-2 from the *HEC-RAS 2D Modeling User Manual* (USACE, 2016).

5.3.2 MAY 2010 VERIFICATION EVENT

After the hydrologic and hydraulic models were calibrated, a second historic event was simulated to verify the parameters in the calibration event. Most of the May 2010 rainfall event occurred from May 24th through the early hours of May 25th. Rainfall depths in the Forest River Watershed upstream of Lake Ardoch during the event ranged from 2.3 to 3.8 inches. The average total rainfall depth for the planning area was approximately 2.8 inches. Total rainfall depths from May 22nd to May 25th are shown on **Figure D-1-19**.

Documented historic data that was used for calibration of the model included: observed rainfall depths at gaging stations, NEXRAD rainfall data, and discharge measurements at the Forest River USGS Streamgage 05084000 near Fordville, ND. The observed discharge hydrograph was used to derive daily flow volumes at the streamgage.

Runoff curve numbers were adjusted to produce the quantity of runoff volume recorded at the USGS gaging station near Fordville, ND. 24-hour curve numbers for subbasins upstream of the Fordville gage were applied with an antecedent moisture condition that was slightly higher than average. This antecedent moisture condition was reviewed based on guidance from the *National Engineering Handbook (NEH)* (NRCS, 2004), and is valid because of the amount of precipitation occurring prior to the event.

The observed discharge hydrograph and the simulated HEC-RAS model discharge hydrograph at the USGS gage near Fordville, ND are shown in **Figure D-1-20**. The peak flow rate from the measured data at the streamgage and the HEC-RAS modeled results differ by less than 1% near Fordville. In addition to a peak flow comparison, volume of runoff at the USGS gage near Fordville, ND was compared for several durations centered on the peak discharge. **Table D-1-7** summarizes the peak flow rates and timing, as well as the 1 through 3-day volumes centered on the peak flow rate. The results from the May 2010 event at the USGS Streamgage near Fordville, ND verify the unit hydrograph parameters in the upper portion of the watershed.

Table D-1-7: *Peak Flow and Volume Comparison at USGS Gage near Fordville, ND in May 2010*

Source	Peak Flow (cfs)	Peak Flow Time	Volume (Ac-Ft)		
			1-Day	2-Day	3-Day
USGS Gage 05084000 at Fordville, ND	1,430	5/24/10 20:00	2,197	3,138	3,830
HEC RAS Model	1,431	5/24/10 20:00	2,084	3,074	3,782
%Difference	0.1%	-	-5.1%	-2.0%	-1.3%

5.4 PROBABLE MAXIMUM PRECIPITATION

The probable maximum precipitation (PMP) event for Bylin Dam was first developed using Hydrometeorological Report No. 51 (HMR51) (Schreiner & Riedel, 1978). Rainfall depths were extracted from the PMP charts located on pages 48 to 77 of HMR51. The charts are made available in a digital format on the National Weather Service's website. Depths for various PMP storm durations and sizes were obtained for the watershed upstream of Bylin Dam.

In addition to the PMP depths developed from HMR 51, PMP depths were also obtained based on a recent study for updated PMP depths in the state of North Dakota. Documentation for the updated PMP values has not been completed at this point, but the depths are considered usable by the steering committee overseeing the development of the PMP depths for the state of North Dakota (the NRCS is involved in the steering committee to develop statewide PMP depths). Two different storm types and various storm durations were simulated to determine the PMP scenario that would produce the largest and most conservative inflow to Bylin Dam.

The two storm types considered are a local PMP event and a general PMP event. A local storm is a high intensity rainfall event that occurs over a short period of time. Durations of the local PMP event do not exceed 24-hours. A general storm is not as intense as a local storm and typically occurs over a longer period of time. Available durations for general storms are 24 to 72 hours. A cool season PMP was also made available through the North Dakota PMP study, however, the cool season PMP was not considered for this analysis because it would not produce higher inflows than the general and/or local storms based on previous simulations done for larger drainage areas in the watershed. Typically, a cool season PMP is less likely to be the critical event for small watersheds.

5.5 SPILLWAY DESIGN HYDROGRAPHS

Spillway design hydrographs were developed based on criteria in *Technical Release 210-60: Earth Dams and Reservoirs* (NRCS, 2019), also known as *TR 210-60*. Based on results previously presented in Section 4, Bylin Dam is classified as a high hazard dam. The minimum precipitation criteria outlined in *TR 210-60* for high hazard dams is shown in **Table D-1-8**, and each of the design hydrographs is described in more detail in the following sub-sections.

Table D-1-8: *TR 210-60 Minimum Precipitation Data for High Hazard Dams*

Design Event	Hydrologic Criteria [1]	Depth (inches)
Principal Spillway	P_{100}	4.65 [2] 7.59 [3]
Auxiliary Spillway	$P_{100} + 0.26(PMP - P_{100})$[4]	9.45 [5]
Freeboard	PMP	21.55 [5]

[1] P_{100} represents the precipitation for the 100-year return period
[2] Runoff depth based on *NEH Part 630 Chapter 21*. See Section 5.5.1
[3] Rainfall depth based on *NOAA Atlas 14*. See Section 5.5.1
[4] P_{100} depth used to calculate the Auxiliary Spillway depth utilized the NOAA Atlas 14 published depth for equivalent duration events.
[5] Depths represent the total rainfall depths that result in the maximum outflow from Bylin Dam during the simulation. See Sections 5.5.2 and 5.5.3

5.5.1 PRINCIPAL SPILLWAY INFLOW HYDROGRAPH

Based on *TR 210-60*, the principal spillway of a high hazard dam must pass the 100-year return period storm (minimum) with a duration not less than 10-days without activating the auxiliary spillway. For Bylin Dam, two methods were used to determine the critical event: runoff volume maps and runoff curve number procedure (NRCS, 2019).

Runoff volume maps presented in Figure 21-2 of *NEH Part 630 Chapter 21* (NRCS, 2019) were used to estimate the 100-year 10-day runoff at 4.65 inches. No areal reduction is applied to the 100-year 10-day runoff depth for the runoff volume maps.

The runoff curve number procedure was used to simulate a summer rainfall event for the principal spillway criteria. A rainfall depth for a 10-day duration was obtained from *NOAA Atlas 14* (NOAA, 2017). Areal reduction factors were applied to the rainfall depth. The areal reduction factors were based on the drainage area to Bylin Dam and were obtained from *Technical Paper No. 49 – Two- to Ten-Day Precipitation for Return Periods of 2 to 100 Years in the Contiguous United States* (Miller, 1964). The resulting depth for the 10-day duration rainfall event considered for this analysis is shown in **Table D-1-9** along with the runoff depths used to simulate the runoff volume maps procedure described previously.

Table D-1-9: Principal Spillway Inflow Hydrograph Data

Method	Duration	Rainfall/Runoff Distribution	Runoff/Rainfall Depth[1] (in)	Peak Inflow to Bylin (cfs)
Runoff Volume Maps	10-day	*TR 210-60* Curve A	4.65	1,729
Runoff Volume Maps	10-day	*TR 210-60* Curve B	4.65	2,100
Runoff Volume Maps	10-day	*TR 210-60* Curve C	4.65	2,264
Runoff Curve Number	10-day	Nested	7.49	2,184

[1] Runoff depth used for the runoff volume maps procedure. Rainfall depth used for the runoff curve number procedure.

Guidance from *NEH Part 630 Chapter 21* was used to develop the principal spillway mass curve, or runoff distribution curve, for the 10-day runoff event. For Bylin Dam, 1-hour time increments were used to develop the distribution. Using equation 21-2 from *NEH Part 630 Chapter 21*, the total runoff at any given time during the event can be calculated. These 1-hour values can then be arranged in either a decreasing order (Curve A), an increasing order (Curve B), or a critical stacking order (Curve C). The principal spillway mass curves are used with the 4.65 inches of runoff from the runoff volume maps in *NEH Part 630 Chapter 21* (NRCS, 2019) and are shown on **Figure D-1-21**.

Rainfall events are simulated using nested distributions which are developed using a method described in in the *NEH, Part 630, Chapter 4* (NRCS, 2015). "Nesting" the distribution means that all shorter duration storms are contained, or "nested", within longer duration storms. That is, the 10-day storm contains the 5-minute storm, 10-minute storm, and so on. The nested distribution for the rainfall event used to produce the principal spillway hydrograph with the runoff curve number procedure is shown on **Figure D-1-21.** Curve numbers used in the simulations represented average antecedent moisture conditions (AMC II).

Quick Return Flow (QRF) is the rate of discharge that persists beyond the flood period of the principal spillway hydrograph. Based on Figure 21-4 in *NEH, Part 630, Chapter 21*, the QRF for Bylin Dam is approximately 1.5 cubic feet per second, per square mile. This results in a QRF of approximately 30.9 cubic feet per second (cfs) for Bylin Dam.

The four different scenarios described were applied to the HEC-HMS model to develop inflow hydrographs at Bylin Dam. The resultant inflows to the dam were input into the SITES program and adequacy of the principal spillway was evaluated (See Section 7). The inflow hydrographs to Bylin Dam for all four scenarios relevant to the principal spillway hydrograph are shown on **Figure D-1-22**. The peak inflow to Bylin Dam is listed in **Table D-1-9**.

5.5.2 AUXILIARY SPILLWAY INFLOW HYDROGRAPH

The auxiliary spillway hydrograph, or stability design hydrograph, was developed by using NOAA Atlas 14 rainfall depths and the rainfall depths from the PMP events described in Section 5.4. The dimensionless rainfall distribution used with the HMR51 PMP depths was obtained from Figure 21-9 in Chapter 21, Part 630 of the National Engineering Handbook (NRCS, 2019) and is shown on **Figure D-1-23**.

The dimensionless rainfall distributions used for the PMP depths associated with the updated statewide PMP study that is currently ongoing for the state of North Dakota were developed as part of that study. Rainfall distributions were developed based on historic PMP storm events. There are three distributions that were tested for this analysis including a synthetic distribution, a distribution representative of storms that produced a higher percentage of rainfall in the early stages of the storm (known as the 90th percentile distribution), and a distribution representative of storms that produced a higher percentage of rainfall in the latter stages of the storm (known as the 10th percentile distribution). The distribution that produced the highest peak inflow and outflow for Bylin Dam was determined to be the 10th percentile distribution for both the general and local PMP storms. The 10th percentile distribution for the 6-hour local storm is shown on **Figure D-1-23**. Any additional precipitation encountered for the longer duration events was added uniformly to the beginning and the end of the distribution. More information on these distributions will be provided when documentation for the statewide PMP study is completed.

Based on the guidance provided in *TR 210-60,* a short duration storm should be used to check the stability of vegetated auxiliary spillways. Therefore, durations of 6-hours and 24-hours were simulated with PMP depths from HMR51 and durations of 6-, 12-, and 24-hours were simulated with local storm PMP depths from the statewide PMP study. The storms produced from the different PMP sources and durations were simulated in the HEC-HMS model to develop inflow hydrographs at Bylin Dam for the stability design hydrograph. The resultant inflows to the dam were input into the SITES program and adequacy of the auxiliary spillway was evaluated (See Section 7). The inflow hydrographs to Bylin Dam for the three durations relevant to the auxiliary spillway hydrograph are shown on **Figure D-1-24**. The peak inflow to Bylin Dam is listed in **Table D-1-10**.

Table D-1-10: *Auxiliary Spillway Inflow Hydrograph Data*

PMP Source	Duration	Maximum Rainfall Depth (in)	Peak Inflow to Bylin (cfs)
HMR 51	6 – hour	9.34	7,812
	24 – hour	10.89	6,498
ND – Local	6 – hour	8.46	6,957
	12 – hour	9.45	7,669
	24 – hour	9.49	7,304

5.5.3 FREEBOARD INFLOW HYDROGRAPH

The minimum design event for the freeboard hydrograph (FBH) associated with a high hazard dam is defined by *TR 210-60* as the probable maximum precipitation event described in Section 5.4. The duration of the FBH was developed based on guidance from *TR 210-60*. That guidance states that both the 6- and 24-hour storm durations shall be analyzed, and *NEH, Part 630, Chapter 21* states that a storm duration equal to or greater than the time of concentration shall be analyzed. The time of concentration for the watershed upstream of Bylin Dam is approximately 7.4 hours. For this analysis, durations beyond the time of concentration for the watershed upstream of the dam were analyzed, and the most critical duration was evaluated for spillway adequacy. 24-hour curve numbers with an average antecedent moisture condition (AMC II) were used to simulate the events.

Four durations were analyzed using PMP depths obtained from HMR51. The four durations analyzed were the 6-, 24-, 48-, and 72-hour PMP events. The rainfall distribution used for each of those events was a SCS Type II distribution. This is a conservative distribution that is representative of distributions that have been used to simulate PMP events in the past. The SCS Type II distribution yields a similar result when compared to the NRCS's 5-point distribution described in Section 3 of Chapter 21, Part 630 in the National Engineering Handbook (NRCS, 2019), but can be easily applied to each of the durations being analyzed. The SCS Type II rainfall distribution is shown in **Figure D-1-25**.

Three durations were analyzed for the local storm PMP depths obtained from the updated statewide PMP study for North Dakota including the 6-, 12-, and 24-hour durations. The rainfall distribution used to analyze the local storms was also developed from the statewide PMP study and was described in Section 5.5.2. The rainfall distribution that produced the highest peak inflow to Bylin Dam was the distribution that represented storms that produced a higher percentage of the total depth in the latter part of the event (10^{th} percentile distribution). The 10^{th} percentile distribution for the 6-hour local storm is shown on **Figure D-1-23**. Additional precipitation for the longer duration events was added uniformly to the beginning and the end of the distribution. The 24-hour distribution used for the local storm PMP event is shown in **Figure D-1-25**.

Three durations were analyzed for the general storm PMP depths obtained from the updated statewide PMP study for North Dakota including the 24-, 48-, and 72-hour durations. The rainfall distribution used to analyze the general storms was also developed from the statewide PMP study. Similar to the local storm PMP, the 10^{th} percentile distribution produced the highest peak inflow into Bylin Dam for the general storm PMP event when compared to the synthetic and 90^{th} percentile distributions. Therefore, the 10^{th} percentile distribution was used to simulate the general storm PMP events. Additional precipitation for the longer duration events was added uniformly to the beginning and the end of the distribution. The 24-hour distribution used for the general storm PMP event is shown in **Figure D-1-25**.

The maximum PMP precipitation depth for each of the durations simulated is shown in **Table D-1-11** along with the peak inflow to Bylin Dam. The resultant inflow hydrographs to the dam were input into the SITES program and adequacy of the auxiliary spillway was evaluated (See Section 7). The inflow hydrographs to Bylin Dam for all durations and storm types that were analyzed relevant to the freeboard hydrograph are shown on **Figure D-1-26**.

Table D-1-11: *Freeboard Inflow Hydrograph Data*

PMP Source	Duration	Maximum Rainfall Depth (in)	Peak Inflow to Bylin (cfs)
HMR 51	6 – hour	21.20	22,497
	24 – hour	27.02	24,459
	48 – hour	29.11	23,151
	72 – hour	30.27	20,866
ND – Local	6 – hour	17.83	18,059
	12 – hour	21.55	21,314
	24 – hour	21.64	20,361
ND - General	24 – hour	19.48	12,922
	48 – hour	20.22	13,043
	72 – hour	20.28	13,102

6 GEOLOGIC INVESTIGATION

A geologic investigation was conducted by Gannett Fleming, Inc. The purpose of the geologic investigation was to develop subsurface profiles and geotechnical data for evaluation of the spillway integrity and for characterization of the embankment and foundation soils. The Geotechnical Engineering Report is provided in **Appendix D-2**.

Soil borings were done at six different locations for Bylin Dam. Several laboratory tests were conducted on soil samples obtained from the soil borings. The tests performed include tests for moisture content, unit weight, soil strength, and several others. A map showing the location of each soil boring is displayed in **Appendix D-2** along with the results of the laboratory tests conducted and the general findings from the geotechnical exploration.

Geotechnical analyses were performed based on the data obtained from the geotechnical exploration. The analyses completed included the SITES analysis (see Section 7.1 for more information on inputs for the SITES program), drain fill compatibility analysis, seepage analysis, and slope stability analysis.

The compatibility analysis completed for the foundation drain fill indicates that the existing fill material does not meet state-of-the-practice gradation criteria for seepage control/conveyance. Gradational analyses show that the existing drain fill is too coarse to provide adequate filtration. The North Dakota Department of Transportation (NDDOT) fine aggregate would be a more appropriate foundation drain fill material during any future rehabilitation efforts.

Seepage analyses through the dam embankment were performed to estimate the phreatic surface in the embankment during normal pool and flood surcharge pool levels for the purpose of evaluating slope stability. Shear strength tests were also completed to accurately predict slope stability of the embankment at Bylin Dam. Model results indicate that the dam meets current *TR 210-60* requirements for normal pool and rapid drawdown conditions, however, the dam does not meet the current requirements for the flood surcharge pool. Calculated factor of safety values and required minimum factor of safety values are shown in Table 15 in the Geotechnical Engineering Report located in **Appendix D-2**. Recommendations for resolving issues related to the flood surcharge slope stability condition are also provided in **Appendix D-2**.

7 SPILLWAY ADEQUACY

Spillway adequacy for Bylin Dam was evaluated using the NRCS's Water Resources Site Analysis Computer Program (USDA and Kansas State University, 2014), which is commonly referred to as SITES. Model inputs for the principal and auxiliary spillways for Bylin Dam were implemented and the spillways were analyzed to determine if they are able to pass the design hydrographs with sufficient capacity, stability, and integrity.

7.1 SITES MODEL INPUTS

Various inputs are required before the analysis of the principal and auxiliary spillways can be conducted. The elevation-storage relationship in the reservoir upstream of Bylin Dam (see Section 2.3.2) was implemented into the SITES model. Inflow design hydrographs discussed in Section 5.5 were also used in the SITES model for the various design events. Inputs for the geometry of the principal and auxiliary spillways of Bylin Dam are discussed in the following sub-sections. Input information for the critical principal spillway, stability design, and freeboard design events can also be found in **Attachment D-1-4**.

7.1.1 PRINCIPAL SPILLWAY INPUTS

The principal spillway for Bylin Dam is a two-stage concrete riser tower. The riser tower consists of a 1.5-foot by 2.5-foot rectangular orifice opening for the first stage and an overflow weir that is approximately 31 feet in length for the second stage. Elevations of the orifice and overflow weir elevation of the riser tower were collected during the survey of the structure in the summer of 2020. The size of the orifice and overflow weir were determined from as-built drawings and verified by survey data. Information on the conduit going from the riser tower through the embankment and to the outlet of the structure was also entered. The length of the conduit was determined from as-built drawings and verified by aerial imagery. The conduit size was also determined from as-built drawings and was verified by survey in the field. The elevation of the conduit is based on survey data collected in the summer of 2020.

After all elements of the principal spillway were entered into the SITES program, an output stage-discharge curve for the principal spillway was produced. The resulting stage-discharge relationship for the principal spillway riser tower at Bylin Dam is shown in **Figure D-1-27**.

7.1.2 AUXILIARY SPILLWAY INPUTS

The auxiliary spillway for Bylin Dam is an earthen channel that runs along the south side of the embankment. The spillway consists of a 300-foot bottom width, 3 to 1 channel side slopes, and has an exit slope of approximately 10% downstream of the crest. The resulting stage-discharge relationship for the auxiliary spillway at Bylin Dam is shown in **Figure D-1-27**. Survey data of the auxiliary spillway was used to develop a surface profile of the spillway. The profile of the auxiliary spillway of Bylin Dam is provided in **Figure D-1-28**.

During the geologic investigation at Bylin Dam, three soil borings were collected in the auxiliary spillway. Soil boring BD2020-212 was located approximately 191 feet upstream of the auxiliary spillway crest. Soil borings BD2020-213 and BD2020-214 (a map of all soil boring locations is provided in **Appendix D-2**) were drilled on the inside and outside edge of the existing spillway near the crest (control section). There are three geologic materials associated with the three soil borings located in the auxiliary spillway. The materials and their associated parameters are shown in **Table D-1-12**. The material parameters shown in **Table D-1-12** were developed based on laboratory test data and correlation with published values. Calculations for all parameters are included in the *Geotechnical Engineering Report* prepared by Gannett Fleming Inc., which is provided in **Appendix D-2**.

Table D-1-12: *Assumed Parameters for Auxiliary Spillway Integrity Analysis*

Material Description	Dry Density (lb/ft^3)	Headcut Index (K_h)	Percent Clay (%)	Plasticity Index	D_{75}/Rep. Diameter (mm)
Overburden	80	0.08	17.7	17	0.32
Pierre Shale “Weathered” (Clay)	95	0.19	40.9	23	0.04
Pierre Shale “Unweathered” (Rock)	90	1.8	-	-	34.9 to 6

A sensitivity analysis was completed to determine which of the two soil borings, either BD2020-213 or BD2020-214, would cause less stability of the auxiliary spillway. The soil boring that causes less stability for the auxiliary spillway was used for the analysis in an attempt to simulate the most conservative scenario. It was determined that BD2020-213 would cause more stability issues associated with the spillway, therefore, that boring was used for the integrity and stability analysis of the spillway. The geologic profile of the auxiliary spillway materials used for the analysis is shown in **Figure D-1-28**.

7.2 PRINCIPAL SPILLWAY RESULTS

The principal spillway hydrologic criteria for a high hazard dam is a 10-day, 100-year event. The rainfall and runoff events simulated were described in Section 5.5. To pass the criteria, the dam must be able to pass the design event without activation of the auxiliary spillway. Based on the results from the SITES analysis, the principal spillway hydrograph that would result in the highest auxiliary crest elevation is the runoff volume maps procedure with incremental runoff depths occurring in an increasing order (Curve B) from **Figure D-1-21**.

According to *TR 210-60*, the principal spillway capacity should empty at least 85 percent of the principal spillway hydrograph routed through the retarding pool in 10 days or less. If more than 15 percent of the retarding storage volume remains after 10 days, the elevation of the crest of the auxiliary spillway should be raised by adding the volume remaining after 10 days to the initial retarding storage volume to determine the raised auxiliary spillway crest elevation. The SITES program automates this process and the results reported reflect the additional storage needed to account for the 10-day drawdown requirements outlined *TR 210-60*.

The amount of time required to empty 85 percent of the volume associated with each of the principal spillway hydrographs is provided in **Table D-1-13**. The 10-day drawdown requirement is not met for any of the principal spillway hydrographs that were simulated, therefore, the volume remaining after 10 days is added to the initial retarding storage volume for all principal spillway hydrographs. The auxiliary spillway crest would need to be raised approximately 6 feet to pass the most critical principal spillway hydrograph. The existing auxiliary spillway elevation and the resulting required spillway elevations for the various principal spillway inflow hydrographs are presented in **Table D-1-13**.

Table D-1-13: *Principal Spillway Hydrograph SITES Output*

Parameter	Existing Condition	SITES Analysis Output for 100-year PSH Events			
		Runoff Volume Maps – Curve A	Runoff Volume Maps – Curve B	Runoff Volume Maps – Curve C	Rainfall with Runoff CN Procedure (10-day)
Required Auxiliary Spillway Crest Elevation (feet, NAVD88)	1,518.6	1,522.2	1,525.9	1,525.0	1,517.7
Time to Drawdown 85% of Flood Storage (days)	-	21.4	19.9	21.0	19.0
Required Flood Storage Volume (Acre-feet)		3,847.3	4,266.4	4,163.0	3,322.3
Amount Auxiliary Spillway Crest Needs to be Raised (feet)	-	3.6	7.3	6.4	0.0

7.3 AUXILIARY SPILLWAY RESULTS

Based on *TR 210-60* criteria, the auxiliary spillways of earthen dams should be analyzed for discharge capacity, stability (surface erosion potential), and integrity (breaching potential). The freeboard hydrograph is used to analyze the capacity and integrity of the dam. The design event for the freeboard hydrograph of a high hazard dam is a probable maximum precipitation event, which produces the probable maximum flood (PMF). The stability design hydrograph is used to assess the stability, or surface erosion potential, of the dam. The design event for the stability design hydrograph is a percentage of the PMP event. Hydrologic criteria for the auxiliary spillway events are discussed in Section 5.5 and a summary of the criteria used to size a high hazard dam is presented in **Table D-1-8**. The results of the various scenarios simulated using the SITES program are presented in the following sub-sections.

7.3.1 AUXILIARY SPILLWAY CAPACITY

To pass the auxiliary spillway capacity criteria described in *TR 210-60*, the dam must be able to pass the PMF through the principal spillway structure and the auxiliary spillway without overtopping the dam. Durations of 6-hours through 72-hours were simulated using PMP depths from HMR51 and using both local and general storm PMP depths obtained from the statewide PMP study for North Dakota. Results for the existing top of dam elevation and required top of dam elevation with PMP depths from all scenarios described are presented in **Table D-1-14**.

The results show that the 12-hour local storm PMP event is the controlling duration and storm type for all events considered from the statewide PMP study for North Dakota. The dam would need to be raised approximately 3.4 feet to pass the 12-hour local storm PMP event. The required top of dam elevation is higher when considering the 48-hour PMP event using depths from HMR51. Results from the analysis completed using the HMR51 depths was included for comparison purposes, however, the methods used to produce the HMR51 storm are considered obsolete. Therefore, the PMP depths that were developed through the recent study that utilized state of the practice methods to develop PMP estimates was used for this study. The HMR51 PMP depths will not be used in future analyses for this structure.

Table D-1-14: *Freeboard Hydrograph SITES Output*

Parameter	Existing Condition	HMR51				Local Storm PMP			General Storm PMP		
		6 hour	24 hour	48 hour	72 hour	6 hour	12 hour	24 hour	24 hour	48 hour	72 hour
Peak Inflow (cfs)	-	22,497	24,459	23,151	20,866	18,059	21,314	20,361	12,922	13,043	13,102
Peak Outflow (cfs)	-	21,036	23,261	22,206	20,151	16,797	20,208	19,291	12,731	12,859	12,706
Required Top of Dam Elevation (feet, NAVD88)	1,523.8	1,527.5	1,528.1	1,527.8	1527.2	1,526.2	1,527.2	1,527.0	1,524.9	1,525.0	1,524.9
Required Rise of Crest Elevation to Pass FBH (feet)	-	3.7	4.3	4.0	0.5	2.4	3.4	3.2	1.1	1.2	1.1

7.3.2 AUXILIARY SPILLWAY STABILITY

According to *TR 210-60*, a short-duration storm should be used to check the stability of vegetated auxiliary spillways. The stability of the auxiliary spillway for Bylin Dam was evaluated using the stability design hydrograph that utilized the 6-hour local storm PMP event from the statewide PMP study described previously (see Section 5.5.2 for information on the stability design inflow hydrograph). *TR 210-60* states that no damage should occur to vegetated spillways during passage of all flows up to the auxiliary spillway hydrograph (also known as the stability design hydrograph).

The soil and vegetal stress of the auxiliary spillway were analyzed to determine the overall stability of the auxiliary spillway. Properties of the topsoil, vegetation of the auxiliary spillway, and output shear stress information from the SITES program were used to calculate the stability of the auxiliary spillway. A spreadsheet made available by NRCS staff was used to develop the stress stability analysis. The spreadsheet uses criteria outlined in *TR 210-60* and concepts from Chapter 3 of the Agricultural Handbook Number 667 (Temple, Robinson, Ahring, & Davis, 1987) to develop allowable soil and vegetal stresses in the auxiliary spillway. **Table D-1-15** below shows the allowable soil and vegetal stresses associated with the auxiliary spillway at Bylin Dam and it shows the resultant stresses obtained from the SITES program. Overall, the auxiliary spillway for Bylin Dam is considered unstable because the stresses produced during the stability design hydrograph are greater than the allowable stresses. The inputs used to compute allowable stresses and the SITES program outputs for the 12-hour local storm event are provided in **Attachment D-1-4**.

Table D-1-15: *Auxiliary Spillway Stability Analysis for Soil and Vegetal Stresses*

Analysis Type	Allowable Stress	SITES 6-HR SDH Stress	Conclusion
Soil Stress	0.065 psf	1.304 psf	Soil Erodes
Vegetal Stress	4.20 psf	11.82 psf	Vegetation Erodes

7.3.3 AUXILIARY SPILLWAY INTEGRITY

TR 210-60 requires that the auxiliary spillway pass the freeboard design hydrograph without breaching the control section of the auxiliary spillway. Based on the geologic profile and parameters described in Section 7.1.2, the SITES auxiliary spillway analysis shows that the auxiliary spillway will completely breach during passage of the freeboard hydrograph. **Figure D-1-29** shows the eroded portion of the spillway during the freeboard hydrograph corresponding to the 12-hour local storm PMP event. The headcut produced during the freeboard hydrograph is approximately 57 feet deep. The auxiliary spillway integrity was evaluated for all storm types and durations that were used to develop the freeboard hydrographs for this analysis. The SITES analysis showed that the spillway would breach for all scenarios simulated. The results of the SITES analysis for the 12-hour local storm event are provided in **Attachment D-1-4**.

7.4 SUMMARY OF IDENTIFIED DEFICIENCIES

7.4.1 PRINCIPAL SPILLWAY

The principal spillway for Bylin Dam does not meet the criteria provided in *TR 210-60*. The results from the analysis indicates that the auxiliary spillway crest would need to be raised by approximately 6 feet to pass the principal spillway hydrograph. When the principal spillway hydrograph is routed through Bylin Dam with the reservoir starting at normal pool elevation the peak reservoir stage does not reach the auxiliary spillway. However, because the principal spillway does not adequately draw down the reservoir in 10 days, the additional storage that remains in the reservoir needs to be added to the peak storage. Therefore, the analysis shows that the current principal spillway is not adequate and raising the auxiliary spillway would be required for Bylin Dam.

The principal spillway outlet works could be modified to increase the discharge capacity through the spillway on the rising limb of the hydrograph and decrease draw down time on the trailing limb of the hydrograph. This is typically not looked upon favorably by residents downstream of the dam as it would cause increased discharge and inundation downstream of the dam. A review of potential downstream impacts with the modified principal spillway outlet works would be necessary before determining the appropriate alternative.

According to *TR 210-60*, if a structural auxiliary spillway is implemented for the dam (possibly to address instability issues associated with the earthen spillway), it could serve a dual purpose as a principal spillway. Therefore, the principal spillway would no longer be required to pass the principal spillway hydrograph without accessing the auxiliary spillway.

7.4.2 AUXILIARY SPILLWAY

The auxiliary spillway capacity is not sufficient to pass the freeboard hydrograph for Bylin Dam. The SITES analysis shows that if the width of the auxiliary spillway remains unchanged the dam would have to be raised a minimum of 3.4 feet. Widening the spillway to increase capacity would likely be a more feasible option rather than raising the dam.

The auxiliary spillway is considered unstable based on criteria outlined in *TR 210-60*. The soil stress and vegetal stress encountered in the spillway during passage of the stability design hydrograph exceed the allowable soil and vegetal stresses for the spillway. Widening the spillway would reduce flow depth and consequently reduce stresses on the spillway. Raising the auxiliary spillway would reduce the frequency with which the spillway is accessed and would cause reduced depths and stresses on the spillway surface. However, raising the spillway may cause an adverse impact to the auxiliary spillway capacity during passage of the freeboard hydrograph. Reducing the auxiliary spillway slope near the outlet may also help to improve the stability in the auxiliary spillway channel. The current slope of the auxiliary spillway channel near the outlet is greater than 25%. Another solution to improving the stability of the auxiliary spillway is to implement a structural spillway design. This would prevent surface erosion and would not require drastic changes to the spillway layout.

The auxiliary spillway integrity is not sufficient to pass the freeboard hydrograph without breaching. Several different PMP storm durations and storm types were simulated and each one caused the auxiliary spillway to breach in the SITES model. One potential mitigation option to reduce shear stress and spillway erosion is to widen the auxiliary spillway. Another option would be to raise the auxiliary spillway elevation, which would cause the top of dam elevation to be raised even higher than what was discussed previously causing decreased access to the spillway during these large rainfall/runoff events. However, raising the dam to the extent necessary to reduce auxiliary spillway erosion would likely be an expensive alternative. The implementation of a structural spillway is a solution that was mentioned for improving auxiliary spillway stability and would also help to prevent headcut erosion in the auxiliary spillway to improve the spillway integrity.

Structural auxiliary spillways have been installed for many NRCS dams in recent years. Roller compacted concrete in the auxiliary spillway has been a popular option for dam rehabilitations throughout the country. Articulated concrete blocks have also been implemented to reduce the likelihood of a dam failure during passage of the freeboard hydrograph. These are just a few examples of structural auxiliary spillway options that could be evaluated in the future.

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FIGURES

Figure D-1-6: Bylin Dam Elevation-Storage Relationship

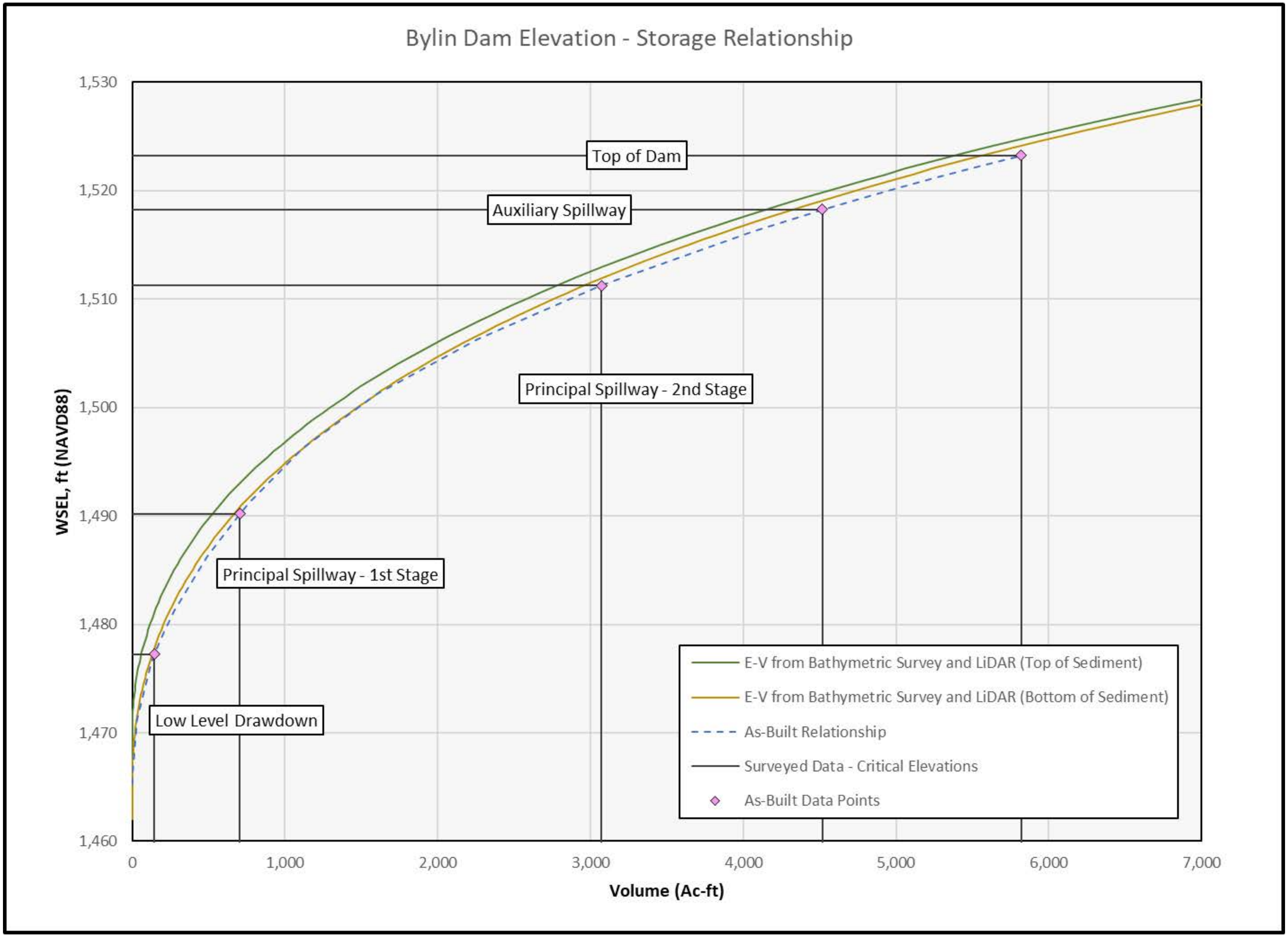


***Figure D-1-7**: Bylin Dam Breach Outflow Hydrograph*

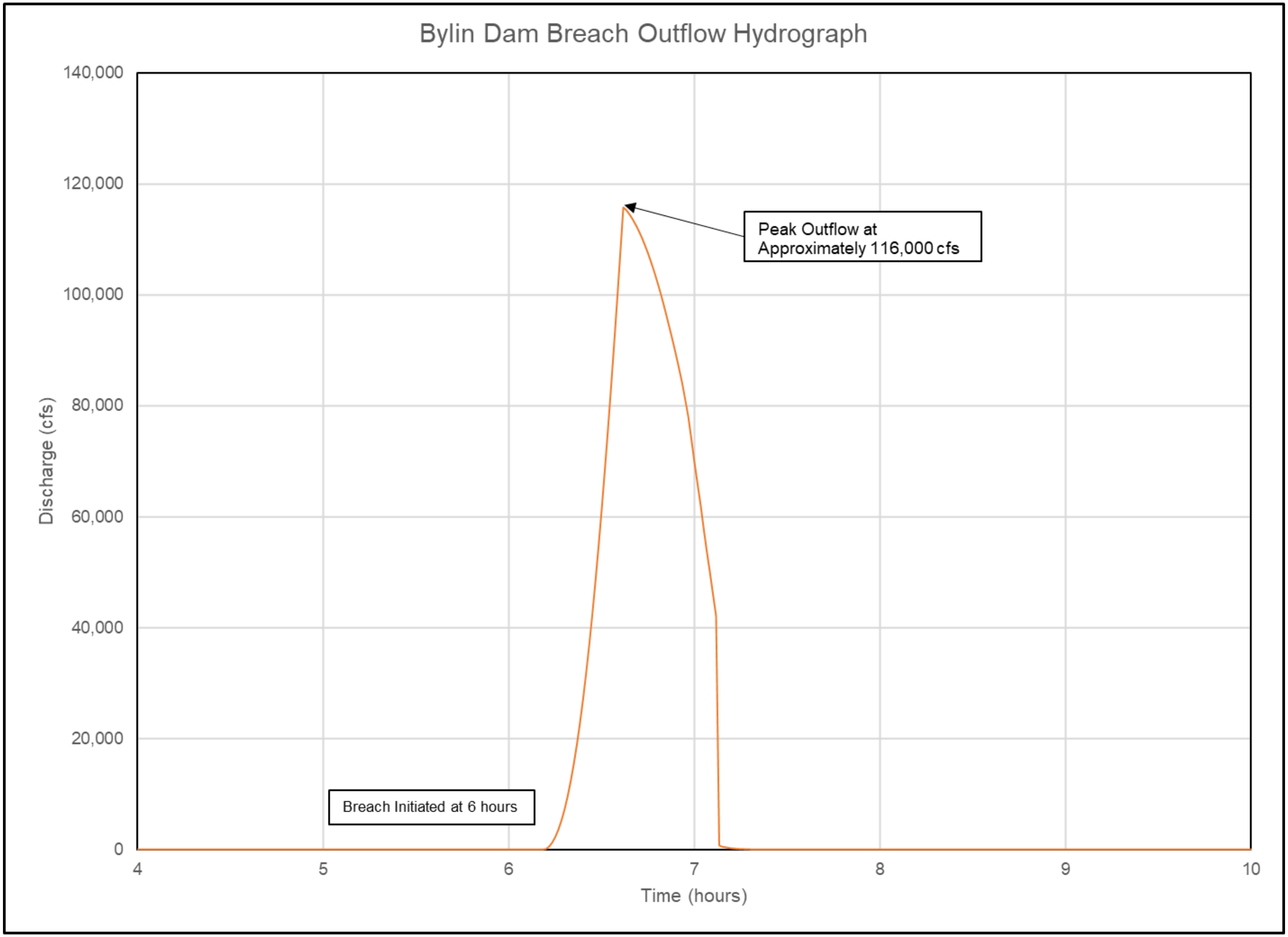


***Figure D-1-13**: Depth-Velocity-Flood Danger Level Relationship for Houses Built on Foundations Downstream of Bylin Dam*

