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Principal Spillway Riser Tower and Reservoir at Bylin Dam – Walsh County, North Dakota – September 2020

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

Appendix D-3 Alternatives Evaluation Report

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Appendix D-3 – Alternatives Evaluation Report

February 29, 2024

Walsh County Water Resource District

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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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ACRONYMS

ACB	Articulated Concrete Block
ASCE	American Society of Civil Engineers
FBH	Freeboard Hydrograph
FEMA	Federal Emergency Management Agency
HEI	Houston Engineering, Inc.
NASS	National Agricultural Statistics Service
NDDWR	North Dakota Department of Water Resources
NDSWC	North Dakota State Water Commission
NRCS	Natural Resources Conservation Service
PMP	Probable Maximum Precipitation
RCC	Roller Compacted Concrete
RRRA	Red River Retention Authority
SAF	St. Anthony Falls
USFWS	U.S. Fish and Wildlife Services
USACE	U.S. Army Corps of Engineers
WCWRD	Walsh County Water Resource District

1 BACKGROUND

This report documents the development of structural alternatives as part of the submittal for Review Point 3 of the Cooperative Agreement between the NRCS and the WCWRD to develop a Watershed Plan for the North Branch Forest River Watershed, Forest River Dam No. 1 (also known as Bylin Dam). Bylin Dam is located in Sections 5 and 6 of Norton Township (T156N, R57W), Walsh County, ND, and has a drainage area of approximately 20.5 square miles. Project maps showing the location of Bylin Dam are provided in **Appendix B** of the Watershed Plan – EA. The dam was built to primarily provide flood control along the North Branch Forest River, and secondarily to provide recreation opportunities.

1.1 PREVIOUS EVALUATIONS

An existing conditions assessment was completed for Bylin Dam during the planning process. The assessment verified that Bylin Dam is a high hazard structure. During the existing conditions assessment, Bylin Dam was evaluated using technical standards and current practices within the industry for a high hazard structure. Three primary categories were evaluated including: geotechnical, structural, and hydrologic and hydraulic. The Existing Conditions Assessment Report located in **Appendix D-1** contains documentation for the evaluation of the dam. A summary of the existing condition assessment is also provided in **Table D-3-1**.

***Table D-3-1**: Existing Conditions Assessment Summary Table*

Criteria	Bylin Dam
Gradation	Sufficient to prevent piping
Foundation Drain Fill	Does not meet state-of-the-practice criteria for seepage control/conveyance
Downstream Slope – Normal Pool	Factor of Safety Met (Required = 1.5, Calculated = 2.2)
Downstream Slope – Flood Surcharge Pool	Factor of Safety Not Met [1] (Required = 1.4, Calculated = 1.1)
Rapid Drawdown	Factor of Safety Met (Required = 1.2, Calculated = 1.5)
Riser Tower / Principal Spillway Inlet	Minor Deficiencies
Principal Spillway Conduit and Outlet	Minor Deficiencies
Embankment and Auxiliary Spillway	Lightly used, some scattered vegetation
Principal Spillway Capacity	Insufficient
Principal Spillway Drawdown	Insufficient
Auxiliary Spillway Capacity	Insufficient
Auxiliary Spillway Stability	Unstable (Soil and Vegetation Erode)
Auxiliary Spillway Integrity	Breach

[1] Transient analysis shows that the required factor of safety is met for Bylin Dam

1.2 PURPOSE

The purpose of this report is to identify all practical alternatives that rehabilitate the dam to meet NRCS and NDDWR (formerly known as the NDSWC) Dam Safety Standards for a high hazard structure. NRCS design and safety standards are provided in *Earth Dams and Reservoirs* (NRCS, 2019). The NDDWR was in the process of updating the minimum standards and requirements for dam design at the time of the initial submittal of this report. The most current design standards at the time of the initial submittal are provided in *North Dakota Dam Design Handbook* (North Dakota State Engineer, 1985). Once a range of practical structural alternatives were identified, comparative concept level cost estimates were prepared for each alternative. The cost estimates were used to assist in the selection of the alternative(s), however, cost alone was not the only factor in determining the structural alternative to be carried forward for detailed analysis. Other considerations include social, environmental, and logistical consequences. After the range of structural alternatives to a high hazard designation was narrowed, non-structural alternatives were identified along with a structural alternative to rehabilitate the dam to a lower hazard classification. The non-structural alternatives and the structural alternative to rehabilitate the dam to a lower hazard classification were then compared to the structural alternative.

1.3 TECHNICAL TEAM

A technical team was formed to aid in the identification of practical structural rehabilitation alternatives to a high hazard classification. The technical team consisted of representatives from the NRCS, NDDWR, RRRA, Gannett Fleming, Inc., and Houston Engineering, Inc (HEI). Throughout the structural alternative identification process, two meetings were held with the technical team.

The first technical team meeting was held on April 12th, 2021. The purpose of the meeting was to review the deficiencies for each dam and identify the categories of practical structural rehabilitation alternatives that should be considered. The categories of alternatives that were discussed included principal spillway modifications, raising the top of dam elevation, widening the auxiliary spillway, various spillway lining options, cutoff walls in the auxiliary spillway, and embankment slope modifications. Following the meeting, concept level alternatives were developed for the categories of structural alternatives that were identified. The main purpose of the meeting was to focus on the structural alternative, therefore, the no-action, structural rehabilitation to a lower hazard classification, and non-structural alternatives were not discussed in significant detail.

The second technical team meeting was held on July 20th, 2021. The purpose of the meeting was to review the structural alternatives that had been identified during the previous meeting with additional technical information developed. Coming out of the meeting, only the structural alternatives identified to be carried forward were brought to the larger interagency review team (described in the following section).

1.4 INTERAGENCY REVIEW TEAM

An interagency review team was established to assist in guiding the overall project. The interagency review team consists of representatives from the NRCS, NDDWR, RRRA, USFWS, USACE, FEMA, and other members of state, local and tribal organizations. The interagency review team met for the existing conditions assessment associated with Bylin Dam in January of 2021.

The interagency review team also met on September 21st, 2021, to discuss the alternatives to be carried forward for detailed review. The primary focus of the meeting was to narrow the range of alternatives for structural, structural with a lower hazard designation, and non-structural alternatives. Following the interagency review team meeting, detailed reviews and analyses for the various alternative categories were completed so that the environmentally preferred, national economic efficiency, and locally preferred alternatives could be established.

2 ALTERNATIVE IDENTIFICATION AND DEVELOPMENT

2.1 RANGE OF ALTERNATIVES

The range of alternatives that are considered for dam rehabilitation are categorized as:

- Future Without Federal Investment
- No Action
- Non-Structural or Decommissioning
- Structural
- Structural to a Lower Hazard Classification

The Future Without Federal Investment (FWOFI) and no action alternatives are to be carried forward for additional analysis. The FWOFI is discussed within the main body of the Watershed Plan – Environmental Assessment. The no action alternative, the methods used to develop the no action breach scenario, and the resulting damage from the no action alternative is described in Section 5.8 of this report. The other non-structural alternative evaluated for Bylin Dam is a full decommissioning of the dam.

2.2 STRUCTURAL ALTERNATIVES

The structural alternatives that were considered consist of various modifications to the principal spillway, auxiliary spillway, and embankment to bring Bylin Dam into compliance with dam safety standards for a high hazard structure. Modifications considered for Bylin Dam are discussed in the following sections. Modifications to the auxiliary spillway typically consist of two main components: modification to the control section (weir crest) and modifications to the exit channel.

2.2.1 AUXILIARY SPILLWAY HYDRAULIC CONTROL SECTION

The capacity required to meet freeboard design criteria is a key component in determining the width of the auxiliary spillway. The hydraulic efficiency of the control section, or weir crest, will define the width of the downstream auxiliary spillway exit channel. Three different hydraulic control sections were identified as practical alternatives, including a broad crested weir, an ogee weir, and a labyrinth weir.

2.2.2 AUXILIARY SPILLWAY EXIT CHANNEL

Four practical auxiliary spillway lining options were identified for the auxiliary spillway exit channels, including earthen grass-lined spillways, articulated concrete block (ACB) armored spillways, roller compacted concrete (RCC) structural spillways, and reinforced concrete chute structural spillways. While earthen grass-lined spillways are generally more economical lining options, they are not always feasible based on the landscape and sub-surface soil conditions. Structural lining treatments typically provide the highest level of erosion resistance; however, they may not be the most economical solution to meet dam safety standards.

For the alternatives analysis, each spillway lining option was conceptually designed to meet hydrologic criteria defined by *TR 210-60* (NRCS, 2019) using appropriate NRCS guidance material. The RCC structural spillways were designed using guidance material developed by ASCE and the Portland Cement Association. Design guidance material used for the structural alternatives is listed in the Reference section of this report.

2.2.3 PRINCIPAL SPILLWAY

Modifications to the principal spillway on Bylin Dam are required to meet capacity requirements identified in *Earth Dams and Reservoirs* (NRCS, 2019). However, if the structural alternative identified includes armoring the auxiliary spillway with non-erodible material such as RCC or reinforced concrete, activation of the auxiliary spillway is allowed during passage of the principal spillway hydrograph. Therefore, if non-erodible material is used for the auxiliary spillway, modifications to the principal spillway would not be necessary as long as the current principal spillway structure does not show signs of deterioration and is adequate in terms of structural stability. Principal spillway modifications would still be required for Bylin Dam if an ACB or a grass-lined auxiliary spillway is used.

The principal spillway structure for Bylin Dam had only minor deficiencies at the time of inspection as noted in **Table D-3-1**. The minor deficiencies can be addressed without complete replacement of the riser tower and conduit. The structural stability of the conduit would be considered during the detailed review of alternatives if necessary. Efforts to determine the adequacy of the existing conduit through Bylin Dam were conducted. The analysis indicated that the conduit would have adequate strength if it were a Class V pipe. If this were the case, the conduit would be adequate to last throughout the extended design of life of the dam. For the purposes of this report, it was assumed that the conduit has adequate strength and will not need to be replaced for alternatives that have non-erosive material in the auxiliary spillways (i.e., structural spillways with RCC and reinforced concrete). This assumption will be revisited, and the type of pipe verified, if the ongoing structural analysis indicates that the conduit through Bylin Dam is inadequate or will become inadequate throughout the expected design life of the project.

2.2.4 EMBANKMENT

The downstream embankment for Bylin Dam does not meet the required factor of safety for the flood surcharge pool (see **Table D-3-1**) under steady state conditions. However, using a transient analysis the calculated factor of safety does pass the requirements outlined in *TR 210-60*. Additional clarification on appropriate methods used to simulate slope stability for the flood surcharge pool will be necessary before moving onto final design and construction of the preferred alternative. For the purposes of this report, any downstream embankment modifications required would be included for all alternatives that were considered. Calculating the concept level costs for the downstream embankment modifications as it relates to slope stability will not influence the selection of the alternative(s) carried forward for further review. Therefore, costs for modifications to the downstream embankment related to slope stability concerns are not included in the conceptual level comparative cost estimate for each alternative.

2.3 UNIT PRICES

Part of this analysis includes developing concept level cost estimates for various alternatives. Unit prices were developed jointly between Houston Engineering Inc. (HEI) and the North Dakota NRCS staff. Unit prices were based on local knowledge of prior projects in the region, dam rehabilitation projects constructed through NRCS planning around the United States, and supplier-provided costs for ACBs. The unit prices used for the different construction elements considered for the concept level costs are provided in **Table D-3-2**.