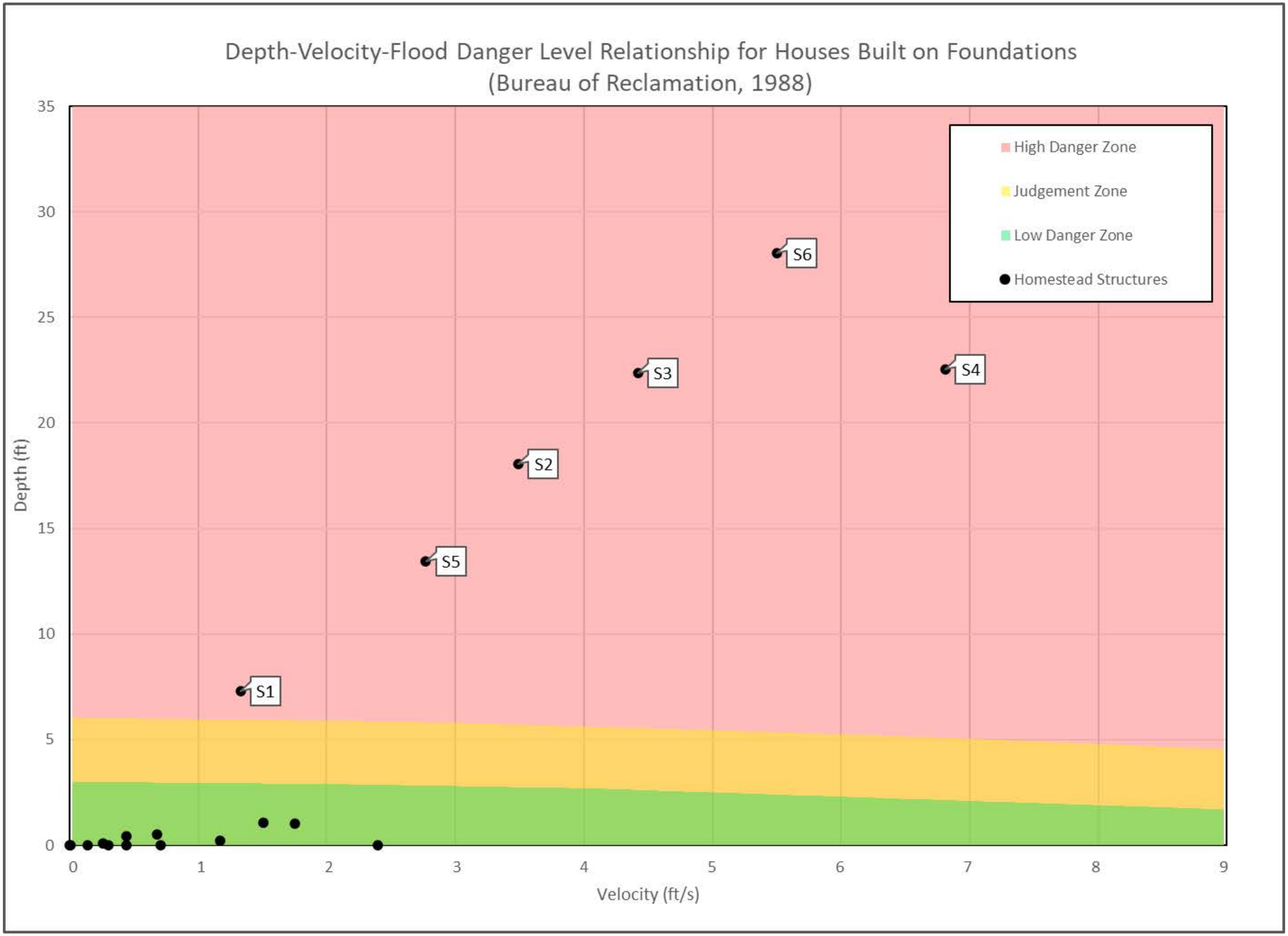


***Figure D-1-14**: Depth-Velocity-Flood Danger Level Relationship for Passenger Vehicles*

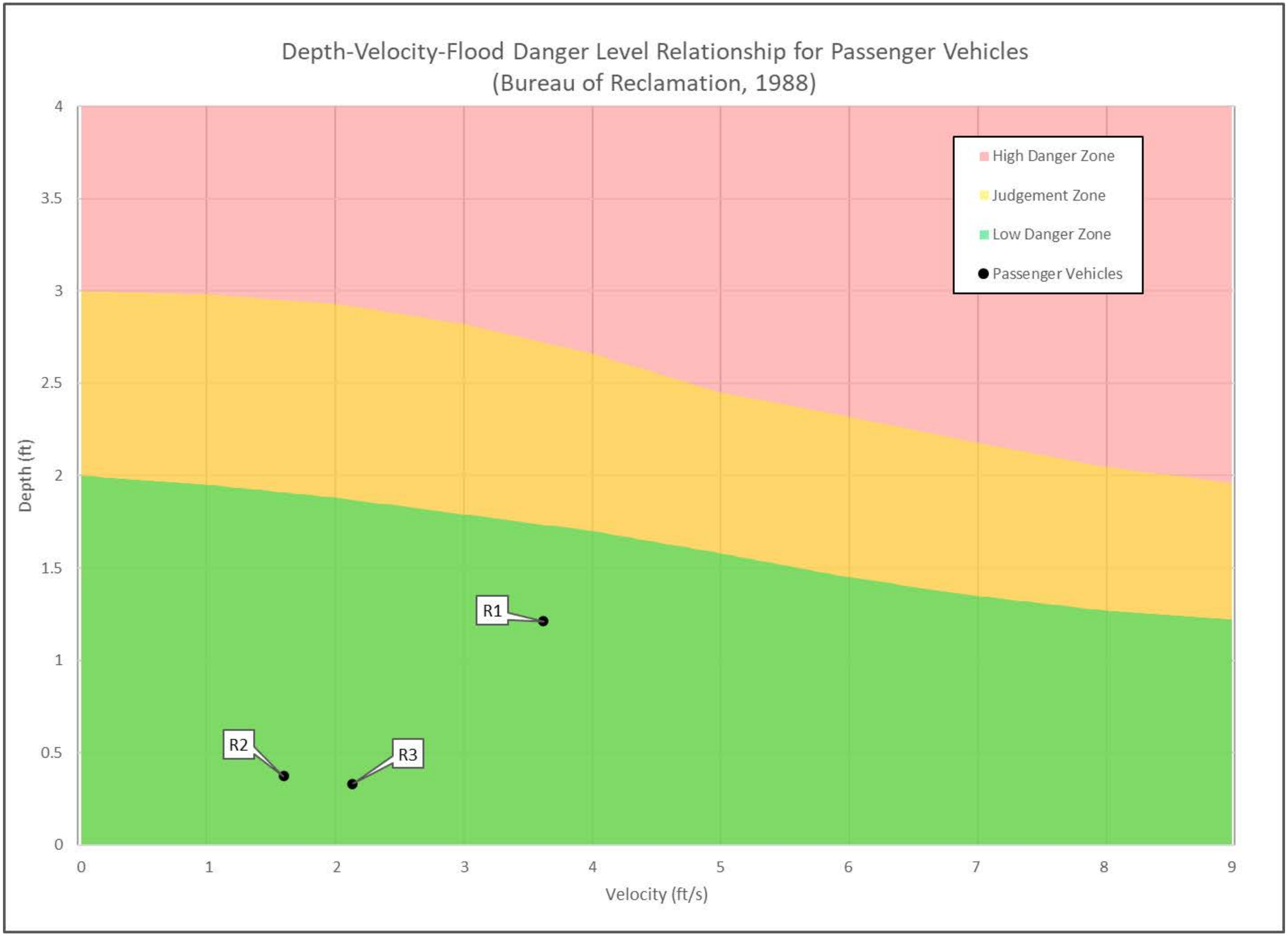


***Figure D-1-18**: 2016 Historic Event – Peak Discharge near Fordville, ND (USGS Gage 05084000)*

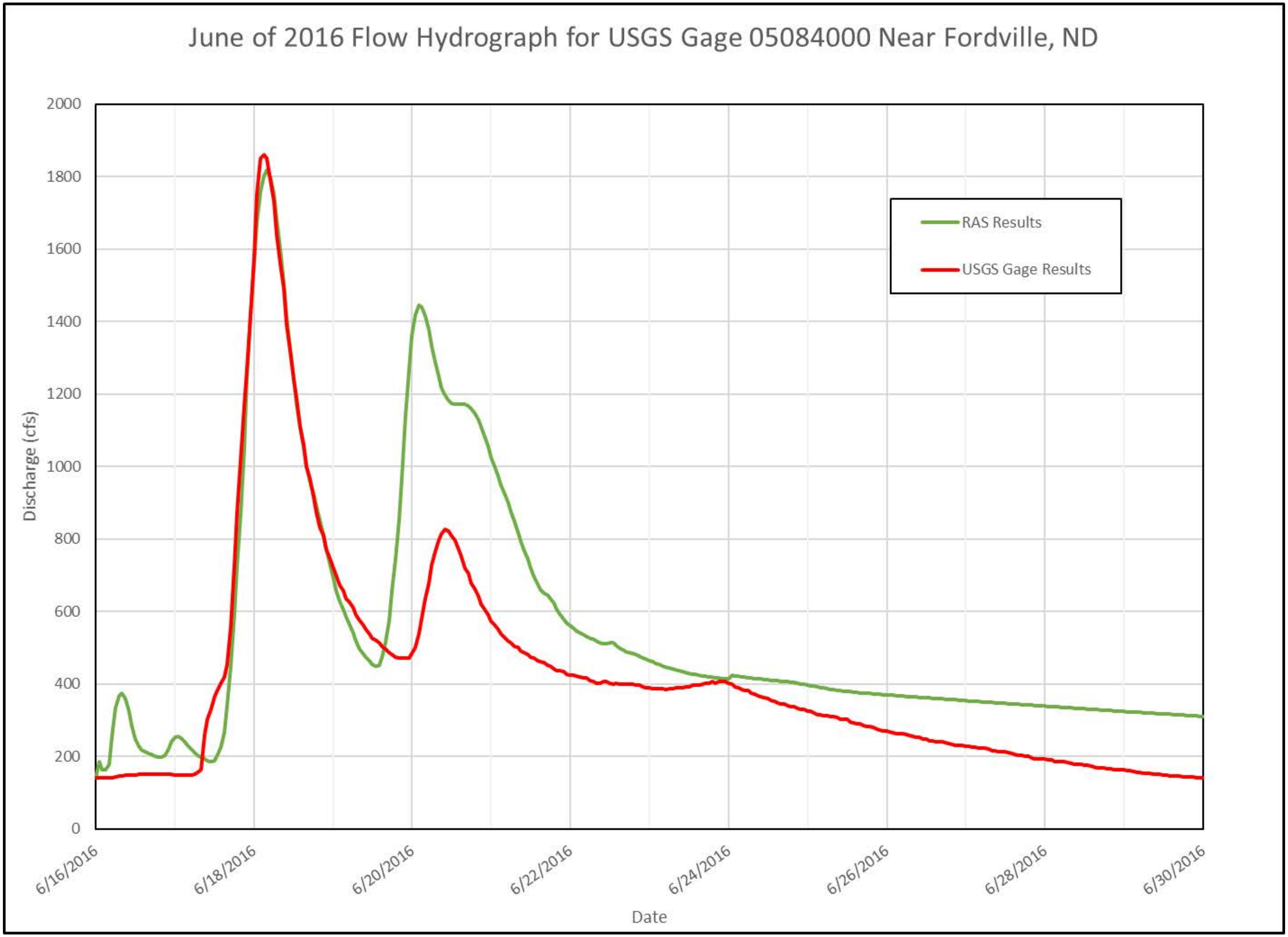


Figure D-1-20: 2010 Historic Event – Peak Discharge near Fordville, ND (USGS Gage 05084000)

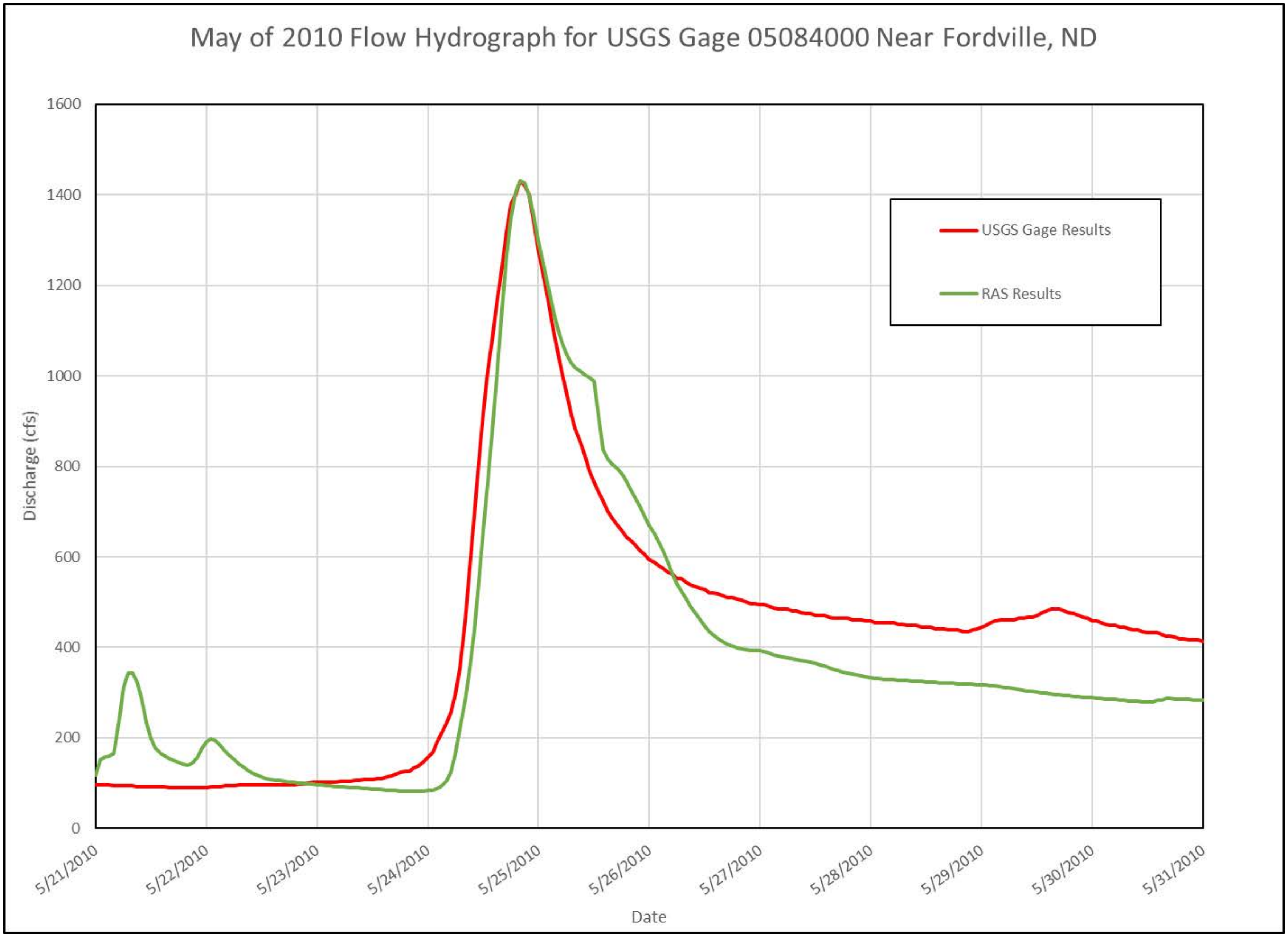


***Figure D-1-21**: Principal Spillway Mass Curves for Runoff Volume*

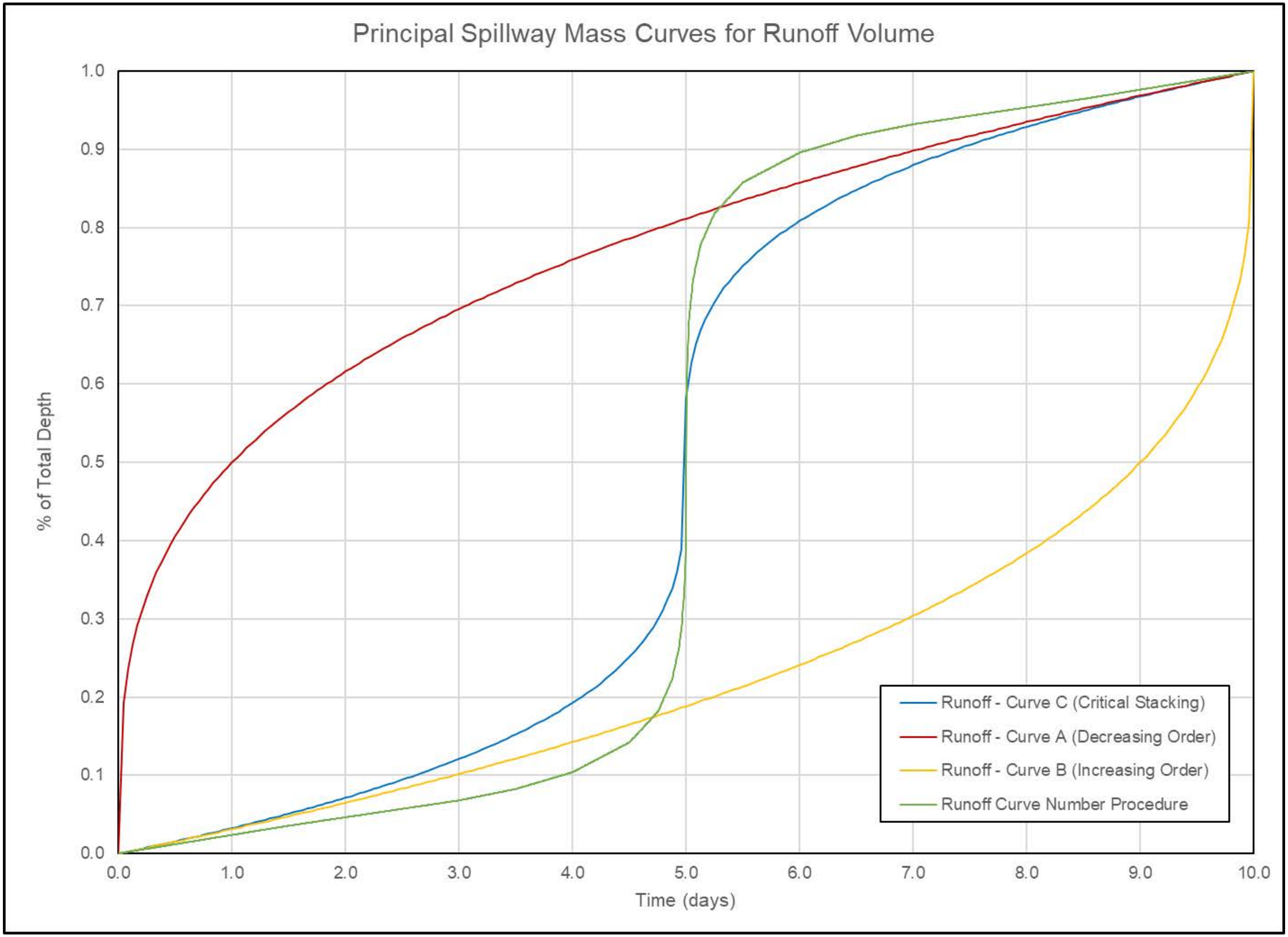


***Figure D-1-22**: Principal Spillway Inflow Hydrographs*

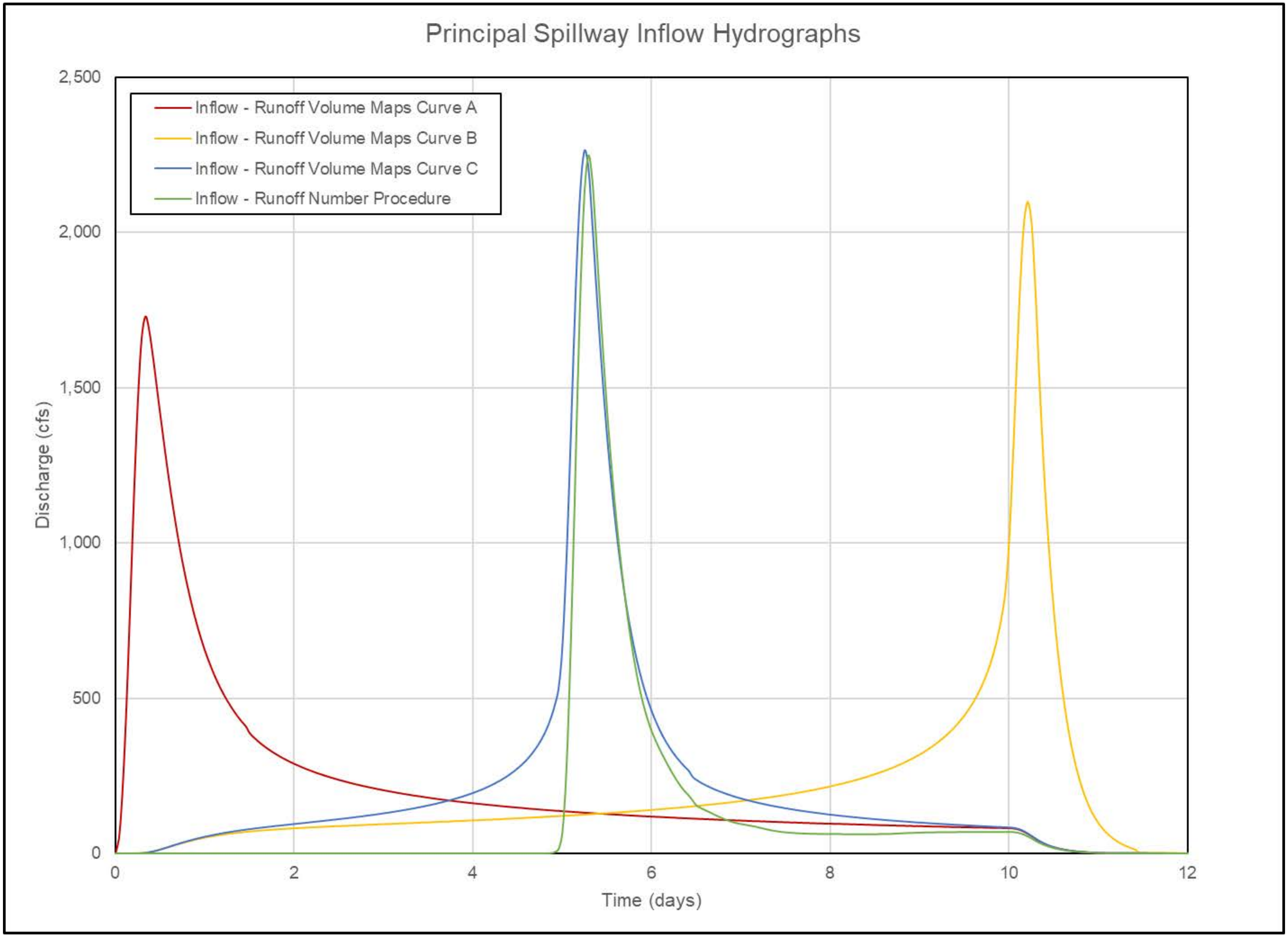


***Figure D-1-23**: Stability Design Mass Curves*

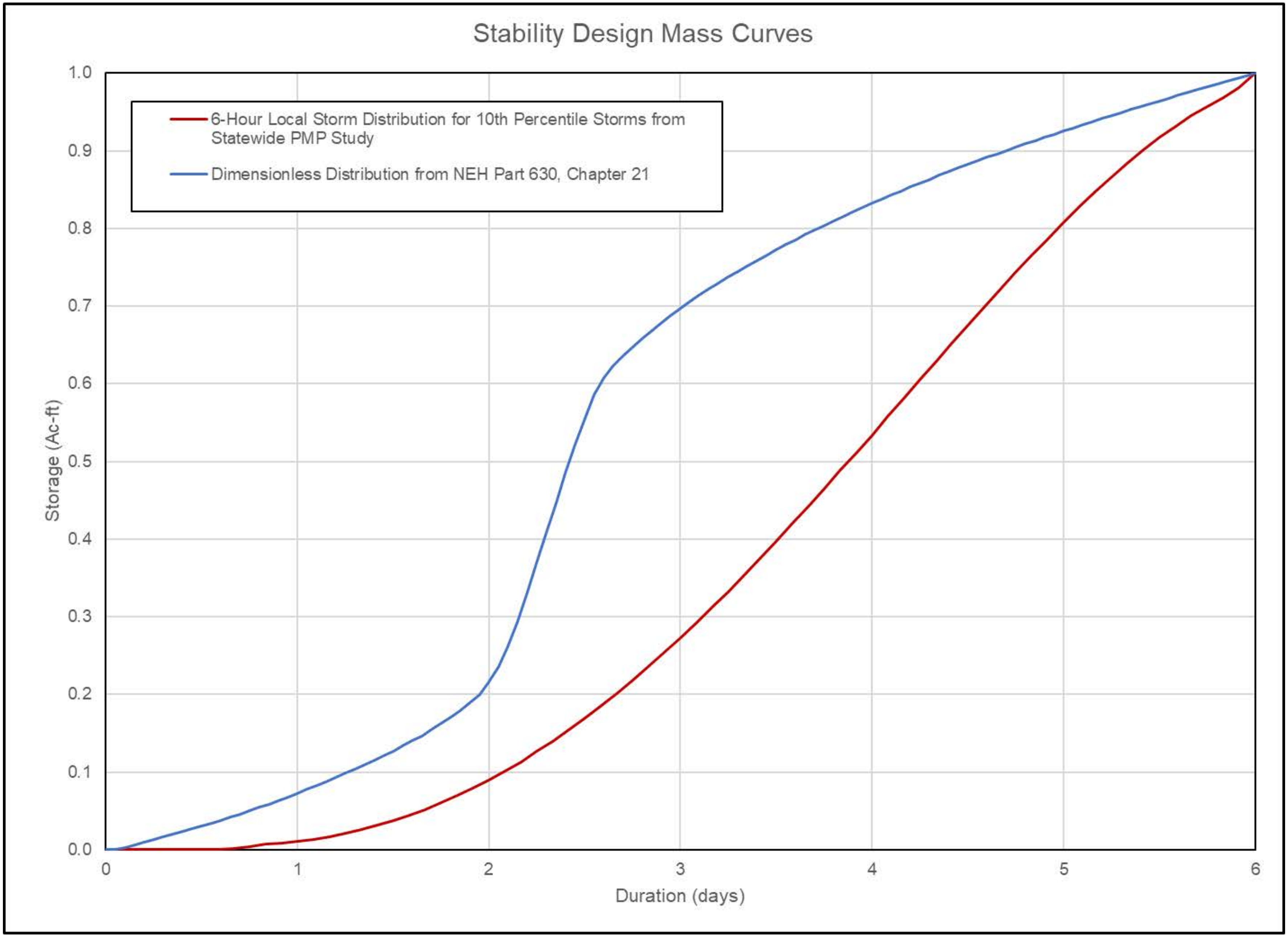


***Figure D-1-24**: Stability Design Inflow Hydrograph*

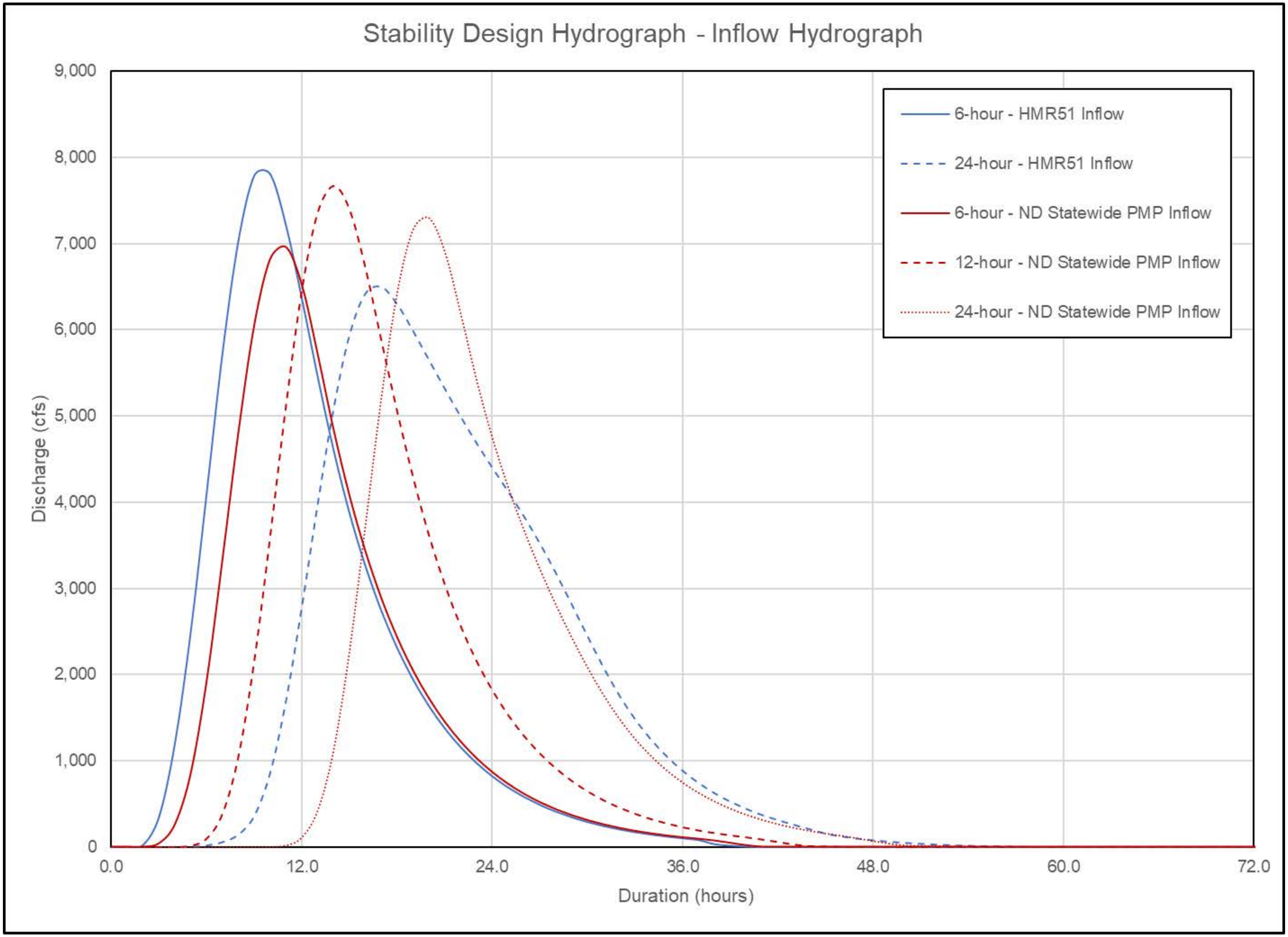


***Figure D-1-25**: Freeboard Design Mass Curves*

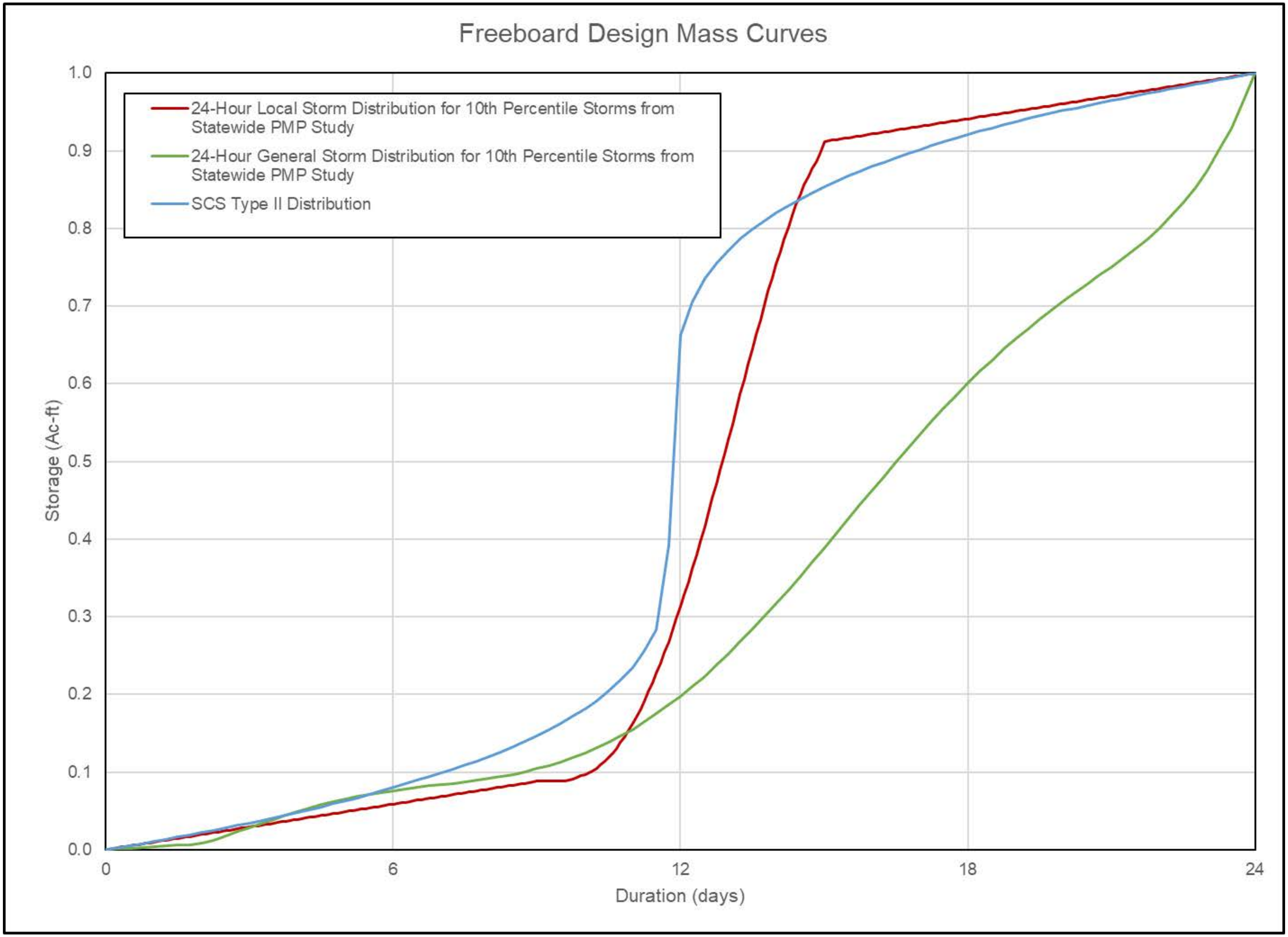


***Figure D-1-26**: Freeboard Design Inflow Hydrographs*

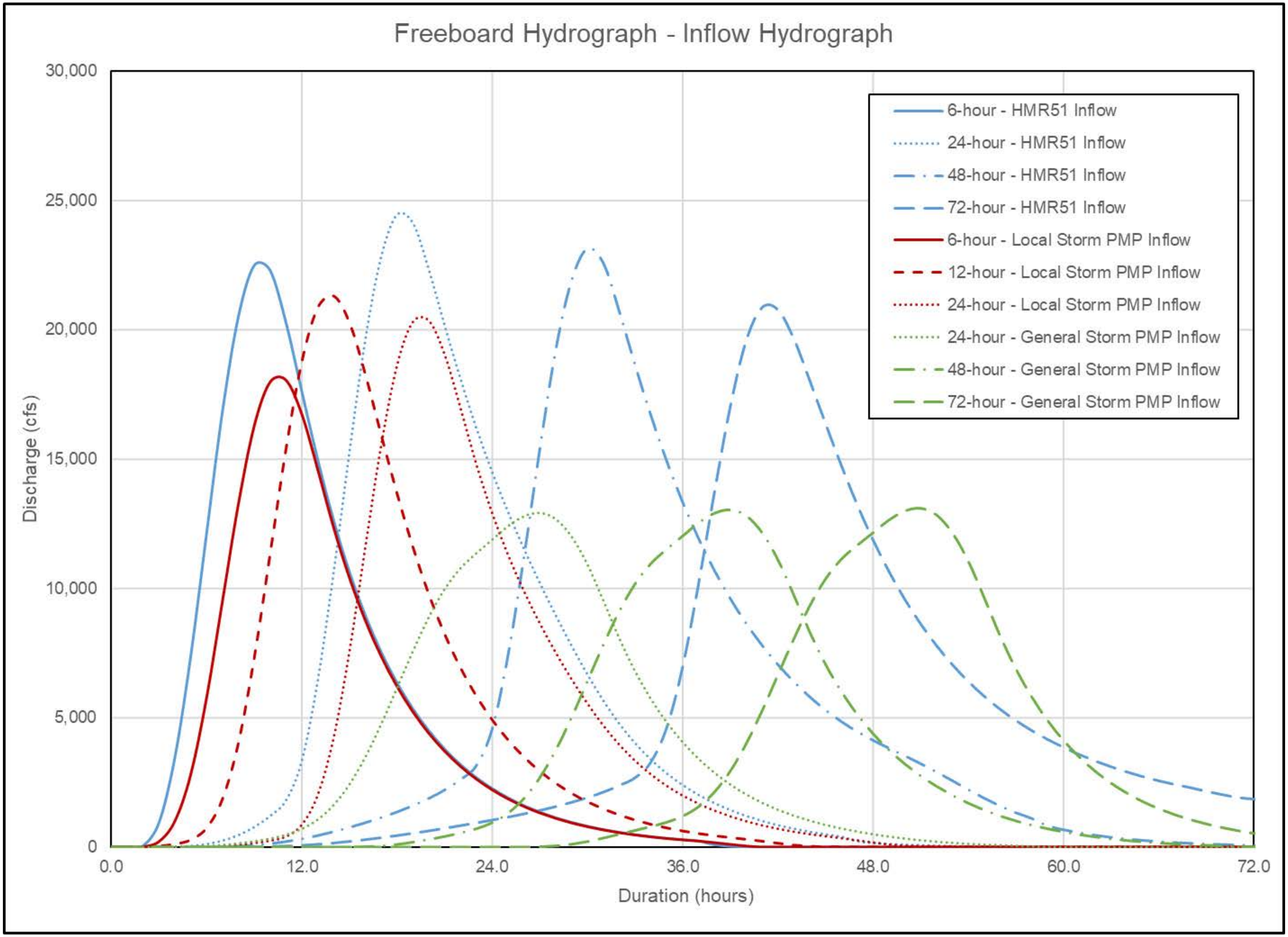


***Figure D-1-27**: Bylin Dam Elevation-Discharge Relationship*

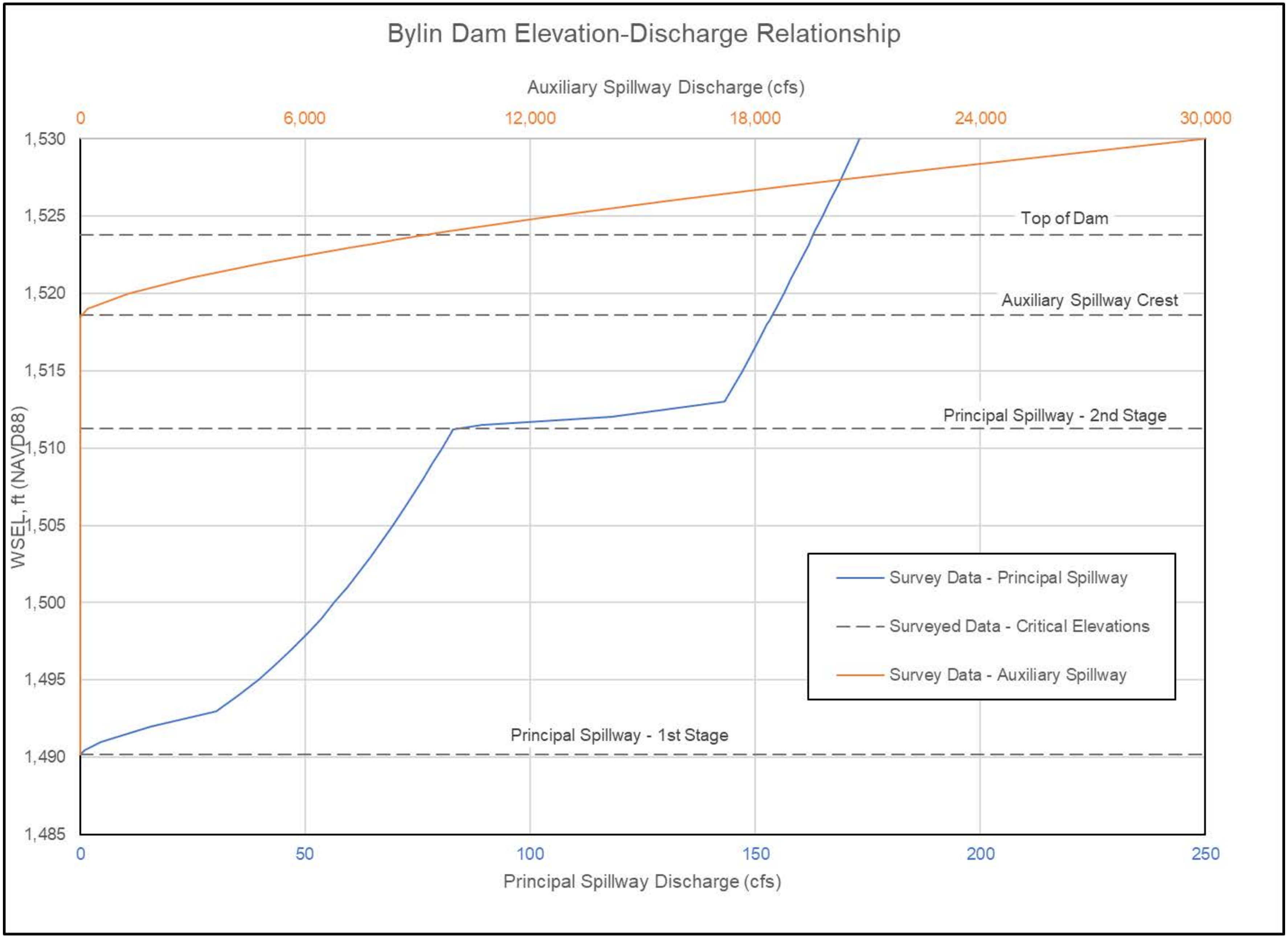


Figure D-1-28: *Bylin Dam Auxiliary Spillway Profile*

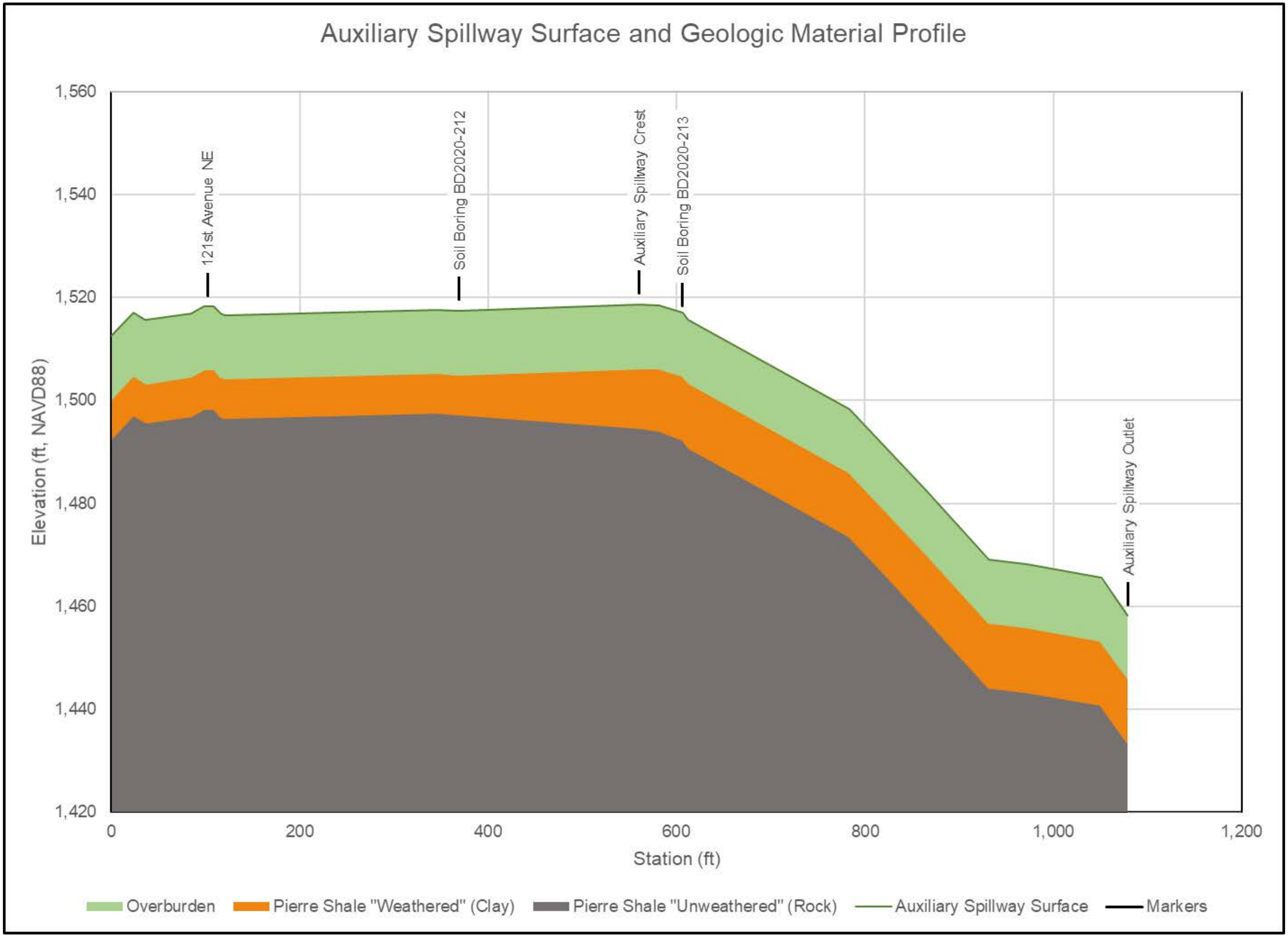
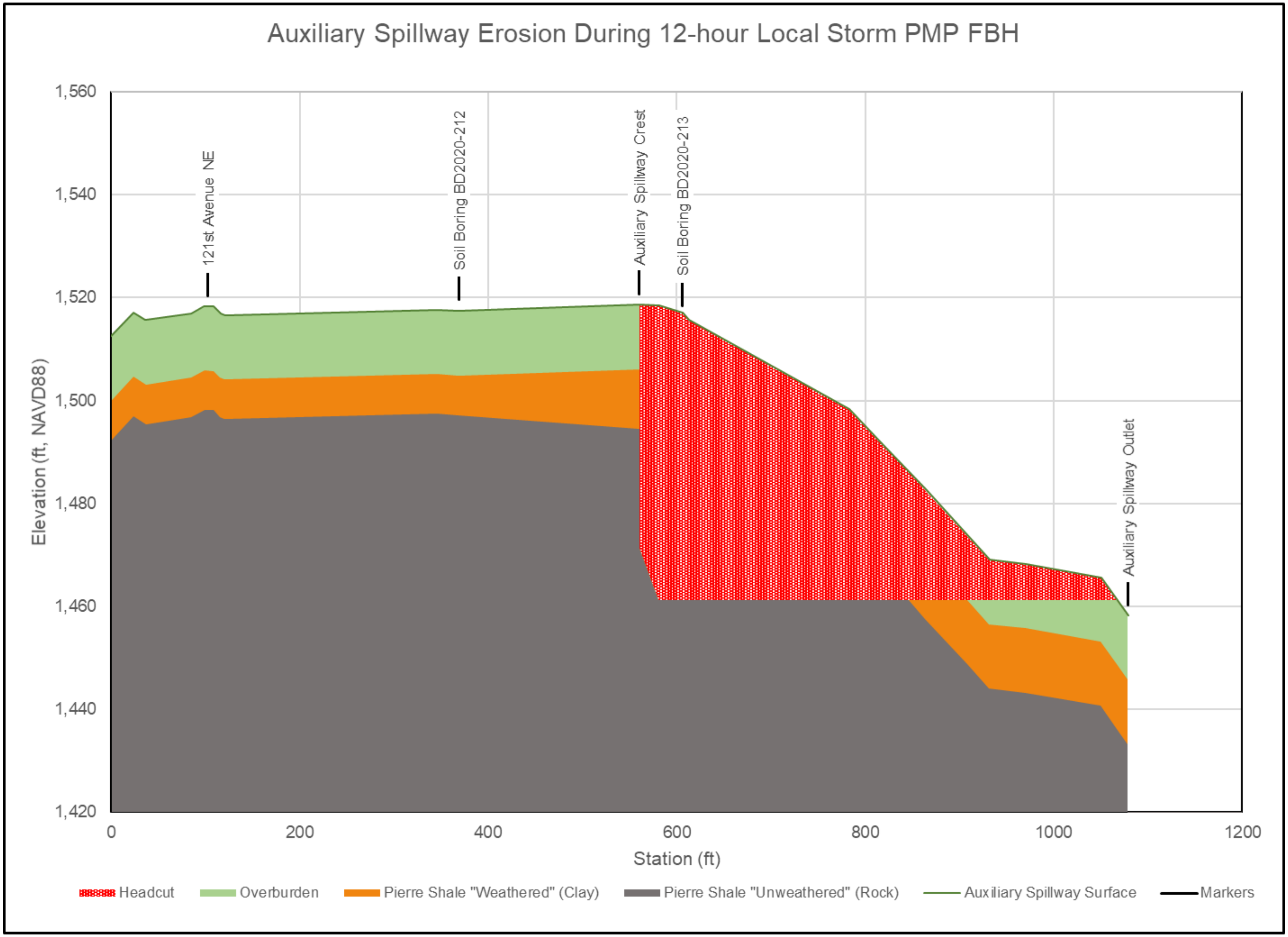
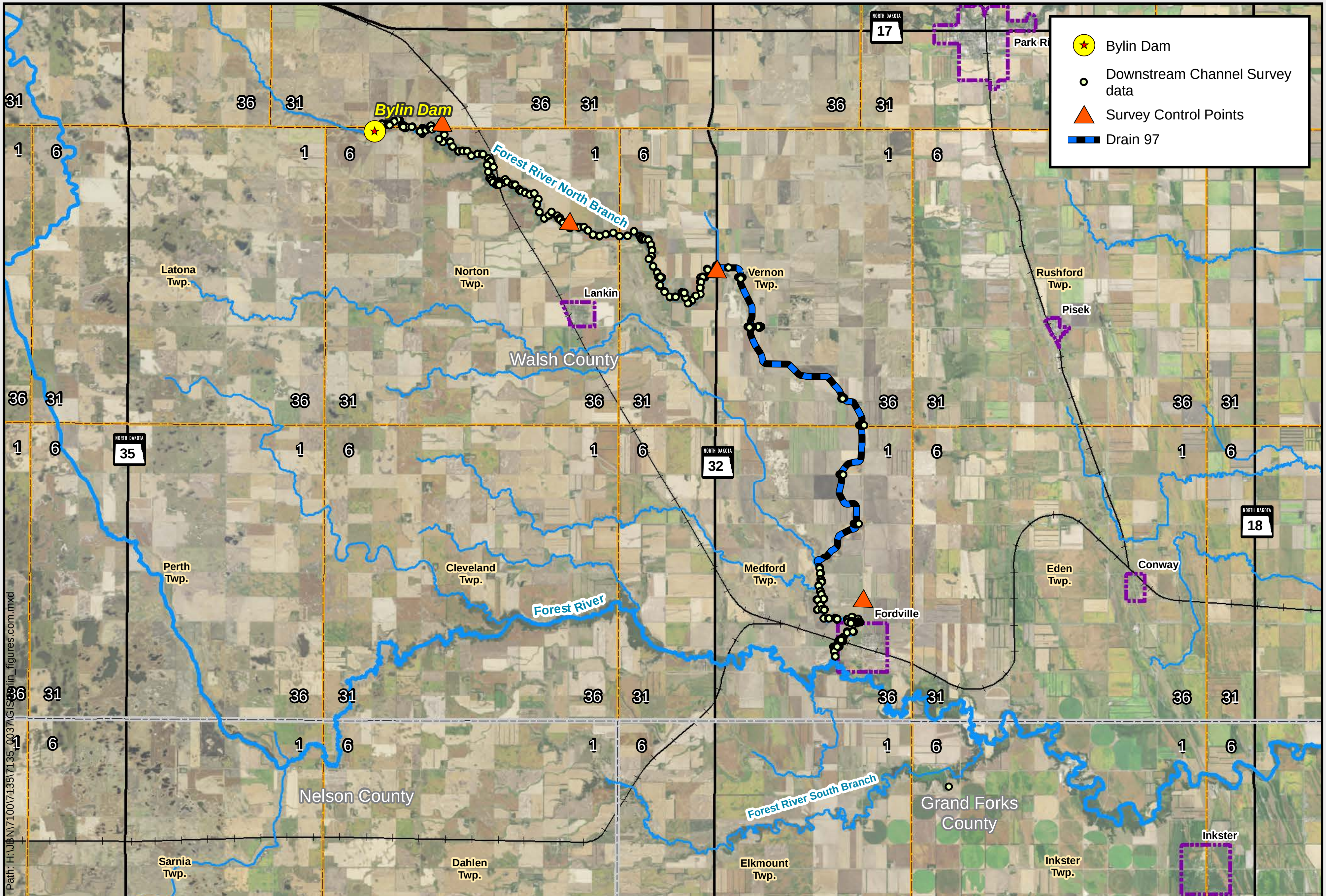


Figure D-1-29: Bylin Dam Auxiliary Spillway Headcut Erosion from SITES Analysis



FIGURES



F D-1-1

Scale:	Drawn by:	Checked by:	Project No.:	Date:
AS SHOWN	NRI	PDL	7135-0037	1/24/2022

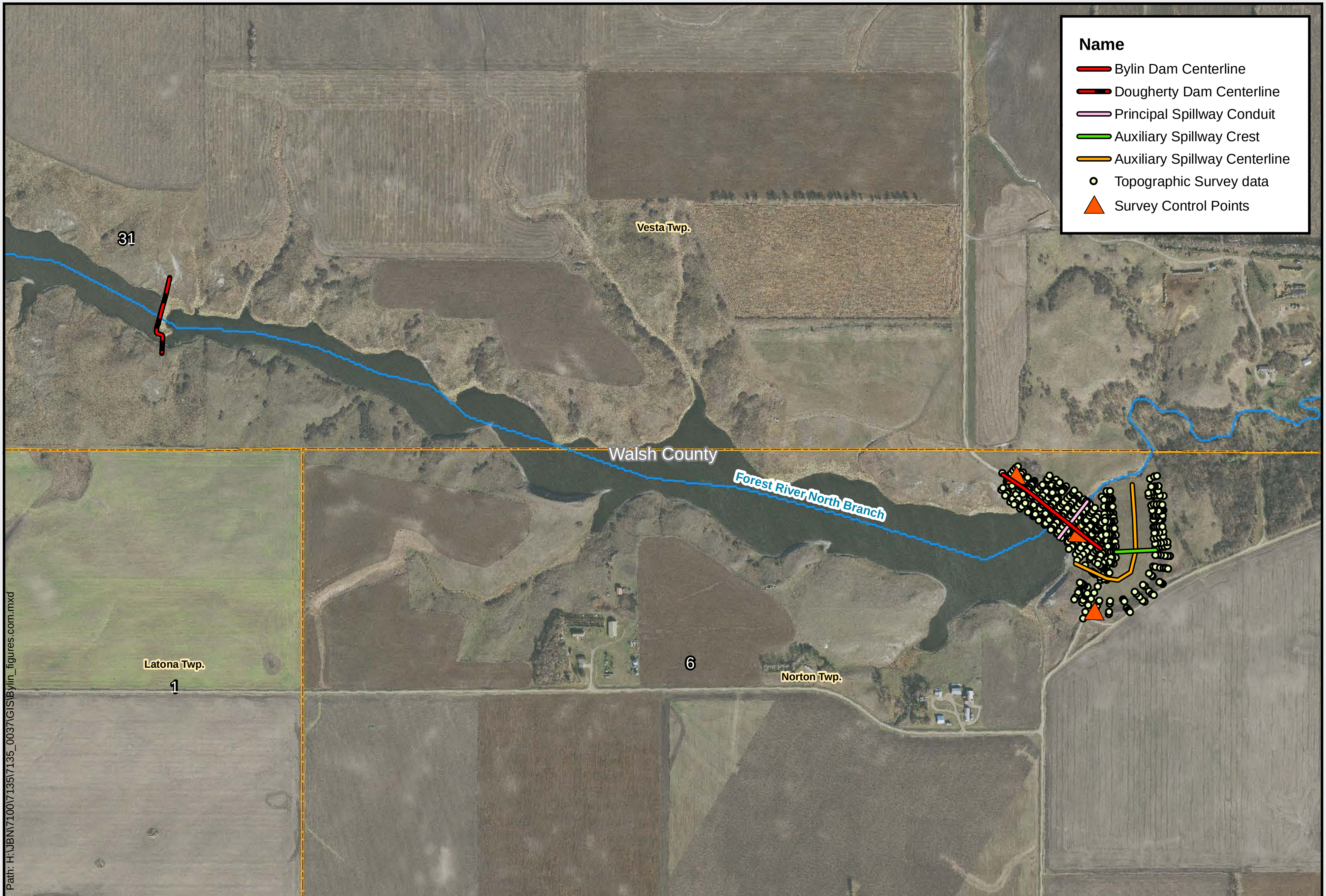
HOUSTON engineering, inc.

Figure D-1-1: Downstream Channel Survey

North Branch Forest River Dam No. 1 (Bylin Dam)
Appendix D-1: Existing Conditions Assessment Report
Forest River Joint Water Resource District

0 2.5 5 Miles

N W E S



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Scale:	Drawn by:	Checked by:	Project No.:	Date:
AS SHOWN	NRI	PDL	7135-0037	1/24/2022

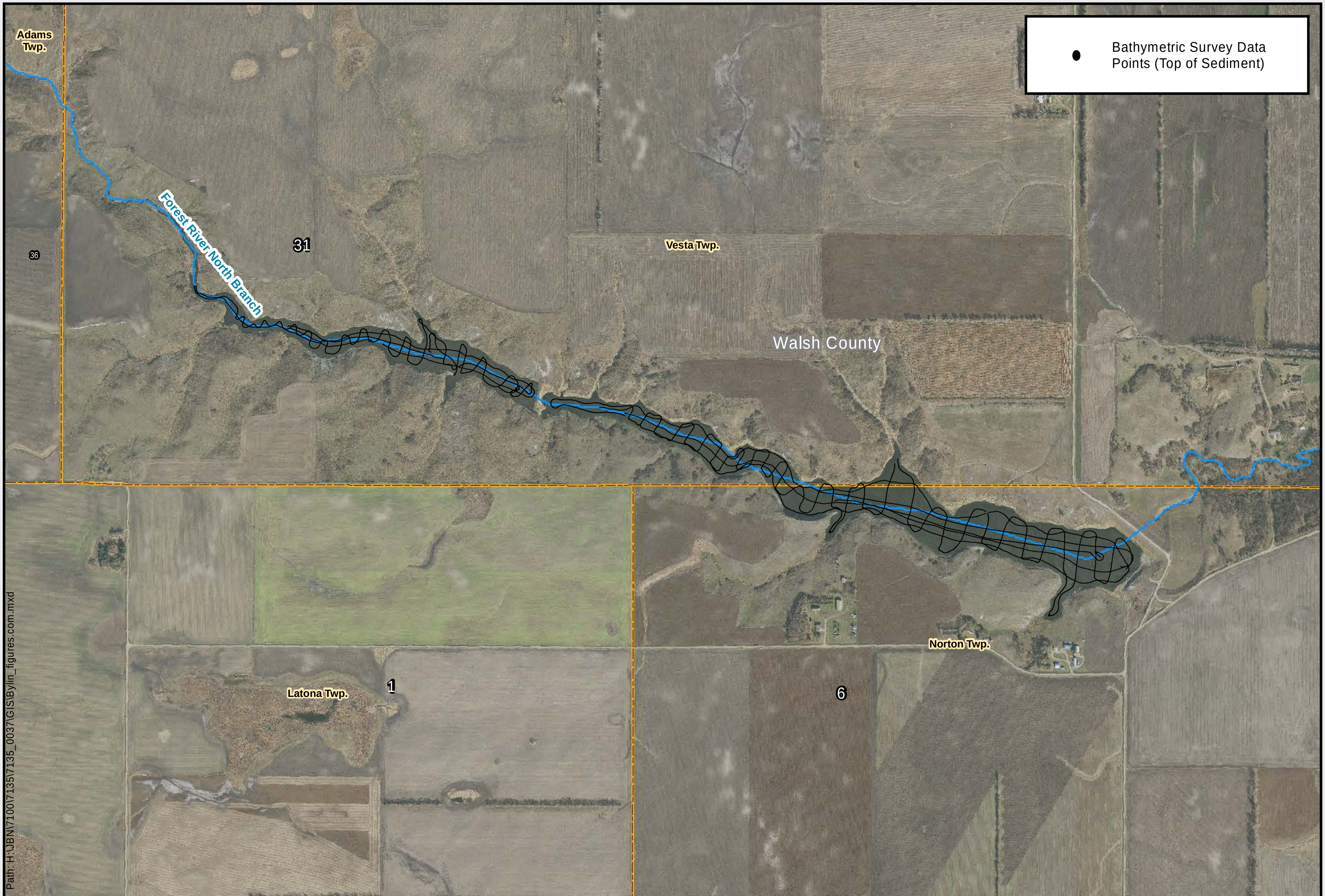
HOUSTON engineering, inc.

Figure D-1-2: Bylin Dam Topographic Survey

North Branch Forest River Dam No. 1 (Bylin Dam)
Appendix D-1: Existing Conditions Assessment Report
Forest River Joint Water Resource District

0 0.15 0.3
Miles

N
W E
S



F D-1-3

Scale:	Drawn by:	Checked by:	Project No.:	Date:
AS SHOWN	NRI	PDL	7135-0037	1/24/2022

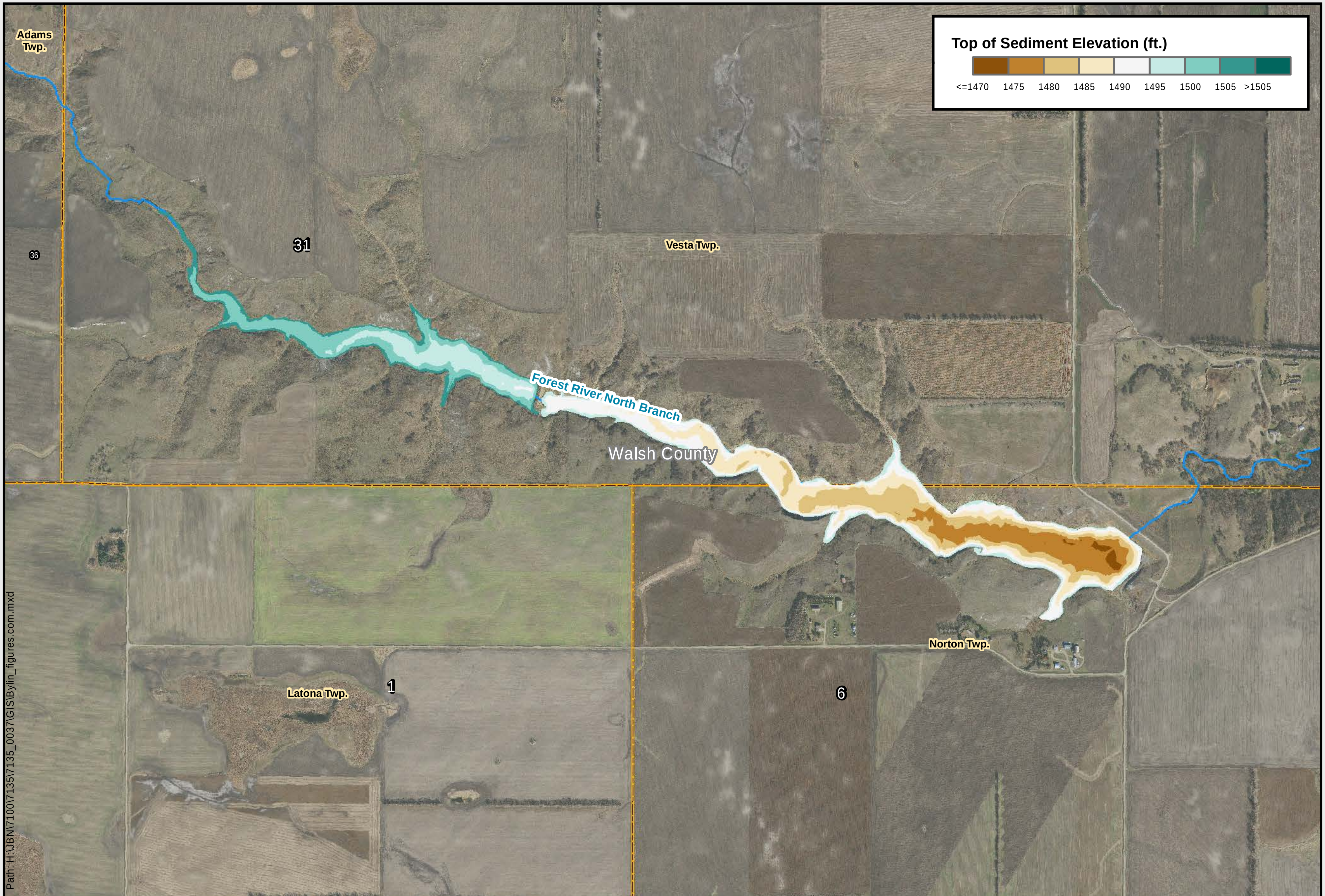
HOUSTON engineering, inc.

Figure D-1-3: Bylin Dam Bathymetric Survey Data Points

North Branch Forest River Dam No. 1 (Bylin Dam)
Appendix D-1: Existing Conditions Assessment Report
Forest River Joint Water Resource District

0 0.25 0.5 Miles

N W E S



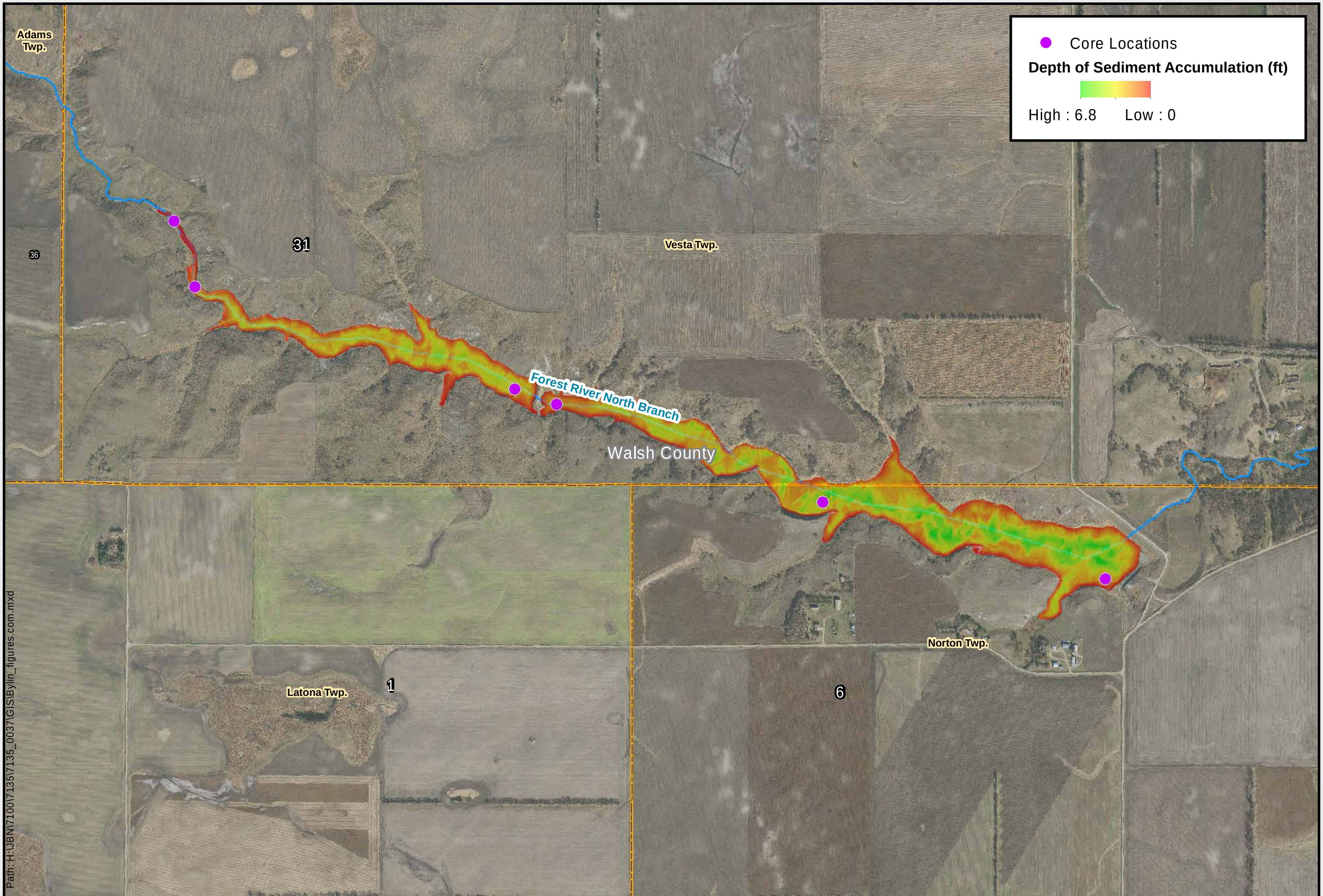
F D-1-4

Scale:	Drawn by:	Checked by:	Project No.:	Date:
AS SHOWN	NRI	PDL	7135-0037	1/24/2022

HOUSTON engineering, inc.

Figure D-1-4: Bylin Dam Existing Ground Surface Below the Normal Pool

North Branch Forest River Dam No. 1 (Bylin Dam)
Appendix D-1: Existing Conditions Assessment Report
Forest River Joint Water Resource District



F D-1-5

Scale:	Drawn by:	Checked by:	Project No.:	Date:
AS SHOWN	NRI	PDL	7135-0037	1/24/2022

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Figure D-1-5: Bylin Dam Sediment Depth in Reservoir

North Branch Forest River Dam No. 1 (Bylin Dam)
Appendix D-1: Existing Conditions Assessment Report
Forest River Joint Water Resource District

***Figure D-1-6**: Bylin Dam Elevation-Storage Relationship*

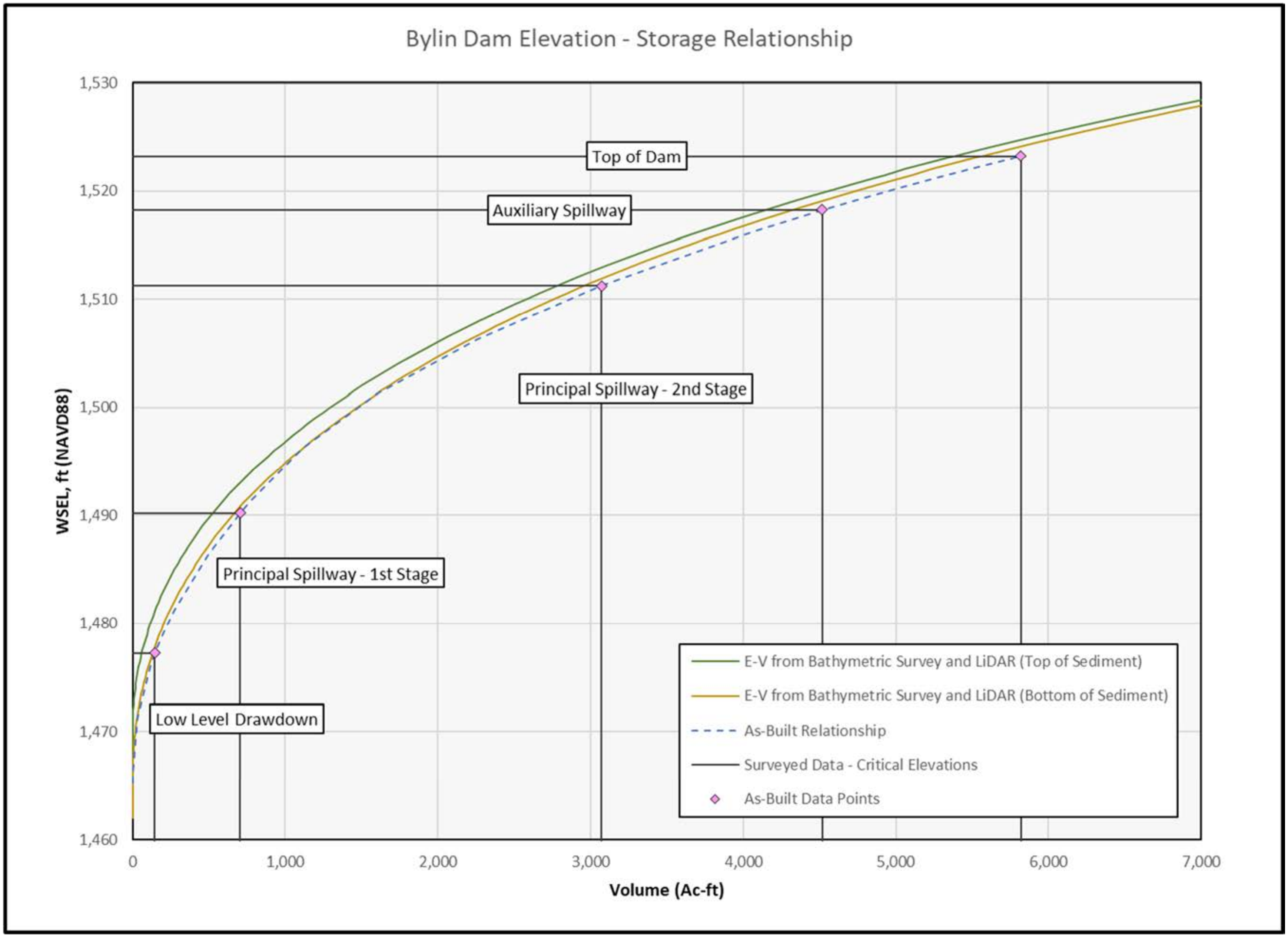
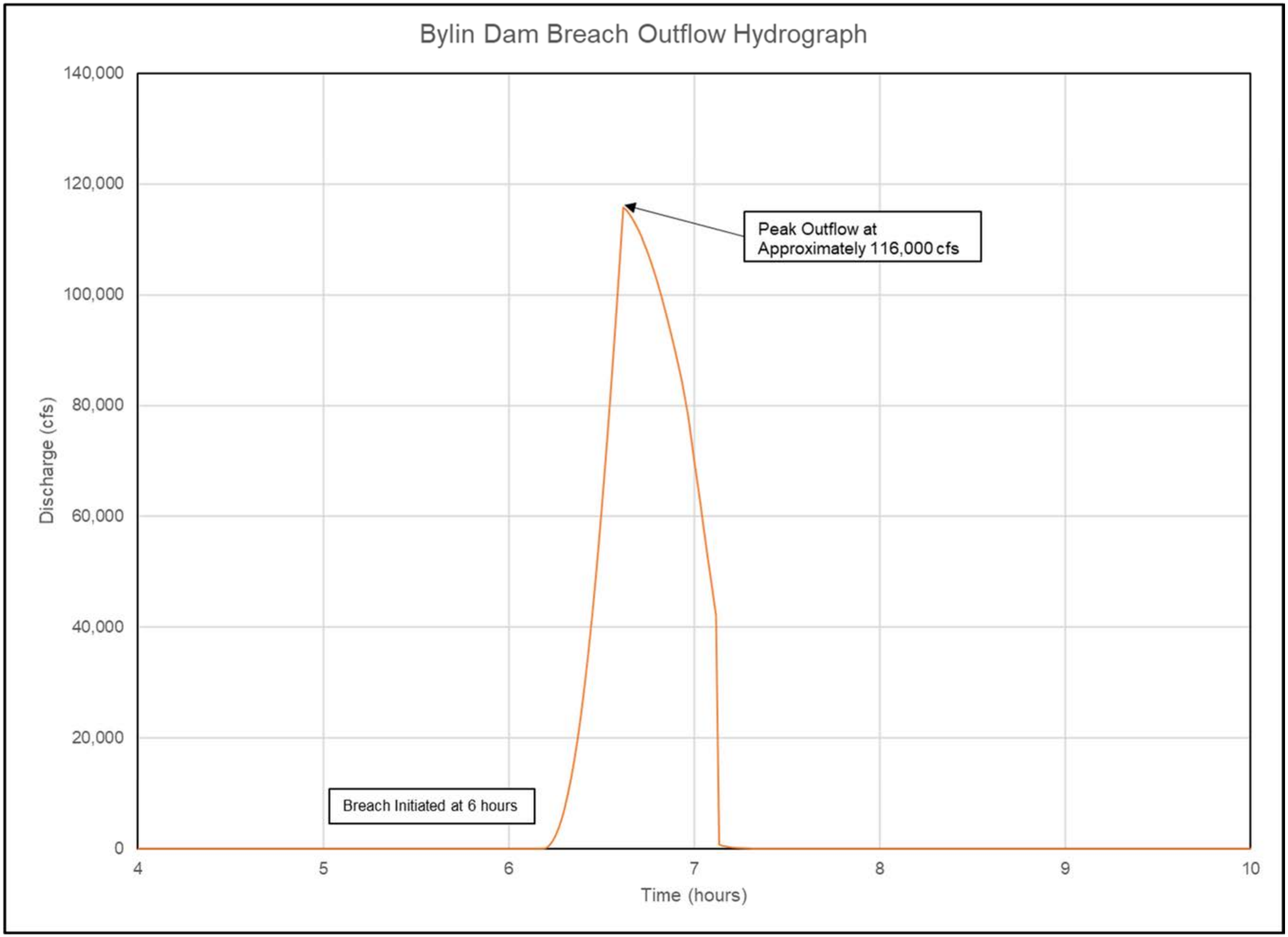
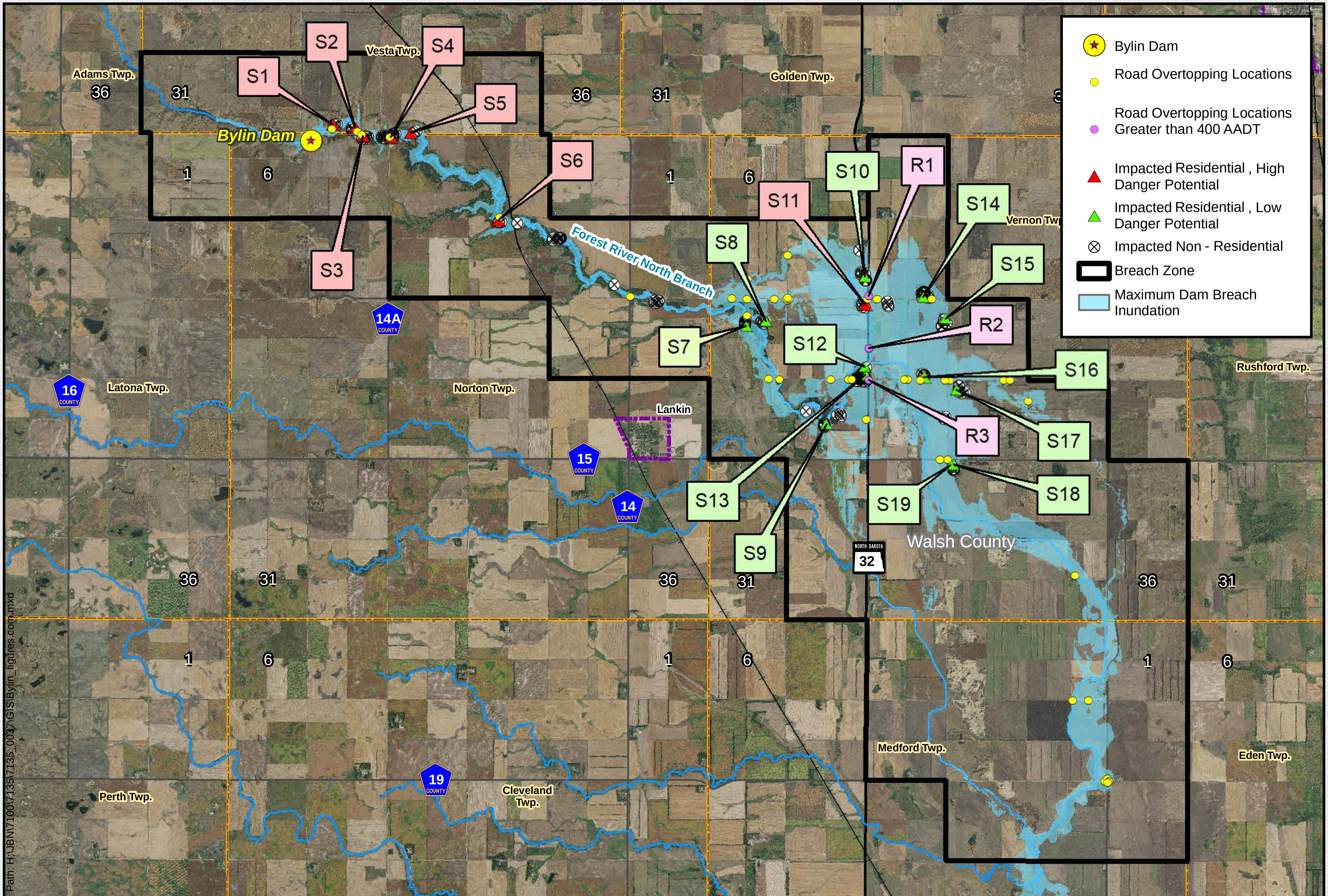


Figure D-1-7: Bylin Dam Breach Outflow Hydrograph





F D-1-8

Scale:	Drawn by:	Checked by:	Project No.:	Date:
AS SHOWN	NRI	PDL	7135-0037	1/24/2022

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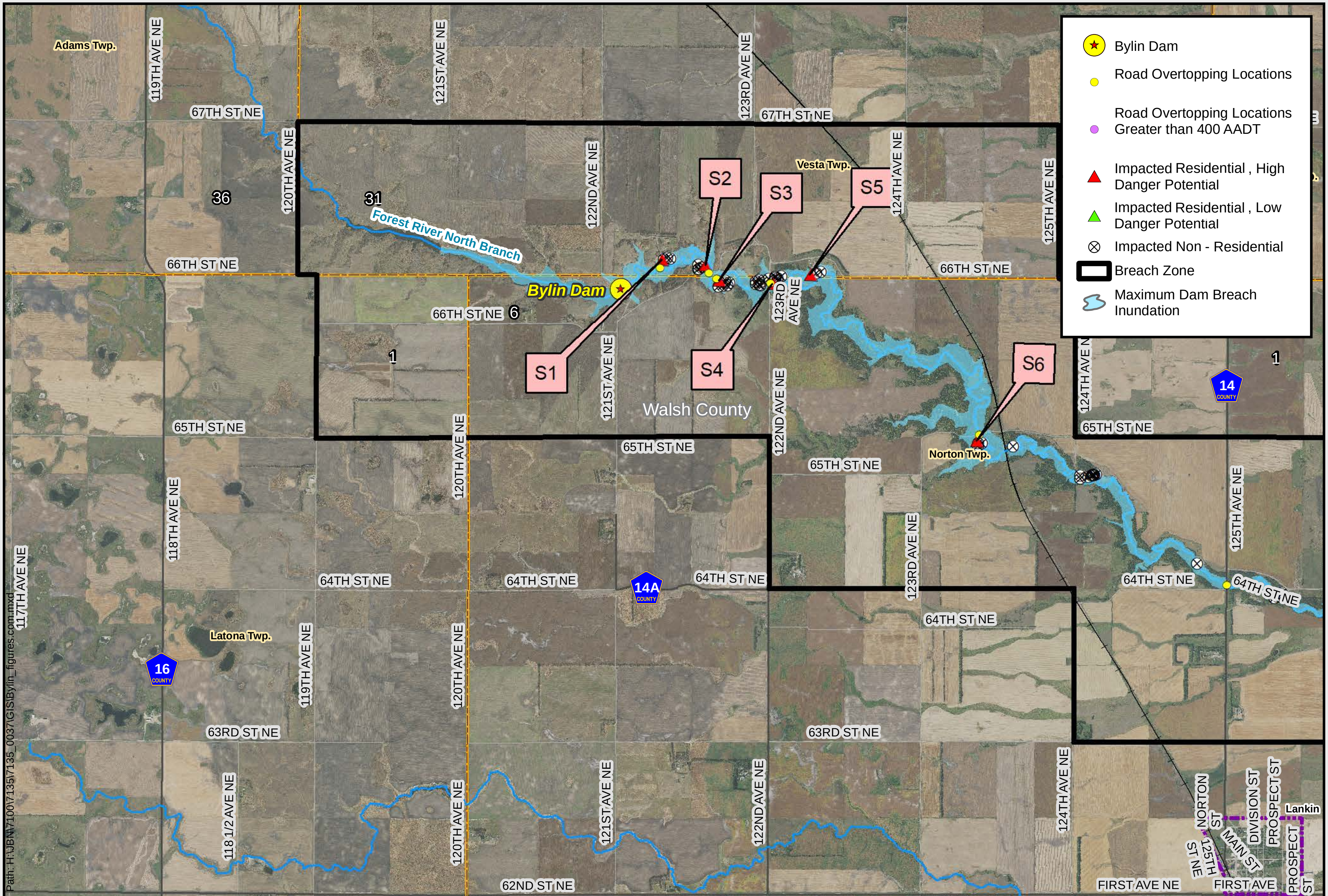
Figure D-1-8: Bylin Dam Breach Inundation - All

North Branch Forest River Dam No. 1 (Bylin Dam)
Appendix D-1: Existing Conditions Assessment Report
Forest River Joint Water Resource District

0 1.5 3 Miles

N W E S



F D-1-9

Scale:	Drawn by:	Checked by:	Project No.:	Date:
AS SHOWN	NRI	PDL	7135-0037	1/24/2022

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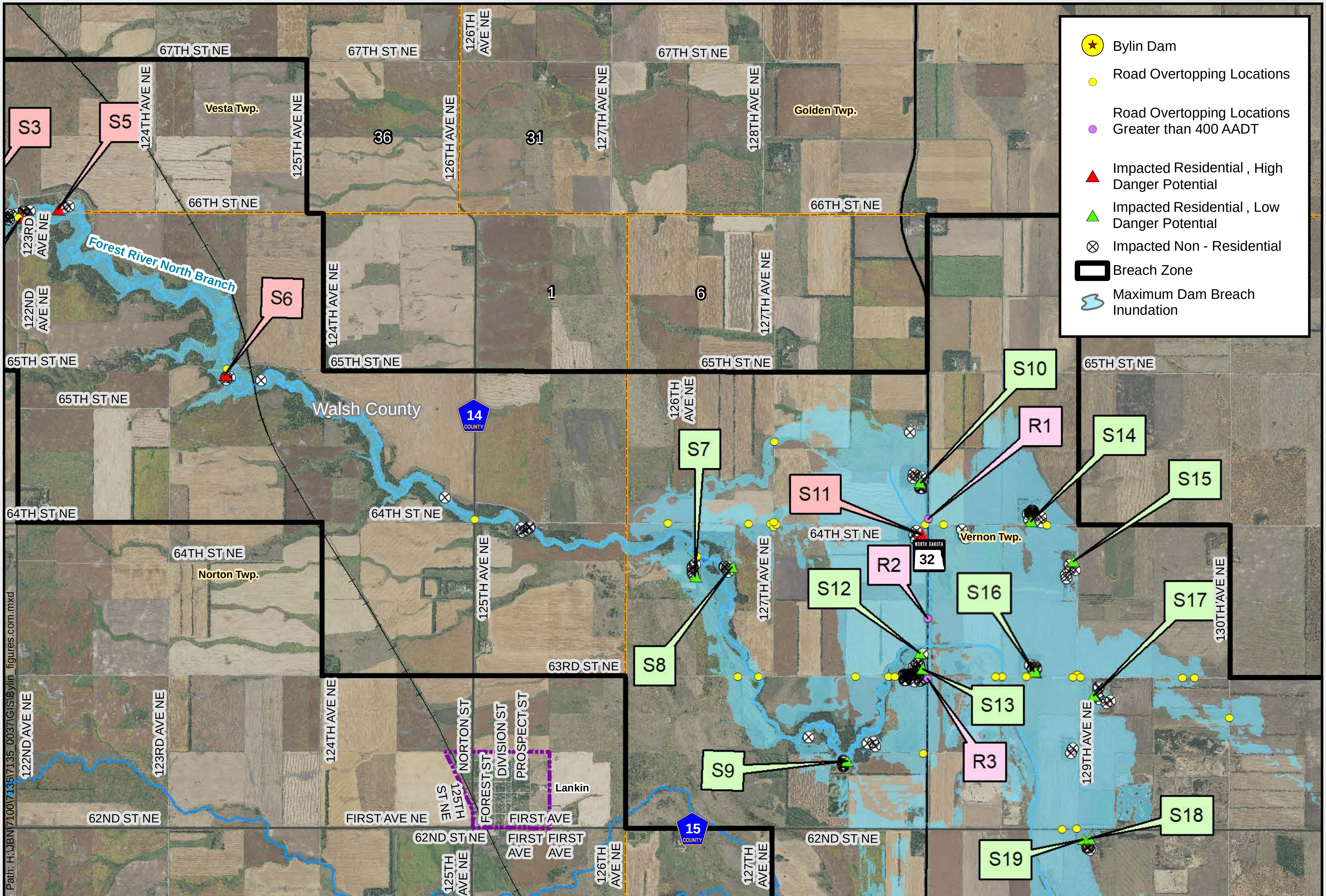
Figure D-1-9: Bylin Dam Breach Inundation - 1

North Branch Forest River Dam No. 1 (Bylin Dam)
Appendix D-1: Existing Conditions Assessment Report
Forest River Joint Water Resource District

0 1 2 Miles

N W E S



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Scale:	Drawn by:	Checked by:	Project No.:	Date:
AS SHOWN	NRI	PDL	7135-0037	1/24/2022

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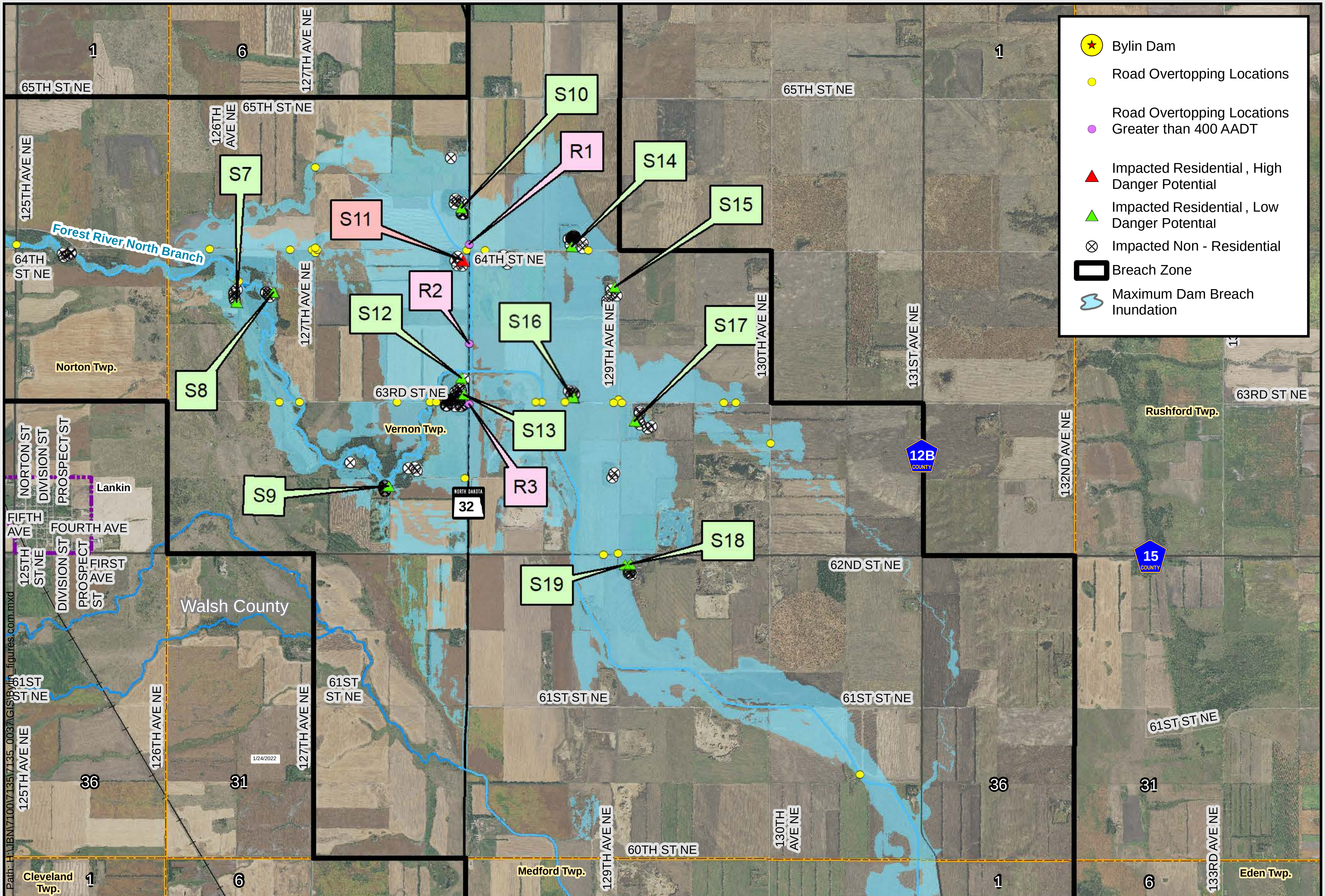
Figure D-1-10: Bylin Dam Breach Inundation - 2

North Branch Forest River Dam No. 1 (Bylin Dam)
Appendix D-1: Existing Conditions Assessment Report
Forest River Joint Water Resource District

0 1 2 Miles

N S E W



F D-1-11

Scale:	Drawn by:	Checked by:	Project No.:	Date:
AS SHOWN	NRI	PDL	7135-0037	1/24/2022

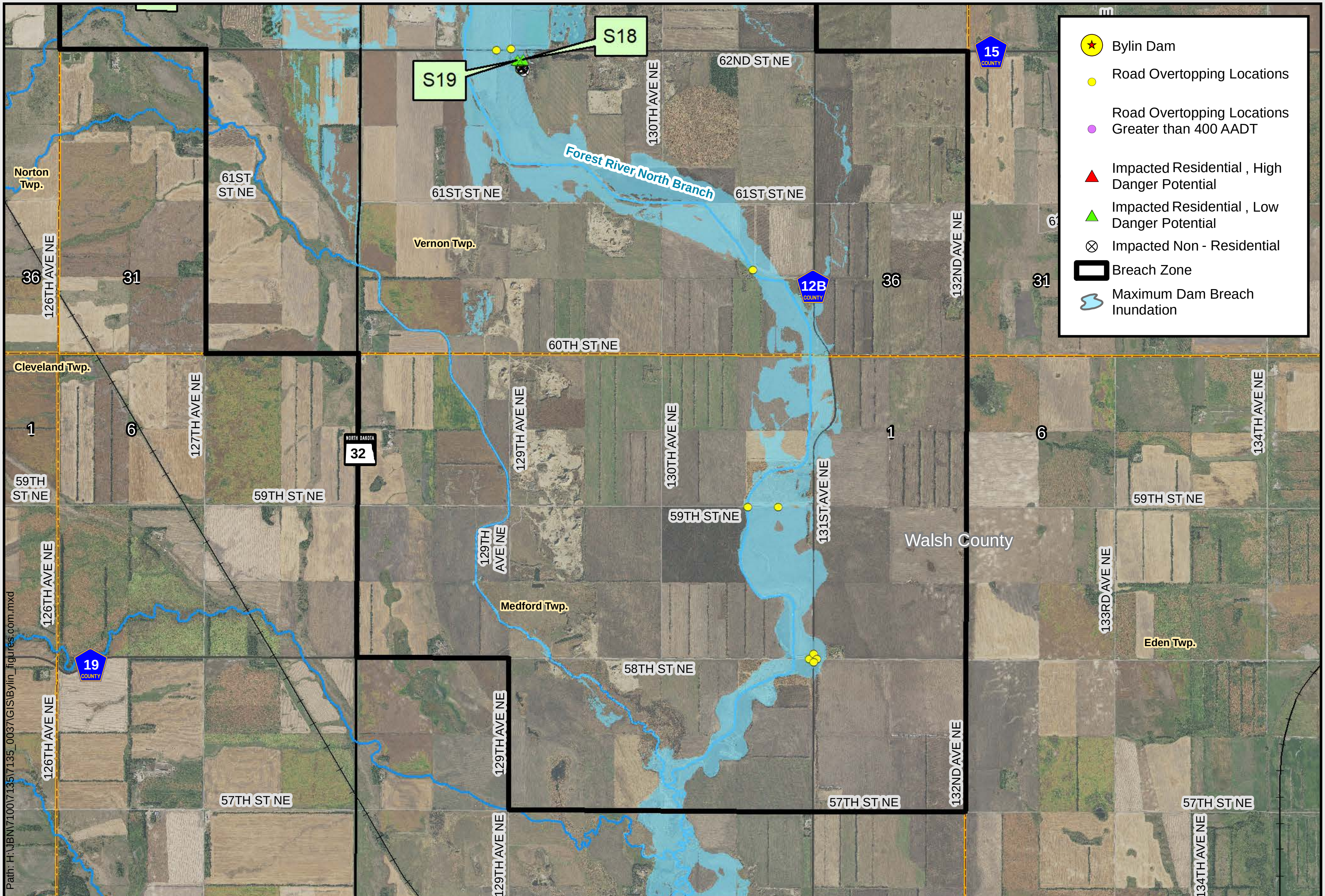
HOUSTON engineering, inc.