Table D-3-2: Unit Prices Used for Various Work Items

Item	Unit	Unit Price	Assumptions
Earthwork - Excavation	CY	$5.00	Includes excavation, haul, spoiling, and stripping and topsoiling of material.
Earthwork - Fill	CY	$10.00	Includes placement, compaction, final grading and seeding. Would be a small quantity relative to the overall project cost.
Structural Concrete	CY	$2,000.00	Includes Concrete, reinforcing steel, form work, and subgrade preparation
RCC	CY	$350.00	Includes batch plant, materials, mixing, conveying, placing and curing
ACBs (EPEC SD 475 OCT)	SF	$11.50	Includes ACB and all geosynthetics
ACBs (EPEC System 900 OCT)	SF	$15.00	Includes ACB and all geosynthetics
ACB - Stone Drainage Layer	CY	$20.00	Drainage Layer required under ACB
Clearing and Grubbing	AC	$10,000.00	Includes all incidentals associated with clearing and grubbing.
Land Acquisition - Not Farmed	AC	$1,200.00	Full purchase required for construction. No flowage easements
Land Acquisition - Farmed	AC	$3,200.00	Full purchase required for construction. No flowage easements
Roadway Realignment	LF	$200.00	Includes cost for excavation, seeding, aggregate base course, and aggregate surface course
P.S. Riser Tower Replacement	LS	$500,000.00	Includes mobilization, dewatering/foundation preparation, structure removals, reinforced Structural Concrete, & debris cage
P.S. Conduit - Jack and Bore 36” Diameter	LF	$1,600.00	Cost includes carrier pipe conduit, slip-lining, and old conduit abandonment
Open Cut Dam Embankment	CY	$25.00	Includes excavation, haul, temporary spoil, placement, compaction, testing, topsoiling seeding
P.S. Conduit – 36” Diameter	LF	$420.00	Cost of pipe and removal of existing conduit. Does not include excavation

3 STRUCTURAL ALTERNATIVES IDENTIFICATION

The practical structural alternatives that were identified for Bylin Dam are shown in **Table D-3-3** and are described in more detail in the following sections. The structural alternatives provided in **Table D-3-3** include modifications to the auxiliary spillway, principal spillway, and embankment.

***Table D-3-3**: Bylin Dam – Structural Alternatives*

Alternative	Auxiliary Spillway Hydraulic Control Section (Weir Crest)	Auxiliary Spillway Exit Channel	Replace Principal Spillway Riser Tower and Conduit	Embankment	Concept Level Comparative Cost Estimate
1	Broad Crested 300 feet	ACB 13% slope (New Alignment)	YES	Raise 3.5 feet	$ 6,910,000
1a	Broad Crested 300 feet	ACB 13% slope (Existing Alignment)	YES	Raise 3.5 feet	$ 5,635,000
2	Broad Crested 720 feet	ACB 13% slope	YES	No Raise	$ 14,713,000
3	Broad Crested 300 feet	RCC 25% slope	NO	Raise 3.5 feet	$ 7,893,000
4	Broad Crested 720 feet	RCC 25% slope	NO	No Raise	$ 25,383,000
5	Broad Crested 300 feet	Reinforced Concrete 25% slope	NO	Raise 3.5 feet	$ 22,547,000
6	Broad Crested 720 feet	Reinforced Concrete 25% slope	NO	No Raise	$ 54,224,000
7	Broad Crested 3,200 feet	Earthen	NO	No Raise	$ 32,182,000
8	Ogee Weir 300 feet	ACB 13% slope	YES	Raise 1.5 feet	$ 10,754,000
9	Ogee Weir 437 feet	ACB 13% slope	YES	No Raise	$ 14,157,000
10	Ogee Weir 300 feet	RCC 25% slope	NO	Raise 1.5 feet	$ 10,370,000
11	Ogee Weir 437 feet	RCC 25% slope	NO	No Raise	$ 14,418,000
12	Ogee Weir 300 feet	Reinforced Concrete 25% slope	NO	Raise 1.5 feet	$ 32,852,000
13	Ogee Weir 437 feet	Reinforced Concrete 25% slope	NO	No Raise	$ 32,535,000
14	Labyrinth Weir 300 feet	ACB 13% slope	YES	No Raise	$ 9,072,000
14a	Labyrinth Weir 216 feet	ACB 10% slope	YES	No Raise	$ 10,359,000
15	Labyrinth Weir 216 feet	RCC 25% slope	NO	No Raise	$ 8,933,000

3.1 ALTERNATIVE 1 – BROAD CRESTED; ACB; RAISE 3.5 FEET

This alternative includes a broad crested hydraulic control section with an ACB lined auxiliary spillway exit channel. The alignment of the auxiliary spillway exit channel is adjusted to a location east of the existing spillway centerline to increase hydraulic efficiency as flows enter the hydraulic control section and to avoid constructing the ACB lined spillway on fill material. The control section and spillway are 300 feet wide. The principal spillway would need to be modified to pass the principal spillway hydrograph because an ACB lined spillway is not classified as a structural spillway. The riser structure and conduit would be replaced using an open cut method. Abandoning the existing conduit and using a jack and bore method to implement the upsized principal spillway conduit was also considered and is discussed in Section 4.2. The dam would need to be raised 3.5 feet to meet freeboard hydrograph capacity requirements. A conceptual drawing of the alternative is shown on **Figure D-3-1**. The technical team recommended carrying this alternative forward for further analysis based on the low cost. The final alignment for the auxiliary spillway may be between what is shown for Alternative 1 and Alternative 1A (discussed in Section 3.1.1) to balance cut and fill volumes while still meeting freeboard requirements. See additional discussion on the auxiliary spillway alignment for Bylin Dam in Section 4.1.

3.1.1 ALTERNATIVE 1A – BROAD CRESTED; ACB; RAISE 3.5 FEET

This alternative includes a broad crested hydraulic control section with an ACB lined auxiliary spillway that matches the existing spillway alignment. The control section and spillway are 300 feet wide located in the existing auxiliary spillway footprint. The principal spillway would need to be modified to pass the principal spillway hydrograph because an ACB lined spillway is not classified as a structural spillway. The riser structure and conduit would be replaced using an open cut method. Abandoning the existing conduit and using a jack and bore method to implement the upsized principal spillway conduit was also considered and is discussed in Section 4.2. The dam would need to be raised 3.5 feet to meet freeboard hydrograph capacity requirements. A conceptual drawing of the alternative is shown on **Figure D-3-2**. The technical team recommended carrying this alternative forward for further analysis based on the low cost. The final alignment for the auxiliary spillway may be between what is shown for Alternative 1 and Alternative 1A to balance cut and fill volumes while still meeting freeboard requirements. See additional discussion on the auxiliary spillway alignment for Bylin Dam in Section 4.1.

3.2 ALTERNATIVE 2 – BROAD CRESTED; ACB; NO RAISE

This alternative includes a broad crested hydraulic control section with an ACB lined auxiliary spillway. The control section and spillway are 720 feet wide located south of the existing embankment. The principal spillway would need to be modified to pass the principal spillway hydrograph because an ACB lined spillway is not classified as a structural spillway. The riser structure and conduit would be replaced using an open cut method. No dam raise would be required to meet freeboard hydrograph capacity requirements for this alternative. A conceptual drawing of the alternative is shown on **Figure D-3-3**. This alternative was eliminated due to the unreasonably high cost and the challenges associated with realigning the road east of the dam.

3.3 ALTERNATIVE 3 – BROAD CRESTED; RCC; RAISE 3.5 FEET

This alternative includes a broad crested hydraulic control section with a RCC lined auxiliary spillway that matches the existing alignment. The control section and spillway are 300 feet wide. The alignment for the auxiliary spillway was modified to improve hydraulic efficiency through the spillway. The dam would need to be raised 3.5 feet to meet freeboard hydrograph capacity requirements. A conceptual drawing of the alternative is shown on **Figure D-3-4**. The technical team recommended carrying this alternative forward for further analysis based on the low cost and the ability to keep the existing principal spillway structure in place. See additional discussion in Section 5.

3.4 ALTERNATIVE 4 – BROAD CRESTED; RCC; NO RAISE

This alternative includes a broad crested hydraulic control section with a RCC lined spillway that matches the existing alignment. The control section and spillway are 720 feet wide located south of the dam embankment. A conceptual drawing of the alternative is shown on **Figure D-3-5**. This alternative was eliminated due to the unreasonably high cost and the challenges associated with realigning the road east of the dam.

3.5 ALTERNATIVE 5 – BROAD CRESTED; REINFORCED CONCRETE; RAISE 3.5 FEET

This alternative includes a broad crested hydraulic control section with reinforced concrete lined auxiliary spillway. The control section and spillway are 300 feet wide, and the alignment of the auxiliary spillway was adjusted to increase hydraulic efficiency of the spillway. The dam would need to be raised 3.5 feet to meet freeboard hydrograph capacity requirements. A conceptual drawing of the alternative is shown on **Figure D-3-4**. The technical team recommended carrying this alternative forward for further analysis to show the larger interagency team that reinforced concrete lined spillways are far more expensive than other options. See additional discussion in Section 5.

3.6 ALTERNATIVE 6 – BROAD CRESTED; REINFORCED CONCRETE; NO RAISE

This alternative includes a broad crested control section with reinforced concrete auxiliary spillway. The control section and spillway are 720 feet wide located south of the dam embankment. The dam would not need to be raised to meet the freeboard hydrograph capacity requirements. A conceptual drawing of the alternative is shown on **Figure D-3-5**. This alternative was eliminated due to the unreasonably high cost and the challenges associated with realigning the road east of the dam.

3.7 ALTERNATIVE 7 – BROAD CRESTED; EARTHEN; NO RAISE

This alternative includes a broad crested control section with an earthen auxiliary spillway. The control section and spillway would need to be 3,200 feet wide to pass the freeboard hydrograph without a complete breach of the spillway. The need for the 3,200-foot-wide control section is largely driven by shear stress on the spillway. High shear stresses cause erosion. Shear stress is dependent on flow depth and flow velocity. Widening the spillway control section will reduce depths in exit channel and prevent a complete breach of Bylin Dam when the control section is 3,200 feet wide. The dam would not need to be raised to meet the freeboard hydrograph capacity requirements. A conceptual drawing of the alternative is shown on **Figure D-3-6**. This alternative would also require modifications to township roads in the area, which would mean that several acres of agricultural land would need to be taken out of production. The technical team recommended carrying this alternative forward for further analysis to show the larger interagency team that the earthen spillway alternative would have a very large footprint and would be quite expensive.

3.8 ALTERNATIVE 8 – OGEE WEIR; ACB; RAISE 1.5 FEET

This alternative includes an ogee hydraulic control section with an ACB lined auxiliary spillway. The control section and spillway are 300 feet wide, and the alignment of the auxiliary spillway was adjusted to increase hydraulic efficiency of the spillway. The principal spillway would need to be modified to pass the principal spillway hydrograph because an ACB lined spillway is not classified as a structural spillway. The riser structure and conduit would be replaced using an open cut method. The dam would need to be raised 1.5 feet to meet freeboard hydrograph capacity requirements. A conceptual drawing of the alternative is shown on **Figure D-3-7**. This alternative was eliminated due to higher cost when compared to the broad crested control section alternatives.

3.9 ALTERNATIVE 9 – OGEE WEIR; ACB; NO RAISE

This alternative includes an ogee hydraulic control section with an ACB lined auxiliary spillway. The control section and spillway are 437 feet wide located south of the embankment. The principal spillway would need to be modified to pass the principal spillway hydrograph because an ACB lined spillway is not classified as a structural spillway. The riser structure and conduit would be replaced using an open cut method. The dam would not need to be raised to meet freeboard hydrograph capacity requirements. A conceptual drawing of the alternative is shown on **Figure D-3-8**. This alternative was eliminated due to the unreasonably high cost and the challenges associated with realigning the road east of the dam.

3.10 ALTERNATIVE 10 – OGEE; RCC; RAISE 1.5 FEET

This alternative includes an ogee hydraulic control section with a roller compacted concrete lined auxiliary spillway. The control section and spillway are 300 feet wide, and the alignment of the auxiliary spillway was adjusted to increase hydraulic efficiency of the spillway. The principal spillway would need to be modified to pass the principal spillway hydrograph because an ACB lined spillway is not classified as a structural spillway. The riser structure and conduit would be replaced using an open cut method. The dam would need to be raised 1.5 feet to meet freeboard hydrograph capacity requirements. A conceptual drawing of the alternative is shown on **Figure D-3-9**. This alternative was eliminated due to higher cost when compared to the broad crested control section alternatives.

3.11 ALTERNATIVE 11 – OGEE; RCC; NO RAISE

This alternative includes an ogee hydraulic control section with a RCC lined auxiliary spillway. The control section and spillway are 437 feet wide located south of the embankment. The dam would not need to be raised to meet freeboard hydrograph capacity requirements. A conceptual drawing of the alternative is shown on **Figure D-3-10**. This alternative was eliminated due to the unreasonably high cost and the challenges associated with realigning the road east of the dam.