Figure D-1-11: Bylin Dam Breach Inundation - 3

North Branch Forest River Dam No. 1 (Bylin Dam)
Appendix D-1: Existing Conditions Assessment Report
Forest River Joint Water Resource District

0 1 2 Miles

N W E S



F D-1-12

Scale:	Drawn by:	Checked by:	Project No.:	Date:
AS SHOWN	NRI	PDL	7135-0037	1/24/2022

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Figure D-1-12: Bylin Dam Breach Inundation - 4

North Branch Forest River Dam No. 1 (Bylin Dam)
Appendix D-1: Existing Conditions Assessment Report
Forest River Joint Water Resource District

0 1 2 Miles

N W E S

***Figure D-1-13**: Depth-Velocity-Flood Danger Level Relationship for Houses Built on Foundations Downstream of Bylin Dam*

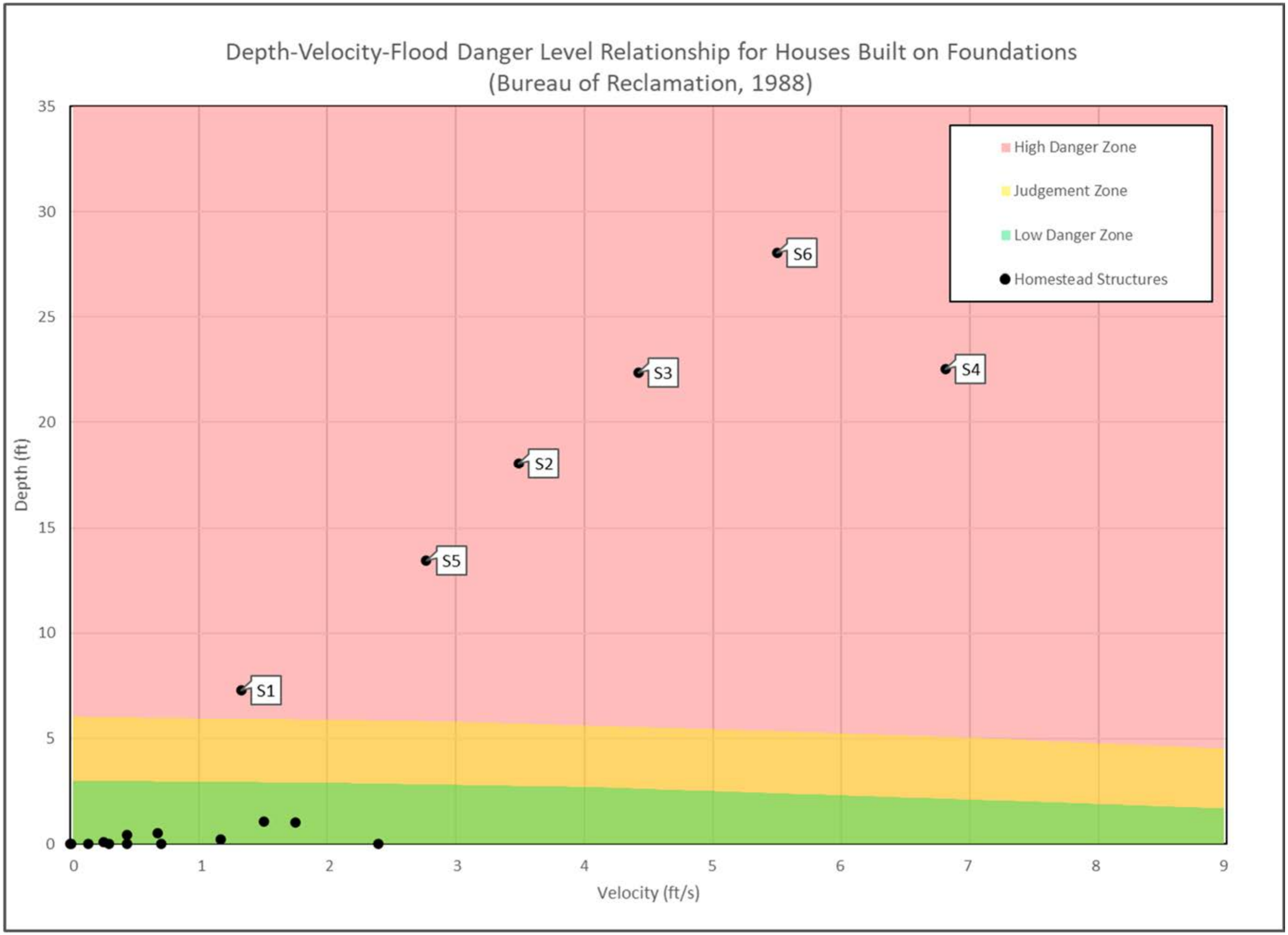
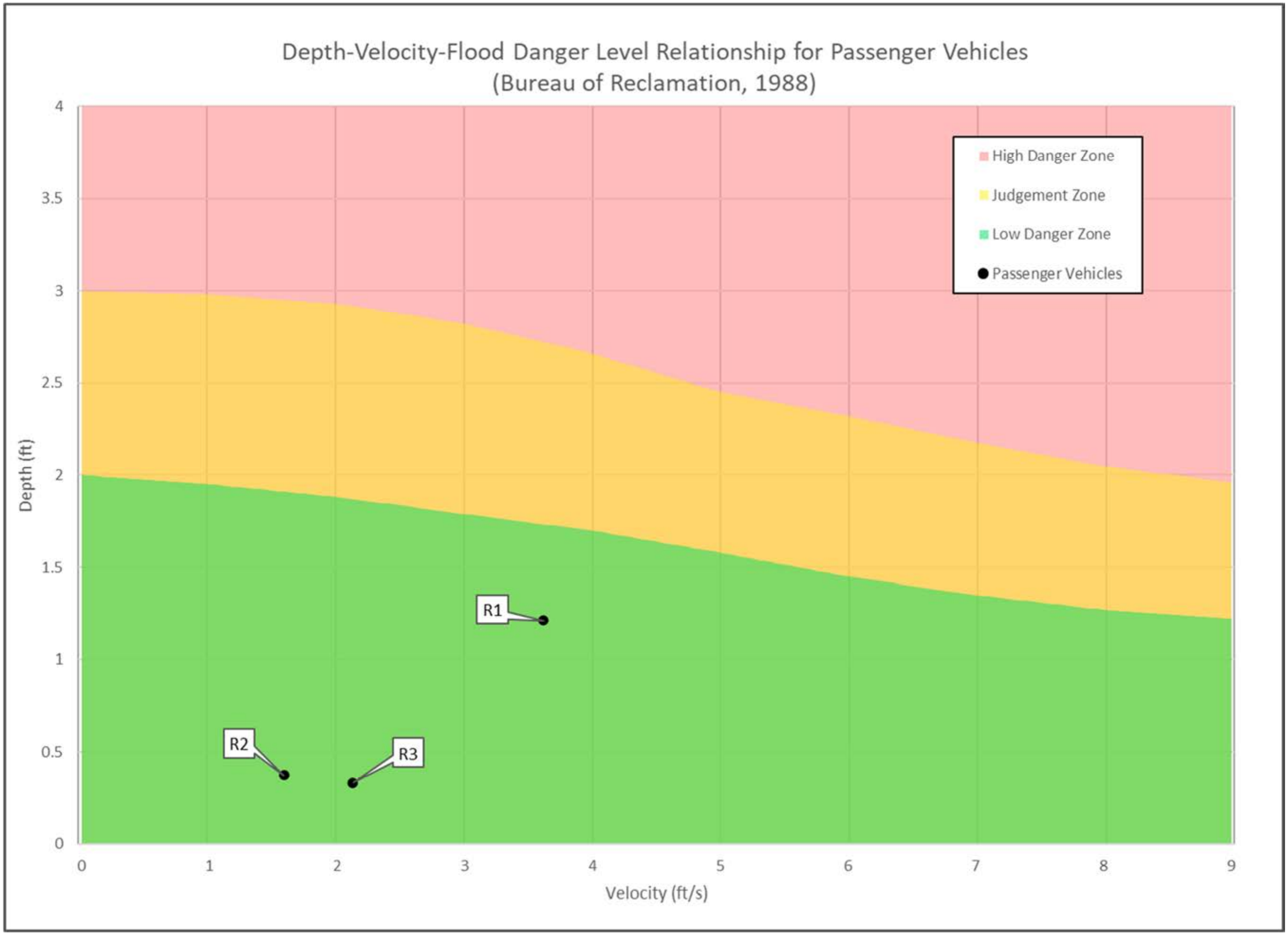
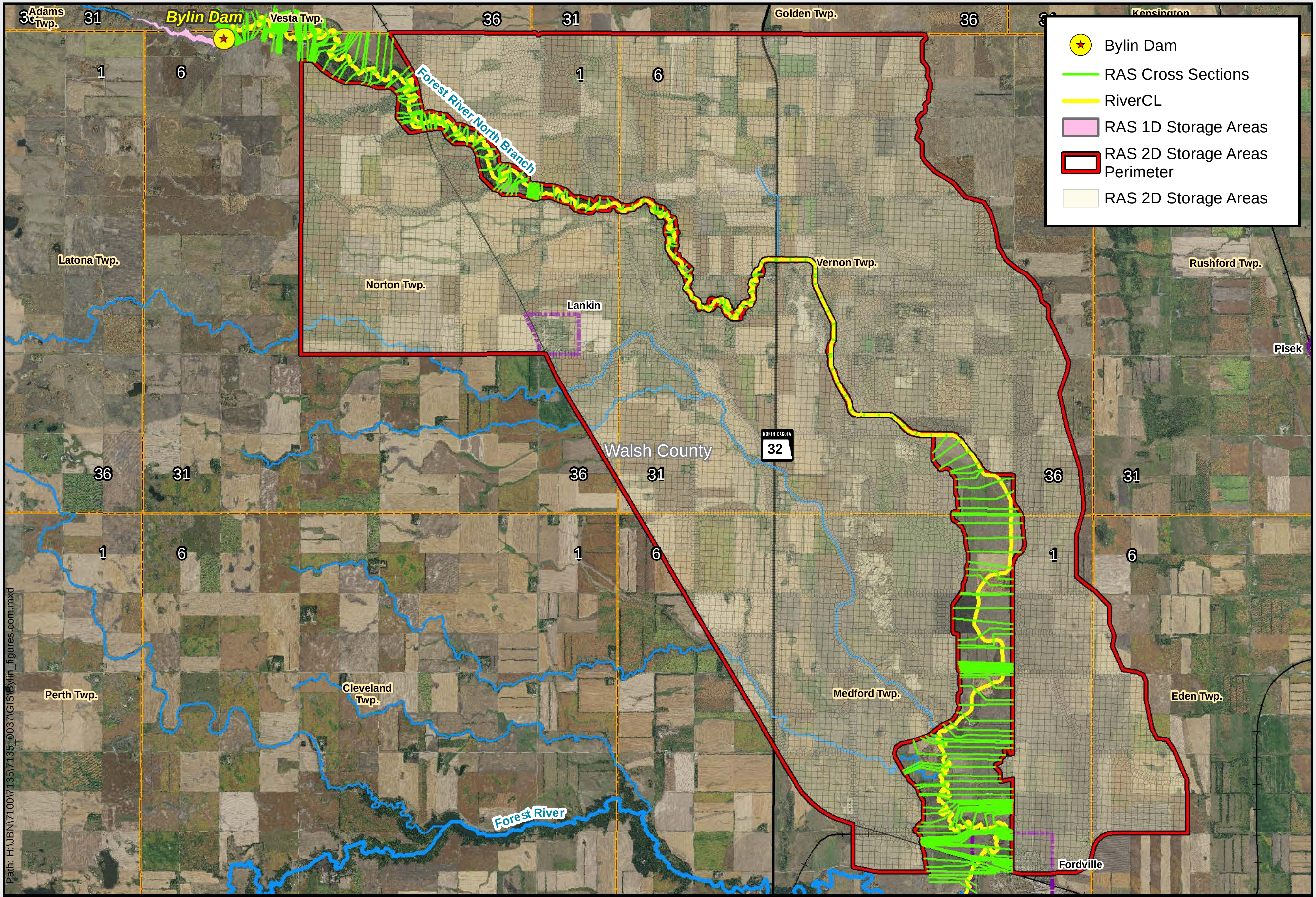


***Figure D-1-14**: Depth-Velocity-Flood Danger Level Relationship for Passenger Vehicles*





F D-1-15

Scale:	Drawn by:	Checked by:	Project No.:	Date:
AS SHOWN	NRI	PDL	7135-0037	1/24/2022

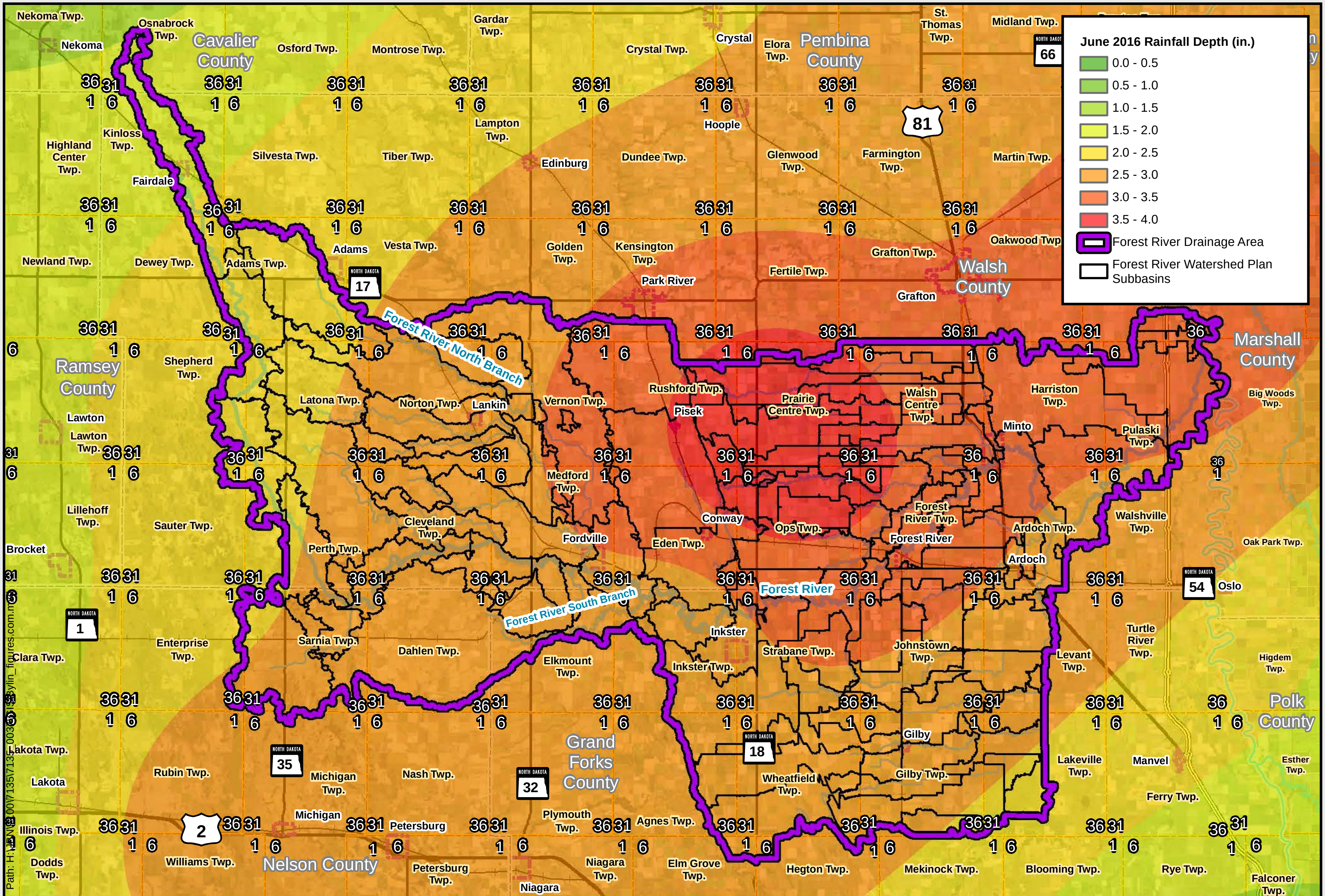
HOUSTON engineering, inc.

Figure D-1-15: HEC-RAS Model Schematic

North Branch Forest River Dam No. 1 (Bylin Dam)
Appendix D-1: Existing Conditions Assessment Report
Forest River Joint Water Resource District

0 1.5 3 Miles

N W E S



F D-1-16

Scale:	Drawn by:	Checked by:	Project No.:	Date:
AS SHOWN	NRI	PDL	7135-0037	1/24/2022

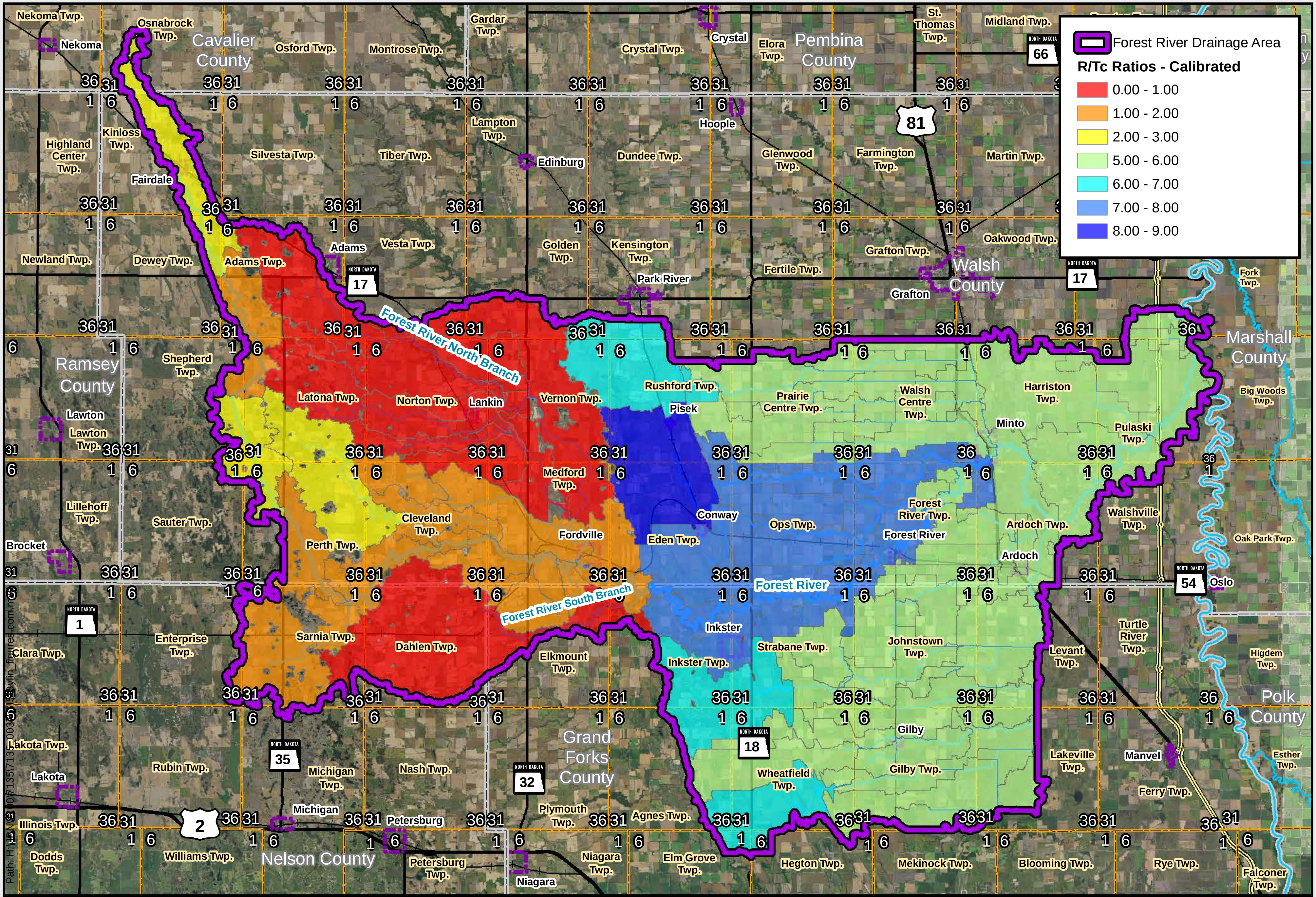
HOUSTON engineering, inc.

Figure D-1-16: 2016 Historic Event Rainfall

North Branch Forest River Dam No. 1 (Bylin Dam)
Appendix D-1: Existing Conditions Assessment Report
Forest River Joint Water Resource District

0 7.5 15 Miles

N W E S



Scale:	Drawn by:	Checked by:	Project No.:	Date:
AS SHOWN	NRI	PDL	7135-0037	1/24/2022

F D-1-17

HOUSTON engineering, inc.

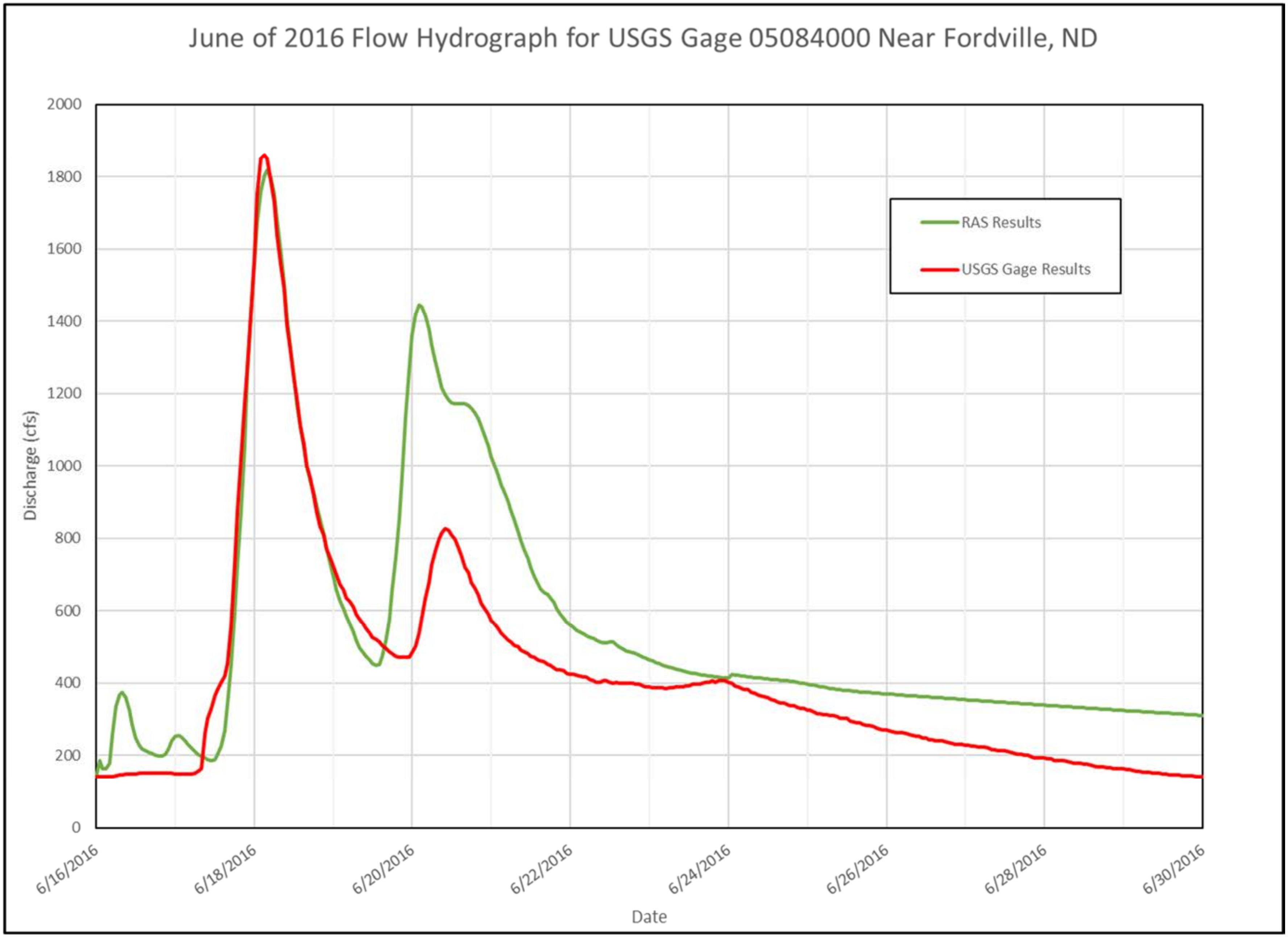
Figure D-1-17: R/Tc Ratios - Calibrated

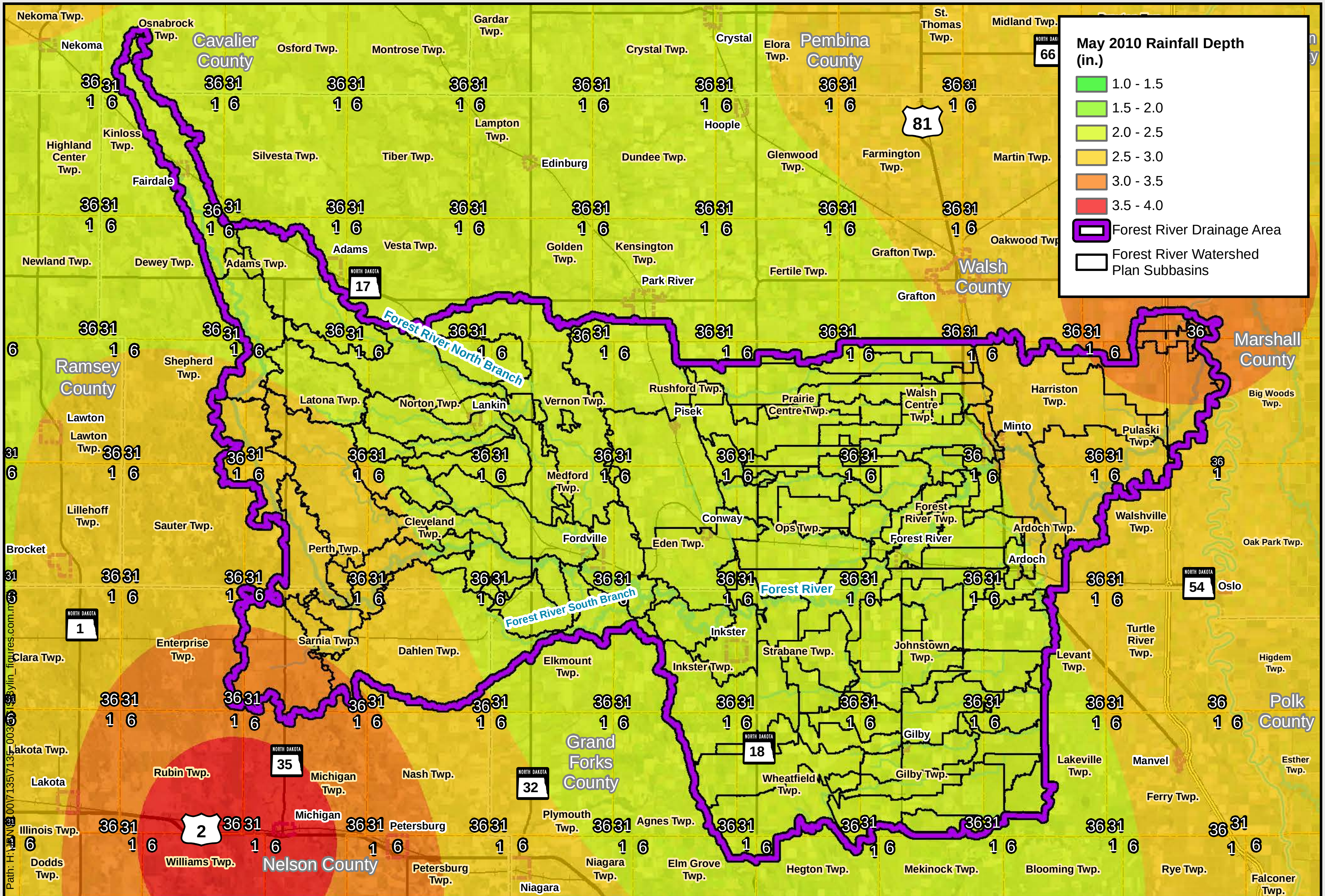
North Branch Forest River Dam No. 1 (Bylin Dam)
Appendix D-1: Existing Conditions Assessment Report
Forest River Joint Water Resource District

0 7 14 Miles

N W E S

__Figure D-1-18__: 2016 Historic Event – Peak Discharge near Fordville, ND (USGS Gage 05084000)





F D-1-19

Scale: AS SHOWN | Drawn by: NRI | Checked by: PDL | Project No.: 7135-0037 | Date: 1/24/2022

HOUSTON engineering, inc.

Figure D-1-19: 2010 Historic Event Rainfall

North Branch Forest River Dam No. 1 (Bylin Dam)
Appendix D-1: Existing Conditions Assessment Report
Forest River Joint Water Resource District