3.12 ALTERNATIVE 12 – OGEE; REINFORCED CONCRETE; RAISE 1.5 FEET

This alternative includes an ogee hydraulic control section with a reinforced concrete lined auxiliary spillway. The control section and spillway are 300 feet wide, and the alignment of the auxiliary spillway was adjusted to increase hydraulic efficiency of the spillway. The dam would need to be raised 1.5 feet to meet freeboard hydrograph capacity requirements. A conceptual drawing of the alternative is shown on **Figure D-3-9**. This alternative was eliminated due to higher cost when compared to the broad crested control section alternatives.

3.13 ALTERNATIVE 13 – OGEE; REINFORCED CONCRETE; NO RAISE

This alternative includes an ogee hydraulic control section with a reinforced concrete lined auxiliary spillway. The control section and spillway are 437 feet wide located south of the embankment. The dam would not need to be raised to meet freeboard hydrograph capacity requirements. A conceptual drawing of the alternative is shown on **Figure D-3-10**. This alternative was eliminated due to the unreasonably high cost and the challenges associated with realigning the road east of the dam.

3.14 ALTERNATIVE 14 – LABYRINTH WEIR; ACB; NO RAISE

This alternative includes a labyrinth weir hydraulic control section with ACB lined spillway. The control section and spillway are 300 feet wide located in the existing auxiliary spillway footprint. The labyrinth weir provides 722 feet of effective weir length. No dam raise would be required to meet freeboard hydrograph capacity requirements for this alternative. A conceptual drawing of the alternative is shown on **Figure D-3-11**. This alternative was eliminated due to high cost, complexity of construction, and anticipated maintenance required for a labyrinth weir.

3.14.1 ALTERNATIVE 14A – LABYRINTH WEIR; ACB; NO RAISE

This alternative includes a labyrinth weir hydraulic control section with ACB lined spillway. The control section and spillway are 216 feet wide located within the existing auxiliary spillway footprint. The labyrinth weir provides 1,577 feet of effective weir length. The slope of the ACB lined spillway would need to be reduced to account for the increased depth in the 216-foot-wide channel (i.e., because of the increased flow depth, flow velocities need to be reduced to ensure structural stability of the ACBs). The No dam raise would be required to meet freeboard hydrograph capacity requirements for this alternative. A conceptual drawing of the alternative is shown on **Figure D-3-12**. This alternative was eliminated due to high cost, complexity of construction, and anticipated maintenance required for a labyrinth weir.

3.15 ALTERNATIVE 15 – LABYRINTH WEIR; RCC; NO RAISE

This alternative includes a labyrinth weir hydraulic control section with RCC lined spillway. The control section and spillway are 216 feet wide located within the existing auxiliary spillway footprint. The labyrinth weir provides 1,577 feet of effective weir length. No dam raise would be required to meet freeboard hydrograph capacity requirements for this alternative. A conceptual drawing of the alternative is shown on **Figure D-3-13**. This alternative was carried forward as an option because of its ability to pass the freeboard hydrograph within the existing spillway footprint without having to raise the top of dam elevation. Additional hydraulic modeling would be required if this alternative were to go to detailed design to ensure that the hydraulic efficiency of the labyrinth weir and auxiliary spillway will not be adversely impacted enough to cause the dam to be overtopped during passage of the freeboard hydrograph.

3.16 STRUCTURAL ALTERNATIVES IDENTIFICATION SUMMARY

At the technical team meeting held on July 20th, 2021, the team recommended Alternative 1 (Section 3.1), Alternative 3 (Section 3.3), Alternative 5 (Section 3.5), Alternative 7 (Section 3.7), and Alternative 15 (Section 3.15) be further refined prior to selecting the alternative(s) to be carried forward for detailed analysis. Alternatives 5 and 7 were carried forward to give the interagency team more insight on the costs associated with the reinforced concrete option and the footprint needed for the earthen spillway option.

4 ADDITIONAL CONSIDERATIONS

4.1 AUXILIARY SPILLWAY ALIGNMENT

The auxiliary spillway alignment was adjusted from the existing alignment due to the sharp turn that flows would need to take when moving through the spillway. Sharp turns on auxiliary spillways like the one at

Bylin Dam tend to reduce hydraulic efficiency and are not accurately represented by the standard weir equation. A two-dimensional HEC-RAS model was developed to simulate flows more accurately through the spillway with the existing spillway alignment and the adjusted spillway alignment shown in **Figure D-3-1**. The results show a minimal difference in headwater elevation between the two spillway alignments. Both scenarios show that a dam raise of approximately 3.9 feet would be needed to pass the FBH with a spillway width of 300 feet where previous analysis showed that the dam would only need to be raised by 3.5 feet.

Because the two spillway alignments produce similar results for the required top of dam elevation, a more robust look at costs and environmental impacts is required to determine the best spillway alignment to use moving forward. This information was determined during the detailed review and design of the alternatives.

4.2 PRINCIPAL SPILLWAY CONDUIT REPLACEMENT

For the conceptual cost comparative analysis completed, all alternatives that include replacement of the principal spillway conduit had costs associated with replacing the conduit using an open cut method (i.e., the embankment would be excavated, the conduit would be removed and replaced with the larger conduit). However, other recent dam rehabilitation projects in other parts of the country have utilized a jack and bore method to replace principal spillway conduits through dam embankments. The cost to replace the conduit on Bylin Dam using an open cut method would be more than two times as much as the cost to implement a new, larger conduit via jack and bore methods according to unit costs agreed upon and discussed earlier in this report (Section 2.3).

The jack and bore methodology is a fairly new process to be used in dam rehabilitation efforts. Clarification on methods used to install the conduits will be necessary during the more detailed review and final design of the alternative(s) that are carried forward. If the jack and bore methodology is deemed to be safe, structurally stable, and non-impactful to the geologic integrity of Bylin Dam, it may be used to replace the conduit.

4.3 ENVIRONMENTAL IMPACTS

A cursory review of environmental impacts for the structural alternatives considered was completed following the cost comparison of the various alternatives. None of the structural alternatives that were identified to be carried forward for additional analysis had environmental impacts that were significantly different when compared to other alternatives. That is, all structural alternatives that were carried forward had comparable environmental impacts. Therefore, none of the alternatives discussed in Section 5 were eliminated due to environmental impacts. A more refined evaluation related to environmental impacts was completed for the preferred alternative and is discussed in the Watershed Plan – Environmental Assessment.

5 ALTERNATIVES CARRIED FORWARD FOR DETAILED ANALYSIS

After consideration of the alternatives discussed in Section 3, five structural alternatives were carried forward for additional discussion with the interagency team during a meeting held on September 21st, 2021. Discussions and decisions on whether to carry alternatives forward or eliminate them during the September 21st meeting are described in the following Sections 5.1 through 5.5. Other alternatives described in this section include the structural rehabilitation to a lower hazard classification and the non-structural alternatives that were considered.

5.1 ALTERNATIVE 1 – BROAD CRESTED; ACB; RAISE 3.9 FEET

During the interagency meeting held on September 21st, 2021, the members present at the meeting decided that Alternative 1 was selected as the recommended structural alternative to be carried forward for discussion within the supplemental watershed plan. Alternative 1 was the least costly structural alternative analyzed. Members of the Walsh County Water Resource District indicated that the lowest cost alternative was the most appealing from their perspective. Some concern was raised over the increased flooding potential downstream with the increased size of the principal spillway conduit. However, preliminary results indicate that the difference in flooding with the proposed conduit in place versus what was produced with the existing principal spillway was negligible.

5.2 ALTERNATIVE 3 – BROAD CRESTED; RCC; RAISE 3.9 FEET

During the interagency meeting held on September 21st, 2021, the members present at the meeting decided that Alternative 3 should be eliminated from further consideration due to the high cost associated with the roller compacted concrete (RCC). While the cost for RCC is lower than reinforced concrete, it is still higher than the cost associated with Alternative 1.

5.3 ALTERNATIVE 5 – BROAD CRESTED; REINFORCED CONCRETE; RAISE 3.9 FEET

During the interagency meeting held on September 21st, 2021, the members present at the meeting decided that Alternative 5 should be eliminated from further consideration due to the high cost associated with the reinforced concrete spillway.

5.4 ALTERNATIVE 7 – BROAD CRESTED; EARTHEN; NO RAISE

During the interagency meeting held on September 21st, 2021, the members present at the meeting decided that Alternative 7 should be eliminated from further consideration due to the high cost associated with the excavation necessary for the earthen spillway and due to the expansive footprint needed to pass the freeboard hydrograph without breaching.

5.5 ALTERNATIVE 15 – LABYRINTH WEIR; RCC; NO RAISE

During the interagency meeting held on September 21st, 2021, the members present at the meeting decided that Alternative 15 should be eliminated from further consideration due to the high cost associated with the labyrinth weir and RCC spillway. In addition to the high cost, concerns with constructability of the labyrinth weir and future maintenance of the structure were raised during the interagency meeting.

5.6 STRUCTURAL ALTERNATIVE TO SIGNIFICANT HAZARD CLASSIFICATION

An additional alternative was brought forward prior to the interagency meeting on September 21st, 2021. The alternative would involve a structural rehabilitation of Bylin Dam to a significant hazard classification. Bylin Dam is currently a high hazard dam because there are several habitable structures downstream of the dam that would have a high susceptibility to loss of life if the dam were to breach using TR-60 requirements (see the *Existing Conditions Assessment Report* for Bylin Dam in **Appendix D-1** for additional information on hazard classification and downstream risk associated with the existing structure). The structural alternative to a significant hazard classification involves property buy-outs for the parcels that contain the habitable structures that make the dam a high hazard structure. Many of the parcels that contain habitable structures are farm sites with other agricultural buildings on the property. Several of the habitable structures would have flood depths that exceed 15 feet during a dam breach scenario. Therefore, floodproofing these structures by means of ring levees or raising the structures was considered impractical and was not considered for this alternative.

The alternative evaluated was similar to Alternative 1 described previously but would not involve a dam raise. An earthen spillway option even with the lower hazard classification was not feasible because of the excessive width required. The cost to buy out the properties with habitable structures was assumed to be a total of $2,700,000. The cost that was developed for purchasing the property with the habitable structures was based on the replacement value for residential and agricultural structures presented in Exhibit D5.1 in Appendix D-5. This added cost for property buy outs combined with the construction cost required to rehabilitate the dam to a significant hazard structure exceeds the total cost to rehabilitate the dam to a high hazard classification. For this reason, rehabilitating Bylin Dam to a lower hazard classification was removed from further consideration.

5.7 NON-STRUCTURAL – DECOMMISSIONING ALTERNATIVE

A full decommissioning of Bylin Dam was considered as a non-structural alternative. **Figures D-3-14** through **D-3-18** show the proposed plan and profile of the decommissioning alternative, details of the channel cross section and grade stabilization of the alternative, the proposed road realignment plan and profile associated with the alternative, and the location of the downstream protection elements considered for the alternative. The overall cost of the decommissioning alternative was calculated to be approximately $37,414,750. Ultimately, this alternative was eliminated from further evaluation due to the high cost associated with it, and the reduction to agricultural production that would result. The following sections describe the various elements of the decommissioning alternative.

5.7.1 RIVER ALIGNMENT AND CORRIDOR

The channel alignment for the river corridor through the Bylin Dam reservoir was developed using historic imagery of the North Branch Forest River before the construction of Bylin Dam. The channel upstream of Bylin Dam and downstream of Dougherty Dam follows the historic channel, which was traced from imagery available in Walsh County in 1962 (North Dakota Department of Water Resources). The proposed channel alignment throughout both reservoir locations is shown in **Figure D-3-14** through **Figure D-3-15**.

The channel dimensions used for the proposed river corridor were determined based on the Rosgen stream classification data collected in the field near the existing dam site (see **Appendix D-8: Rosgen Stream Classification and Riparian Assessment Memorandum**). The channel width and depth were set equal to the bankfull channel depth and width determined from field data for the North Branch Forest River. The channel bankfull width is 12.8 feet and the maximum bankfull depth is 2.8 feet. The floodplain width used for the proposed channel is approximately 92 feet, which was computed based on a ratio of floodplain width to bankfull width developed for E type channels in Minnesota. The Minnesota Department of Natural Resources developed the ratio based on several E type channel evaluations. Additionally, the floodplain width of 92 feet is similar to the floodplain width for the North Branch Forest River channel upstream of Bylin Dam. The profile of the proposed channel was based on field data collected adjacent to the dam and outside of the reservoir footprint. The proposed typical section of the restored channel is shown on **Figure D-3-16**.