0 7.5 15 Miles

N W E S

***Figure D-1-20**: 2010 Historic Event – Peak Discharge near Fordville, ND (USGS Gage 05084000)*

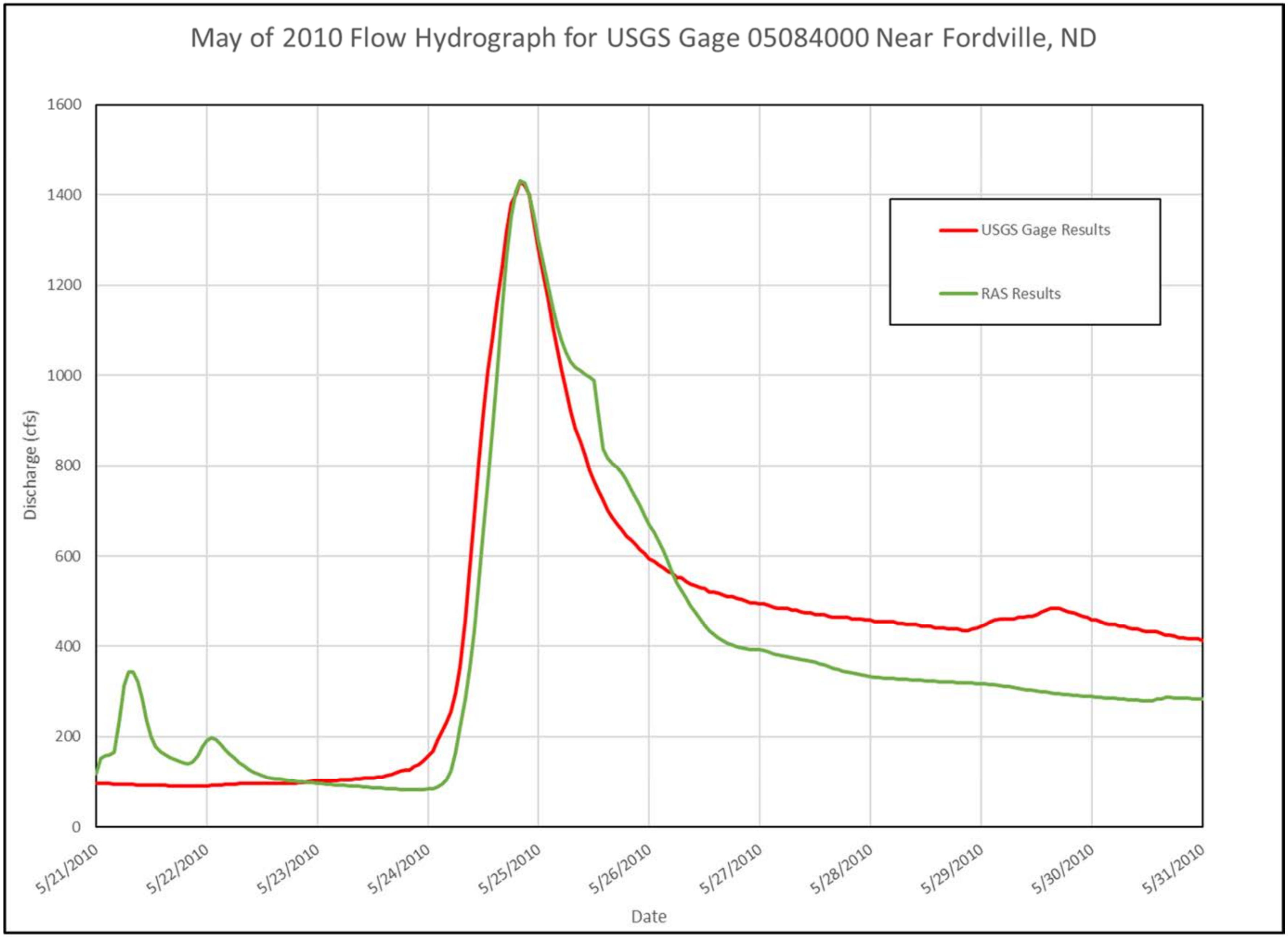


***Figure D-1-21**: Principal Spillway Mass Curves for Runoff Volume*

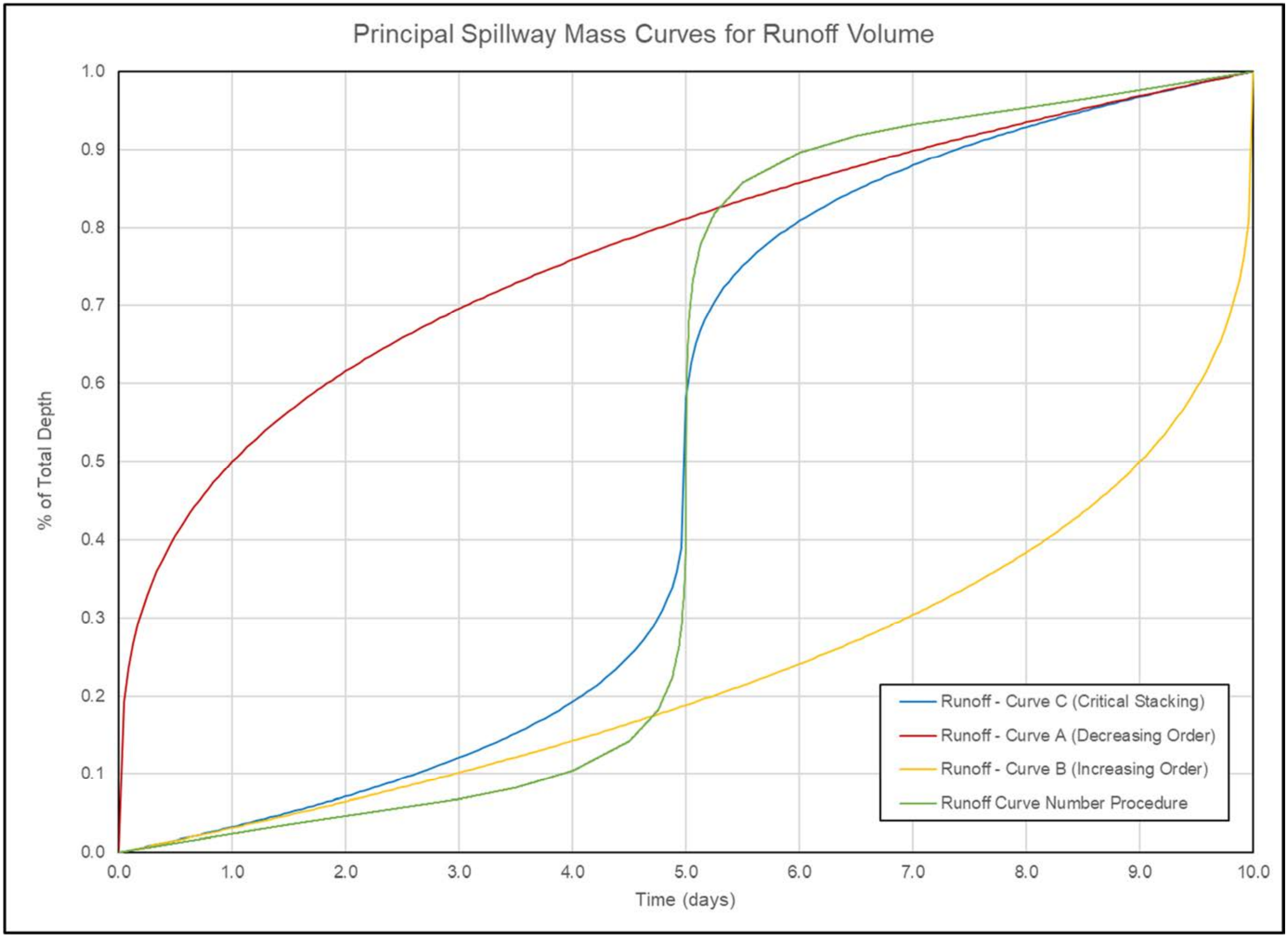


***Figure D-1-22**: Principal Spillway Inflow Hydrographs*

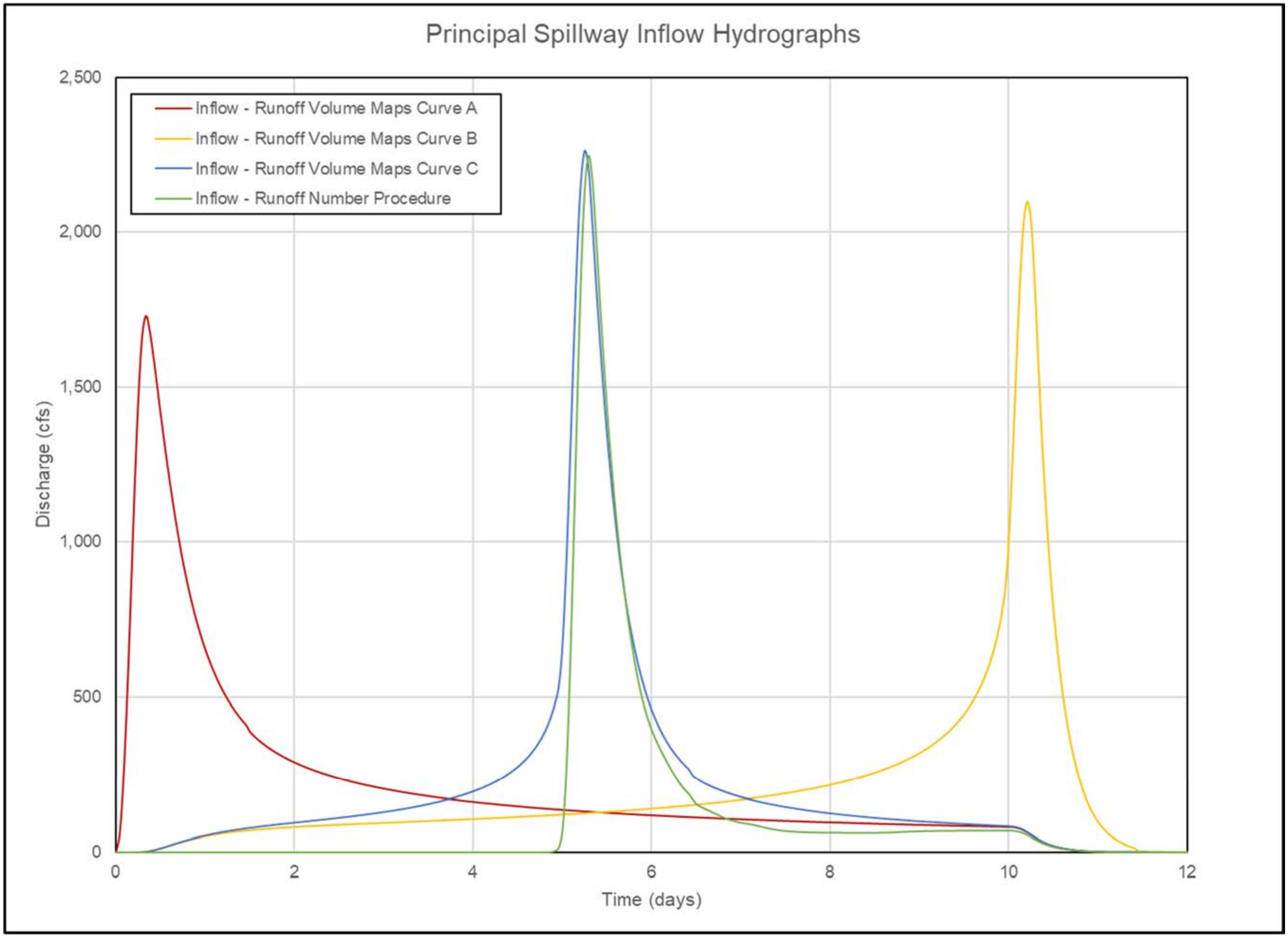


Figure D-1-23: Stability Design Mass Curves

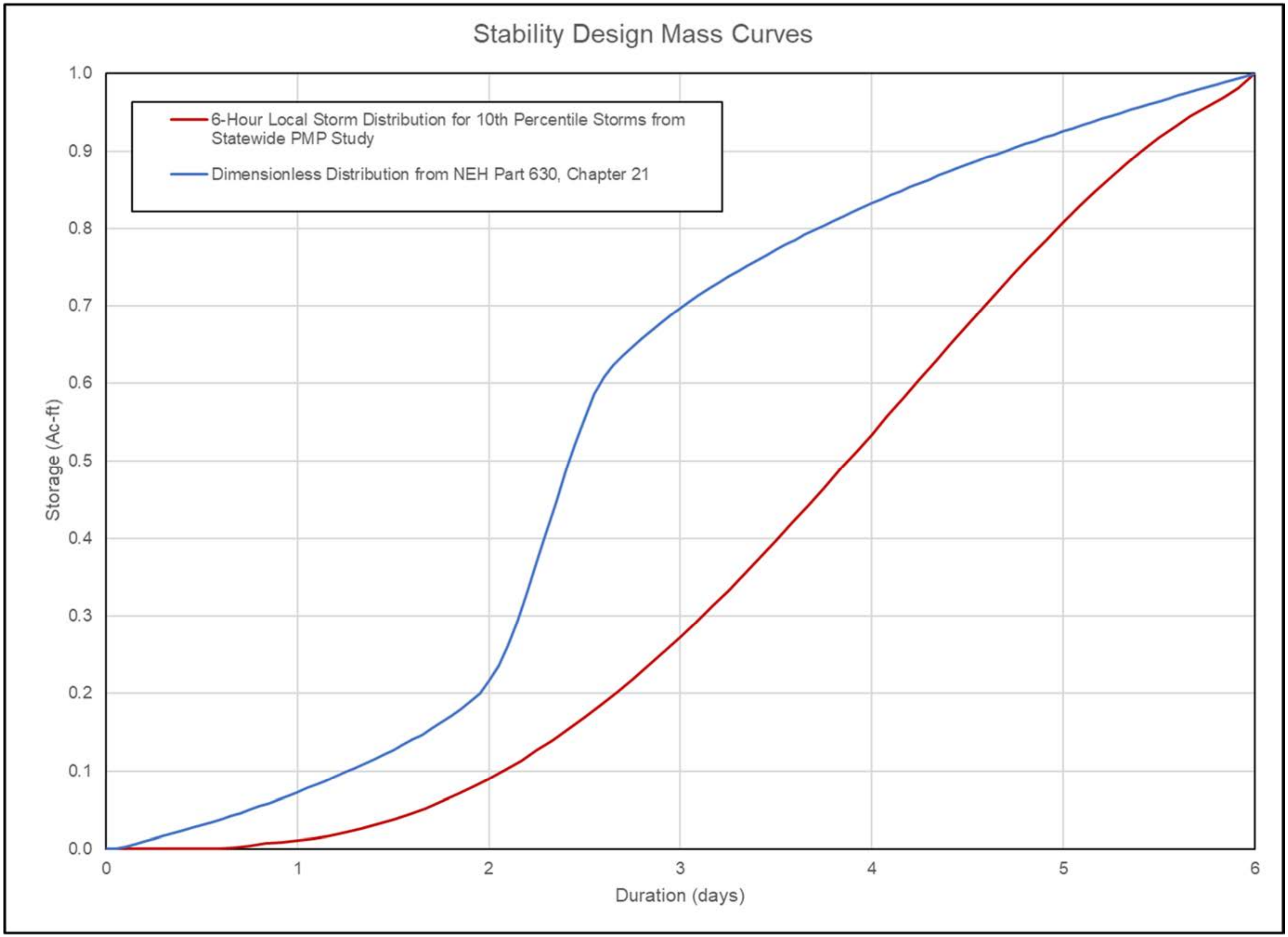


***Figure D-1-24**: Stability Design Inflow Hydrograph*

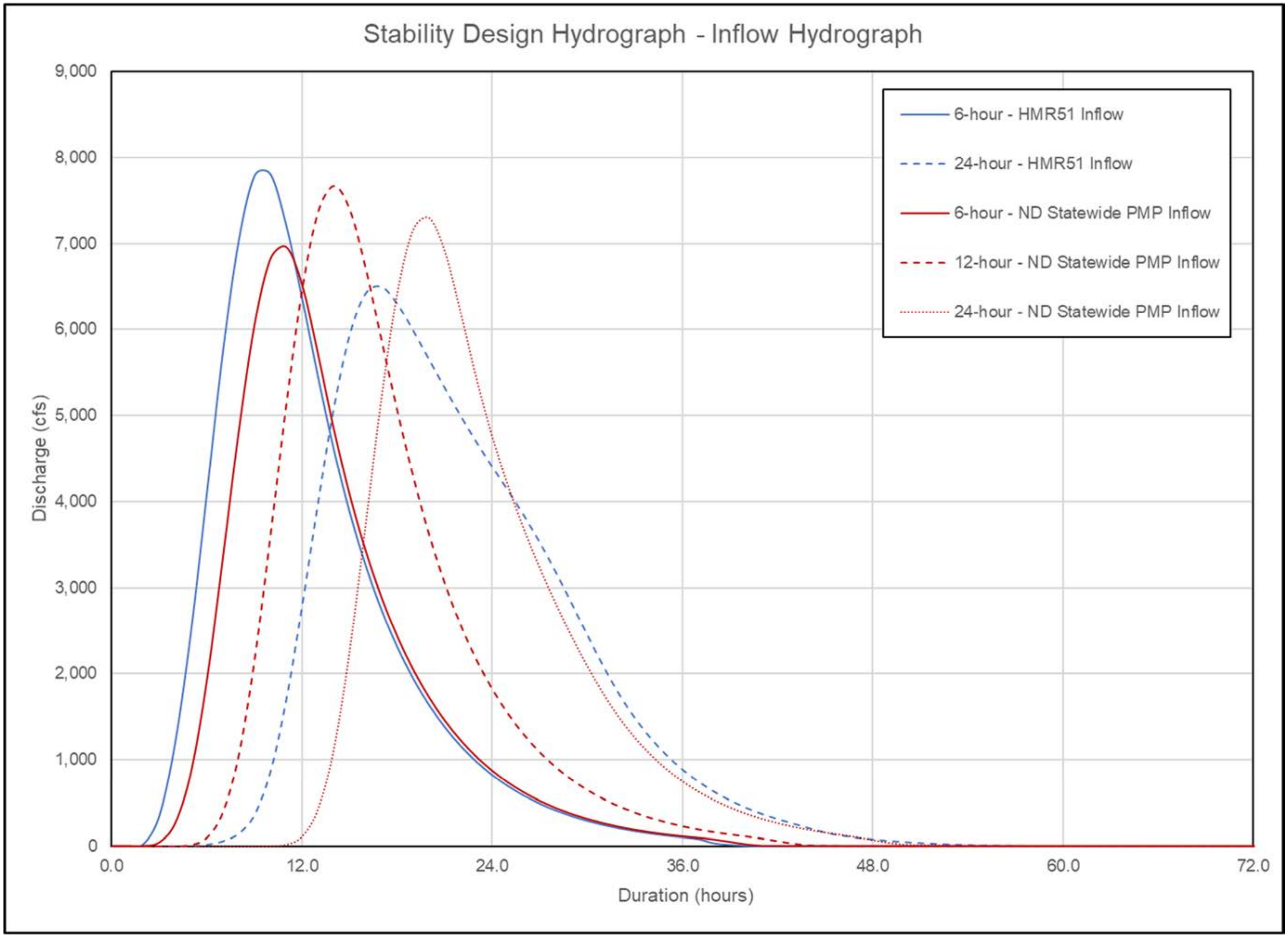


***Figure D-1-25**: Freeboard Design Mass Curves*

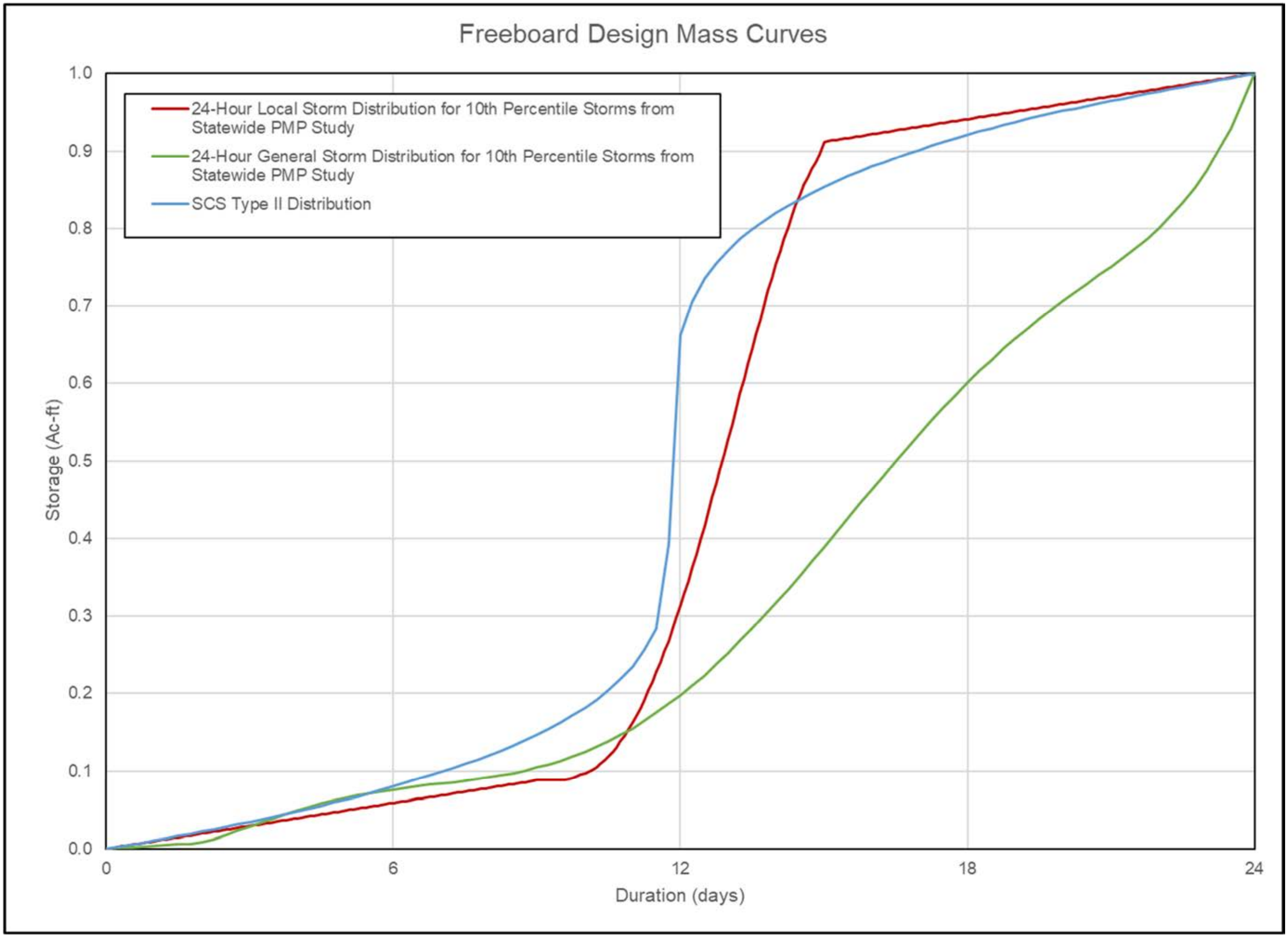


***Figure D-1-26**: Freeboard Design Inflow Hydrographs*

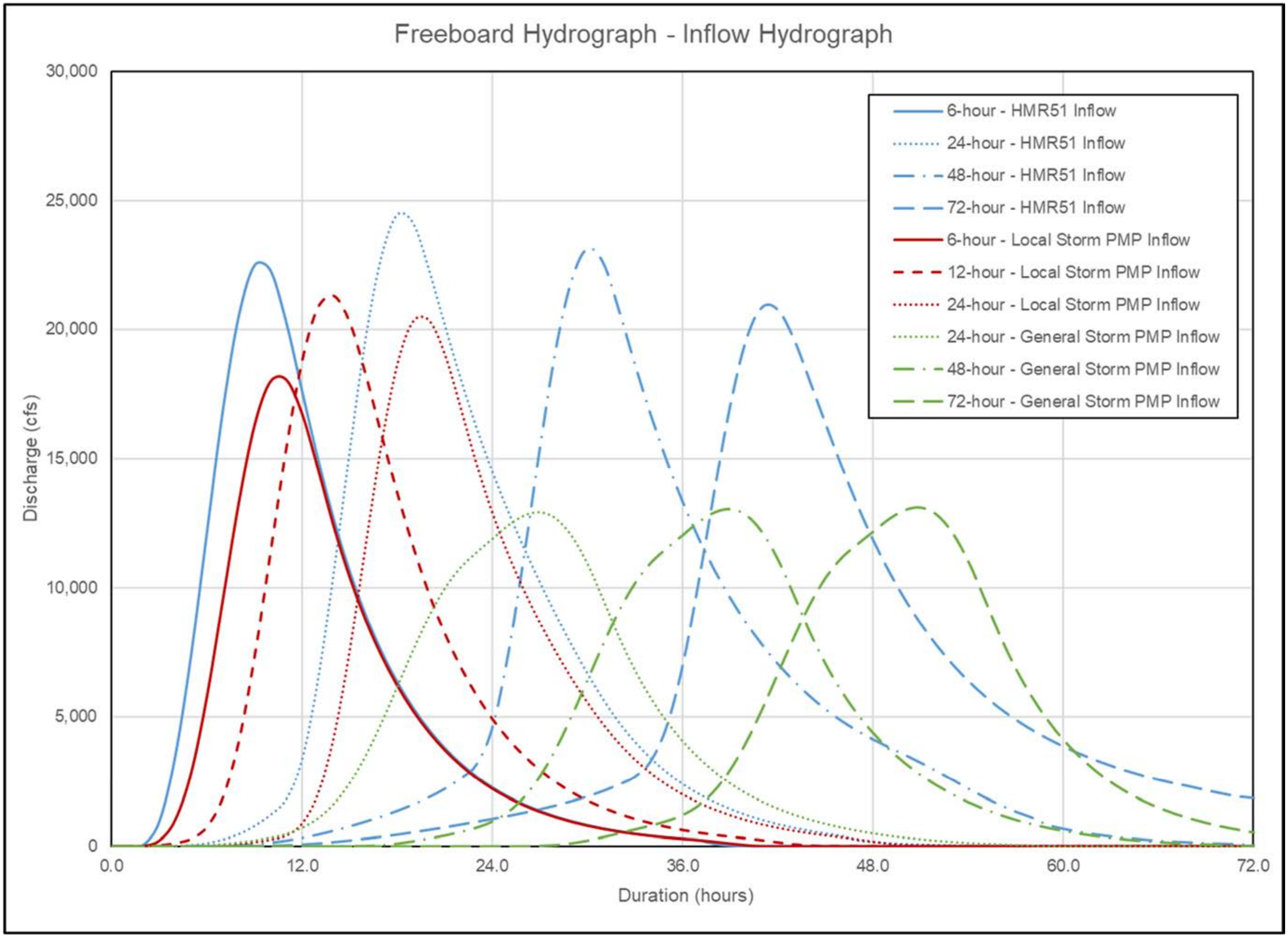


***Figure D-1-27**: Bylin Dam Elevation-Discharge Relationship*

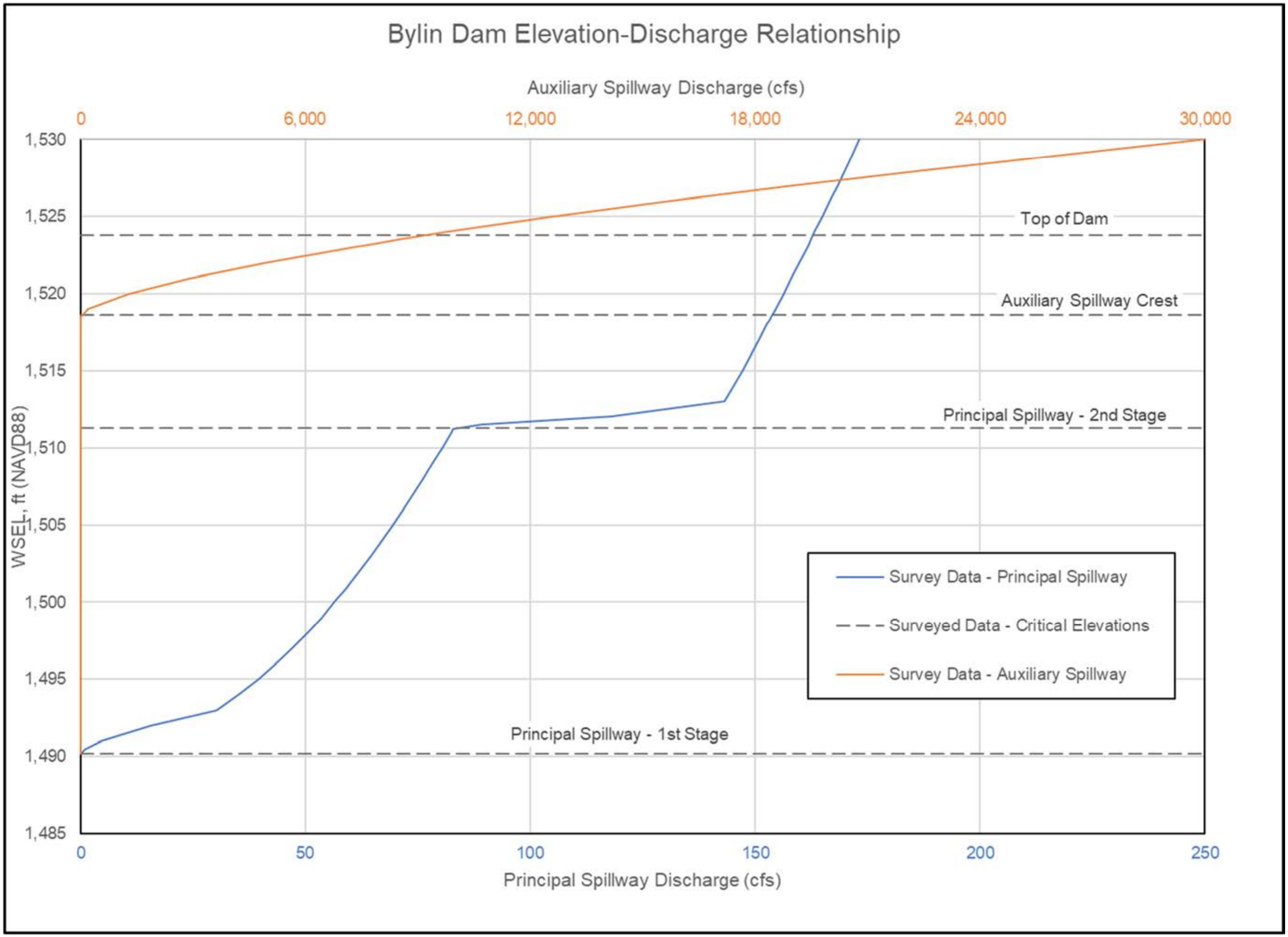


Figure D-1-28: *Bylin Dam Auxiliary Spillway Profile*

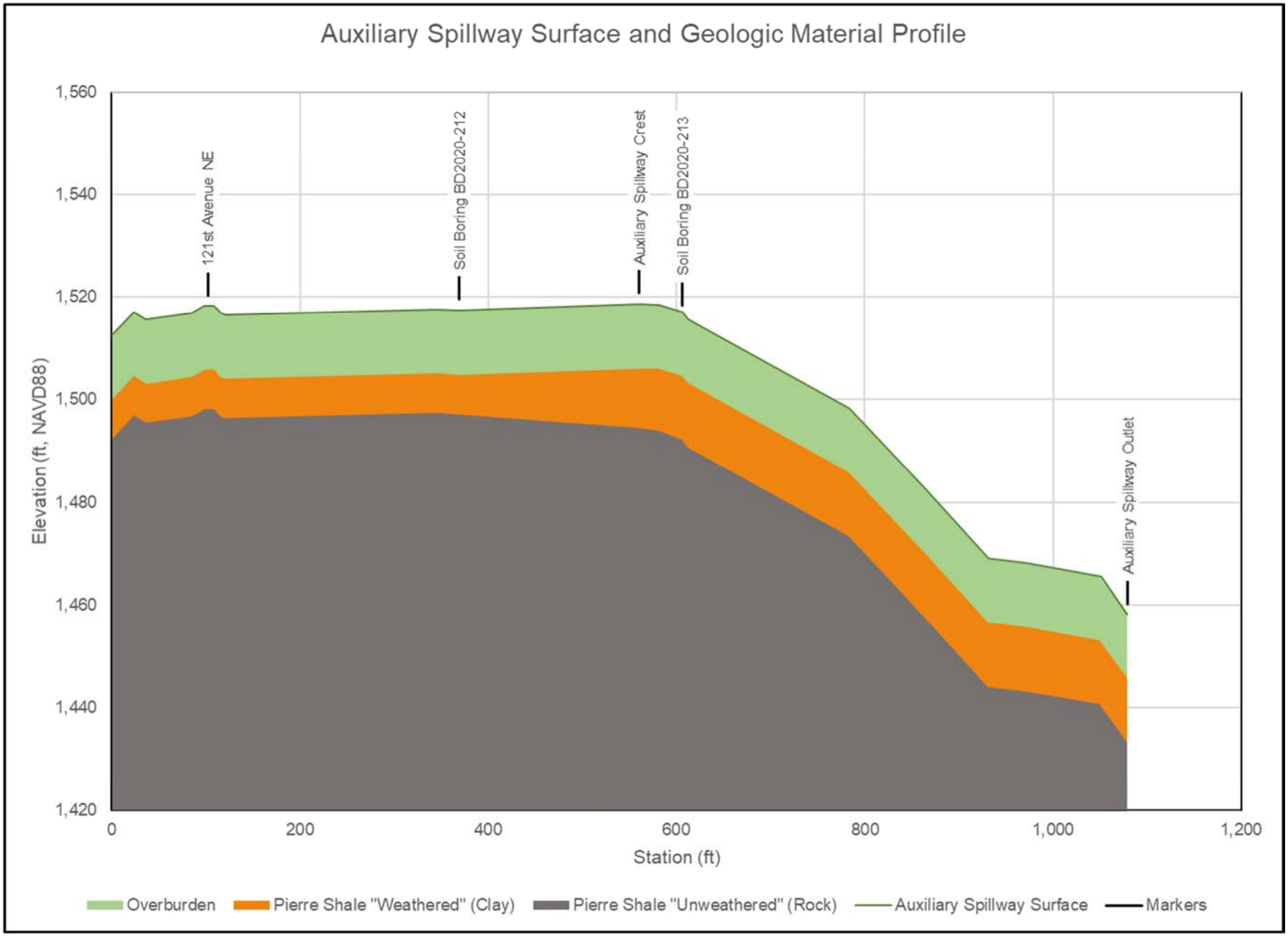
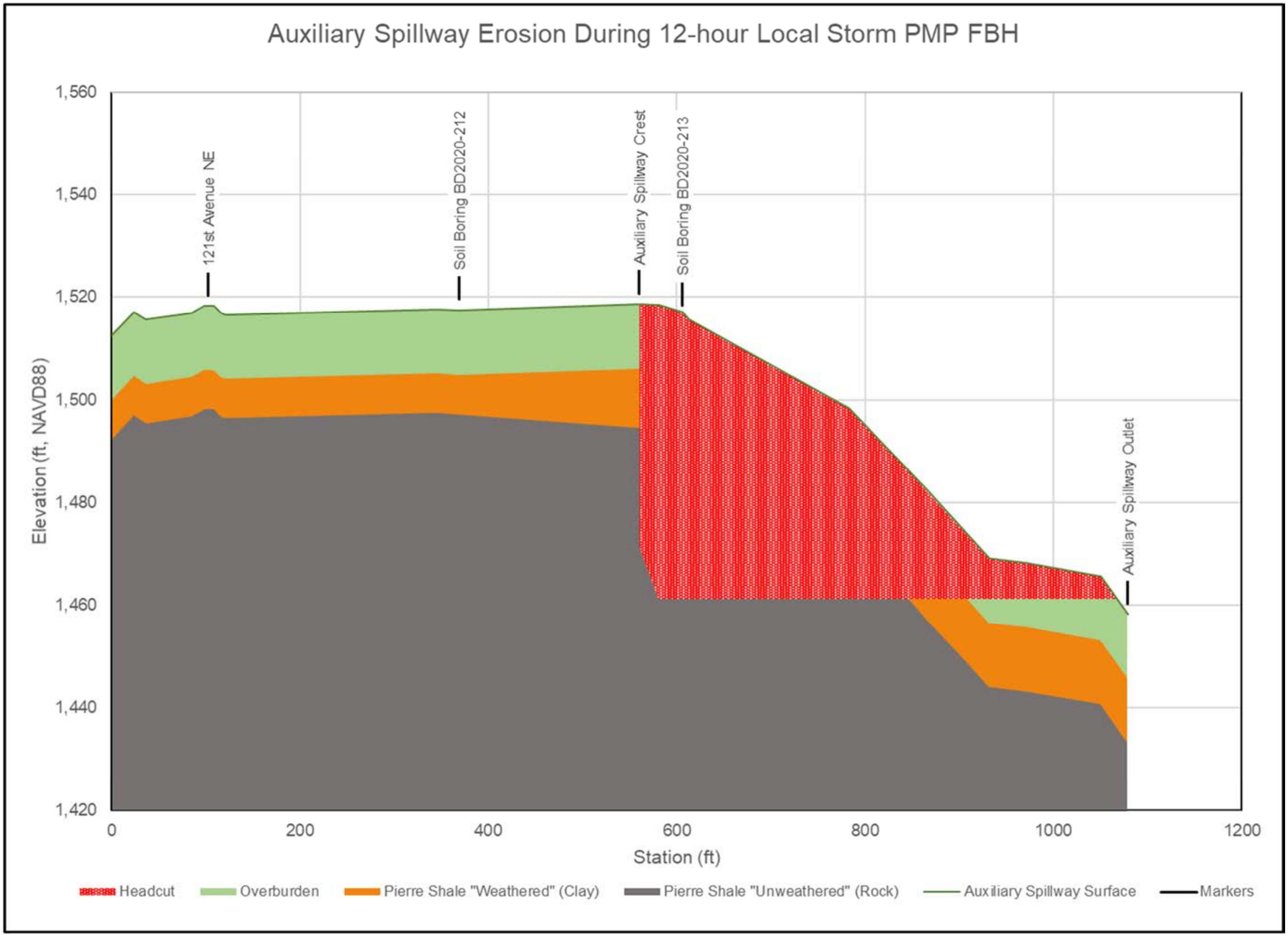


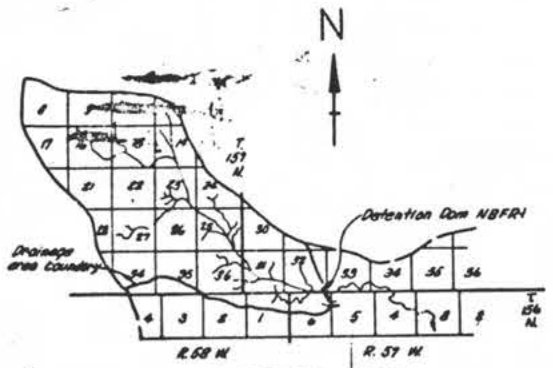
Figure D-1-29: *Bylin Dam Auxiliary Spillway Headcut Erosion from SITES Analysis*



ATTACHMENT D-1-1

As-Built Drawings

Bylin



LOCATION MAP

Drainage area = 22.1 Sq. Mile
Scale: 1" = 1 Mile

TABLE OF QUANTITIES

ITEM NO.	ITEM	UNIT	QUANTITY	
1.	COMPACTED EARTH FILL, CLASS A-2, IN DAM, DAM FOUNDATION, EMERGENCY SPILLWAY, SPILLWAY DIKE, WING DIKE AND CUTOFF TRENCH	CU. YDS.	[illegible]	314,883
2.	COMPACTED EARTH FILL, CLASS A-2, ON SLOPES OF DAM UNDER BERMS	CU. YDS.	[illegible]	
3.	EXCAVATION A. DAM FOUNDATION	CU. YDS.	[illegible]	56,467 *
	B. EMERGENCY SPILLWAY AND OUTLET DITCH	CU. YDS.	[illegible]	41,796 *
	C. PIPE TRENCH	CU. YDS.	[illegible]	
	D. CUTOFF TRENCH — Included in foundation	CU. YDS.	[illegible]	
	E. STRUCTURAL	CU. YDS.	[illegible]	
4.	PIPE TRENCH BACKFILL — Included in Earth Fill	CU. YDS.	[illegible]	
5.	CONCRETE, CLASS B (AIR ENTRAINED) A. INLET	CU. YDS.	43.5	43.9
	B. APPURTENANCE	CU. YDS.	77.1	77.1
6.	STEEL BAR REINFORCEMENT	LBS.	11,042	ok
7.	TRASH RACKS (PER DETAILS)	EACH	3	ok
*8.	30" DIA. PRESTRESSED REINFORCED CONCRETE CYLINDER PIPE WITH STEEL RING JOINTS AND RUBBER GASKETS	LIN. FT.	[illegible]	301.3
9.	12" O.D. 14 GA. WELDED STEEL PIPE, ASPHALT COATED	LIN. FT.	62	ok
10.	FLEXIBLE COUPLING, DRESSER STYLE 38 (OR EQUAL) WITH 7" X 1/4" MIDDLE RING FOR 12" O.D. WELDED STEEL PIPE	EACH	3	ok
11.	12" DIA. FLANGED GATE VALVE (CRANE NO. 791 OR EQUAL) WITH 10' OF STEM EXTENSION, HANDWHEEL, AND BAR AND SLEEVE ASSEMBLY, PER DETAILS	EACH	1	ok
12.	VALVE WELL, 30" DIA. 14 GA. C.M. PIPE, 14' LENGTH, WITH BAR BRACKET AND COVER ASSEMBLY AND DRAIN PIPE, PER DETAILS	EACH	1	ok
13.	SAND-GRAVEL FILTER MATERIAL FOR VALVE WELL	CU. YDS.	0.5	ok
14.	FOUNDATION DRAINS: A. GRADED FILTER MATERIAL	CU. YDS.	[illegible]	573
	B. 6" DIA. ASBESTOS CEMENT PERFORATED PIPE (JOHNS-MANVILLE TRANSITE, CLASS 150, PRESSURE PIPE, OR EQUAL)	LIN. FT.	900	ok
	C. 6" DIA. ASBESTOS CEMENT NONPERFORATED PIPE (JOHNS-MANVILLE TRANSITE, CLASS 150, PRESSURE PIPE, OR EQUAL)	LIN. FT.	196	ok
15.	ROCK RIPRAP WITH SAND-GRAVEL FILTER BLANKET	SQ. YDS.	[illegible]	2240
16.	CLEARING OR CLEARING AND GRUBBING TREES AND BRUSH	LUMP SUM		
17.	SALVAGING AND PLACING TOPSOIL IN EMERGENCY SPILLWAY	SQ. YDS.	[illegible]	9424

* Pay Item Common Excavation
** Not Computed

*THE MINIMUM STRENGTH BY THE 3 EDGE BEARING TEST (ASTM SPECIFICATION C-76) SHALL BE 6800 LBS. PER LINEAR FT. TO PRODUCE A 0.001 IN CRACK. THE JOINT SHALL MAINTAIN WATERTIGHTNESS FOR OPENINGS UP TO 1 3/4" FROM THE ORIGINAL LAYING POSITION.

RESERVOIR CAPACITY TABLE

	ELEV.	ACRES	ACRE FEET	ACCUM. ACRE FEET
	1464.0	0	0	0
	1465.0	2.5	1.3	1.3
	1470.0	9.8	30.7	32.0
	1475.0	24.9	86.8	118.8
DRAWDOWN	1476.0	27.3	26.1	144.9
TOP OF SEDIMENT POOL	1477.86	31.8	55.1	200.0
	1480.0	36.9	73.3	273.3
	1485.0	49.5	216.0	489.3
F.L. ORIFICE (1ST STAGE)	1489.0	59.9	218.8	708.1
	1490.0	62.5	61.2	769.3
	1495.0	75.5	345.0	1114.3
	1500.0	117.1	481.5	1595.8
	1505.0	147.2	660.7	2256.5
CREST OF INLET (2ND STAGE)	1510.0	179.5	816.8	3073.3
	1515.0	217.4	992.2	4065.5
CREST OF EMERG. SPWY.	1517.0	236.9	463.3	4518.8
	1518.0	245.1	240.5	4759.3
	1519.0	254.4	249.7	5009.0
	1520.0	263.8	258.1	5264.1
	1521.0	275.7	269.8	5537.9
	1522.0	287.6	281.8	5819.7

708
200
508

4519
708
5811

508 f+w

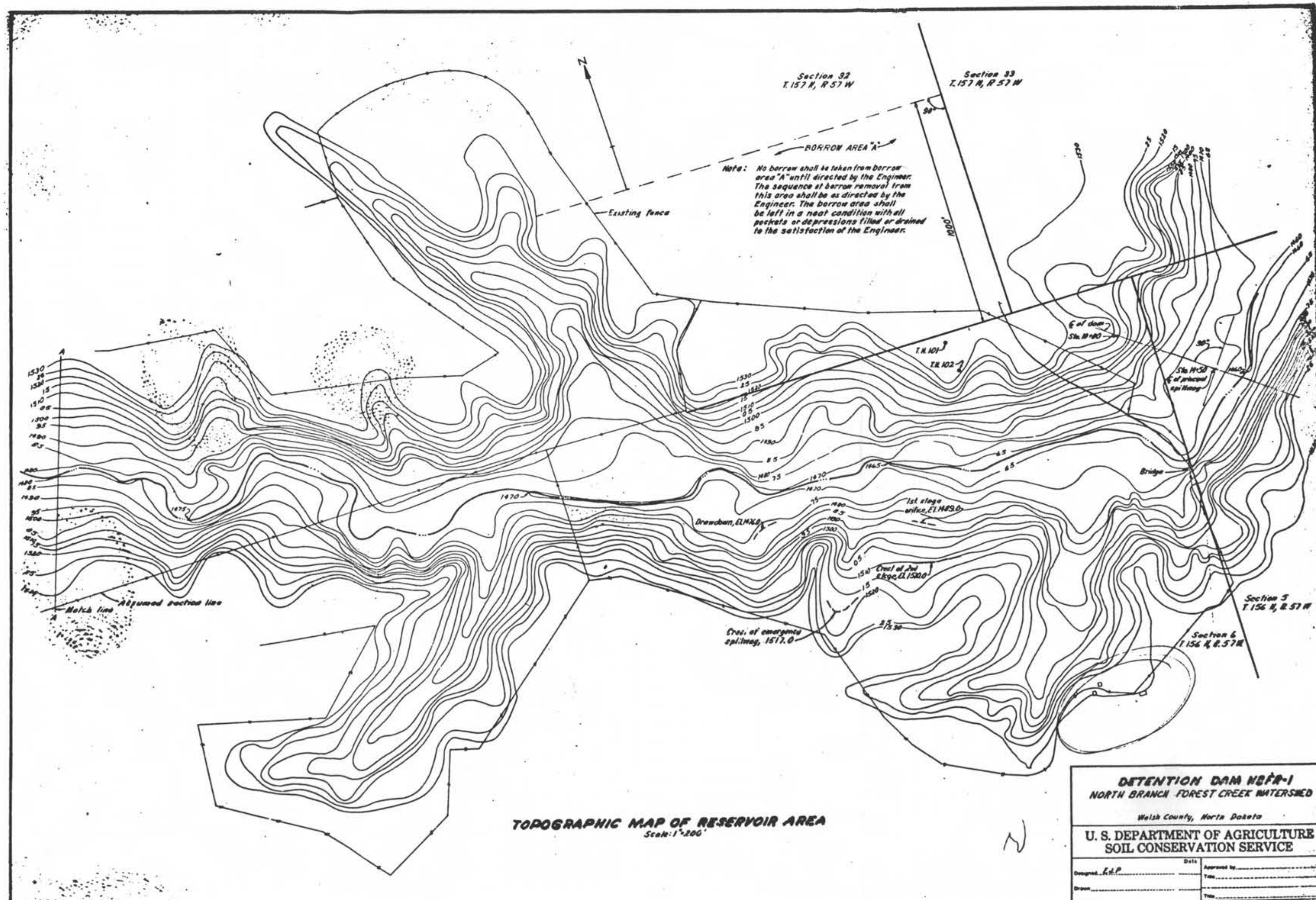
Completed Aug. 1964
Con't Wm Clairmont
Proj Eng Willis Demke
Insp. Mel Askew

"AS BUILT."

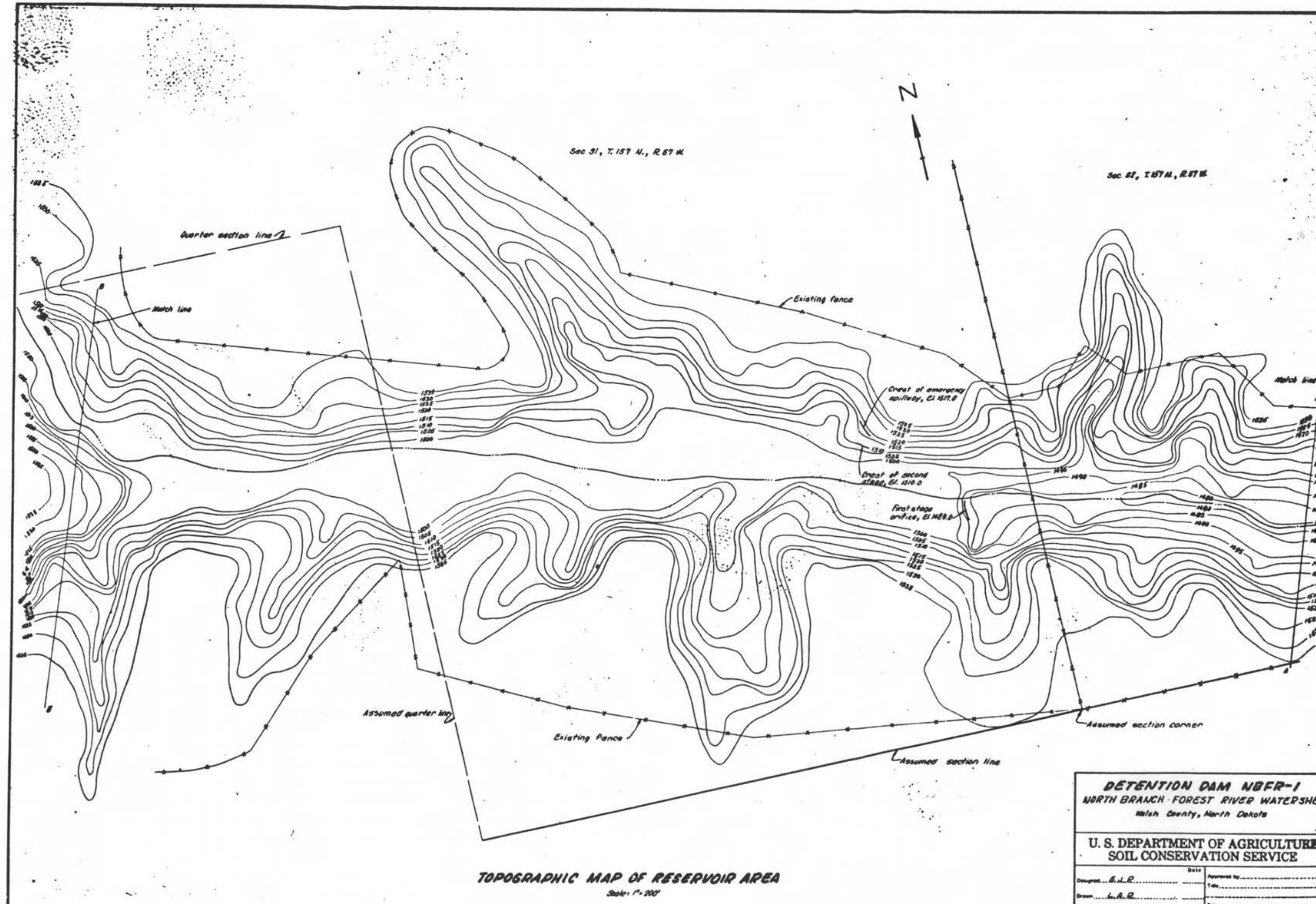
DETENTION DAM NBFR-1
NORTH BRANCH FOREST RIVER WATERSHED
NE¼ Sec 6 and NW¼ Sec 5, R57W, T156N.
Walsh County, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed E.J.P., DGM. Drawn J.R.D. Traced



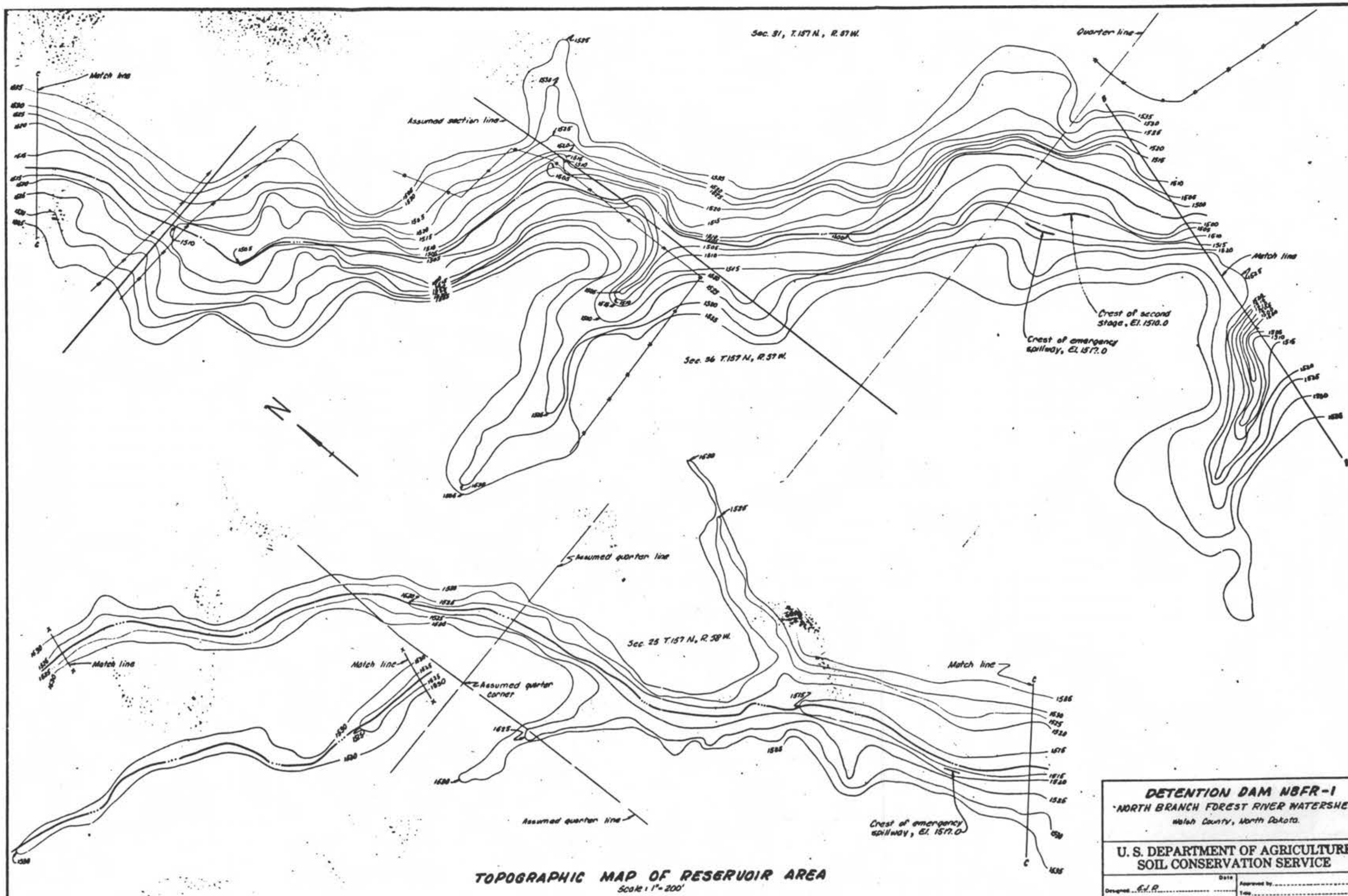
N.D.S.P. PHASE I INSPECTION REPORT PLATE C-2



TOPOGRAPHIC MAP OF RESERVOIR AREA

Scale: 1" = 200'

N.D.S.P. PHASE I INSPECTION REPORT PLATE C-3



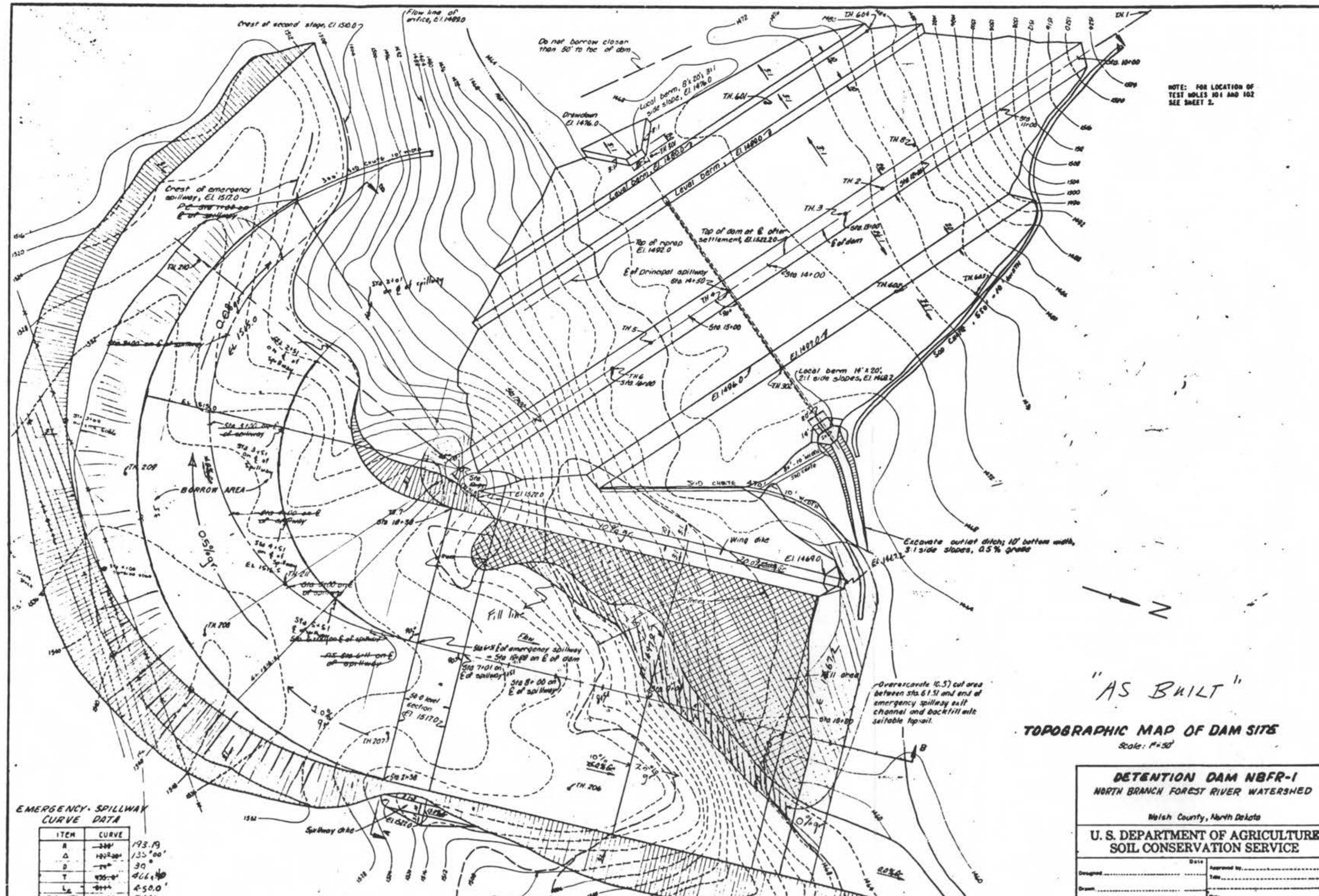
TOPOGRAPHIC MAP OF RESERVOIR AREA
Scale: 1" = 200'

DETENTION DAM NBFR-1
NORTH BRANCH FOREST RIVER WATERSHED
Walsh County, North Dakota.

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

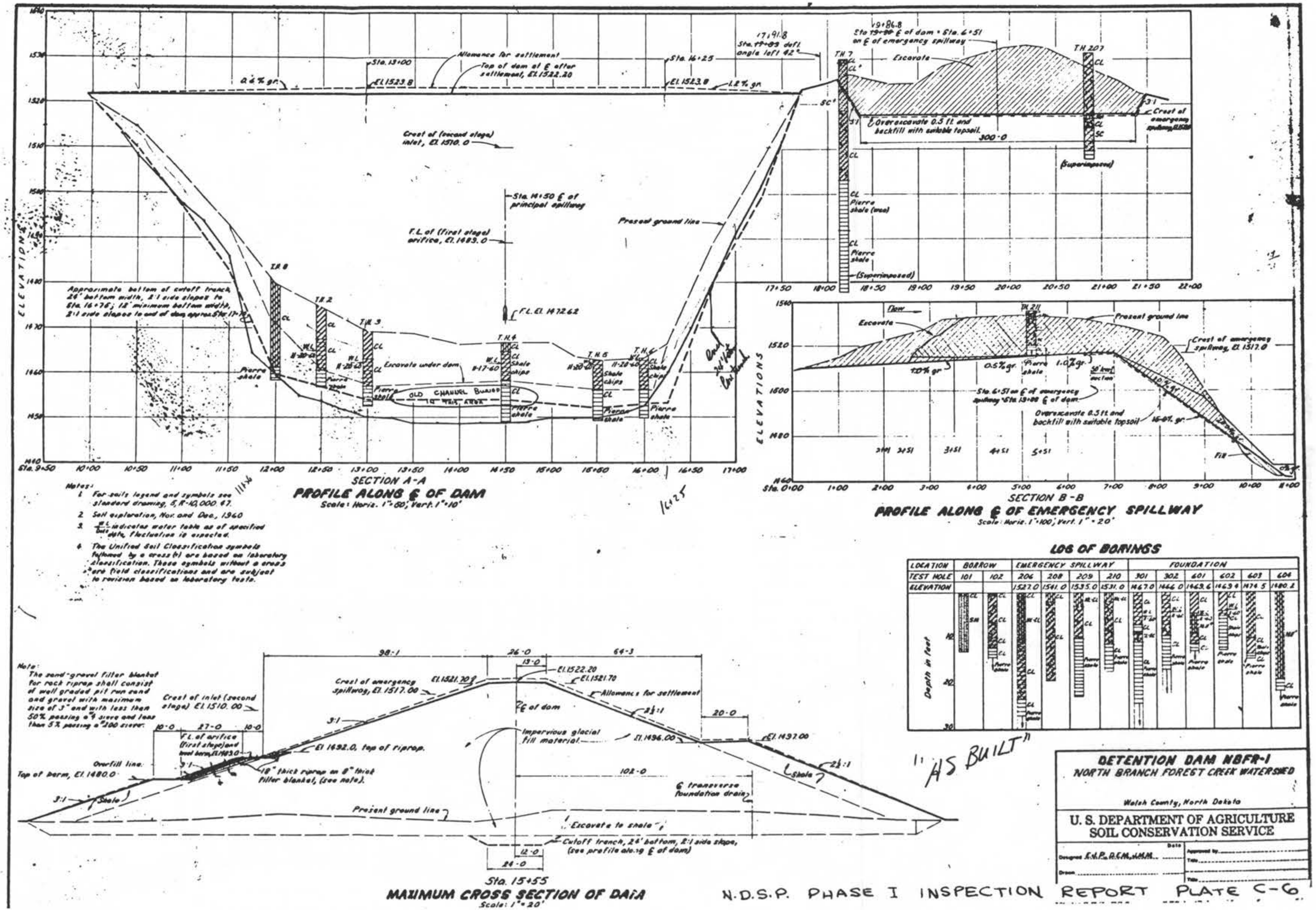
Designed E.J.R.

N.D.S.P. PHASE I INSPECTION REPORT PLATE C-4

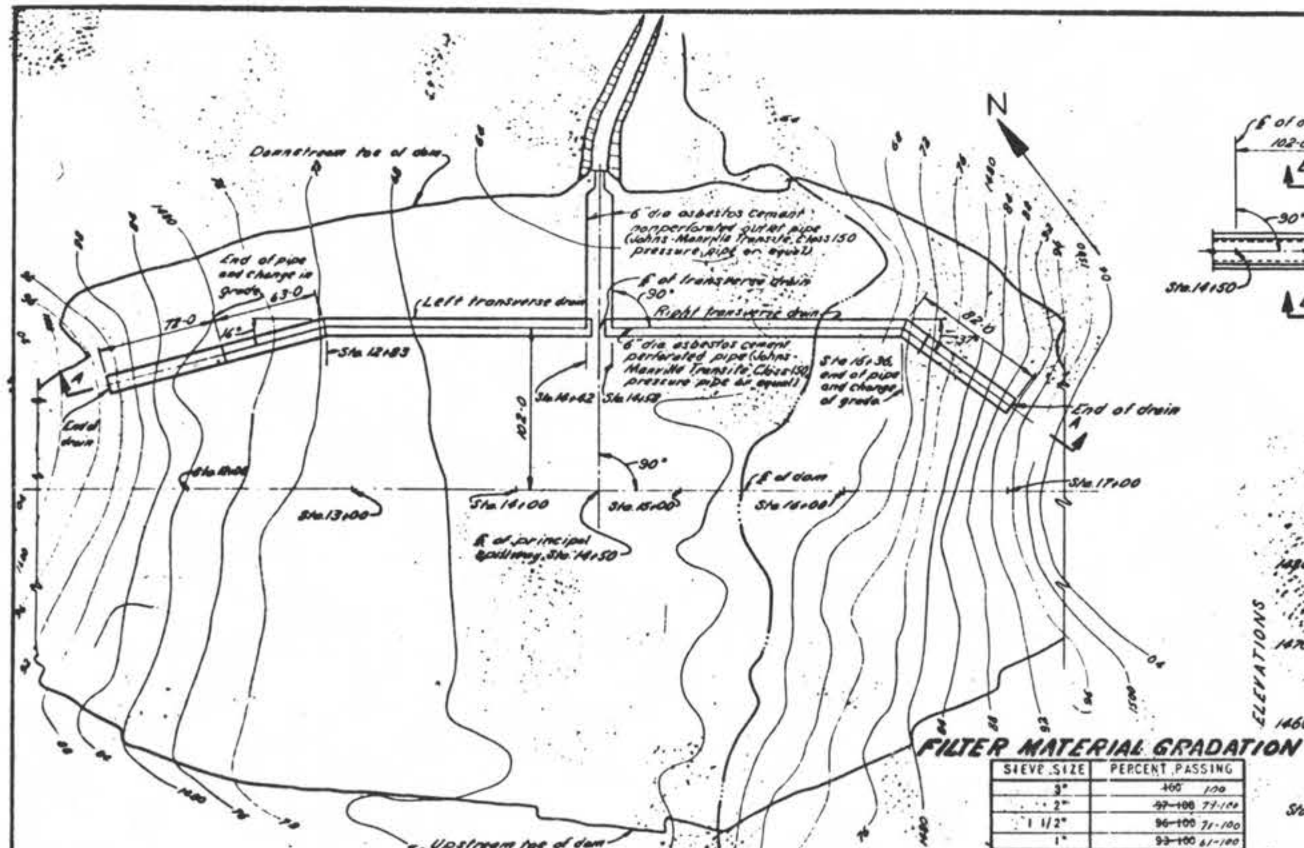


ITEM	CURVE	
R	~~200'~~	193.19
Δ	~~102°20'~~	135°00'
D	~~29°~~	30°
T	~~435.0'~~	466.40
L_c	~~[illegible]~~	450.0'
P.C. STA.	~~1+00~~	2+01
P.T. STA	~~6+11~~	6+51

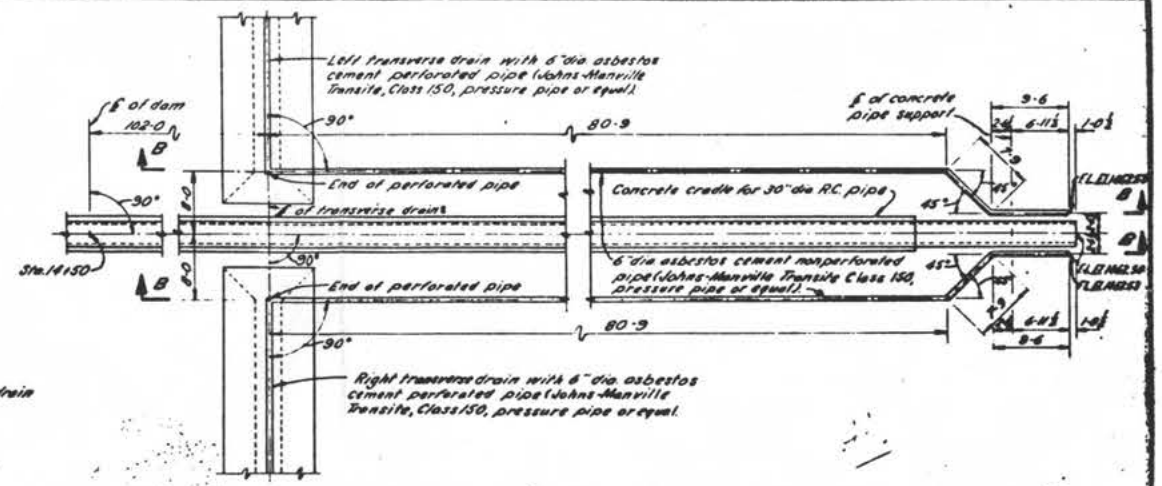
N.D.S.P. PHASE I INSPECTION REPORT PLATE C-5



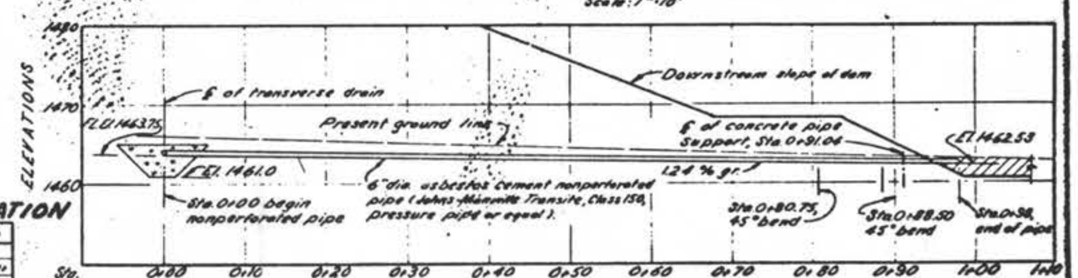
Allowance for settlement
Top of dam at ℄ after settlement, El. 1522.20
Sta. 13+00
El. 1523.8
Sta. 16+25
El. 1523.8
1.2% gr.
17+91.8
Sta. 17+83 defl. angle left 42°
Crest of (second stage) inlet, El. 1510.0
Sta. 14+50 ℄ of principal spillway
F.L. of (first stage) orifice, El. 1483.0
F.L. El. 1472.62
Present ground line
Approximate bottom of cutoff trench 26' bottom width, 2:1 side slopes to Sta. 16+75; 12' minimum bottom width, 2:1 side slopes to end of dam approx. Sta. 17+71
Excavate under dam
OLD CHANNEL BURIED
Pierre shale
ELEVATIONS
SECTION A-A
PROFILE ALONG ℄ OF DAM
Scale: Horiz. 1" = 50', Vert. 1" = 10'
Notes:
1. For soils legend and symbols see standard drawing, 5, R-10,000 47.
2. Soil exploration, Nov. and Dec., 1960
3. W.L./Date indicates water table as of specified date, fluctuation is expected.
4. The Unified Soil Classification symbols followed by a cross (+) are based on laboratory classification. Those symbols without a cross are field classifications and are subject to revision based on laboratory tests.
Sta. 19+86.8 ℄ of dam = Sta. 6+51 on ℄ of emergency spillway
Excavate
Overexcavate 0.5 ft. and backfill with suitable topsoil.
300.0
Crest of emergency spillway, El. 1517.0
(Superimposed)
Flow
Present ground line
Crest of emergency spillway, El. 1517.0
Sta. 6+51 on ℄ of emergency spillway = Sta. 19+86 ℄ of dam
Overexcavate 0.5 ft. and backfill with suitable topsoil
Fill
SECTION B-B
PROFILE ALONG ℄ OF EMERGENCY SPILLWAY
Scale: Horiz. 1" = 100', Vert. 1" = 20'
LOG OF BORINGS
LOCATION: BORROW | EMERGENCY SPILLWAY | FOUNDATION
TEST HOLE: 101 | 102 | 206 | 208 | 209 | 210 | 301 | 302 | 601 | 602 | 603 | 604
ELEVATION: 1527.0 | 1541.0 | 1535.0 | 1531.0 | 1467.0 | 1466.0 | 1463.6 | 1463.4 | 1474.5 | 1480.2
Depth in feet
Note:
The sand-gravel filter blanket for rock riprap shall consist of well graded pit run sand and gravel with maximum size of 3" and with less than 50% passing a #4 sieve and less than 5% passing a #200 sieve.
Crest of inlet (second stage) El. 1510.00
F.L. of orifice (first stage) and level berm, El. 1483.0
Overfill line.
Top of berm, El. 1480.0
El. 1492.0, top of riprap.
18" thick riprap on 8" thick filter blanket, (see note).
Crest of emergency spillway, El. 1517.00
El. 1521.70
El. 1522.20
El. 1521.70
Allowance for settlement
℄ of dam
Impervious glacial fill material
El. 1496.00
El. 1497.00
Shale
℄ transverse foundation drain
Present ground line
Excavate to shale
Cutoff trench, 26' bottom, 2:1 side slope, (see profile along ℄ of dam)
Sta. 15+55
MAXIMUM CROSS SECTION OF DAM
Scale: 1" = 20'
"AS BUILT"
DETENTION DAM NBFR-1
NORTH BRANCH FOREST CREEK WATERSHED
Walsh County, North Dakota
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
N.D.S.P. PHASE I INSPECTION REPORT PLATE C-6



PLAN OF BASE OF DAM SHOWING FOUNDATION DRAINS
Scale: 1"=50'



PLAN OF OUTLET PIPES FOR FOUNDATION DRAINS
Scale: 1"=10'



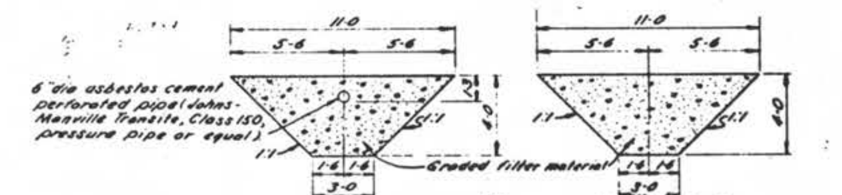
SECTION B-B
PROFILE ALONG ℄ OF OUTLET PIPES
Scale: 1"=10'

S = 1.22/98
= .012449

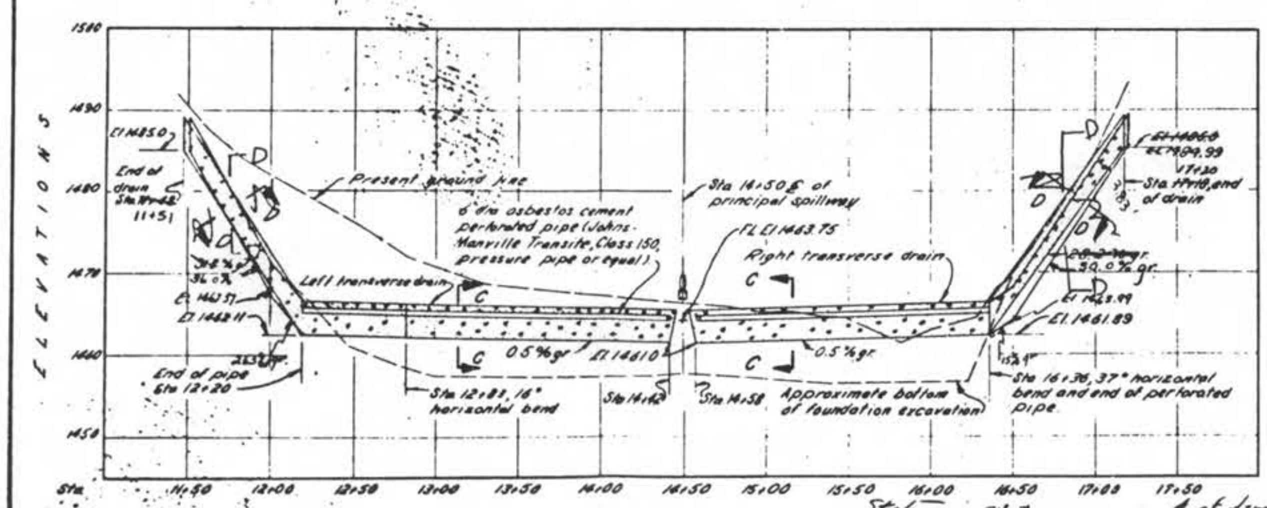
FILTER MATERIAL GRADATION

SIEVE SIZE	PERCENT PASSING
3"	~~100~~ 100
2"	~~97-100~~ 77-100
1 1/2"	~~96-100~~ 71-100
1"	~~93-100~~ 61-100
3/4"	~~91-97~~ 55-100
1/2"	~~86-94~~ 47-82
3/8"	~~80-90~~ 43-73
#4	~~67-78~~ 33-57
#10	~~50-61~~ 24-42
#20	~~33-45~~ 15-30
#50	~~13-25~~ 7-19
#100	~~6-12~~ 0-12
#200	LESS THAN 5

See Modification No. 1



DETAILS OF TRANSVERSE FOUNDATION DRAINS
Scale: 1"=4'



SECTION A-A
PROFILE ALONG ℄ OF TRANSVERSE FOUNDATION DRAINS
Scale Horiz 1"=50', Vert. 1"=10'

Stationing 7to7 same as ℄ of dam stationing based

QUANTITIES FOR FOUNDATION DRAINS

ITEM NO.	ITEM	UNIT	QUANTITY
1	EXCAVATION	CU. YDS.	590
2	GRADED FILTER MATERIAL	CU. YDS.	~~500~~ 578
3	BACKFILL	CU. YDS.	20
4	6" DIA. ASBESTOS CEMENT PERFORATED PIPE (JOHNS-MANVILLE TRANSITE, CLASS 150, PRESSURE PIPE OR EQUAL)	LIN. FT.	400 OK
5	6" DIA. ASBESTOS CEMENT NONPERFORATED PIPE (JOHNS-MANVILLE TRANSITE, CLASS 150, PRESSURE PIPE OR EQUAL)	LIN. FT.	196 OK

NOTES:

1. PLUG UPPER END OF ASBESTOS CEMENT PIPE WITH 6" OF CONCRETE OR PREFABRICATED END PLUG.
2. PLACE COMPACTED FILL TO TOP OF DRAIN (WHERE DRAIN IS ABOVE BOTTOM OF FOUNDATION EXCAVATION) AND EXCAVATE DRAIN IN COMPACTED FILL.
3. PROVIDE 1" X 1", 12 GA. GALVANIZED WOVEN WIRE MESH OVER OUTLET ENDS OF OUTLET PIPES: CLAMP IN PLACE WITH 1" X 1/16" GALVANIZED STRAP, 2'-2" LONG, USE 1/4" DIA. GALVANIZED BOLTS.

"AS BUILT"

DETENTION DAM NBFR-1
NORTH BRANCH FOREST RIVER WATERSHED
Walsh County, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed D.E.M. Date	Approved by
	Title
Drawn	Title

N.D.S.P. PHASE I INSPECTION REPORT PLATE C-7

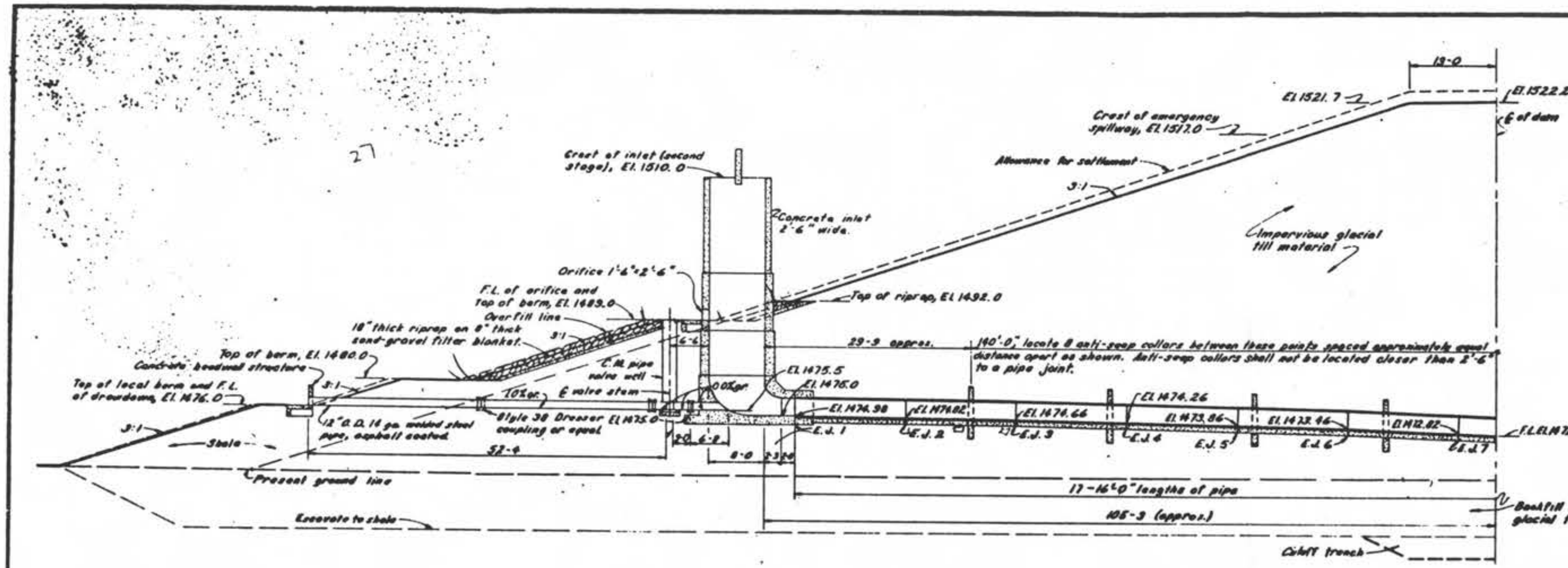
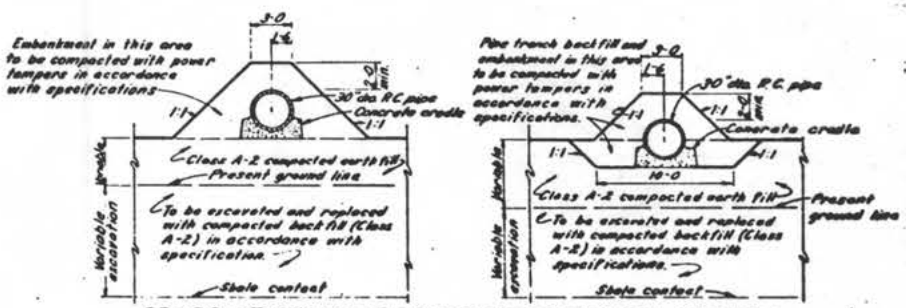


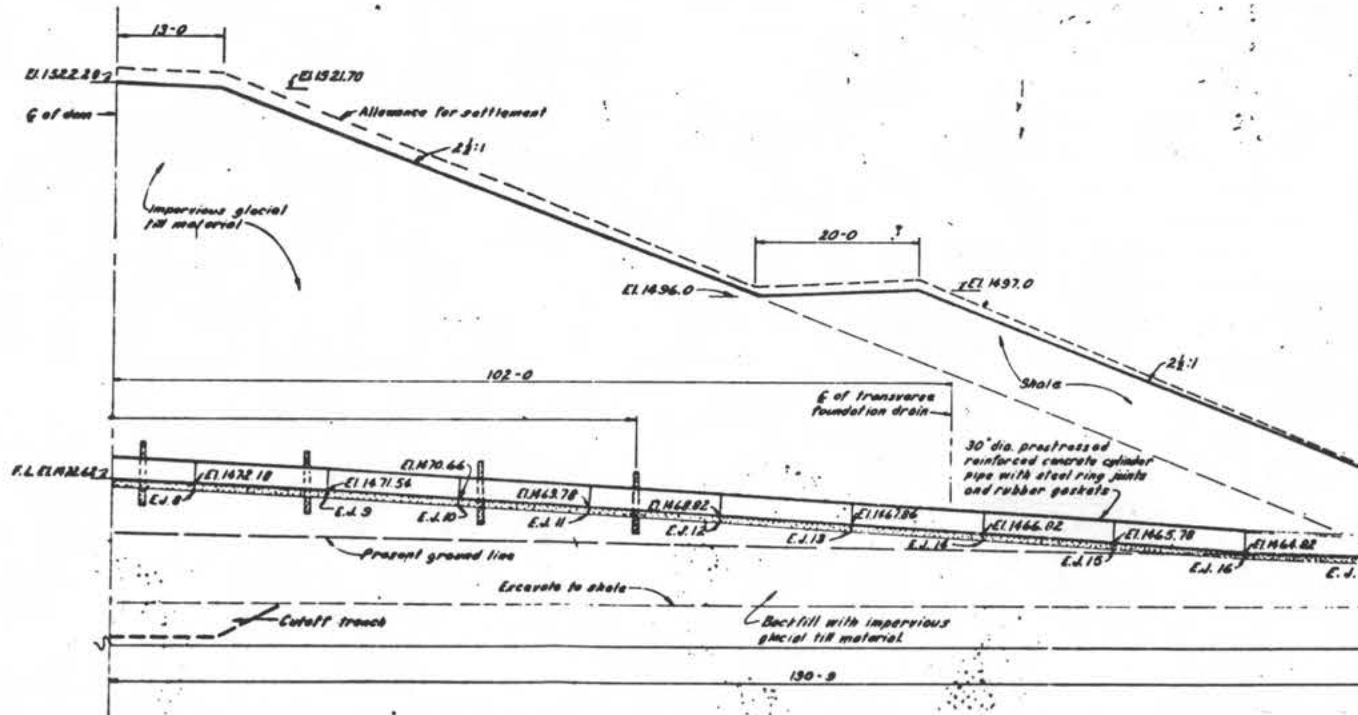
TABLE OF PIPE GRADES

LOCATION	GRADE
Inlet to E.J. 1	0.5%
E.J. 1 to E.J. 3	1.0%
E.J. 3 to E.J. 6	2.5%
E.J. 6 to E.J. 9	4.0%
E.J. 9 to E.J. 11	5.5%
E.J. 11 to E.J. 13	6.0%
E.J. 13 to E.J. 15	6.5%
E.J. 15 to E.J. 16	6.0%
E.J. 16 to E.J. 17	8.0%
E.J. 17 to E.J. 18	4.0%
E.J. 18 to E.J. 19	3.5%
E.J. 19 to outlet	3.0%

E.J. = Expansion Joint



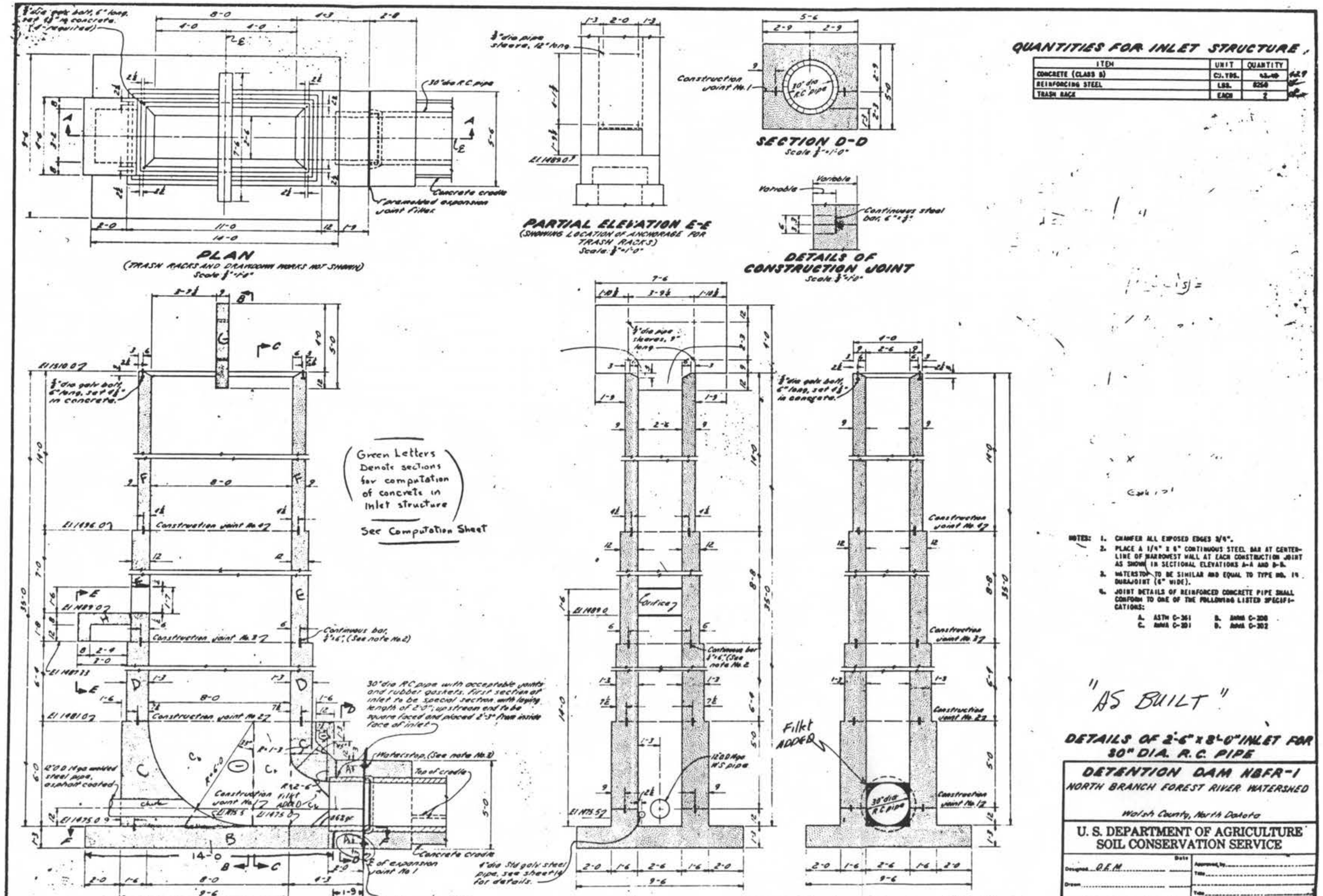
CROSS SECTIONS OF PRINCIPAL SPILLWAY SHOWING DETAILS OF EXCAVATION, BACKFILL, AND EMBANKMENT
Scale 1"=6'



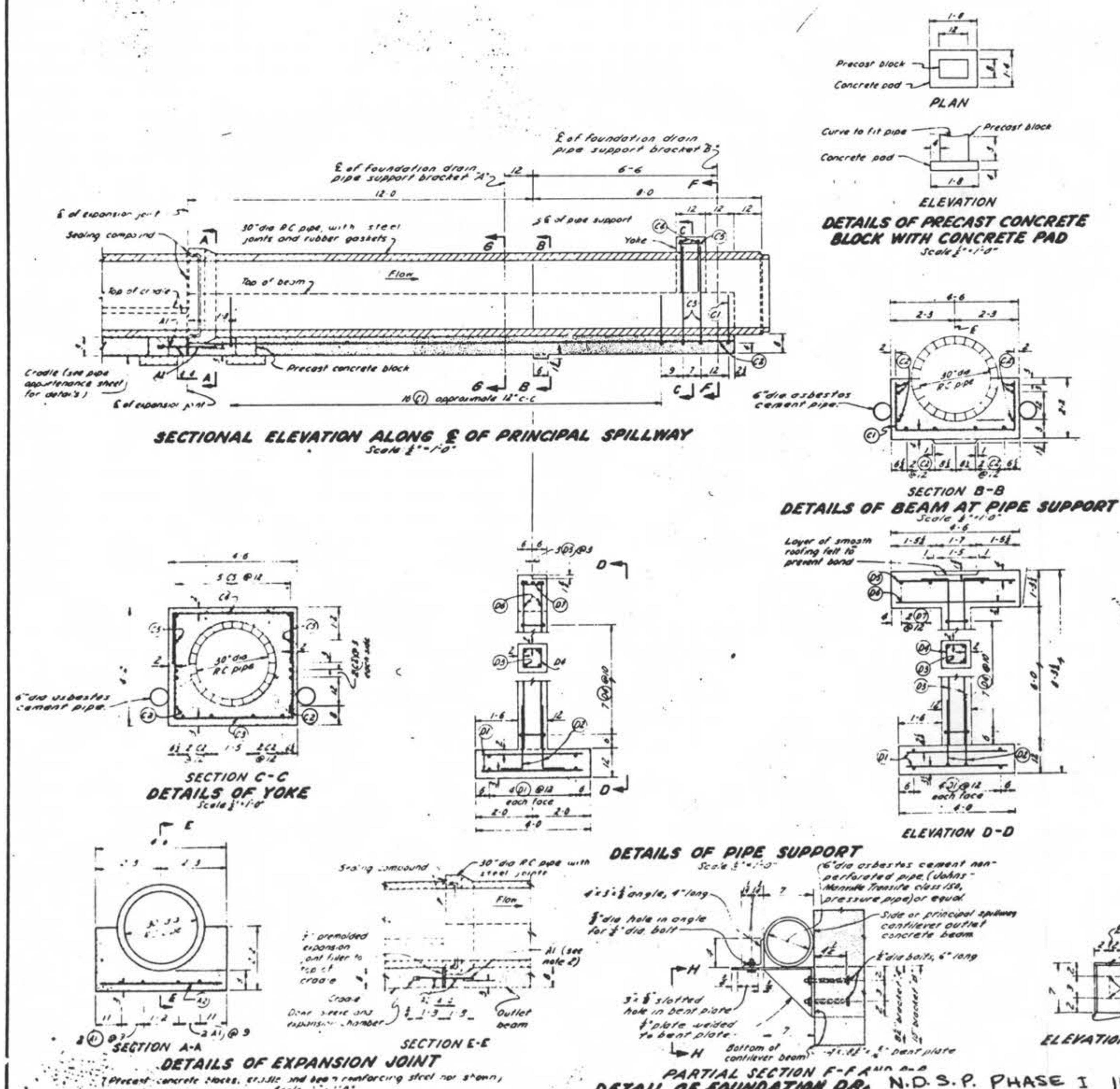
CROSS SECTION OF DAM ALONG ℄ OF PRINCIPAL SPILLWAY
(Trash rack not shown)
Scale 1"=10'

"AS BUILT"

DETENTION DAM NBFR-1
NORTH BRANCH FOREST RIVER WATERSHED
Walsh County, North Dakota
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed EMB, DEM, JMM



N.D.S.P. PHASE I INSPECTION REPORT PLATE C-9

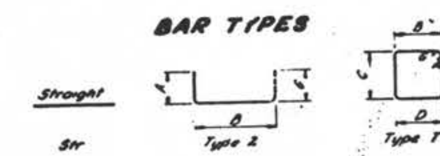


BAR SCHEDULE FOR CANTILEVER OUTLET

MARK	LOCATION	SIZE	QUANTITY	LENGTH	TOTAL LENGTH	TYPE	A	B	C	D	E	G
C1	CANTILEVER BEAM	4	17	7-8	130-4	2	1-9	4-2				1-0
C2	CANTILEVER BEAM	6	10	10-6	105-0	STR.						
C3	CANTILEVER BEAM	4	2	11-6	23-0	2	3-8	4-2				3-8
C4	CANTILEVER BEAM	4	2	7-10	15-8	2	1-10	4-2				1-10
C5	CANTILEVER BEAM	4	7	C-9	5-3	STR.						
D1	PIPE SUPPORT	4	16	3-6	56-0	STR.						
D2	PIPE SUPPORT	5	4	3-0	12-0	2	0-9	2-3				
D3	PIPE SUPPORT	5	4	7-11	31-8	2	7-0	0-11				
D4	PIPE SUPPORT	2	7	3-0	21-0	T1	0-2	0-8	0-6	0-8	0-6	0-2
D5	PIPE SUPPORT	5	3	4-3	12-9	STR.						
D6	PIPE SUPPORT	4	2	4-3	8-6	STR.						
D7	PIPE SUPPORT	4	4	0-9	3-0	STR.						

NO. 2 = 1/4" DIA. NO. 4 = 1/2" DIA. NO. 5 = 5/8" DIA. NO. 6 = 3/4" DIA.

BAR TYPES



SITE #7 NBFR "A" 2 Bm1

QUANTITIES FOR CANTILEVER OUTLET

ITEM	* CONCRETE (CU. YDS.)	REINFORCING STEEL (LBS.)
CANTILEVER BEAM	~~4.56~~ 4.68	394
PIPE SUPPORT	1.02 OK	108

* CLASS B CONCRETE

NOTES:

1. ALL DIMENSIONS SHOWING DISTANCE FROM FACE OF CONCRETE TO REINFORCING STEEL DESIGNATE THE CLEAR DISTANCE.
2. MARK (A) AND (A1) BARS ARE LISTED IN BAR SCHEDULE FOR CRADLE, ALSO SEE NOTE 6 ON PIPE APPURTENANCE SHEET.
3. RADIUS OF BENDS OF REINFORCING BARS = 3 X DIA. OF BAR.
4. ALL BAR DIMENSIONS ARE OUT TO OUT OF BAR.
5. JOINT DETAILS OF REINFORCED CONCRETE PIPE SHALL CONFORM TO ONE OF THE FOLLOWING LISTED SPECIFICATIONS:
   A. ASTM C-361
   B. AWWA C-300
   C. AWWA C-301
   D. AWWA C-302
6. THE LOCATION OF JOINTS IS NOT SHOWN. ANY COMBINATION OF LENGTHS WHICH TOTAL 20 FEET MAY BE USED.
7. THE SPACING AND NUMBER OF PRECAST BLOCKS PER PIPE SECTION SHALL BE DETERMINED BY THE ENGINEER SO THAT THE SOIL BEARING PRESSURE DUE TO THE WEIGHT OF THE PIPE AND BLOCKS SHALL NOT EXCEED 1300 LBS. PER SQ.FT.

"AS BUILT"

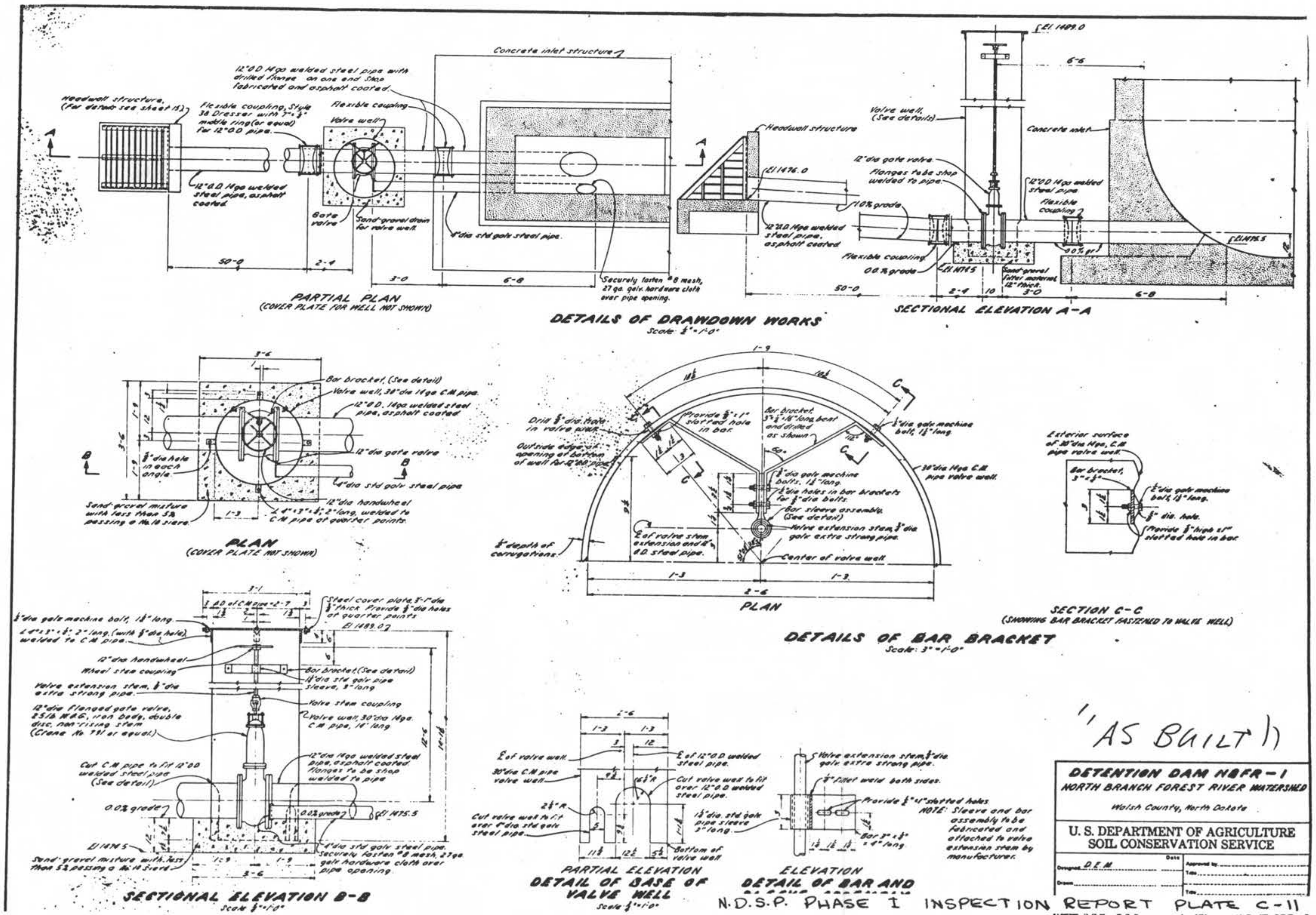
CANTILEVER OUTLET FOR 30" DIA. R.C. PIPE

DETENTION DAM NBFR-1
NORTH BRANCH FOREST RIVER WATERSHED
Walsh County, North Dakota

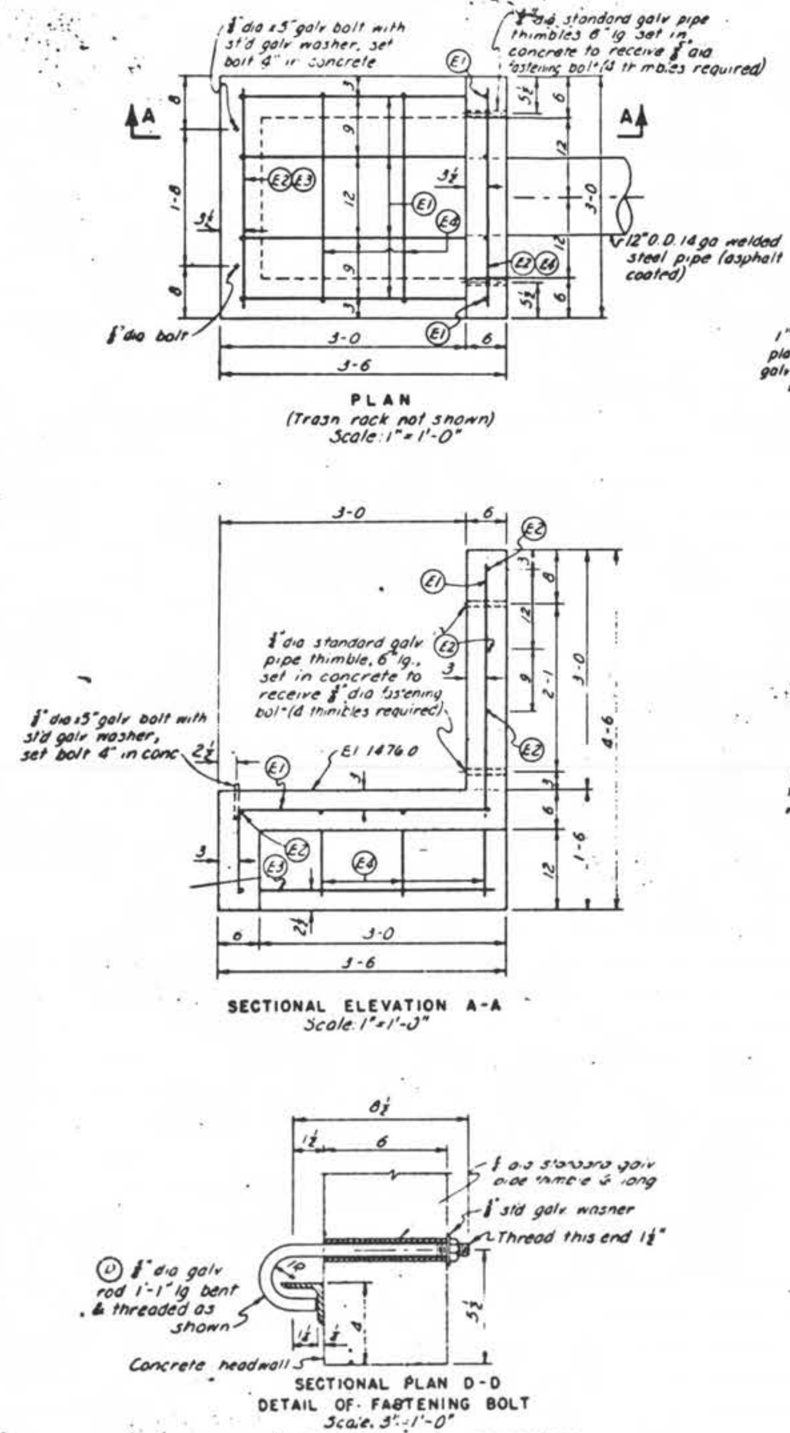
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed O.E.M. Drawn B.L.R.