The floodplain would be seeded with vegetation native to the project area after channel construction has been completed. Materials excavated from the sediment that has accumulated in the reservoir is to be hauled off site to ensure that chemical runoff from the sediment is not introduced into the river system. All channel dimensions that were determined are based on a riffle section of the river. Pools within E type river channels are approximately 1.6 times larger in cross sectional area than riffle sections based on E type channel data obtained for several rivers in Minnesota. To account for river pools, the total excavation through the proposed channel corridor that was computed for the decommissioning alternative was multiplied by 1.3.

5.7.2 GRADE STABILIZATION

A rock riprap section would be placed where the existing embankment is located to provide controlled passage of flood flows through the embankment. A riffle section helps improve fish passage and reduces sediment migration downstream. Sheet pile will be installed at a depth of 5 feet at the beginning and end of the proposed riprap section (riffle) to ensure that the riprap ramp is not undercut in any way. The grade of the proposed riffle is 3% with a total elevation drop of approximately 5.5 feet. The riffle footprint is 48 feet wide, approximately 180 feet long, and approximately 36 inches deep. The width of the proposed riffle was selected to keep the 100-year flood event at or below the current bankfull channel depth of 2.8 feet. Details of the grade stabilization section are shown in **Figure D-3-16**.

5.7.3 ROAD RECONSTRUCTION

The existing top of dam, 121st Ave NE, is used by local farmers to get heavy machinery from the south side of the North Branch Forest River to North Dakota Highway 17. 121st Avenue NE would need to be reconstructed if the dam is decommissioned. The proposed road realignment will approximately follow the road alignment before the construction of Bylin Dam, which is approximately 500 feet west of the current road alignment. Vertical and horizontal curves of the road were designed following guidance from *A Policy on Geometric Design of Highways and Streets* (AASHTO, 2018). The vertical sag curves use comfort criteria and have a required “K” value of 47. The maximum grade for rural arterial road with a rolling terrain at a design speed of 55 mph is 5 percent according to table 7-2 in *A Policy on Geometric Design of Highways and Streets*. A plan and profile view of the proposed road corridor with the decommissioning alternative is shown in **Figure D-3-17**. A culvert was sized to be installed through 121st Avenue NE based on requirements in the North Dakota Century Code (North Dakota Legislature, 2015). The design event used to size culverts through a township road (like 121st Avenue NE) is a 10-year flood event. The proposed culvert is a 90-inch diameter corrugated metal pipe (CMP) that is 226 feet in length.

5.7.4 DOWNSTREAM FLOOD PROTECTION

There are 13 downstream structures that would be impacted by decommissioning the dam and 12 ring dikes would need to be put in place to protect them. Ring dikes would be put around the structures to protect them up to a 100-year flood event with Bylin Dam removed. The ring dikes are designed to have a 10-foot top width and 4:1 side slopes down to existing ground. The dikes would be seeded after construction is completed. Some sites require pipes with flap gates to allow for one directional flow through the embankment. Excavation, embankment placement, culverts, topsoiling and seeding quantities were developed for each ring dike. The location of the ring dikes downstream of Bylin Dam are shown in **Figure D-3-18**.

Setback levees were also considered for the protection of downstream agricultural land. The assumed setback levee alignments are shown in **Figure D-3-18**. Setback levees were designed with an 8-foot top width and 4:1 side slopes down to existing ground. A benefit to cost analysis was completed to determine the appropriate recurrence interval to use for a design height of the setback levees. The 5-, 10-, 25-, 50-, and 100-year events were considered for the analysis. Damages to agricultural lands for these various recurrence intervals that are presented in Appendix D-5 were utilized to attain the total annual benefit provided by the setback levees.

Setback levees would be designed to remove all damages to agricultural lands during the specified design event (i.e., the benefit provided by the setback levees would be equal to the annual damages without Bylin Dam in place). The cost of the setback levees varies for each recurrence interval analyzed because the water surface elevation increases as the flood frequency decreases. Therefore, designing setback levees to the 100-year elevation would result in a levee height that is considerably higher than designing to the 5-year event, and the costs would then be higher. An incremental analysis was completed to determine the most appropriate recurrence interval to use for the design of the setback levees based on the benefit to cost ratio calculated for each design event. The results from the incremental analysis are provided in **Table D-3-4**. The total cost of the decommissioning alternative is shown and described in Section 5.7.5. The difference in the total costs listed in **Table D-3-4** are based only on the change in setback levee height. All other elements of the decommissioning alternative would remain unchanged.

***Table D-3-4**: Incremental Benefits for Various Recurrence Intervals Associated with the Decommissioning Alternative*

Recurrence Interval	Annual Benefits from Decommissioning Alternative	Total Cost of Decommissioning Alternative	Amortized Cost[1]	B/C Ratio
5-year	$423,365.00	$36,896,850.00	$885,600.00	0.478
10-year	**$431,789.00**	**$37,414,750.00**	**$898,000.00**	**0.481**
25-year	$435,810.00	$37,882,350.00	$909,200.00	0.479
50-year	$438,337.00	$38,272,350.00	$918,600.00	0.477
100-year	$440,885.00	$38,704,650.00	$929,000.00	0.475

1 – installation cost is amortized for 102 years at 2.25% (price base is 2023)

The recurrence interval that results in the highest benefit to cost ratio is the 10-year event. Based on this information, the setback levees would be constructed using the10-year recurrence interval as the design event. The setback levee height was set to the 10-year water surface elevation along the channel plus one foot, or at the existing ground level, whichever value is greater. An inspection trench was also assumed to be excavated beneath the setback levees at a depth equal to the levee height, or to a maximum depth of 6 feet. Seeding and mulching was assumed to be applied over the setback levee footprint.

5.7.5 ENGINEER'S OPINION OF PROBABLE COST

Unit costs for recent construction projects were utilized to develop unit prices for the various items needed to complete the earthwork necessary to re-establish the North Branch Forest River through the former Bylin Dam reservoir, to construct the grade stabilization through the former dam embankment, and to re-construct 121st Avenue NE. Similarly, unit costs to construct the ring dikes and setback levees were applied to the engineer's opinion of probable cost. The costs for all elements to construct the federal decommissioning alternative were compiled and are provided in **Table D-3-5**.

In addition to the construction cost associated with the decommissioning alternative, land rights were also considered for land within the proposed setback levees. A recent appraisal of farmland in the area resulted in a land value of $7,000 per acre. The $7,000 per acre unit cost was applied to all agricultural land within the setback levees and within the footprint needed to construct the levees. Costs for easements on non-agricultural land were assumed to be at $500 per acre. With these assumptions, total non-construction costs exceed $21,000,000. Agricultural and non-agricultural lands where easements that are necessary for the federal decommissioning alternative are shown in **Figure D-3-18**.

***Table D-3-5**: Engineer's Opinion of Probable Cost*

No.	Item	Unit	Quantity	Unit Price	Total Price
1	Mobilization	LS	1	$ 650,000.00	$ 650,000.00
2	Excavation	CY	282,300	$ 5.00	$ 1,411,500.00
3	Excavation Material Haul	CY	134,200	$ 15.00	$ 2,013,000.00
4	Fill material	CY	535,700	$ 10.00	$ 5,357,000.00
5	Stripping and Topsoiling	CY	40,900	$ 5.00	$ 204,500.00
6	Sheetpile Cutoff	SF	960	$ 50.00	$ 48,000.00
7	Rip Rap (NDDOT Grade II 28")	CY	1,660	$ 100.00	$ 166,000.00
8	Seeding	AC	117	$ 2,000.00	$ 234,000.00
9	Construction Dewatering	LS	1	$ 200,000.00	$ 200,000.00
10	Riser Tower - Removal of Existing Structural	LS	1	$ 30,000.00	$ 30,000.00
11	Removal of Existing Principal Spillway	LF	304	$ 100.00	$ 30,400.00
12	Traffic Control	LS	1	$ 10,000.00	$ 10,000.00
13	15-inch Corrugated Metal Pipe	LF	1,150	$ 65.00	$ 74,750.00
14	Road Realignment	LS	1	$ 1,020,000.00	$ 1,020,000.00
Construction Subtotal					**$ 11,449,550.00**
Non-Agricultural Land Easements					$ 674,000.00
Agricultural Land Easements					$ 20,411,000.00
Non-Construction Cost					**$ 21,085,000.00**
Contingencies (15%)					**$ 4,880,200.00**
Total Construction Cost					**$ 37,414,750.00**

5.8 NO-ACTION ALTERNATIVE

The no action alternative represents a scenario where the existing dam remains in place with no measures taken to address the dam safety inadequacies associated with the dam. In this scenario, the dam would remain in place until it fails, and would not be subsequently rebuilt. This alternative is required to ensure that all reasonable alternatives are considered based on guidance in Title 390 – National Instruction, Part 303 – Clarification and Instructions for the No-Action Alternative in Supplemental Watershed Rehabilitation Plans (NRCS, 2022). Additional information on the analysis completed for the no-action alternative is available in the following sections. Discussion on the environmental impacts and economic implications of the no action alternative are described in more detail in the Watershed Plan – Environmental Assessment.

5.8.1 NO ACTION BREACH EVENT

The analysis described in the *Existing Conditions Assessment Report* (**Appendix D-1**) shows that Bylin Dam would breach during the probable maximum precipitation event (PMP). To assess the no action alternative, an additional analysis was completed to determine the highest frequency rainfall event that would cause a breach of the dam. Various rainfall depths were applied to the hydrologic model and then the resulting hydrograph was routed through the dam using the NRCS's Water Resources Site Analysis Computer Program (USDA and Kansas State University, 2014), which is commonly referred to as the SITES program. The auxiliary spillway of Bylin Dam breached when a rainfall depth of 8.53 inches was applied to the upstream watershed. This was the minimum 24-hour rainfall depth applied to the models that resulted in a breach of the auxiliary spillway of Bylin Dam. The NRCS's "Dam Failure Probability Estimation Tool" was then utilized to attain the return interval associated with the 8.53 inches of rain. The resultant return interval for the breach event was 625-year (this is a rainfall event that has a 0.16% chance of occurrence). The 625-year rainfall event and breach of Bylin Dam were then routed through the hydraulic model.

5.8.2 BREACH HYDROGRAPH

The breach hydrograph at Bylin Dam resulting from the 625-year rainfall event was developed using methods similar to what is described in Section 4.1 of the *Existing Conditions Assessment Report* (**Appendix D-1**), which involved using equations in Chapter 1 of *Technical Release 210-60 Earth Dams and Reservoirs* (NRCS, 2019). The peak water surface elevation that occurs during the 625-year event is approximately 1519.7 and the resultant peak breach discharge is 76,000 cubic feet per second.

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 same HEC-RAS model described in the *Existing Conditions Assessment Report* was used to route flows for the no action breach event. 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 breach elevation (1519.7), and the breach formation time within the hydraulic model was altered to yield a peak flow of 76,000 cubic feet per second. The progression of the breach occurred 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).

5.8.3 BREACH RESULTS

5.8.3.1 POPULATION AT RISK

The inundation produced from the simulated breach based on *TR 210-60* criteria is shown through the breach zone on **Figure D-3-19**. All residential structures that were potentially impacted by the dam breach are summarized in **Table D-3-6** and are labeled in **Figure D-3-19** as well. The structures shown in **Table D-3-6** were the only potential residential structures impacted by the no action breach event within the breach zone. The flood depth and velocity for these structures was also evaluated to determine if the potential for loss of life exists for the no action breach event. 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-3-20**.