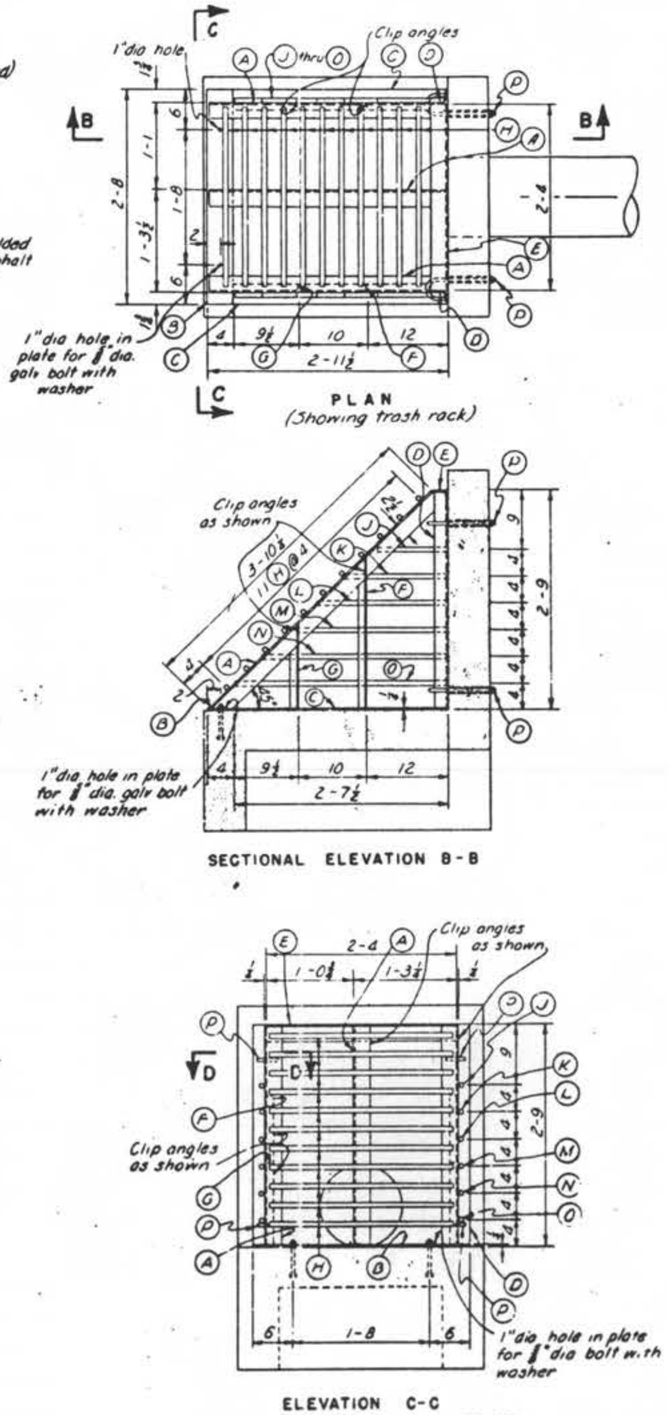
N.D.S.P. PHASE I INSPECTION REPORT PLATE C-10



N.D.S.P. PHASE I INSPECTION REPORT PLATE C-11



DETAILS OF HEADWALL STRUCTURE



DETAILS OF TRASH RACK
Scale: 1" = 1'-0"

MATERIAL LIST FOR TRASH RACK

MARK	ITEM	LENGTH	QUANTITY
A	∠s 2 1/2" X 2 1/2" X 1/4" (CLIP LEG AS SHOWN)	3'-10 1/4"	3
B	PLATE 4" X 1/4"	2'-8"	1
C	PLATE 3" X 1/4"	2'-7 1/2"	2
D	∠s 2" X 2" X 1/4"	2'-9"	2
E	∠ 2 1/2" X 2 1/2" X 1/4"	2'-4"	1
F	∠s 1 1/4" X 1 1/4" X 1/4" (CLIP LEG AS SHOWN)	1'-10 1/2"	2
G	∠s 1 1/4" X 1 1/4" X 1/4" (CLIP LEG AS SHOWN)	1'-0 1/2"	2
H	3/4" DIA. PLAIN BARS	2'-3"	11
J	3/4" DIA. PLAIN "	0'-10"	2
K	3/4" DIA. PLAIN "	1'-3"	2
L	3/4" DIA. PLAIN "	1'-7"	2
M	3/4" DIA. PLAIN "	1'-10"	2
N	3/4" DIA. PLAIN "	2'-3"	2
O	3/4" DIA. PLAIN "	2'-7"	2
P	5/8" DIA. BOLT, GALV. WITH WASHER (PER DETAIL)		4

TOTAL QUANTITIES FOR HEADWALL STRUCTURE

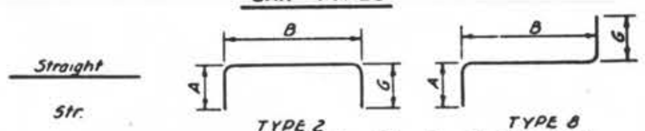
ITEM	UNIT	QUANTITY
CONCRETE (CLASS B)	CU.YD.	0.52 ok
REINFORCING STEEL	LBS.	42 ok
STRUCTURAL STEEL	LBS.	185 ok

BAR SCHEDULE

MARK	SIZE	QUANTITY	LENGTH	TYPE	A	B	G	SPACING (INCHES)	TOTAL LENGTH PER MARK
E1	4	4	7-1	8	1-1	3-0	3-0	9	28-4
E2	4	4	2-9	STR.				12	11-0
E3	4	1	8-10	2	3-2	2-6	3-2	--	8-10
E4	4	3	4-9	2	1-1	2-7	1-1	12	14-3
							TOTAL LENGTH		62-5

SIZE 4 BARS = 1/2" DIA.

BAR TYPES



Radius of bends = 3 x dia. of bar

NOTES:
1. ALL ANGLES AND BARS ARE TO BE WELDED AT ALL JUNCTIONS.
2. CLIP LEGS OF ANGLES AS REQUIRED.
3. TRASH RACK TO BE PAINTED IN ACCORDANCE WITH SPECIFICATIONS.
4. ALL DIMENSIONS SHOWING DISTANCE FROM FACE OF CONCRETE TO REINFORCING STEEL DESIGNATE THE CLEAR DISTANCE.

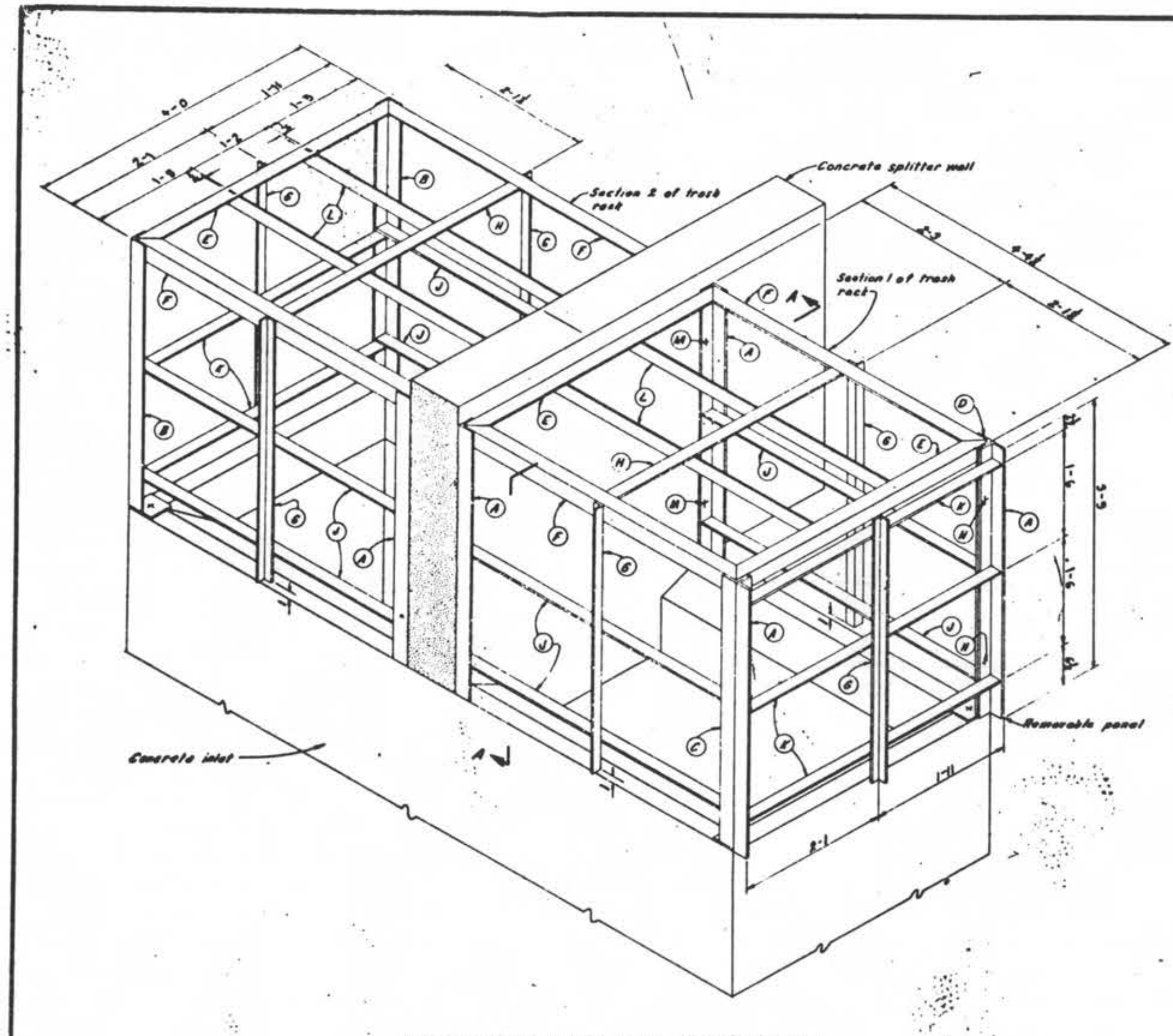
"AS BUILT"

DETAILS OF HEADWALL STRUCTURE & TRASH RACK FOR DRAWDOWN PIPE

DETENTION DAM NBFR-1
NORTH BRANCH FOREST RIVER WATERSHED
Walsh County, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed D.E.M. Date
Drawn
Traced
Approved by
Title

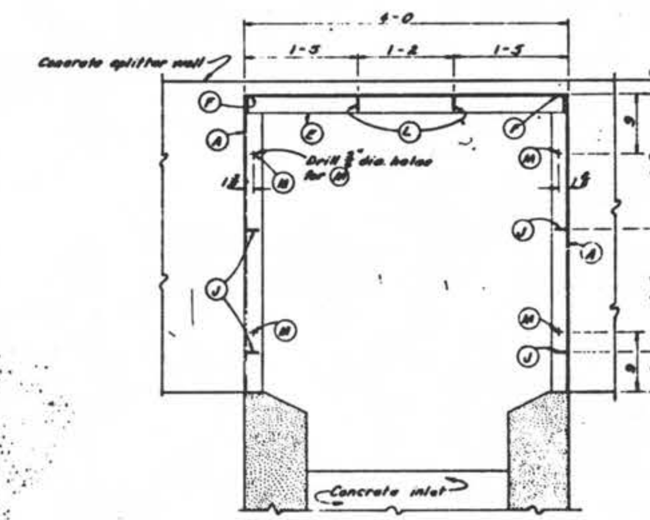


ISOMETRIC VIEW OF TRASH RACK
(Portion of splitter wall removed)

MATERIAL LIST FOR TRASH RACK

MARK	DESCRIPTION	QUANTITY
A	∠S 2 1/2" X 2 1/2" X 1/4", 3'-9" LONG	6
B	∠S 2 1/2" X 2 1/2" X 1/4", 3'-8 3/4" LONG, WITH PL 4" X 4" X 1/4" PER DETAIL	2
C	∠S 2 1/2" X 2 1/2" X 1/4", 3'-8 3/4" LONG, WITH PL 4" X 4" X 1/4" PER DETAIL	1
D	∠S 2 1/2" X 2 1/2" X 1/4", 3'-8 3/4" LONG, WITH PL 4" X 4" X 1/4" PER DETAIL	1
E	∠S 2 1/2" X 2 1/2" X 1/4", 3'-11 1/2" LONG	4
F	∠S 2 1/2" X 2 1/2" X 1/4", 4'-4" LONG	4
G	∠S 1 1/2" X 1 1/2" X 1/4", 3'-8" LONG	6
H	BARS, 2" X 1/4", 3'-6 1/2" LONG	2
J	BARS, 2" X 1/4", 4'-4" LONG	8
K	BARS, 2" X 1/4", 3'-11 1/2" LONG	5
L	BARS, 2" X 1/4", 4'-3 1/2" LONG	4
M	BOLTS, 5/8" DIA. GALV., 10 1/2" LONG	4
N	BOLTS, 5/8" DIA. GALV., 1 1/2" LONG	4

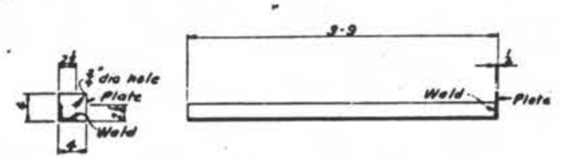
TOTAL WEIGHT OF STRUCTURAL STEEL = 405 LBS.



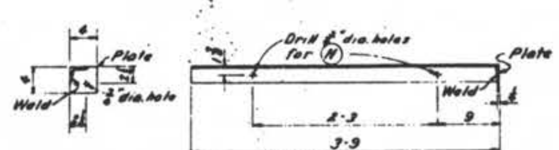
SECTIONAL ELEVATION A-A

NOTES:
1. CLIP ANGLES AS SHOWN.
2. ALL ANGLES, BARS AND PLATES TO BE SECURELY WELDED AT JUNCTIONS UNLESS INDICATED OTHERWISE.
3. TRASH RACKS TO BE PAINTED IN ACCORDANCE WITH SPECIFICATIONS.
4. REMOVABLE PANEL IN SECTION I ONLY.

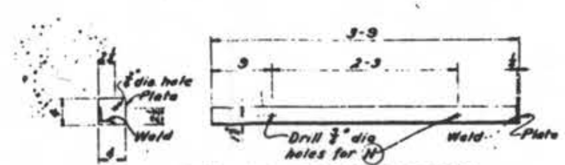
"AS Built"



DETAILS OF MEMBER (B)



DETAILS OF MEMBER (C)



DETAILS OF MEMBER (D)

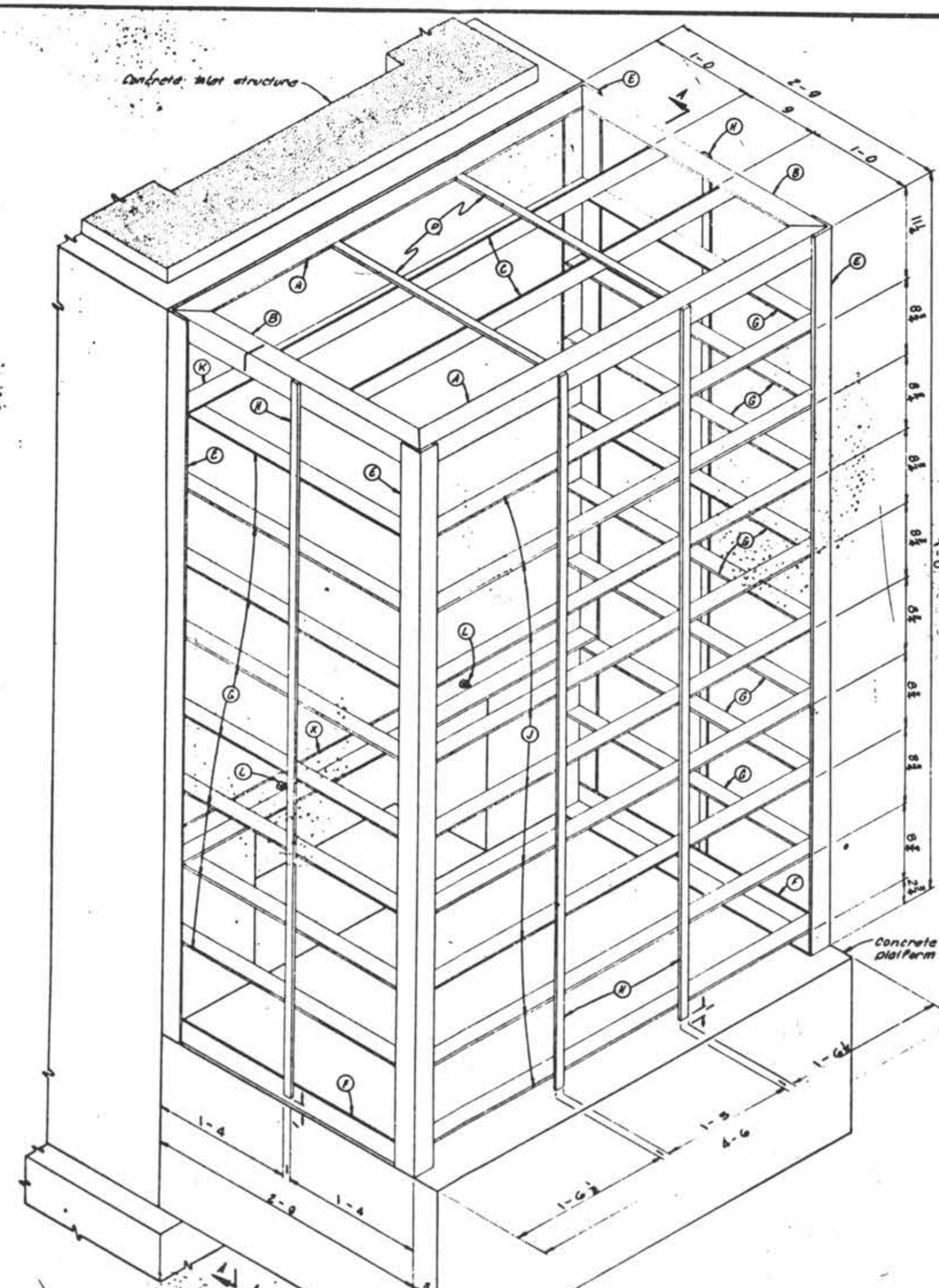
Scale: 1" = 1'-0"
DETAILS OF TRASH RACK FOR TOP OF INLET

DETENTION DAM NBFR-1
NORTH BRANCH FOREST RIVER WATERSHED

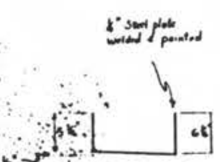
Walsh County, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

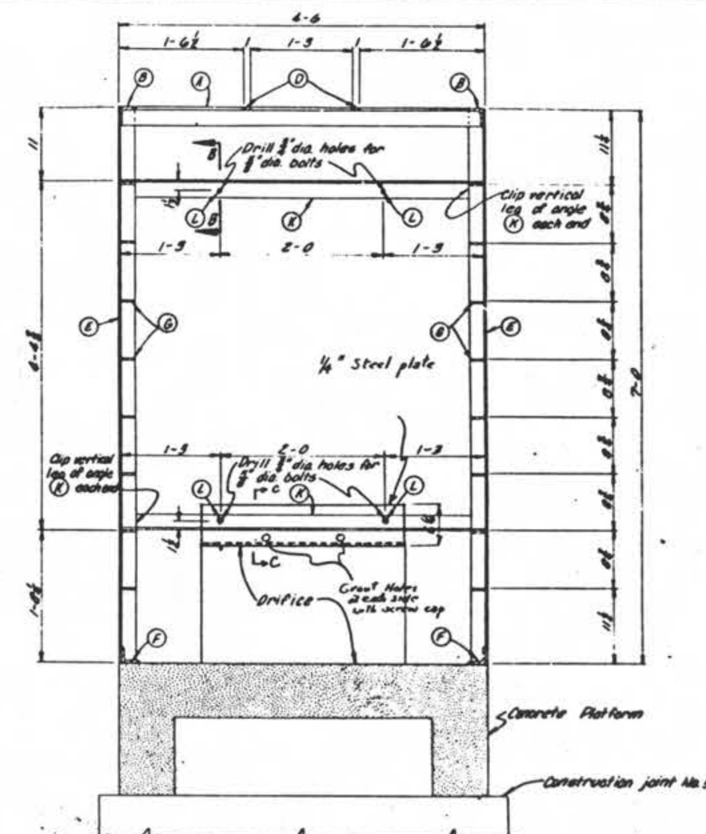
Designed D.E.M. | Date | Approved by | Title
Drawn | | Title



ISOMETRIC VIEW OF TRASH RACK
Scale: 1½" = 1'-0"



SECTION C-C



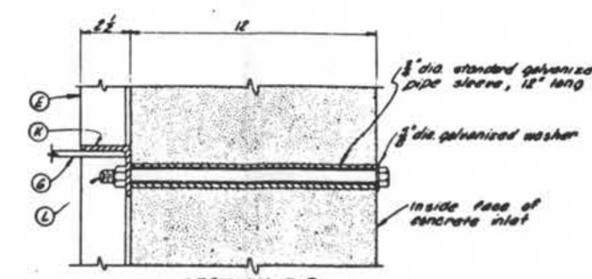
SECTIONAL ELEVATION A-A
Scale: 1" = 1'-0"

TABLE OF QUANTITIES

MARK	ITEM	QUANTITY
A	∠S 2 1/2" X 2 1/2" X 1/4", 4'-5 1/2" LONG	2
B	∠S 2 1/2" X 2 1/2" X 1/4", 2'-8 1/2" LONG	2
C	BAR, 2" X 1/4", 4'-5" LONG	2
D	BAR, 1" X 1/4", 2'-3 1/2" LONG	2
E	∠S 2 1/2" X 2 1/2" X 1/4", 7'-0" LONG	4
F	∠S 2 1/2" X 2 1/2" X 1/4", 2'-8 1/8" LONG	2
G	BAR, 2" X 1/4", 2'-8 1/2" LONG	16
H	BAR, 1" X 1/4", 6'-11" LONG	4
J	BAR, 2" X 1/4", 4'-5 1/2" LONG	9
K	∠S 2 1/2" X 2 1/2" X 1/4", 4'-5 1/2" LONG	2
L	BOLTS 5/8" DIA. GALV., 1'-1 1/2" LONG, WITH WASHERS	4
TOTAL WEIGHT OF STRUCTURAL STEEL 423 LBS.		

NOTES:
1. CLIP ANGLES AS SHOWN.
2. ALL ANGLES AND BARS TO BE SECURELY WELDED AT JUNCTIONS.
3. TRASH RACK TO BE PAINTED IN ACCORDANCE WITH SPECIFICATIONS.

(AS BUILT)



SECTION B-B
DETAIL OF ANCHORAGE
Scale: 3" = 1'-0"

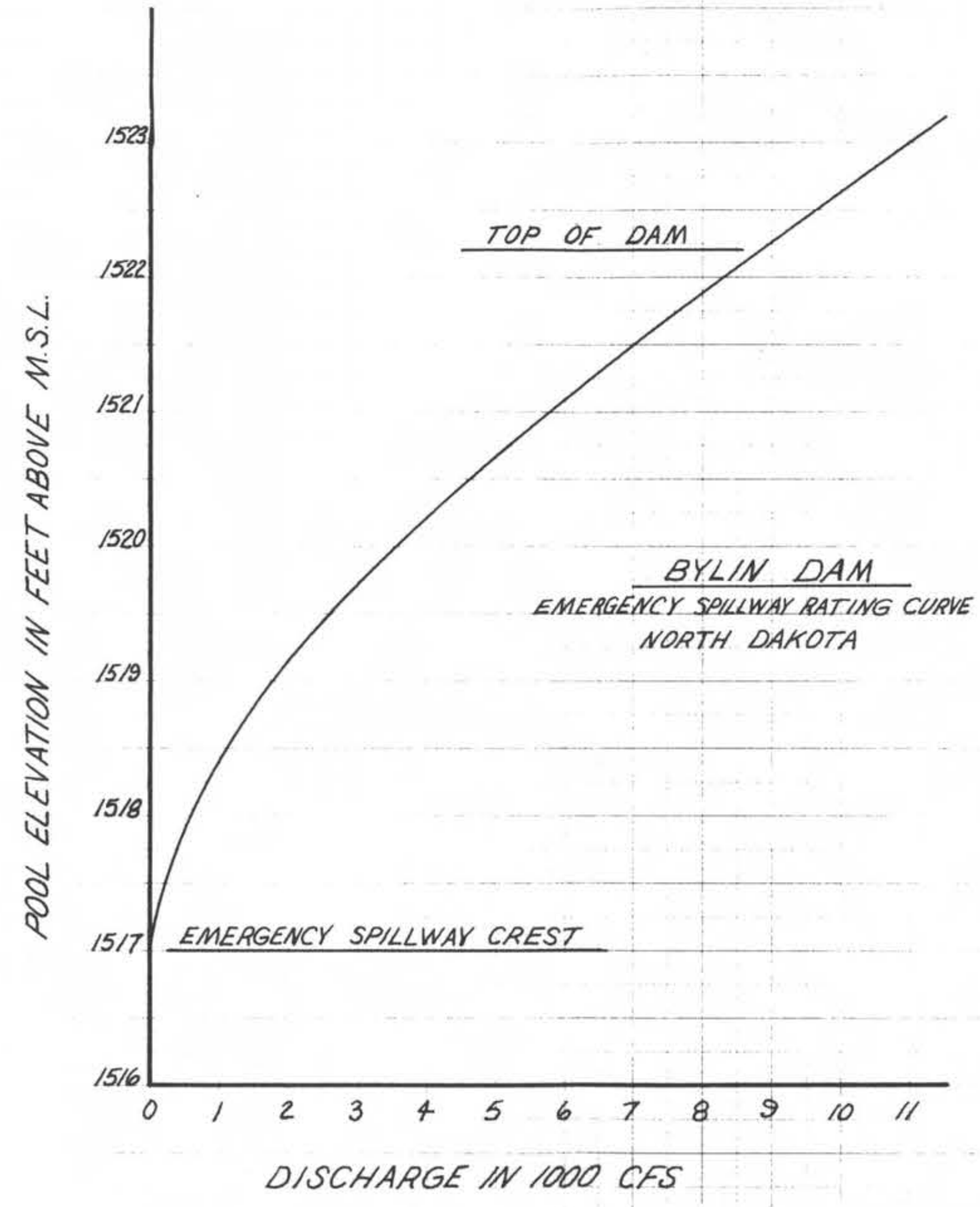
DETAILS OF ORIFICE TRASH RACK

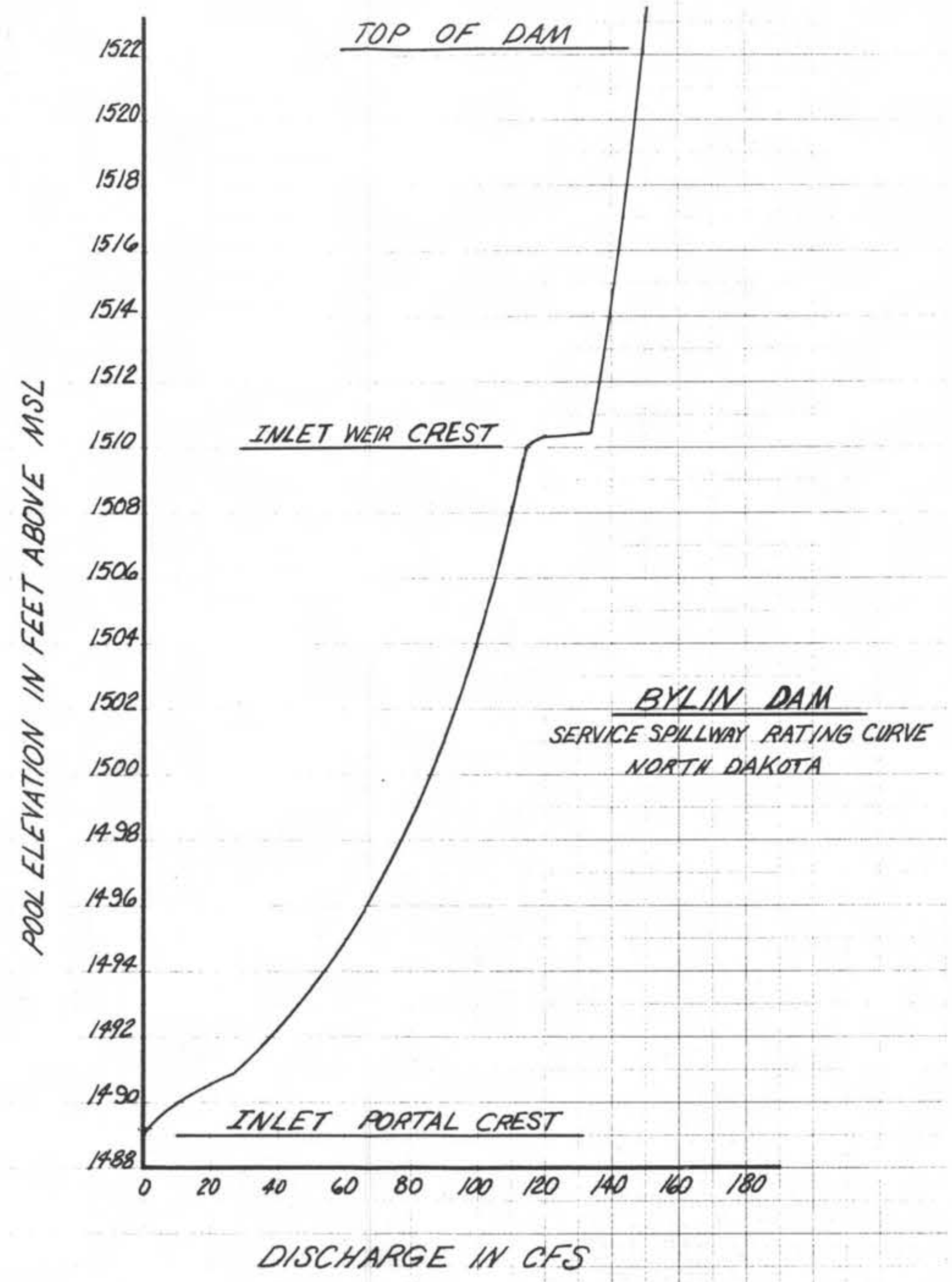
DETENTION DAM NBFR-1
NORTH BRANCH FOREST RIVER WATERSHED
Walsh County, North Dakota

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed D.E.M.
Drawn G.O.H.

N.D.S.P. PHASE I INSPECTION REPORT PLATE C-14





BYLIN DAM
I.D. No. ND 00036
EMERGENCY SPILLWAY RATING CURVE,
SERVICE SPILLWAY RATING CURVE,

ATTACHMENT D-1-2

Site Inspection Photos

GENERAL

1. THRASH RACK & CAPPED VALVE WELL (FRONT OF RISERS)

2. PRINCIPLE SPILLWAY RISER STRUCTURE

INLET STRUCTURE AND GATE VALVES

3. MINOR SPALLING WEST FACE OF RISER

4. MINOR SPALLING NORTHEAST CORNER OF RISER

5. MINOR SPALLING SOUTH FACE OF RISER

6. MINOR SPALLING NORTHEAST CORNER OF RISER

7. OPEN ANCHOR HOLES (NORTH RISER FACE)

8. INTERIOR RISER (LOOKING DOWN)

9. INTERIOR RISER MINOR SPALLING (LOOKING EAST)

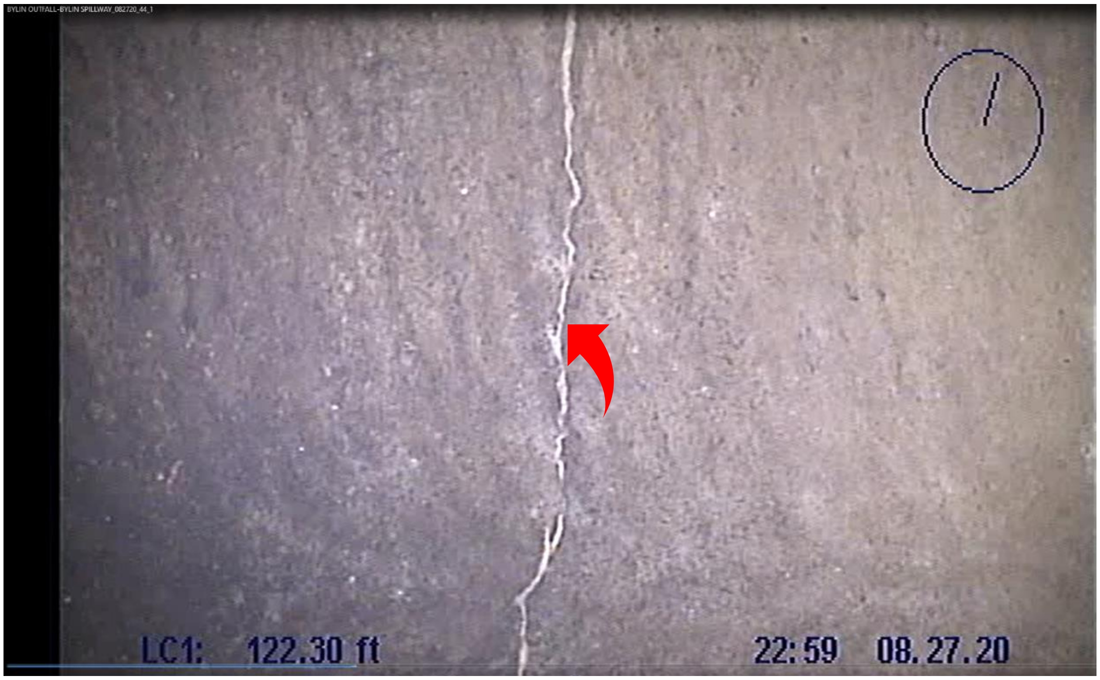
10. INTERIOR RISER MINOR SPALLING (SOUTH WALL)

11. INTERIOR RISER (LOOKING UP)

PRINCIPAL SPILLWAY CONDUIT

12. RIGHT (SOUTH) FOUNDATION DRAIN

13. LEFT (NORTH) FOUNDATION DRAIN (MISSING RODENT SCREEN)



14. PRINCIPAL SPILLWAY CONDUIT PIPE CRACK (NEAR JOINT 4)

15. PRINCIPAL SPILLWAY CONDUIT PIPE CRACK (NEAR JOINT 11)

PRINCIPAL SPILLWAY RELEASE CHANNEL

16. PRINCIPAL SPILLWAY OUTLET

17. PRINCIPAL SPILLWAY PLUNGE POOL

18. PRINCIPAL SPILLWAY OUTLET CONCRETE LOSS

EMBANKMENT

19. FRONT EMBANKMENT SLOPE

20. DOWNSTREAM EMBANKMENT SLOPE

21. DAM CREST

AUXILIARY SPILLWAY

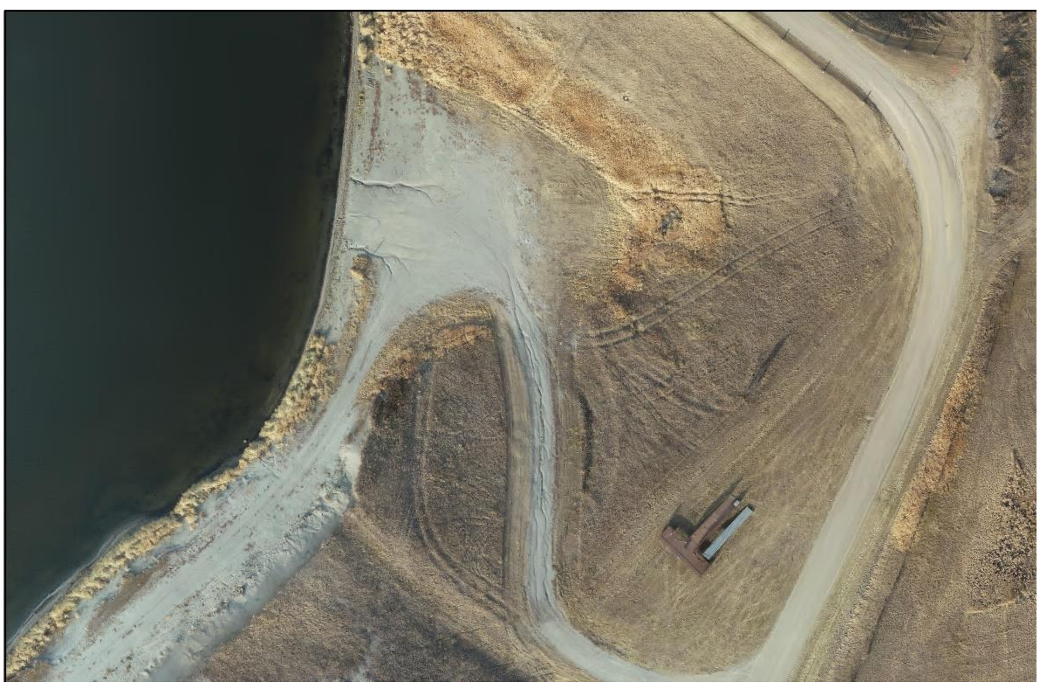
22. AUXILIARY SPILLWAY MID SLOPE

23. AUXILIARY SPILLWAY MID SLOPE

24. AUXILIARY SPILLWAY DOWNSTREAM SLOPE

OBSERVED DEFICIENCIES

25. BOAT RAMP, BEACH, AND FISHING DOCK



26. ACCESS ROAD AND BEACH EROSION (PHOTO TAKEN NOVEMBER 6TH, 2020)

ATTACHMENT D-1-3

TR 210-60 Peak Breach Discharge Calculations

Attachment D-1-4 TR 210-60 Breach Qmax

H:\JBN\7100\7135\7135_0037\Engineering\Water Resources\RAS\TR60 breach peak (Bylin Dam)

Watershed Name:	**North Branch Forest**	Date	**Jan 18, 2022**
		Prepared By:	**Rachel Glatt**
County, ST	Walsh County, ND	Checked By:	**Paul LeClaire**

Elevations						
Top of Dam	1,523.8	Ft msl	Top Width	24	Ft	
Water Surface@Breach	1,523.8	Ft msl	Upstream Slope Above Berm	3:1		
Wave Berm	1,481.2	Ft msl	Upstream Slope Below Berm	3:1		
Average Valley Floor	1,467.4	Ft msl	Downstream Slope Above Berm	2.5:1		
Stability Berm	1,499.2	Ft msl	Downstream Slope Below Berm	2.5:1		
Length of Dam at Breach Elev	760	Ft	Wave Berm Width	10	Ft	L
Volume of Breach	5,554	Ac-ft	Stability Berm Width	20	Ft	

Breach Discharge Computations

Hw < 103 - Low Dam

Volume of Breach (Vs)	5,554	Ac-ft	
Height Of Breach (Hw)	56	Ft	Hw
Cross-Section Area at Breach from CAD dwg (A)		Ft^2	
Cross-Section Area at Breach (A)	10,861	Ft^2	
$T = 65(H^{0.35})/0.416$ - theoretical breach width	641	Ft	T

L > T - Wide Dam

Q_{max} NOT GREATER THAN		Upper Bound Check			
$Q_{max} = 65(HW^{1.85})$	L>T Wide		112,774	cfs	UpBndWide
$Q_{max} = 0.416\ (L)(Hw^{1.5})$	L<T Narrow		133,771	cfs	UpBndNarrow

$Br = (Vs * Hw)/A$	Value	28.82		Br
$Q_{max} = 1{,}100\ (Br)^{1.35}$		102,807	cfs	

Q_{max} NOT LESS THAN	Lower Bound Check			
$Q_{max} = 3.2(Hw^{5/2})$		76,309	cfs	LowBnd

TR-60 Breach Q_{max} for Hazard Class: **103,000** cfs

Technical Release 210-60 Earth Dams and Reservoirs
TR-210-60, March 2019. Pg. 1-2 and 1-3

Spreadsheet used to develop this attachment was originally created by the NRCS (Version 2.8, 2013). All calculations were verified using TR 210-60 (March, 2019). Spreadsheet was modified by Houston Engineering Inc.