***Table D-3-6**: Residential Structures Impacted by a Breach of Bylin Dam During the 625-year Rain Event*

Structure ID	Finished Floor Elevation (ft, NAVD88)	Depth (ft)	Velocity (ft/s)
S1	1475.2	6.80	0.10
S2	1456.2	15.30	1.10
S3	1447.9	20.60	0.45
S4	1438.3	17.30	0.20
S5	1440.2	9.90	0.00
S6	1383.1	28.10	0.40
S7	1232.4	1.30	2.30
S8	1228.7	0.20	0.00
S9	1193.4	0.70	0.30
S10	1180.4	1.90	0.60
S11	1178.6	3.80	1.60
S12	1179.0	0.70	0.80
S13	1178.5	1.90	0.40
S14	1175.7	2.10	1.00
S16	1168.0	1.90	1.70
S17	1164.0	1.40	0.20
S18	1163.4	1.20	1.00
S19	1161.3	2.30	1.40

The structures corresponding to **Table D-3-6** are also plotted on **Figure D-3-20**. 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-3-20** shows that there are six structures in the high danger (red) zone and one structure in the judgment (yellow) zone. There are a total of 6 structures that fall in the high danger potential category, which matches the number of structures in high danger when the dam breaches at the top of dam elevation. Population at risk during a dam failure was determined based on the number of people downstream that are impacted by the breach (Graham, 1999), which was assumed to be all habitable structures that were impacted by inundation at any depth during the breach. There are a total of 18 habitable structures affected by inundation during the breach event analyzed. Based on the latest information from the United States Census Bureau, there are an average of 2.3 persons per household (US Census Bureau, 2023). Therefore, the 18 structures impacted by inundation would result in a population at risk of approximately 42.

Road overtopping instances were not analyzed in detail to assess the population at risk during the no action breach event because there were not any roads with an average annual daily traffic volume in excess of 400 that fell within the high danger potential category for a breach when the water surface elevation was at the top of the dam. The hazard potential is expected to decrease because of the decreased volume of stored water. There would likely be township roads that are damaged as a result of the no action breach, but these were not considered to determine the population at risk. Costs to repair the roads damaged during the event are described in the *Economics Evaluation* in **Appendix D-5**.

5.8.3.2 OTHER DAMAGES ASSOCIATED WITH THE NO ACTION BREACH

The landscape at the dam site and downstream of the dam would also be negatively impacted by a breach of Bylin Dam. The amount of sediment eroded from the auxiliary spillway of the dam during the no action breach event was estimated to be 323,400 cubic yards. Breach dimensions were developed based on the Froehlich Equations (Froehlich, 2008), and resulted in a bottom width of 130 feet. Froehlich equations also assume a 1:1 (horizontal:vertical) side slope for the headcut area. The assumed footprint that the breach would create within the existing auxiliary spillway is shown on **Figure D-3-21**. The sediment volume eroded during the breach was computed assuming that the breach would stop after it reaches the upstream valley floor. The headcut would continue to advance upstream through accumulated sediments that have deposited in the reservoir of Bylin Dam as time goes on. Eventually, the headcut would progress to the toe of Dougherty Dam. Dougherty Dam was constructed before Bylin Dam, so there would likely be measures in place near the toe of that structure that would prevent the headcut from progressing further upstream. The amount of sediment that erodes from the continued headcut up to Dougherty Dam was not computed because of the high variability associated with the headcut path and dimensions. All 323,400 cubic yards of sediment eroded from the spillway, and any additional material that is eroded from the deposited sediment in the reservoir, would be deposited somewhere downstream of the dam. Some sediment deposits would continue on through the channel and be deposited within the North Branch Forest River, but most of the deposits would likely settle out in the floodplain. Sediment deposited in the floodplain would have negative impacts to the adjacent grass and forest land, as well as the agricultural land.

There is also the potential for erosion and scouring in the floodplain during the breach event as the breach flood wave travels downstream. Concepts from Chapter 51 – Earth Spillway Erosion Model of Part 628 in the National Engineering Handbook (NRCS, 2014) were used to develop an estimate for erosion in the downstream floodplain that would occur as a result of the no action breach event. Equation 51-2 from Chapter 51 was used to develop an erosion rate of sediment in the floodplain. The erosion rate is a function of allowable shear stress, the shear stress on the surface, and a detachment rate coefficient. Allowable (or critical) shear stress for the floodplain was determined using concepts from Chapter 8 – Threshold Channel Design of part 654 in the National Engineering Handbook (NRCS, 2007). Allowable shear stress is a function of soil type, plasticity index, and void ratio of the soil. All of those parameters can be estimated from data that is readily available online via the USGS Web Soil Survey (NRCS, 2019). A tool was developed in ArcGIS to create a grid for allowable shear stress in the floodplain of the North Branch Forest River watershed based on the gridded data attained from the USGS Web Soil Survey. Similarly, the detachment rate coefficient is also a function of soil data that is available on the USGS Web Soil Survey website. The ArcGIS tool also creates a grid for the detachment rate coefficient in the floodplain of the North Branch Forest River watershed. The shear stress on the surface of the floodplain is estimated based on output from the hydraulic model that was used for the existing conditions analysis. The hydraulic model is described in more detail in the *Existing Conditions Assessment Report* in Appendix D-1.

The analysis was simplified by assuming that only agricultural land would be affected by erosion because of limited vegetal cover. Agricultural land use areas were identified using grids available from the National Agricultural Statistics Service (NASS). With gridded data for the detachment rate coefficient, the allowable shear stress throughout the floodplain, and the shear stress on the surface resulting from the no action breach event, the erosion rate was calculated for the no action breach event on agricultural land. Shear stress grids were available at eight-hour time increments from the hydraulic model output. The erosion rate was computed for each eight-hour time increment, and then summed to get the total erosion expected across the landscape. The resultant cumulative erosion throughout the floodplain is shown in **Figure D-3-22**. Areas shown as blue on the map experience inundation but will not be susceptible to erosion based on the allowable shear stress values calculated or because there is assumed to be vegetal cover that would prevent the erosion. The portion of the North Branch Forest River that is contained within the river valley does not experience erosion because the floodplain is heavily forested in that area. The highest erosion rates are at locations where the floodplain slopes away from the river, the terrain is steep, and the land use is agricultural.

The expected erosion volume at incremental depths was determined to assess the damage caused by erosion. The deeper the incision on the landscape, the lower the value for agricultural production. **Table D-3-7** shows the volume of erosion for each half-foot increment up to a depth of 5 feet. The majority of the erosion that occurs in agricultural production areas as a result of the breach is less than one foot (71%). Approximately 95% of the erosion volume is expected to be at depths less than three feet. The total, cumulative volume of material that is eroded from the floodplain is estimated to be 915,000 cubic yards based on the results shown in **Figure D-3-22** and in **Table D-3-7**.

The soil material eroded from the floodplain and from the auxiliary spillway of Bylin Dam would then be transported downstream and deposited somewhere either in the floodplain or in one of the downstream river channels. A high-level analysis was completed to determine an estimated quantity of how much of the eroded material would be deposited on agricultural land. The analysis involved comparing the shear velocity of the no-action breach event to the settling (terminal) velocity of the sediment that was eroded from the landscape. The shear velocity was determined for various timesteps on the trailing limb of the hydrograph for the no action event. Shear velocity was computed using the relationship provided in equation 8-19 in *Chapter 8 – Threshold Channel Design* within Part 654 – Stream Restoration Design of the National

Engineering Handbook (NRCS, 2007). The settling velocity of the soil particles eroded from the landscape was determined using Stokes' Law. The settling velocity of soil particles using Stokes' Law requires information on soil density and particle size. Soil density information was obtained from the USGS Web Soil Survey. The particle size of the soils was estimated based on the dominant soil types present in the downstream floodplain area that is impacted by breach inundation. The dominant soil types in the downstream floodplain are silt loams, clay loams, and silty clay loams based on a review of the soil types using the Web Soil Survey. Furthermore, an investigation of the soils in Walsh County by Bluemle (1973) found that till samples had an average of 6 percent gravel, 30 percent sand, 40 percent silt, and 24 percent clay. Therefore, the median particle size for the downstream floodplain was assumed to be a silt material, which typically range in size from 0.05 millimeters to 0.002 millimeters. The average particle diameter was assumed to be 0.026 millimeters.

***Table D-3-7**: Incremental Erosion Depth and Volume Resulting from No-Action Breach Event*

Erosion Depth Range	Cubic Yards of Incremental Volume (% of Total)	Cubic Yards of Cumulative Volume (% of Total)
0.0 - 0.5	453,019 (49.5%)	453,019 (49.5%)
0.5 - 1.0	196,193 (21.4%)	649,212 (71.0%)
1.0 - 1.5	104,859 (11.5%)	754,071 (82.4%)
1.5 - 2.0	57,941 (6.3%)	812,012 (88.8%)
2.0 - 2.5	33,587 (3.7%)	845,599 (92.4%)
2.5 - 3.0	22,321 (2.4%)	867,920 (94.9%)
3.0 - 3.5	14,851 (1.6%)	882,771 (96.5%)
3.5 - 4.0	10,040 (1.1%)	892,811 (97.6%)
4.0 - 4.5	6,726 (0.7%)	899,537 (98.3%)
4.5 - 5.0	4,527 (0.5%)	904,063 (98.8%)
5.0 <	10,753 (1.2%)	914,816 (100.0%)

Comparison of the settling and shear velocities showed that approximately 55% of the eroded soil material would be deposited on agricultural land. An assumption was made that sediment deposits on agricultural land would be cleaned up or removed. All deposits in the river channel and floodplain that is non-agricultural were assumed to be left in place, resulting in impacts to habitat from the sediment deposition. The soil material eroded from the auxiliary spillway (323,400 cubic yards) along with the erosion that was calculated for the floodplain (915,000 cubic yards) would leave a total amount of material suspended in the system of approximately 1,240,000 cubic yards. With 55% of the eroded material being deposited on agricultural land, a total volume of 682,000 cubic yards would need to be removed from the floodplain.

5.8.4 ESTIMATED COSTS ASSOCIATED WITH THE NO-ACTION BREACH EVENT

Costs to repair and clean up the watershed downstream of Bylin Dam as a result of the no-action breach event were estimated. Estimated quantities for repair and clean up work are based on the erosion and deposition analyses completed and described in Section 5.8.3.2. The estimated cost for the various activities that would be required for the repair and clean up work are provided in **Table D-3-8** below.

***Table D-3-8**: Estimated Costs Associated with No-Action Breach Event*

Item	Unit	Quantity	Unit Price	Total Price
Rework of Soil (Erosion Areas <1.0 feet)	AC	2,600	$ 85.00	$ 221,000.00
Embankment Haul and Placement (Erosion Areas >1.0 feet)	CY	265,600	$ 15.00	$ 3,984,000.00
Topsoil Preparation (Erosion Areas >1.0 feet)	CY	282,600	$ 15.00	$ 4,239,000.00
Clean Up of Soil Deposition on Cropland	CY	682,000	$ 10.00	$ 6,820,000.00
Rework of Soil in Deposition Zones on Cropland	AC	2,600	$ 85.00	$ 221,000.00
Construction Total				**$ 15,485,000.00**

Areas with less than one foot of erosion depth were assumed to only require tilling practices to recover the agricultural land. Three passes were assumed for reworking the agricultural land affected by erosion depths less than one foot. There were approximately 2,600 acres of agricultural land that experienced erosion depths of less than one foot. Embankment was assumed to be hauled onto site in areas where erosion depths exceeded one foot. Topsoil for areas experiencing erosion depths greater than one foot would also need to be imported. The assumed depth of topsoil to be hauled to areas with excessive erosion was one foot. Clean up is also assumed to be necessary for sediment deposition areas. All of the deposited soil would need to be removed and hauled off site. Tilling practices to recover ag land in the depositional areas were also assumed. Overall, the total clean up and repair cost associated with the no-action breach event is $15,485,000. The cost for cleanup associated with the no-action breach event (625-year flood) is not included for other flood events due to the extreme nature of the breach.