ATTACHMENT D-1-4

Stability Analysis Data

- SITES Output
- Auxiliary Spillway 6-Hour SDH Stability Analysis

SITES MODEL OUTPUT

– PSH RUNOFF DISTRIBUTION B

```
*******************************************************************************
SITES XEQ 04/14/2021   WATER RESOURCE SITE ANALYSIS COMPUTER PROGRAM
    VER 2005.1.8            (USER MANUAL - DATED DECEMBER 2005)
    TIME 15:24:21

************************* 80-80 LIST OF INPUT Data **************************

SITES     01/01/20051        Bylin                    20.862721 A1
SAVMOV    0    101
SAVMOV    101  1                                       1
*       Drainage Area to Bylin Dam
*       - Subbasins F-NB500 (20.863 sq mi)
*       - Principal Spillway Hydrograph event (Runoff Curve B)
*       - Principal spillway info based off of survey and as-builts
*       - Elevation Storage data from TOS Bathymetry Survey 2020
STRUCTURE 1        Bylin Dam (Data from TOS Bathymetric Survey)
                1467.5                     0
                1468                       0.00258140
                1469                       0.10121566
                1470                       0.56925364
                1472                       4.78690536
                1475                       27.9623818
                1478                       73.1568186
                1481                       142.693408
                1485                       275.723087
                1490                       512.922751
                1495                       849.914497
                1500                       1292.81099
                1505                       1867.80562
                1510                       2579.06160
                1515                       3460.24527
                1520                       4553.52237
                1530                       7573.13981
                1540                       12443.3122
                1550                       19557.6906
                1563                       32461.9658
ENDTABLE
WSDATA    5C 1            20.862721                1.5
QDIRECT          2.35     4.7
POOLDATA  ELEV            1490.2    1477.24                 TC
PSINLET   ELEV     0.75     19.5     1511.274  1.5      2.5
PSDATA    1       304      30              0.013     1465
GRAPHICS  I
GO,DESIGN LCPN
SAVMOV    2    101  1              1
ENDJOB
*******************************************************************************
```

```
1SITES XEQ 04/14/2021 ------------- COMMENT PAGE ------------------------------
     VER 2005.1.8               Bylin               WSID = 1

 Drainage Area to Bylin Dam

 - Subbasins F-NB500 (20.863 sq mi)
 - Principal Spillway Hydrograph event (Runoff Curve B)
 - Principal spillway info based off of survey and as-builts
 - Elevation Storage data from TOS Bathymetry Survey 2020

1SITES ---------------------------------------------------------------------
 XEQ 04/14/2021               Bylin                   WSID= 1
 VER 2005.1.8     Bylin Dam (Data from TOS Bathymetric Survey)     SUBW= 1
 TIME 15:24:21          SITE = 1            PASS=   1    PART=   1
 ****************************    BASIC Data    *********************************
 CLIMATE AREA - NOT DEFINED                   DESIGN CLASS  C

 STORM DISTRIBUTION USED FOR AUXILIARY SPILLWAY IS;
 NRCS DESIGN STORM RAINFALL DISTRIBUTION  (CHAPTER 21, NEH4 & TR-60).

 INFLOW HYDROGRAPH(S) ENTERED

PRECIP. - Q-PS,1-DAY   Q-PS,10-DAY    Q-SD      Q-FB
             2.35          4.70          0.00      0.00

 WSDATA -      CN       DA-SM       TC/L       -/H       QRF
              0.00       20.86       0.00       0.00      1.50

 SITEDATA- PERM POOL    CREST PS     FP SED     VALLEY FL     378?
               0.00        1490.20    1477.24      0.00         NO

       BASEFLOW     INITIAL EL    EXTRA VOL     SITE TYPE
          0.00          0.00          0.00         DESIGN

 PSDATA -  NO. COND      COND L      DIA/W       -/H
              1.00         304.00      30.00       0.00

         PS N        KE       WEIR L      TW EL
        0.013       0.75      19.50     1465.00

        2ND STG      ORF H       ORF L    START AUX.
        1511.27       1.50        2.50        0.00

 ASCRESTS -   AUX.1       AUX.2      AUX.3       AUX.4       AUX.5
              0.00        0.00       0.00        0.00        0.00

 AUX.Data -  REF.NO.    RETARD. Ci   TIE STATION   INLET LENGTH
               0           0.00         0.00              0
```

AUX.Data - INLET N	SIDE SLOPE	EXIT N	EXIT SLOPE	ACTUAL AUX?
0.000	0.00	0.000	0.000	NO

BTM WIDTH - BW1	BW2	BW3	BW4	BW5
0.00	0.00	0.00	0.00	0.00

1********************* DETAILED LIST OF BASIC Data *********************

WEIR COEF. FOR ORIFICES.......... 3.10 RATIO OF Ia TO S (CH.10,NEH4). 0.20
WEIR COEF. FOR DROP INLET........ 3.10 TIME INCS TO PEAK OF UNIT HYD. 10.
DISCHARGE COEF. FOR ORIFICES..... 0.60 NO. POINTS FOR DESIGN HYD. ... 5000

HOOD, WEIR INLET COEF. .... 0.60 DRAWDOWN TIME LIMIT - DAYS.... 10.0
HOOD, PIPE ENTRANCE COEF. .... 0.60 DRAWDOWN RATIO STORAGE LIMIT.. 0.15
HOOD, SLUG FLOW COEF. .... 0.00 OTHER DRAWDOWN RATIOS APPLY ?. NO

PS ACCURACY OF FULL FLOW CALC.,FT 0.01 WSP ALLOWABLE FSS VEL. CHANGE. 0.05
FILLET SIZE FOR BOX CONDUITS..... 6.00 WSP FSS CALC. PRECISION, FT.. 0.005

GRAVITATIONAL CONSTANT.......... 32.16 AUX. SPILLWAY MIN. CAP. COEF. 237.0
MIN. NHCP378 PS PIPE AREA SQFT.. 0.545 AUX. SPILLWAY MIN. CAP. EXP. 0.493

MIN. TR60 DEPTH AUX. TO TOP DAM.. 3.00 MIN. AUX. BW IN BW SOLUTION,FT 20.0
MIN. NHCP378 DEPTH AUX.TO TOP DAM 2.00 PRECISION OF BW SOLUTION...... 1.0
MIN. NHCP378 DEPTH PS - AUX.CREST 1.00 OLD TR60 CRITERIA USED .... NO
MIN. NHCP378 DEPTH DESIGN Q - TOD 1.00 OLD NHCP378 CRITERIA USED .... NO

EMBANKMENT TEMPLATE: TOP WIDTH = (calc.), MAX. CROWN = 0.667 ft,

SIDE SLOPE RATIOS		WAVE BERM WIDTH	MULTIPLE STABILITY BERMS		SEPARATE STABILITY BERMS			
			U&D/S WIDTHS	DELTA H	WIDTHS, ft		HEIGHTS, ft	
U/S	D/S	ft	ft	ft	U/S	D/S	U/S	D/S
2.50	2.50	10.0	0.0	0.00	0.00	0.00	0.00	0.00

DIMENSIONLESS UNIT HYDROGRAPH
STANDARD DIMENSIONLESS UNIT HYDROGRAPH
PEAK FACTOR = 484.0 | TIME INC. =0.020 | NO. INC. TO PEAK = 10.
VOLUME FACTOR = 48.3429

0.0000	0.0300	0.1000	0.1900	0.3100
0.4700	0.6600	0.8200	0.9300	0.9900
1.0000	0.9900	0.9300	0.8600	0.7800
0.6800	0.5600	0.4600	0.3900	0.3300
0.2800	0.2410	0.2070	0.1740	0.1470
0.1260	0.1070	0.0910	0.0770	0.0660
0.0550	0.0470	0.0400	0.0340	0.0290
0.0250	0.0210	0.0180	0.0150	0.0130
0.0110	0.0090	0.0080	0.0070	0.0060
0.0050	0.0040	0.0030	0.0020	0.0010
0.0000				

1NRCS DESIGN STORM RAINFALL DISTRIBUTION (CHAPTER 21, NEH4 & TR-60).

0.000	0.008	0.016	0.025	0.033
0.043	0.052	0.063	0.074	0.086
0.099	0.112	0.126	0.142	0.160
0.180	0.205	0.255	0.345	0.437
0.530	0.603	0.633	0.660	0.684
0.705	0.724	0.742	0.759	0.775
0.790	0.804	0.818	0.831	0.844
0.856	0.868	0.879	0.890	0.900
0.910	0.920	0.930	0.939	0.948
0.957	0.966	0.975	0.983	0.992
1.000				

1SITES ---

XEQ 04/14/2021 Bylin WSID= 1

VER 2005.1.8 Bylin Dam (Data from TOS Bathymetric Survey) SUBW= 1

TIME 15:24:21 SITE = 1 PASS= 1 PART= 2

MESSAGE ---- Climatic Index changed from 0.0 to 1.0 for this run.

INFLOW HYDROGRAPH PROVIDED IN LOCATION 1, PEAK= 2099.90 CFS, AT 245.00 HRS.

TITLE = Runoff B at Bylin

CREST PS 1490.20 FT 526.4 ACFT 0.00 AC 127.4 CFS

SED ACCUM 1490.20 FT 526.4 ACFT 0.00 AC 127.4 CFS

2ND STAGE 1511.27 FT 2803.6 ACFT 0.00 AC 209.7 CFS

START ELEV 1490.20 FT 526.4 ACFT 0.00 AC 0.0 CFS

NRCS-PSH RAINFALL 1-DAY = 0.00 IN 10-DAY = 0.00 IN DA = 20.86 SM

RUNOFF 1-DAY = 0.00 IN 10-DAY = 0.00 IN

CLIMATIC INDEX = 1.00 CN 10-DAY = 0. CN 1-DAY = 0.

QRF = 31.29 CFS 1495.55 FEET, GIVEN Value.

PEAK = 2099.9 CFS, AT 245.0 HRS.

ROUTED RESULT - HYD TYPE	EMAX	VOL-MAX	AMAX	QMAX
NRCS-PSH	1519.81 FT	4512.8 ACFT	0.00 AC	134.2 CFS

PS STORAGE 3986.4 ACFT, BETWEEN AUX. CREST AND SED. ACCUM ELEVATIONS.

DRAWDOWN (DDT) TEST 1498.10 FT 1124.4 ACFT 47.94 CFS

CONTROL IS 0.150 DETENTION STORAGE

TIME LIMIT REACHED = 10.00 DAYS. FLOW WAS 74.78 CFS, ELEV = 1508.29
(ELEVATION TO START ROUTING SDH AND/OR FBH HAS BEEN RAISED.)

TIME TO DDT TEST DISCHARGE IS 19.92 DAYS - DRAWDOWN STOPPED.

***** NOTE - CREST OF AUX. RAISED TO HOLD 1809.59 ACFT NOT EVACUATED IN
DRAWDOWN TIME LIMIT. TOTAL STORAGE REQUIRED = 6322.36 ACFT,
NEW ELEVATION OF AUXILIARY SPILLWAY CREST = 1525.86 FT.

****

RATING TABLE DEVELOPED, SITE = 1 :
WITH PS DEVELOPED BY PROGRAM AND NO AUX. DATA GIVEN.

RATING TABLE NUMBER 1

	ELEV.	Q-TOTAL	Q-PS	Q-AUX.	VOLUME	AREA
	FEET	CFS	CFS	CFS	AC-FT	ACRE
1	1490.20	0.00	0.00	0.00	526.40	0.00
2	1490.49	1.21	1.21	0.00	545.95	0.00
3	1490.78	3.42	3.42	0.00	565.50	0.00
			TRANSITION TO ORIFICE FLOW, ELEV = 1491.07 FT			
4	1491.07	6.29	6.29	0.00	585.04	0.00
5	1497.80	47.24	47.24	0.00	1098.35	0.00
6	1504.54	66.52	66.52	0.00	1814.83	0.00
7	1511.27	81.35	81.35	0.00	2803.57	0.00
8	1511.54	90.28	90.28	0.00	2850.86	0.00
9	1511.81	106.16	106.16	0.00	2898.12	0.00
			FULL CONDUIT FLOW, ELEV = 1512.08 FT			
10	1512.08	126.57	126.57	0.00	2945.39	0.00
11	1529.05	147.70	147.70	0.00	7287.03	0.00
12	1546.03	166.12	166.12	0.00	16730.61	0.00
13	1563.00	182.69	182.69	0.00	32461.96	0.00

1SITES ---
XEQ 04/14/2021 Bylin WSID= 1
VER 2005.1.8 Bylin Dam (Data from TOS Bathymetric Survey) SUBW= 1
TIME 15:24:21 SITE = 1 PASS= 1 PART= 3

AUX. CREST 1525.86 FT 6322.4 ACFT 0.00 AC 143.0 CFS

PS STORAGE 5796.0 ACFT, BETWEEN AUX. CREST AND SED. ACCUM ELEVATIONS.

START ELEV 1508.29 FT 2336.0 ACFT 0.00 AC 74.8 CFS

ELEVATION OF LOW POINT IS ZERO. NO CRITERIA CHECK MADE FOR
STRUCTURE CLASSIFICATION.

***** MESSAGE - NO INPUT DATA GIVEN FOR AUXILIARY SPILLWAY CREST AND/OR
BOTTOM WIDTH. NO AUXILIARY SPILLWAY ROUTINGS PERFORMED.

Inflow Hyd 1 PSH-Peak = 134.20 CFS at 262.00 hrs., Location Point
HYDOUT 1 1

1SITES....JOB NO. 1 COMPLETE.
----

1 Bylin

0 SUBWATERSHED(S) ANALYZED.
1 STRUCTURE(S) ANALYZED.
1 HYDROGRAPHS ROUTED AT LOWEST SITE.
0 TRIALS TO OBTAIN BOTTOM WIDTH FOR SPECIFIED STRESS OR VELOCITY.

****

SITES.....COMPUTATIONS COMPLETE

SUMMARY TABLE 1 SITES VERSION 2005.1.8
---------------- DATED 01/01/2005

WATERSHED ID	RUN DATE	RUN TIME
1	04/14/2021	15:24:21

>>>	SITE ID	SUBWS ID	SUBWS DA (SQ MI)	CURVE NO.	TC (HRS)	TOTAL DA (SQ MI)	TYPE DESIGN	STRUC CLASS	<<<
	1	1	20.86	0.	0.00	20.86	TR60	C	

PASS NO.	DIA./ WIDTH (IN/FT)	AUX.CREST ELEV (FT)	BTM. WIDTH (FT)	MAX. HP (FT)	MAX. ELEV (FT)	EMB. VOL. (CY)	INTEGR.* DIST. (FT)	EXIT* VEL. (FT/SEC)	TYPE HYD

SITES.......SUMMARY TABLE 1 COMPLETED.

NRCS SITES VERSION 2005.1.8 ,01/01/2005
1 FILES

INPUT = h:\JBN\7100\7135\7135_0037\Deliverables\2021-02-22 Final Review Point 2 to NRCS\Models\SITES\Bylin\Bylin_RunoffB.D2C
OUTPUT = h:\JBN\7100\7135\7135_0037\Deliverables\2021-02-22 Final Review Point 2 to NRCS\Models\SITES\Bylin\Bylin_RunoffB.OUT
DATED 04/14/2021 15:24:21

GRAPHICS FILES GENERATED

OPTION "L" = h:\JBN\7100\7135\7135_0037\Deliverables\2021-02-22 Final Review Point 2 to NRCS\Models\SITES\Bylin\Bylin_RunoffB.DRG DATED 04/14/2021 15:24:21

OPTION "P" = h:\JBN\7100\7135\7135_0037\Deliverables\2021-02-22 Final Review Point 2 to NRCS\Models\SITES\Bylin\Bylin_RunoffB.DHY DATED 04/14/2021 15:24:21

OPTION "E" = h:\JBN\7100\7135\7135_0037\Deliverables\2021-02-22 Final Review Point 2 to NRCS\Models\SITES\Bylin\Bylin_RunoffB.DEM DATED 04/14/2021 15:24:21

SITES MODEL OUTPUT

– SDH / FBH ND PMP 12H LOCAL

```
********************************************************************************
 SITES XEQ 04/14/2021   WATER RESOURCE SITE ANALYSIS COMPUTER PROGRAM
    VER 2005.1.8          (USER MANUAL - DATED DECEMBER 2005)
    TIME 15:24:07

 ************************* 80-80 LIST OF INPUT Data **************************

 SITES     01/01/20051       Bylin                   20.862721 C2
 SAVMOV    0    101
 SAVMOV    101  1                                    1
 *       Drainage Area to Bylin Dam
 *       - Subbasins F-NB500 (20.863 sq mi)
 *       - Stability Design and Freeboard Hydrographs 12H Loc (TR-60)
 *       - ND Local PMP values used
 *       - Principal spillway info based off of survey and as-builts
 *       - Elevation Storage data from TOS Bathymetry Survey 2020
 STRUCTURE 1       Bylin Dam (Data from TOS Bathymetric Survey)
             1467.5                   0
             1468                     0.00258140
             1469                     0.10121566
             1470                     0.56925364
             1472                     4.78690536
             1475                     27.9623818
             1478                     73.1568186
             1481                     142.693408
             1485                     275.723087
             1490                     512.922751
             1495                     849.914497
             1500                     1292.81099
             1505                     1867.80562
             1510                     2579.06160
             1515                     3460.24527
             1520                     4553.52237
             1530                     7573.13981
             1540                     12443.3122
             1550                     19557.6906
             1563                     32461.9658
ENDTABLE
WSDATA    2C 1           20.862721
 PDIRECT                        0.00     0.00
 POOLDATA  ELEV     1490.2      1490.2    1477.24              1461.25   TC
 PSINLET      ELEV      0.75         19.5       1511.274      1.5        2.5
 PSDATA       1          304          30                      0.013     1465
 ASSURFACE  41        1079.13    .002
               0           89.66      0.035     0.5       3        1
               89.66     109.07     0.013     0          1
               109.07    1079.13   0.035     0.5        1        1
 ENDTABLE
```

```
ASDATA    41                       3                        1
 BTMWIDTH  FEET     300
 ASMATERIAL
        1       17      0.0125984217.7     80      0.08
        2       23      0.0015748040.9     95      0.19
        3               1.37401574         90      1.8
 ENDTABLE
ASCOORD   1      Overburden
        0          1512.6   23.21     1517.1   36.13      1515.6
        85.13      1517.0   98.48     1518.4   108.84     1518.3
        116.04     1517.0   120.86    1516.6   345.65     1517.6
        368.8      1517.4   560.61    1518.6   581.34     1518.5
        606.12     1517.1   612.6     1515.7   783.23     1498.4
        816.69     1491.9   865.02    1482.6   931.97     1469.1
        971.32     1468.2   1050.84   1465.6   1079.13    1458.2
 ENDTABLE
 ASCOORD   2      Clay
        0          1500.1   23.21     1504.6   36.13      1503.1
        85.13      1504.5   98.48     1505.9   108.84     1505.8
        116.04     1504.5   120.86    1504.1   345.65     1505.1
        368.8      1504.9   560.61    1506.1   581.34     1506.0
        606.12     1504.6   612.6     1503.2   783.23     1485.9
        816.69     1479.4   865.02    1470.1   931.97     1456.6
        971.32     1455.7   1050.84   1453.1   1079.13    1445.7
 ENDTABLE
 ASCOORD   3      Rock
        0          1492.4   23.21     1496.9   36.13       1495.4
        85.13      1496.8   98.48     1498.2   108.84      1498.1
        116.04     1496.8   120.86    1496.4   345.65      1497.4
        368.8      1497.2   560.61    1494.5   581.34      1494.0
        606.12     1492.1   612.6     1490.7   783.23      1473.4
        816.69     1466.9   865.02    1457.6   931.97      1444.1
        971.32     1443.2   1050.84   1440.6   1079.13     1433.2
 ENDTABLE
 GRAPHICS  I
 GO,DESIGN LCP                                 1508.29
 SAVMOV   2   101  1              1
 ENDJOB

 ******************************************************************************
1SITES XEQ 04/14/2021 ------------- COMMENT PAGE -------------------------------
     VER 2005.1.8               Bylin                 WSID = 1

Drainage Area to Bylin Dam
 - Subbasins F-NB500 (20.863 sq mi)
 - Stability Design and Freeboard Hydrographs 6H (TR-60)
 - Principal spillway info based off of survey and as-builts
 - Elevation Storage data from TOS Bathymetry Survey 2020
```

***** MESSAGE - DEFAULT TOPSOIL FILL MATERIAL PARAMETERS USED.
***** WARNING - HEADCUT ERODIBILITY INDEX OF 1.8 (MATERIAL 3)
APPEARS INCONSISTENT WITH DENSITY OF 90.0.
***** MESSAGE - AUXILIARY SPILLWAY CREST ELEVATION IS SET TO 1518.60
FROM THE ASCOORD RECORDS.
***** MESSAGE - VALUES FROM ASSURFACE, REACH 2 IMPLY NO VEGETAL COVER WITH
"n" OF 0.013.
***** WARNING - DOWNWARD SLOPE FOUND IN INLET CHANNEL OF EXISTING AUX. SPILLWAY
STARTING AT X = 346., Y = 1517.60; NEXT Y = 1517.40.

1SITES ---
XEQ 04/14/2021 Bylin WSID= 1
VER 2005.1.8 Bylin Dam (Data from TOS Bathymetric Survey) SUBW= 1
TIME 15:24:07 SITE = 1 PASS= 1 PART= 1

********************** MATERIAL PROPERTIES ****************************

MATERIAL	PI	DRY DENSITY lbs/CuFt	Kh	PERCENT CLAY	DETACH. RATE (Ft/H)/(lb/SqFt)	REP. DIAMETER inches
Overburden	17.	80.	0.08	17.7	--	0.01260
Clay	23.	95.	0.19	40.9	--	0.00157
Rock	0.	90.	1.80	0.0	--	1.37402
TS_FILL	0.	100.	0.05	0.0	--	0.05000
GEN_FILL	17.	80.	0.08	17.7	--	0.01260

**************************** BASIC Data **********************************

HUMID- SUBHUMID CLIMATE AREA DESIGN CLASS C

INFLOW HYDROGRAPH(S) ENTERED

PRECIP. - Q-PS,1-DAY	Q-PS,10-DAY	Q-SD	Q-FB
0.00	0.00	0.00	0.00

WSDATA - CN	DA-SM	TC/L	-/H	QRF
0.00	20.86	0.00	0.00	0.00

SITEDATA- PERM POOL	CREST PS	FP SED	VALLEY FL	378?
1490.20	1490.20	1477.24	1461.25	NO

BASEFLOW	INITIAL EL	EXTRA VOL	SITE TYPE
0.00	0.00	0.00	DESIGN

PSDATA - NO. COND	COND L	DIA/W	-/H
1.00	304.00	30.00	0.00

PS N	KE	WEIR L	TW EL
0.013	0.75	19.50	1465.00

2ND STG	ORF H	ORF L	START AUX.
1511.27	1.50	2.50	1508.29

ASCRESTS -	AUX.1	AUX.2	AUX.3	AUX.4	AUX.5
	1518.60	0.00	0.00	0.00	0.00

AUX.Data -	REF.NO.	RETARD. Ci	TIE STATION	INLET LENGTH
	41	0.00	560.61	0

AUX.Data -	INLET N	SIDE SLOPE	EXIT N	EXIT SLOPE	ACTUAL AUX?
	0.035	3.00	0.035	0.005	YES

BTM WIDTH -	BW1	BW2	BW3	BW4	BW5
ft	300.00	0.00	0.00	0.00	0.00

AUXILIARY SPILLWAY RATING DEVELOPED USING WSPVRT.

1********************* DETAILED LIST OF BASIC Data *********************

WEIR COEF. FOR ORIFICES.......... 3.10 RATIO OF Ia TO S (CH.10,NEH4). 0.20
WEIR COEF. FOR DROP INLET........ 3.10 TIME INCS TO PEAK OF UNIT HYD. 10.
DISCHARGE COEF. FOR ORIFICES..... 0.60 NO. POINTS FOR DESIGN HYD. ... 5000

HOOD, WEIR INLET COEF. .... 0.60 DRAWDOWN TIME LIMIT - DAYS.... 10.0
HOOD, PIPE ENTRANCE COEF. .... 0.60 DRAWDOWN RATIO STORAGE LIMIT.. 0.15
HOOD, SLUG FLOW COEF. .... 0.00 OTHER DRAWDOWN RATIOS APPLY ?. NO

PS ACCURACY OF FULL FLOW CALC.,FT 0.01 WSP ALLOWABLE FSS VEL. CHANGE. 0.05
FILLET SIZE FOR BOX CONDUITS..... 6.00 WSP FSS CALC. PRECISION, FT.. 0.005

GRAVITATIONAL CONSTANT.......... 32.16 AUX. SPILLWAY MIN. CAP. COEF. 237.0
MIN. NHCP378 PS PIPE AREA SQFT.. 0.545 AUX. SPILLWAY MIN. CAP. EXP. 0.493

MIN. TR60 DEPTH AUX. TO TOP DAM.. 3.00 MIN. AUX. BW IN BW SOLUTION,FT 20.0
MIN. NHCP378 DEPTH AUX.TO TOP DAM 2.00 PRECISION OF BW SOLUTION...... 1.0
MIN. NHCP378 DEPTH PS - AUX.CREST 1.00 OLD TR60 CRITERIA USED .... NO
MIN. NHCP378 DEPTH DESIGN Q - TOD 1.00 OLD NHCP378 CRITERIA USED .... NO

EMBANKMENT TEMPLATE: TOP WIDTH = (calc.), MAX. CROWN = 0.667 ft,

SIDE SLOPE RATIOS		WAVE BERM WIDTH	MULTIPLE STABILITY BERMS U&D/S WIDTHS	DELTA H	SEPARATE STABILITY BERMS WIDTHS, ft		HEIGHTS, ft	
U/S	D/S	ft	ft	ft	U/S	D/S	U/S	D/S
2.50	2.50	10.0	0.0	0.00	0.00	0.00	0.00	0.00

DIMENSIONLESS UNIT HYDROGRAPH
STANDARD DIMENSIONLESS UNIT HYDROGRAPH
PEAK FACTOR = 484.0 | TIME INC. =0.020 | NO. INC. TO PEAK = 10.
VOLUME FACTOR = 48.3429

0.0000	0.0300	0.1000	0.1900	0.3100
0.4700	0.6600	0.8200	0.9300	0.9900
1.0000	0.9900	0.9300	0.8600	0.7800
0.6800	0.5600	0.4600	0.3900	0.3300
0.2800	0.2410	0.2070	0.1740	0.1470
0.1260	0.1070	0.0910	0.0770	0.0660
0.0550	0.0470	0.0400	0.0340	0.0290
0.0250	0.0210	0.0180	0.0150	0.0130
0.0110	0.0090	0.0080	0.0070	0.0060
0.0050	0.0040	0.0030	0.0020	0.0010
0.0000				

EXISTING SURFACE OF AUXILIARY SPILLWAY - X,Y COORDINATES:

0.	1512.60
23.	1517.10
36.	1515.60
85.	1517.00
98.	1518.40
109.	1518.30
116.	1517.00
121.	1516.60
346.	1517.60
369.	1517.40
561.	1518.60
581.	1518.50
606.	1517.10
613.	1515.70
783.	1498.40
817.	1491.90
865.	1482.60
932.	1469.10
971.	1468.20
1051.	1465.60
1067.	1461.25

1NRCS DESIGN STORM RAINFALL DISTRIBUTION (CHAPTER 21, NEH4 & TR-60).

0.000	0.008	0.016	0.025	0.033
0.043	0.052	0.063	0.074	0.086
0.099	0.112	0.126	0.142	0.160
0.180	0.205	0.255	0.345	0.437
0.530	0.603	0.633	0.660	0.684
0.705	0.724	0.742	0.759	0.775
0.790	0.804	0.818	0.831	0.844
0.856	0.868	0.879	0.890	0.900
0.910	0.920	0.930	0.939	0.948
0.957	0.966	0.975	0.983	0.992
1.000				

1SITES ---
XEQ 04/14/2021 Bylin WSID= 1
VER 2005.1.8 Bylin Dam (Data from TOS Bathymetric Survey) SUBW= 1
TIME 15:24:07 SITE = 1 PASS= 1 PART= 2

***** MESSAGE - AREAL CORRECTIONS BASED ON DRAINAGE AREA OF 20.9 SQ. MILES.

DESIGN 0.94319 PS-1 DAY 0.96892 PS-10 DAY 0.98593.
MESSAGE ---- Climatic Index changed from 0.0 to 1.0 for this run.

PERM POOL	1490.20 FT	526.4 ACFT	0.00 AC	127.4 CFS
CREST PS	1490.20 FT	526.4 ACFT	0.00 AC	127.4 CFS
SED ACCUM	1490.20 FT	526.4 ACFT	0.00 AC	127.4 CFS
2ND STAGE	1511.27 FT	2803.6 ACFT	0.00 AC	209.7 CFS
START ELEV	1508.29 FT	2335.8 ACFT	0.00 AC	74.3 CFS

****
RATING TABLE DEVELOPED, SITE = 1 :
BY PROGRAM FOR PS AND AUX. SPILLWAYS
AUX. RATING USED WSPVRT METHOD.

RATING TABLE NUMBER 1

	ELEV. FEET	Q-TOTAL CFS	Q-PS CFS	Q-AUX. CFS	VOLUME AC-FT	AREA ACRE
1	1490.20	0.00	0.00	0.00	526.40	0.00
2	1490.49	1.21	1.21	0.00	545.95	0.00
3	1490.78	3.42	3.42	0.00	565.50	0.00
			TRANSITION TO ORIFICE FLOW, ELEV = 1491.07 FT			
4	1491.07	6.29	6.29	0.00	585.04	0.00
5	1497.80	47.24	47.24	0.00	1098.35	0.00
6	1504.54	66.52	66.52	0.00	1814.83	0.00
7	1511.27	81.35	81.35	0.00	2803.57	0.00
8	1511.54	90.28	90.28	0.00	2850.86	0.00
9	1511.81	106.16	106.16	0.00	2898.12	0.00
			FULL CONDUIT FLOW, ELEV = 1512.08 FT			
10	1512.08	126.57	126.57	0.00	2945.39	0.00
11	1529.05	147.70	147.70	0.00	7287.03	0.00
12	1546.03	166.12	166.12	0.00	16730.61	0.00
13	1563.00	182.69	182.69	0.00	32461.96	0.00

INFLOW HYDROGRAPH PROVIDED IN LOCATION 3, PEAK= 7669.20 CFS, AT 14.00 HRS.
TITLE = SDH_12H_Local
INFLOW HYDROGRAPH PROVIDED IN LOCATION 5, PEAK= 21314.30 CFS, AT 14.00 HRS.
TITLE = FBH_12H_Local

1SITES --
XEQ 04/14/2021 Bylin WSID= 1
VER 2005.1.8 Bylin Dam (Data from TOS Bathymetric Survey) SUBW= 1
TIME 15:24:07 SITE = 1 PASS= 1 PART= 3

AUX. CREST 1518.60 FT 4247.4 ACFT 0.00 AC 132.9 CFS

PS STORAGE 3721.0 ACFT, BETWEEN AUX. CREST AND SED. ACCUM ELEVATIONS.

START ELEV 1508.29 FT 2335.8 ACFT 0.00 AC 74.8 CFS

ELEVATION OF LOW POINT IS ZERO. NO CRITERIA CHECK MADE FOR
STRUCTURE CLASSIFICATION.

NRCS-SDH INFLOW HYDROGRAPH INPUT, DA = 20.86 SQUARE MILES

PEAK = 7669.2 CFS, AT 14.0 HRS.

NRCS-FBH INFLOW HYDROGRAPH INPUT, DA = 20.86 SQUARE MILES

PEAK = 21314.3 CFS, AT 14.0 HRS.
AUX. AREAL CORRECTION USED =0.9432

****
RATING TABLE DEVELOPED, SITE = 1 :
BY PROGRAM FOR PS AND AUX. SPILLWAYS
AUX. RATING USED WSPVRT METHOD.

RATING TABLE NUMBER 2

	ELEV. FEET	Q-TOTAL CFS	Q-PS CFS	Q-AUX. CFS	VOLUME AC-FT	AREA ACRE
1	1490.20	0.00	0.00	0.00	526.40	0.00
2	1490.49	1.21	1.21	0.00	545.95	0.00
3	1490.78	3.42	3.42	0.00	565.50	0.00
			TRANSITION TO ORIFICE FLOW, ELEV = 1491.07 FT			
4	1491.07	6.29	6.29	0.00	585.04	0.00
5	1497.80	47.24	47.24	0.00	1098.35	0.00
6	1504.54	66.52	66.52	0.00	1814.83	0.00
7	1511.27	81.35	81.35	0.00	2803.57	0.00
8	1511.54	90.28	90.28	0.00	2850.86	0.00
9	1511.81	106.16	106.16	0.00	2898.12	0.00
			FULL CONDUIT FLOW, ELEV = 1512.08 FT			
10	1512.08	126.57	126.57	0.00	2945.39	0.00
11	1514.25	129.51	129.51	0.00	3328.50	0.00
12	1516.43	132.34	132.34	0.00	3772.08	0.00
13	1518.60	135.11	135.11	0.00	4247.37	0.00
14	1520.82	2276.65	137.88	2138.77	4801.11	0.00
15	1523.04	6625.14	140.59	6484.54	5471.50	0.00

16	1527.04	19487.88	145.35	19342.53	6678.13	0.00
17	1531.92	41885.04	150.97	41734.07	8508.23	0.00
18	1540.80	102360.62	160.67	102199.95	13012.50	0.00
19	1551.90	203546.66	172.03	203374.62	21443.72	0.00
20	1563.00	335606.50	182.69	335423.81	32461.96	0.00

****

SUMMARY OF AUXILIARY SPILLWAY SURFACE CONDITIONS USED IN COMPUTATIONS BY REACH

REACH	FROM STA (ft)	TO STA (ft)	SLOPE (%)	RETARDANCE CURVE INDEX@	VEGETAL COVER FACTOR	MAINT. CODE +	ROOTING DEPTH (ft)	REACH LOCATION *
1	0.	23.	-19.4	0.035	**	**	**	INLET
2	23.	36.	11.6	0.035	**	**	**	INLET
3	36.	85.	-2.9	0.035	**	**	**	INLET
4	85.	90.	-10.5	0.035	**	**	**	INLET
5	90.	98.	-10.5	0.013	**	**	**	INLET
6	98.	109.	1.0	0.013	**	**	**	INLET
7	109.	116.	18.1	0.035	**	**	**	INLET
8	116.	121.	8.3	0.035	**	**	**	INLET
9	121.	346.	-0.4	0.035	**	**	**	INLET
10	346.	369.	0.9	0.035	**	**	**	INLET
11	369.	561.	-0.6	0.035	**	**	**	INLET
12	561.	581.	0.5	0.035	0.50	1	1.0	EXIT !
13	581.	606.	5.6	0.035	0.50	1	1.0	EXIT
14	606.	613.	21.6	0.035	0.50	1	1.0	EXIT
15	613.	783.	10.1	0.035	0.50	1	1.0	EXIT
16	783.	817.	19.4	0.035	0.50	1	1.0	EXIT
17	817.	865.	19.2	0.035	0.50	1	1.0	EXIT
18	865.	932.	20.2	0.035	0.50	1	1.0	EXIT
19	932.	971.	2.3	0.035	0.50	1	1.0	EXIT
20	971.	1051.	3.3	0.035	0.50	1	1.0	EXIT
21	1051.	1067.	26.2	0.035	0.50	1	1.0	EXIT

@ The program interprets retardance curve index entries of less than 1 as Manning's n values.

+ The minimum maintenance code value of 2 is used in INTEGRITY computations (the program changes values of 1 to 2 during computation).

* Upper case indicates a reach of constructed spillway channel.

** The program does not use vegetal cover factor, maintenance code, and rooting depth for inlet and crest reaches in computations.

! Reach 12 used in computing exit channel velocities.

****

ROUTED RESULTS	BTM WIDTH FT	MAX ELEV FT	VOL-MAX ACFT	AREA-MAX AC	AUX.-HP FT	VOL-AUX. ACFT
NRCS-SDH	300.0	1522.57	5328.3	0.0	3.97	1080.9

PEAK - CFS	Q-PS	Q-AUX.	Q-TOT.
DISCHARGE =	140.	5556.	5696.

	CRITICAL DEPTH	CRITICAL VELOCITY	CRITICAL SLOPE-Sc	25% OF Q Sc
AUXILIARY	FT	FT/SEC	FT/FT	FT/FT
SPILLWAY ---	2.18	8.30	0.014	0.019

AUXILIARY SPILLWAY DURATION FLOW = 30.0 HOURS

EXIT CHANNEL FLOW SUBCRITICAL: MAX VELOCITY= 6.0 FT/SEC
EXIT SLOPE = 0.005 FT/FT
FLOW DEPTH = 3.0 FT

***** WARNING - SOD STRIPPING WILL PROBABLY OCCUR DUE TO GROSSSTRESS LIMIT IN
STABILITY CONTROL REACH WHICH STARTS AT STATION 1050.84.

****

EROSIONALLY EFFECTIVE STRESS FOR STABILITY ANALYSIS OF AUX. EXIT CHANNEL
(Refer to Ag. Handbook 667, Chapt. 3, for allowable stresses.)
Aux. Spillway Discharge = 5556. cfs; Bottom Width = 300. ft

REACH NO.	FROM STA	TO STA	SLOPE %	MANNING`S n	VELOCITY ft/s	TOTAL STRESS lb/ft^2	EFFECTIVE STRESS lb/ft^2	
12	561.	581.	0.48	0.035	6.00	0.90	0.090	
13	581.	606.	5.65	0.035	12.71	5.06	0.503	
14	606.	613.	21.61	0.035	19.09	12.96	1.287	
15	613.	783.	10.14	0.035	15.18	7.63	0.758	
16	783.	817.	19.43	0.035	18.48	12.03	1.195	
17	817.	865.	19.24	0.035	18.43	11.95	1.187	
18	865.	932.	20.16	0.035	18.69	12.35	1.226	
19	932.	971.	2.29	0.035	9.66	2.69	0.267	
20	971.	1051.	3.27	0.035	10.77	3.45	0.343	
21	1051.	1067.	26.16	0.035	20.22	14.83	1.472	max.

****

ROUTED RESULTS	BTM WIDTH FT	MAX ELEV FT	VOL-MAX ACFT	AREA-MAX AC	AUX.-HP FT	VOL-AUX. ACFT
NRCS-FBH	300.0	1527.23	6737.0	0.0	8.63	2489.6

PEAK - CFS	Q-PS	Q-AUX.	Q-TOT.
DISCHARGE =	146.	20062.	20208.

	CRITICAL DEPTH	CRITICAL VELOCITY	CRITICAL SLOPE-Sc	25% OF Q Sc
AUXILIARY	FT	FT/SEC	FT/FT	FT/FT
SPILLWAY ---	5.09	12.50	0.011	0.014

INTEGRITY ANALYSIS - REACH SURFACE PERFORMANCE SUMMARY
(The auxiliary spillway began flow at time = 10.0 hours
and peaked at time = 16.0 hours.)

REACH 12: FROM STATION 561. TO 581. ON 0.5% SLOPE.
Vegetal cover failed and concentrated flow developed
at time = 40.0 hours.

REACH 13: FROM STATION 581. TO 606. ON 5.6% SLOPE.
Vegetal cover failed and concentrated flow developed
at time = 15.0 hours.

REACH 14: FROM STATION 606. TO 613. ON 21.6% SLOPE.
Vegetal cover failed and concentrated flow developed
at time = 13.0 hours.

REACH 15: FROM STATION 613. TO 783. ON 10.1% SLOPE.
Vegetal cover failed and concentrated flow developed
at time = 13.0 hours.

REACH 16: FROM STATION 783. TO 817. ON 19.4% SLOPE.
Vegetal cover failed and concentrated flow developed
at time = 13.0 hours.

REACH 17: FROM STATION 817. TO 865. ON 19.2% SLOPE.
Vegetal cover failed and concentrated flow developed
at time = 13.0 hours.

REACH 18: FROM STATION 865. TO 932. ON 20.2% SLOPE.
Vegetal cover failed and concentrated flow developed
at time = 13.0 hours.

REACH 19: FROM STATION 932. TO 971. ON 2.3% SLOPE.
Vegetal cover failed and concentrated flow developed
at time = 13.0 hours.

REACH 20: FROM STATION 971. TO 1051. ON 3.3% SLOPE.
Vegetal cover failed and concentrated flow developed
at time = 16.0 hours.

REACH 21: FROM STATION 1051. TO 1067. ON 26.2% SLOPE.
Vegetal cover failed and concentrated flow developed
at time = 13.0 hours.

INTEGRITY ANALYSIS - HEADCUT EROSION DAMAGE SUMMARY

The headcut BREACHED the spillway crest at
time equal approximately 15.0 hours.

Computations terminated at that point!

The most upstream headcut began at station 606.
and progressed upstream to station 561.
The final height of the headcut was 57.3 ft.

The deepest headcut is also the furthest upstream.

	DURATION FLOW HRS	ATTACK OE/B ACFT/FT	DIST. FROM MOST U/S HEADCUT TO U/S EDGE AUX. CREST, FT
AUXILIARY SPILLWAY----	37.0	58.9	>>>BREACH<<< Depth = 57.3 ft

EXIT CHANNEL FLOW SUBCRITICAL: MAX VELOCITY= 9.8 FT/SEC
EXIT SLOPE = 0.005 FT/FT
FLOW DEPTH = 6.4 FT

Inflow Hyd 1 SDH-Peak = 5696.28 CFS at 17.00 hrs., Location Point

Inflow Hyd 1 FBH-Peak = 20207.86 CFS at 15.00 hrs., Location Point
HYDOUT 1 1

1SITES....JOB NO. 1 COMPLETE.
----
1 Bylin

0 SUBWATERSHED(S) ANALYZED.
1 STRUCTURE(S) ANALYZED.
2 HYDROGRAPHS ROUTED AT LOWEST SITE.
0 TRIALS TO OBTAIN BOTTOM WIDTH FOR SPECIFIED STRESS OR VELOCITY.

****

SITES.....COMPUTATIONS COMPLETE

SUMMARY TABLE 1 SITES VERSION 2005.1.8
DATED 01/01/2005

WATERSHED ID	RUN DATE	RUN TIME
1	04/14/2021	15:24:07

>>> SITE ID	SUBWS ID	SUBWS DA (SQ MI)	CURVE NO.	TC (HRS)	TOTAL DA (SQ MI)	TYPE DESIGN	STRUC CLASS <<<
1	1	20.86	0.	0.00	20.86	TR60	C

PASS NO.	DIA./ WIDTH (IN/FT)	AUX.CREST ELEV (FT)	BTM. WIDTH (FT)	MAX. HP (FT)	MAX. ELEV (FT)	EMB. VOL. (CY)	INTEGR.* DIST. (FT)	EXIT* VEL. (FT/SEC)	TYPE HYD
1	30.0	1518.6	300.0	8.6	1527.2	0.	<BREACH>	9.8	NRCS-FBH

* INTEGRITY DIST. AND EXIT VEL. VALUES ARE BASED ON THE ROUTED HYDROGRAPH SHOWN UNDER TYPE HYD.

SITES.......SUMMARY TABLE 1 COMPLETED.

NRCS SITES VERSION 2005.1.8 ,01/01/2005
1 FILES

INPUT = h:\JBN\7100\7135\7135_0037\Deliverables\2021-02-22 Final Review Point 2 to NRCS\Models\SITES\Bylin\Bylin_FBH_SDH_12H_Local.D2C
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DATED 04/14/2021 15:24:07

GRAPHICS FILES GENERATED

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OPTION "E" = h:\JBN\7100\7135\7135_0037\Deliverables\2021-02-22 Final Review Point 2 to NRCS\Models\SITES\Bylin\Bylin_FBH_SDH_12H_Local.DEM DATED 04/14/2021 15:24:07

AUX.GRAPHICS = h:\JBN\7100\7135\7135_0037\Deliverables\2021-02-22 Final Review Point 2 to NRCS\Models\SITES\Bylin\Bylin_FBH_SDH_12H_Local.DG* DATED 04/14/2021 15:24:07

AUXILIARY SPILLWAY 6H STABILITY ANALYSIS

AH667/TR-60 Auxiliary Spillway 6-hr SDH Stability Analysis from SITES

Project Data

Date: Apr 15, 2021
Designer: Rachel Glatt
Project: Bylin Dam
County: Walsh
State: ND
SITES file name: Bylin_FBH_SDH_6H_Local.D2C
AS Width: 300 ft wide

Checked By: Paul LeClaire
Check Date: 1/6/2021

Topsoil Properties

CL	Dominant Textural Soil Class of Aux Spwy Topsoil
17	Plasticity Index of Aux Spwy Topsoil (for CH, CL, GC, GM, MH, ML, OH, OL, SC, SM)
1.500 in	
80 pcf	Dry Density of Topsoil (lbs/ft^3)
2.70	Specific Gravity of Topsoil, G_s

Vegetation C — Aux Spwy Retardance Class (A-E) or Retardance Curve Index (2.88-10)

AS Flow Frequency 1.0% — Auxiliary spillway anticipated average use (see TR-60 2nd ed., pg 7-3)

SITES 6-hr SDH values

see *Erosionally Effective Stress For Stability Analysis of Aux Exit Channel* tbl

13.12 psf — Total Stress, from SITES 6-hr SDH (psf)
1.304 psf — Soil Effective Stress, from SITES 6-hr SDH (psf)

Soil Stress Analysis

Soil	Plasticity Index **PI** or **D_{75}**	Allowable Effective Stress τ_{ab}	Void Ratio **e**	Void Ratio Correction C_e	$= \tau_{ab}$ * (Ce)^2 τ_a	TR-60 AS Use Freq Multiplier	AH 667 Adjusted **Allowable** Stress τ_a	**SITES** 6-hr SDH Soil Effective Stress
CL	PI=17	0.060 psf	1.11	0.850	0.043 psf	1.5	**0.065 psf**	**1.304 psf**

Soil erodes--effective soil stress exceeds adjusted allowable soil stress!! Consider widening to 6029 ft, raising the auxiliary spillway or selecting a higher plasticity topsoil.

Vegetal Stress Analysis

C_I - Retardance curve index AH 667 Table 3.2	AH 667 Allowable vegetal stress (AH 667 Eqn 1.17) $\tau_{va} = C_I * 0.75$	SITES 6-hr SDH Vegetal Stress $\tau_{veg} = \tau_{tot} - \tau_{eff}$
5.6	**4.20 psf**	**11.82 psf**

Vegetation erodes--actual vegetal stress exceeds allowable!! Consider widening or raising auxiliary spillway crest, flatten exit slope, or use higher retardance vegetation.

Overall Stability

Unacceptable design. Soil and/or vegetation predicted to erode.

Version: **2.8** 4/21/2011

Notes: This spreadsheet facilitates the USDA-NRCS TR-60 2nd edition stability analysis for earthen/vegetated auxiliary spillways with SITES software output.
Users enter project data, auxiliary spillway width, topsoil data, vegetation, auxiliary spillway flow frequency, and SITES 6-hr SDH stress values. Depending on the soil, either PI or D75 input is needed.
The allowable vegetal and effective soil stresses are computed using USDA-ARS Ag Handbook 667 "Stability Design of Grass-Lined Open Channels". The design SITES stresses are compared to the AH 667 stresses (as modified by TR-60). An appropriate design has equal or lower design stresses than allowable stresses.
Based on input auxiliary spillway width and ratio of allowable effective stress:design effective stress the minimum auxiliary spillway width for stability is computed. Integrity analysis may require a wider auxiliary spillway.