6 SUMMARY – ALTERNATIVES CARRIED FORWARD

Meetings with the technical team on April 12th, 2021, and July 20th, 2021, were used to narrow the range of alternatives to be brought forward to the full interagency team. Ultimately, there were 6 structural alternatives carried forward after review from the technical team along with a structural alternative that would rehabilitate Bylin Dam to a lower hazard classification, and a non-structural – decommissioning alternative. Following the technical team meetings, a meeting with the full interagency team took place on September 21st, 2021. During the interagency meeting, all but one of the structural alternatives to rehabilitate the dam to a high hazard classification were not recommended. The structural alternative to rehabilitate the dam to a significant hazard classification and the non-structural – decommissioning alternative were also not recommended during the September 21st meeting. The only structural alternative to be recommended to be carried forward for detailed review is Alternative 1 described in Section 5.1. Alternative 1 involves the use of articulated concrete block (ACB) within the auxiliary spillway, replacing the existing principal spillway with a new riser tower and conduit, and raising the dam embankment by approximately 3.9 feet. This alternative was evaluated in greater detail during the following phases of the planning effort. Refer to **Appendix D-4: Concept Design Report** for additional information on Alternative 1.

Additionally, the no-action alternative described in Section 5.8 was carried forward within the Watershed Plan – Environmental Assessment (EA) along with the Future Without Federal Investment (FWOFI) alternative. The FWOFI is described in more detail within the main body of the EA document. The no action and FWOFI alternatives were compared to the structural alternative to ensure that the appropriate alternative was selected moving forward.

7 REFERENCES

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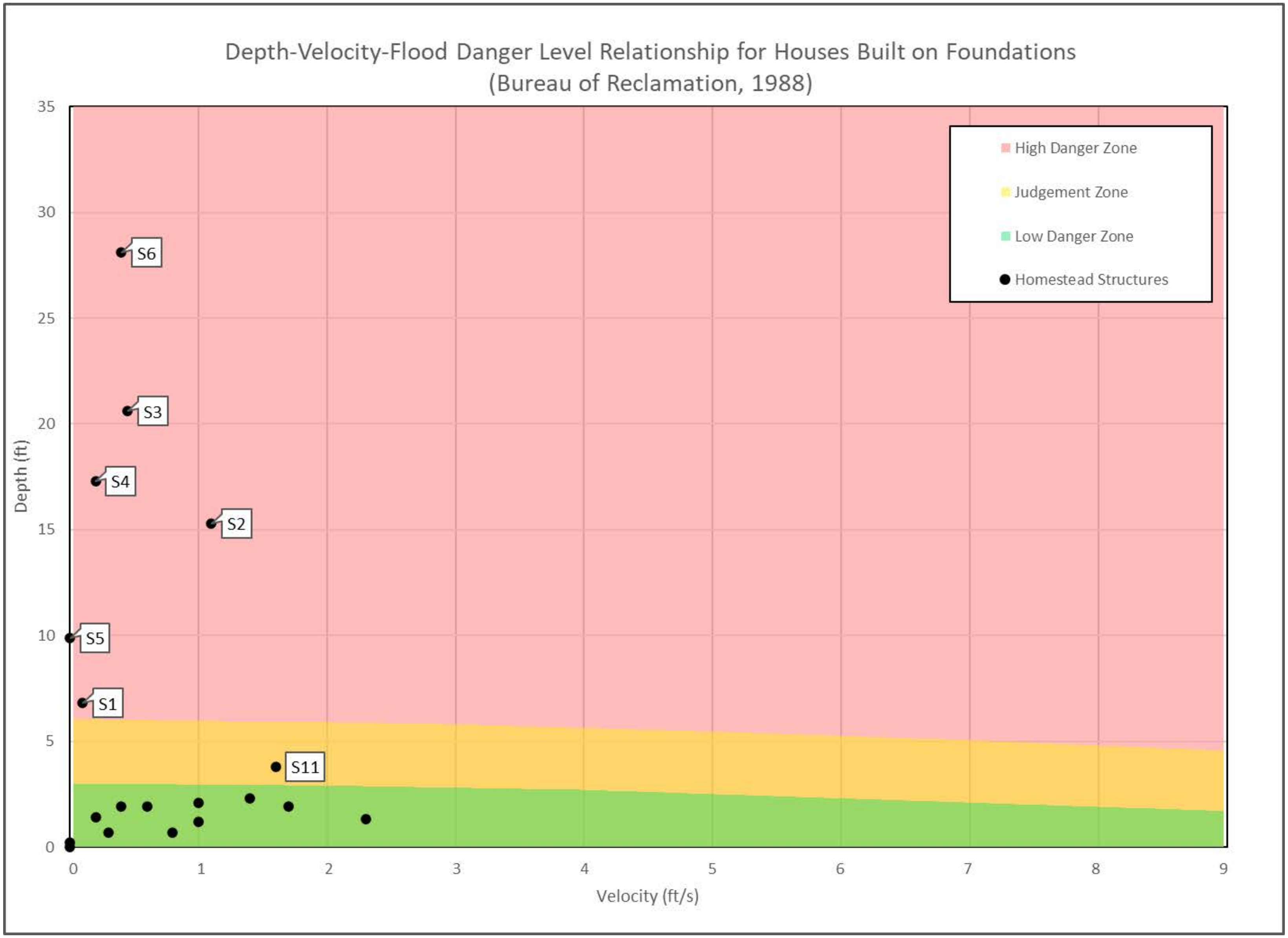
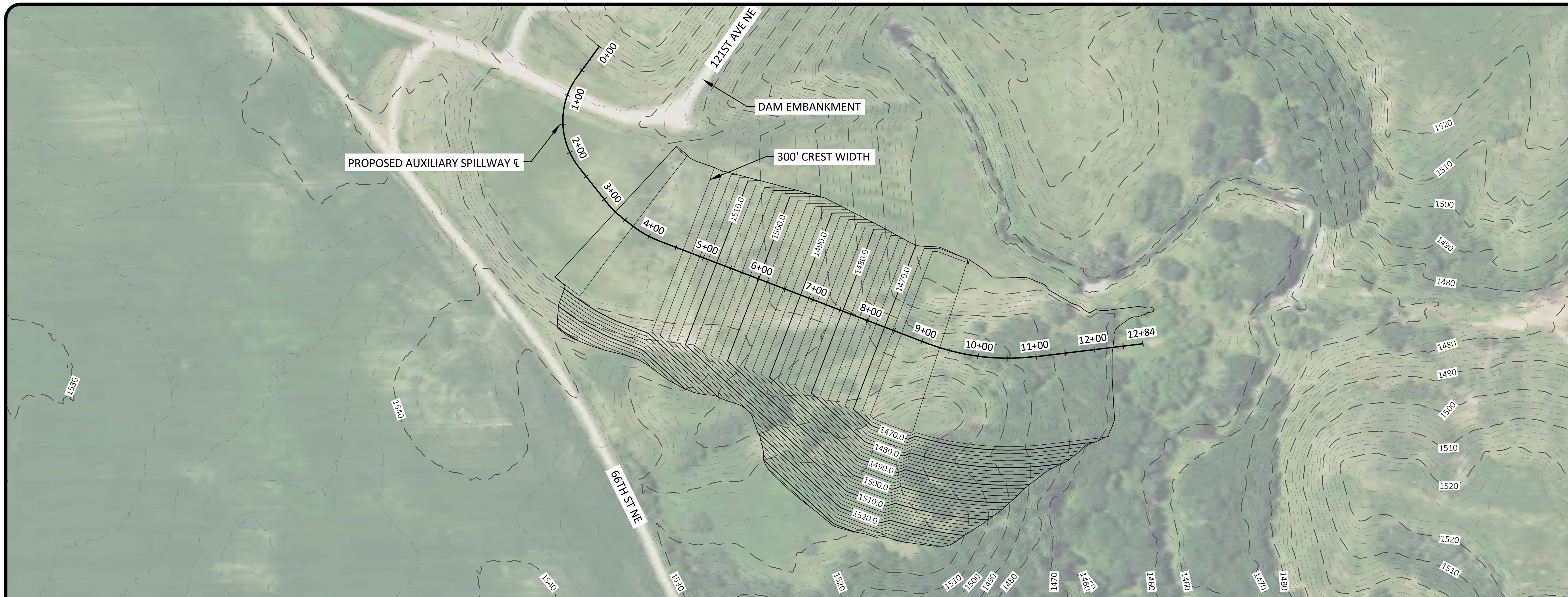
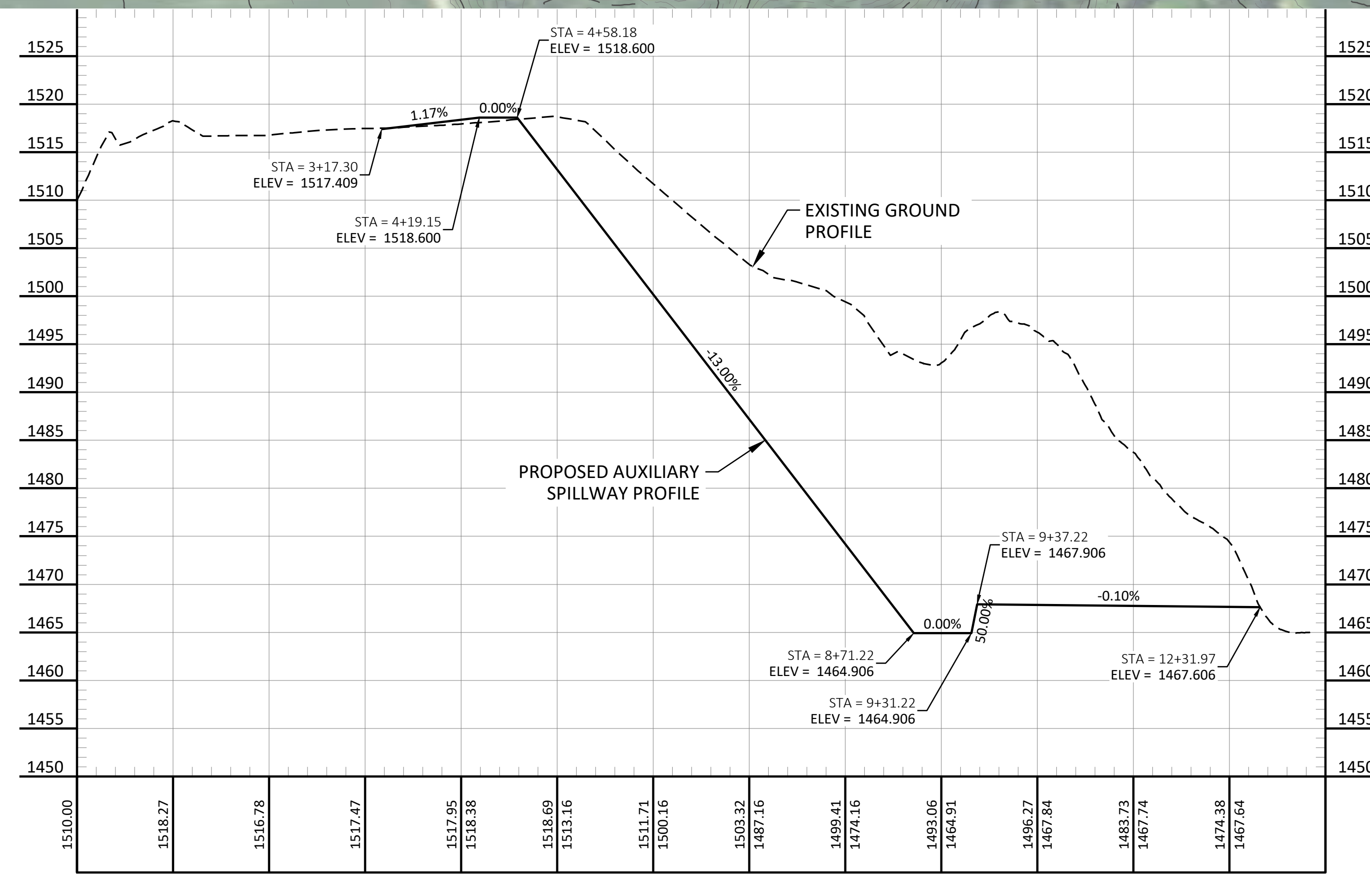
FIGURES

***Figure D-3-20**: Depth-Velocity-Flood Danger Level Relationship for Houses Built on Foundations Downstream of Bylin Dam for the No Action Breach Event*







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Scale 100 0 100 200 Feet

FIGURE D-3-1

Bylin Dam
Option 1

Broad Crested 300-feet located near existing spillway

ACBs @ -13% slope (EPEC SD 900 OCT)

Modify principal spillway to pass PSH without activating auxiliary spillway

Dam Raised 3.5'

Feasibility Level Cost:
$ 6,910,000

PRELIMINARY
NOT FOR CONSTRUCTION

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No.	Revision	Date	By

HOUSTON engineering, inc.

Drawn by	Date
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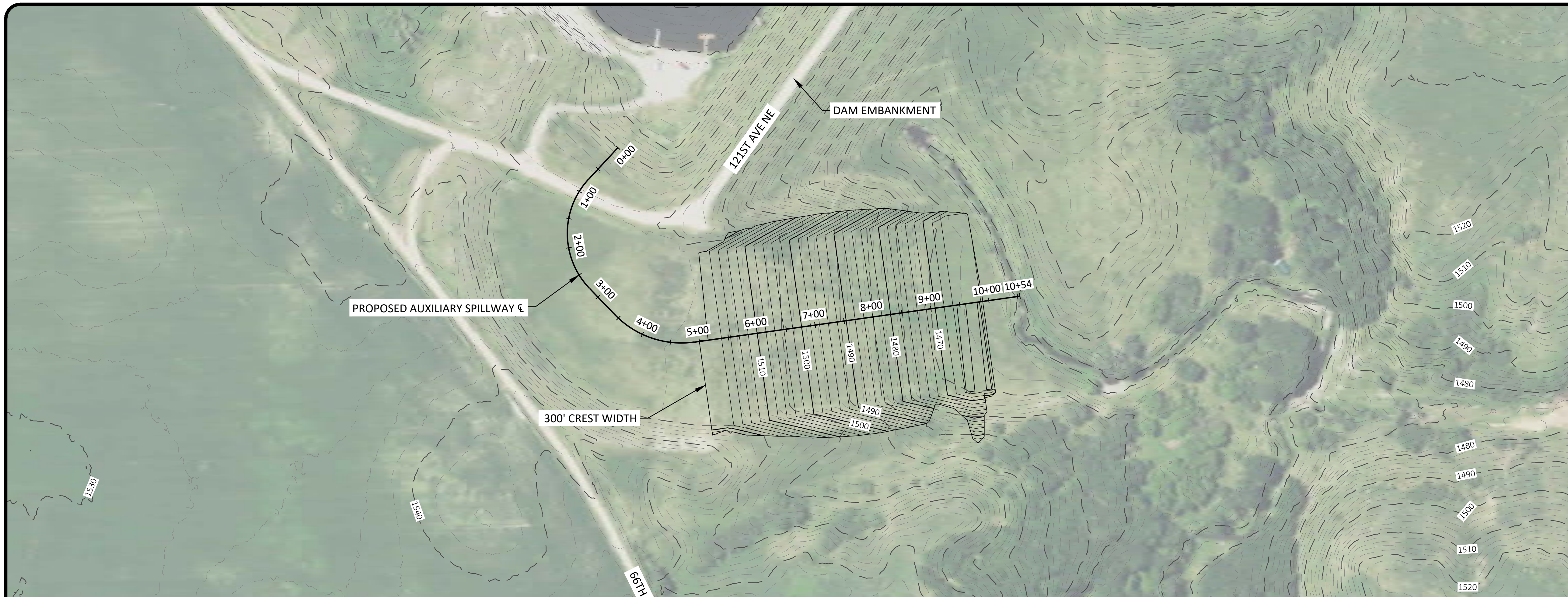

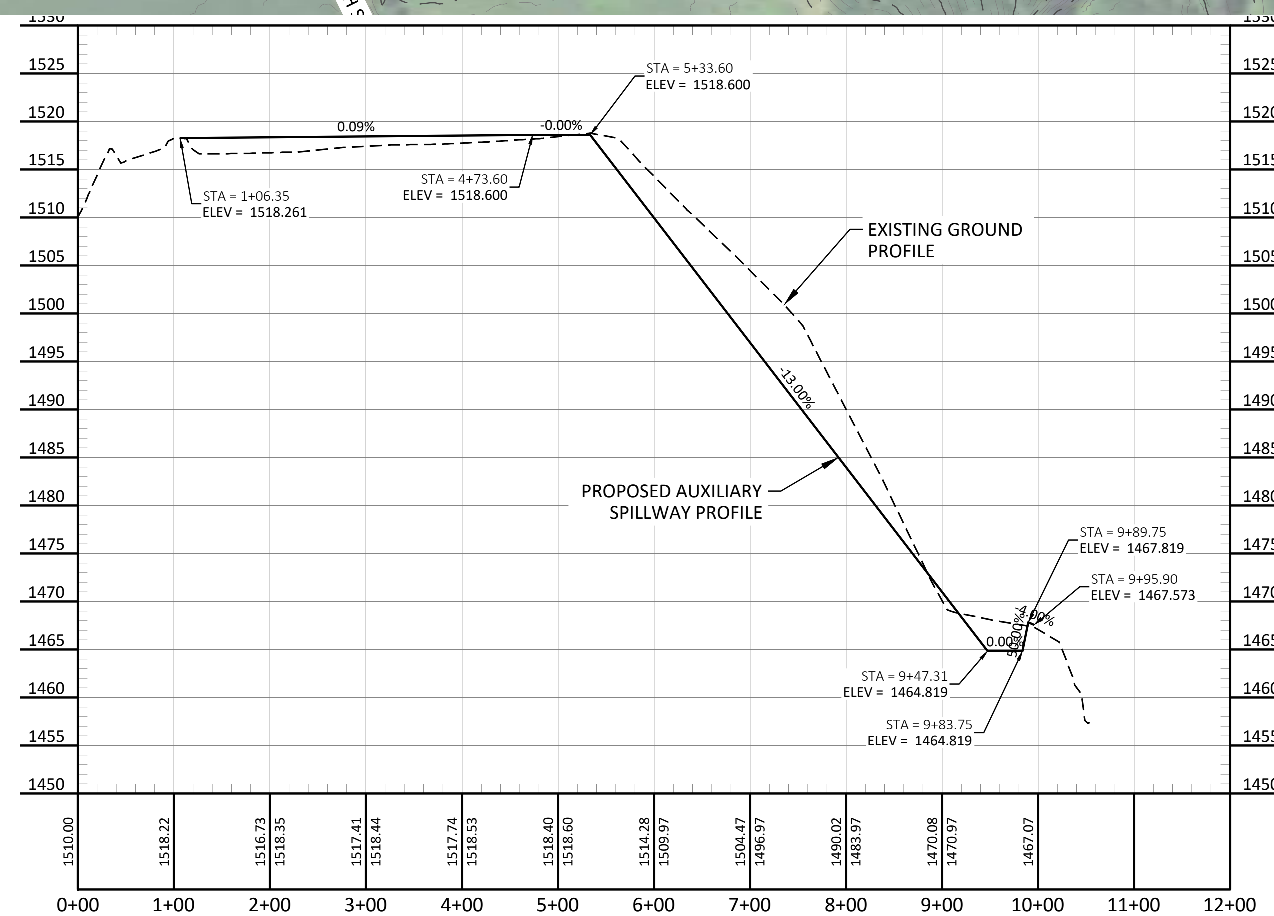

FIGURE D-3-2

Bylin Dam

Option 1A

Broad Crested 300-feet located near existing spillway

ACBs @ -13% slope (EPEC SD 900 OCT)

Modify principal spillway to pass PSH without activating auxiliary spillway

Dam Raised 3.5'

Feasibility Level Cost:
$ 5,635,000

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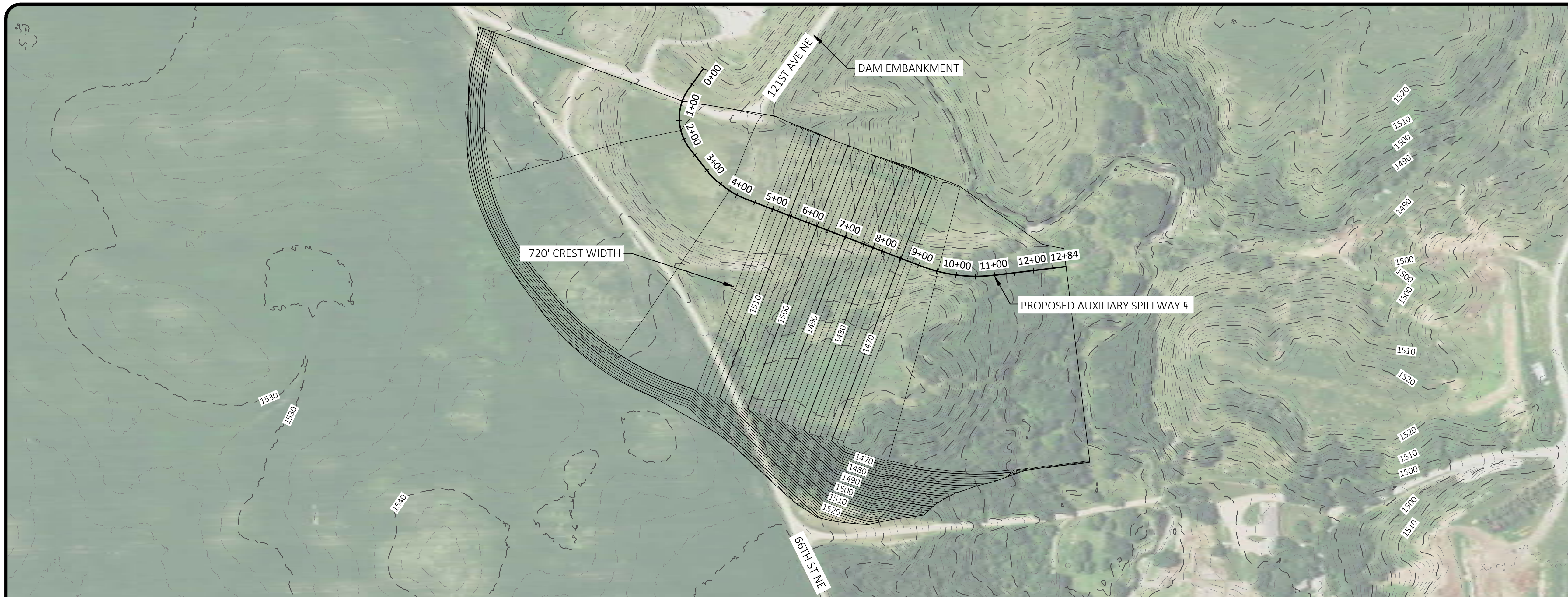

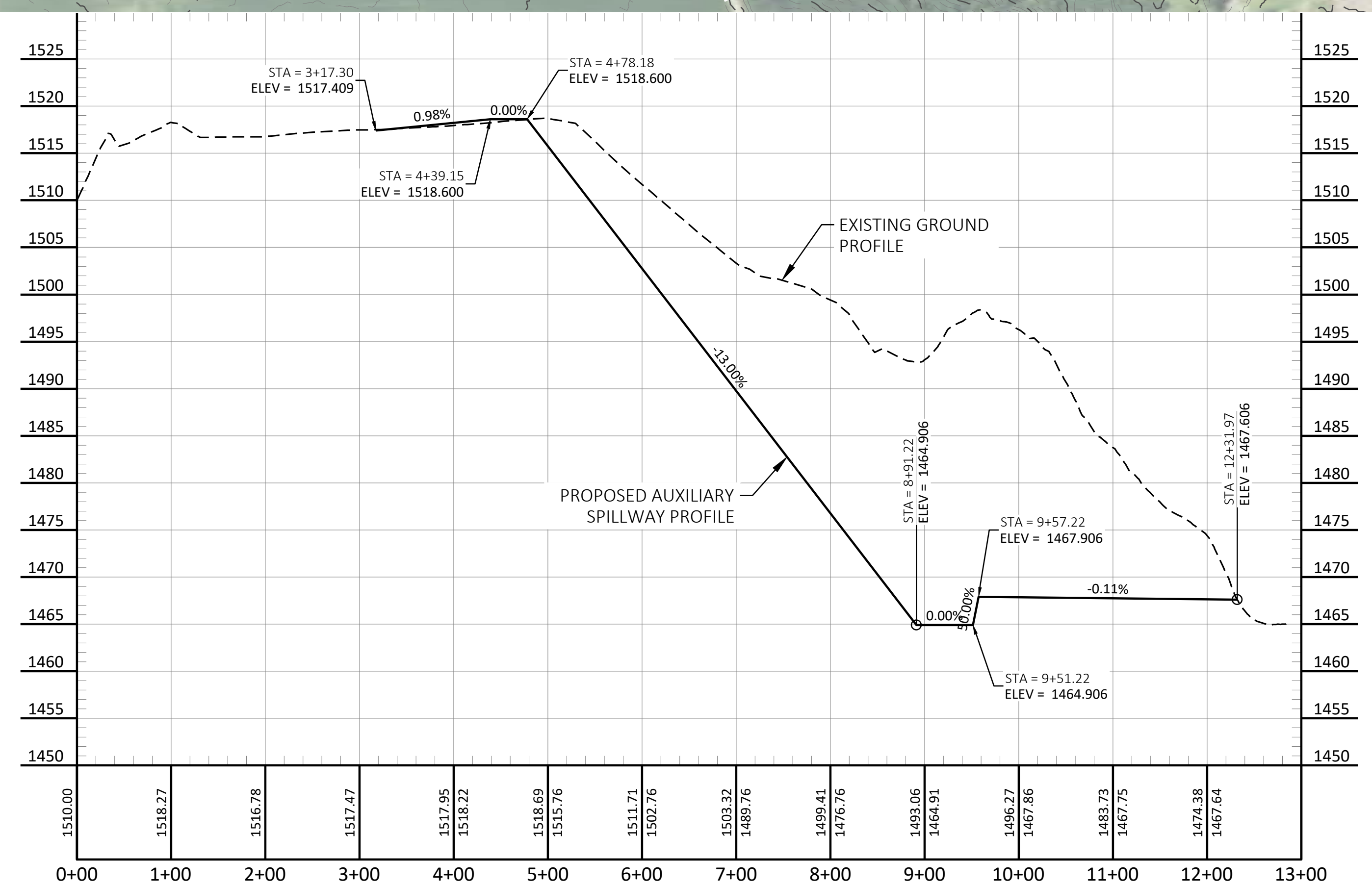

FIGURE D-3-3

Bylin Dam

Option 2

Broad Crested 720-feet located near existing spillway

ACBs @ -13% slope (EPEC SD 900 OCT)

Modify principal spillway to pass PSH without activating auxiliary spillway

Dam not Raised

Feasibility Level Cost:
$ 14,713,000

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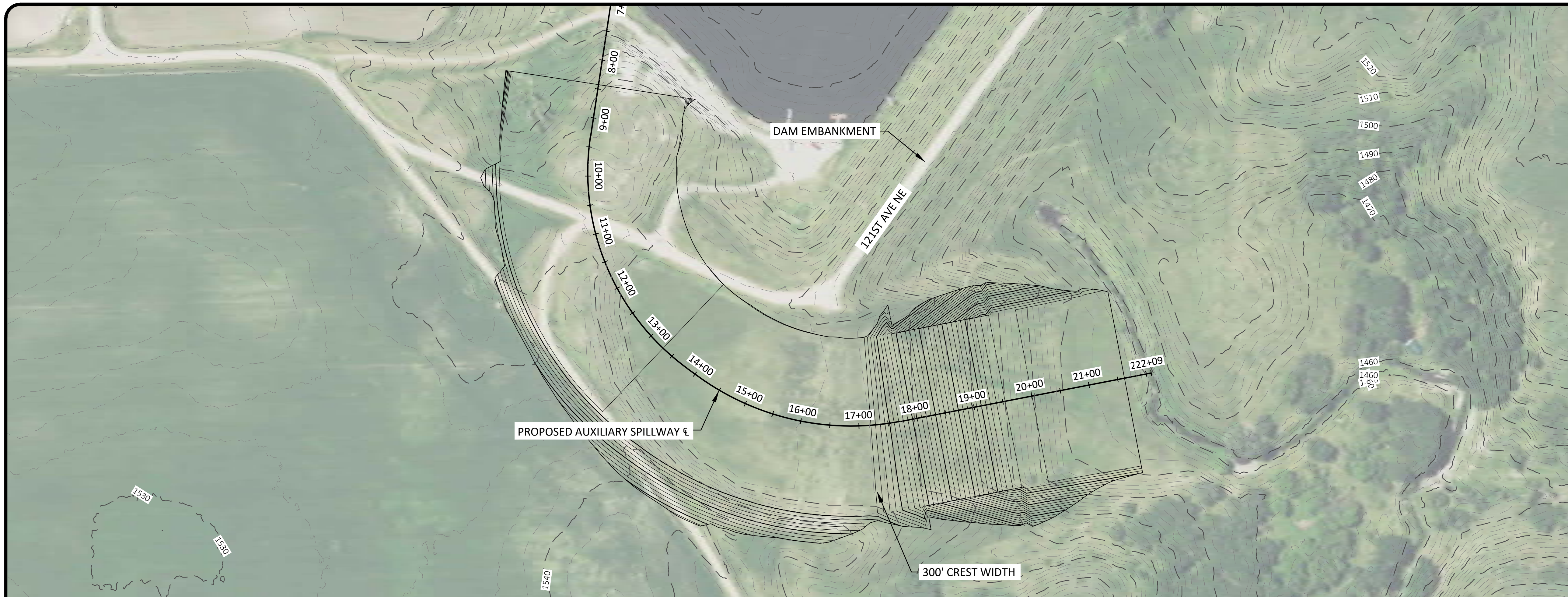

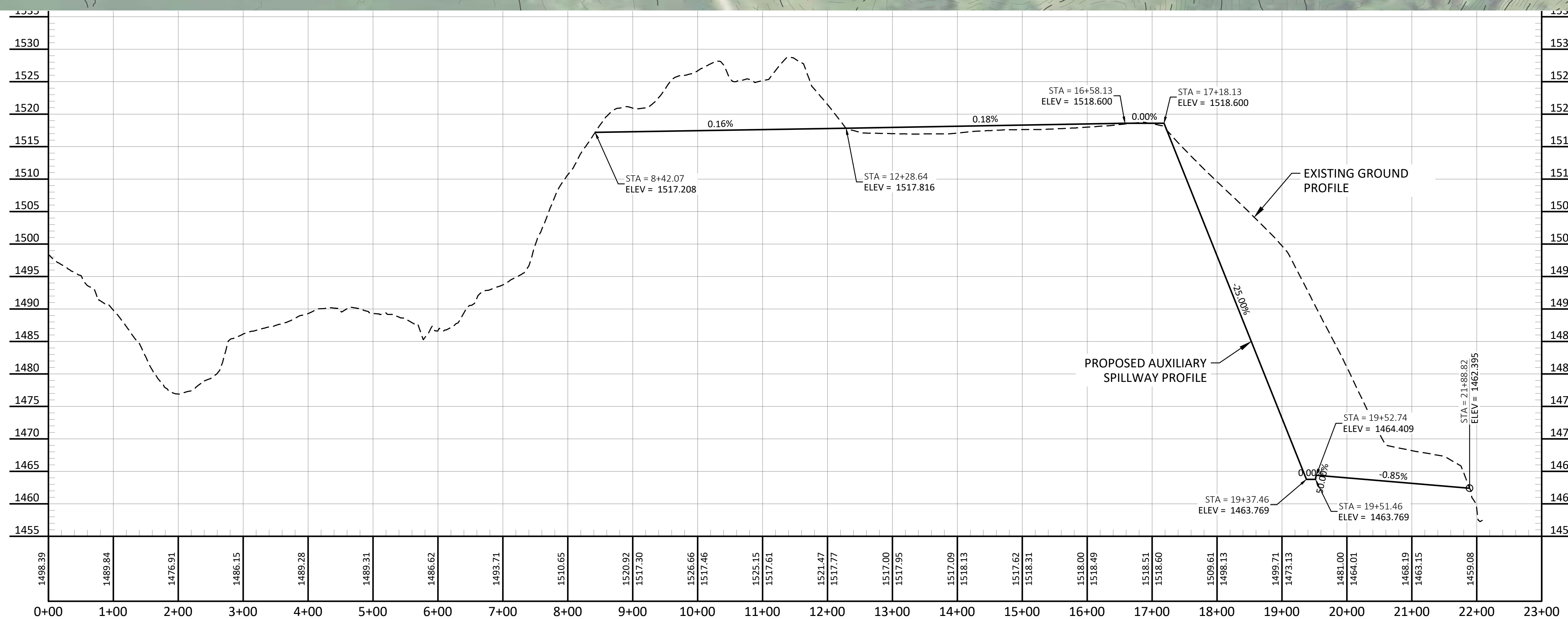

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FIGURE D-3-4

Bylin Dam
Option 3

Broad Crested 300-feet located near existing spillway

RCC @ -25% slope

Dam Raised 3.5'

Feasibility Level Cost:
$ 7,893,000

Bylin Dam
Option 5

Broad Crested 300-feet located near existing spillway

Reinforced Concrete @ -25% slope

Dam Raised 3.5'

Feasibility Level Cost:
$ 22,547,000

PRELIMINARY
NOT FOR CONSTRUCTION

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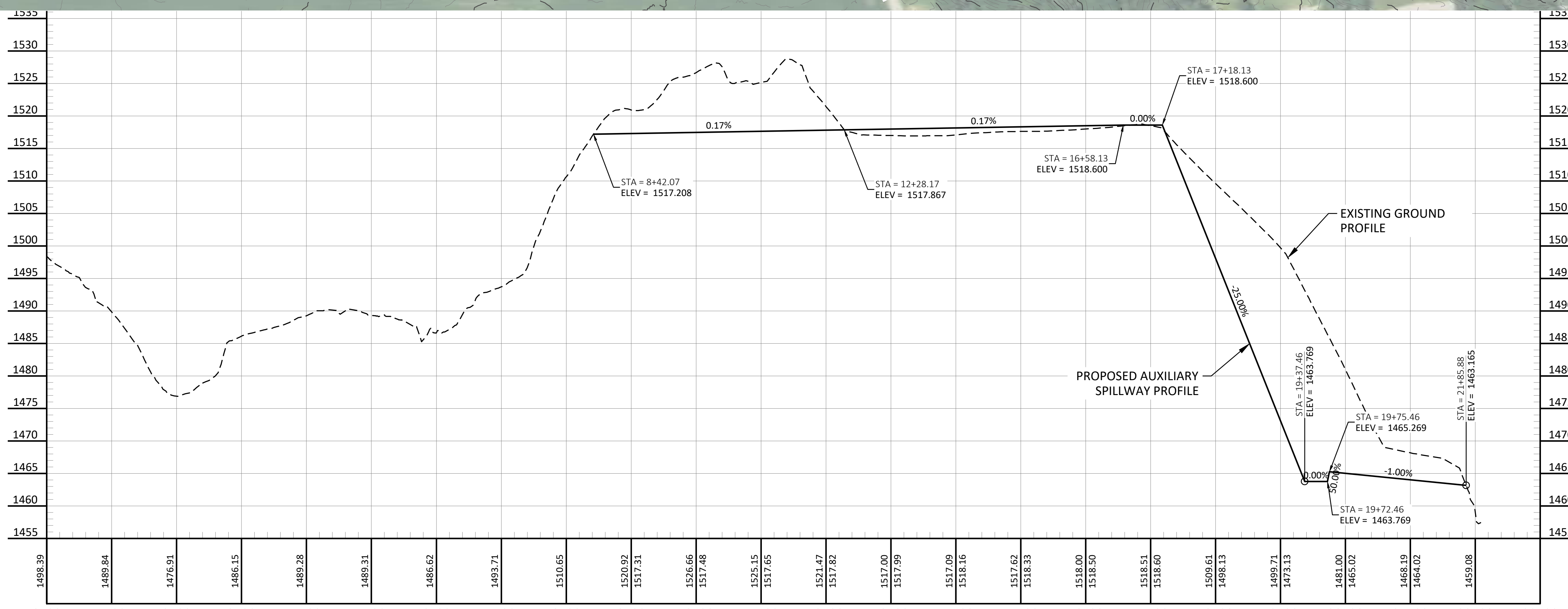

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FIGURE D-3-5

Bylin Dam
Option 4

Broad Crested 720-feet located near existing spillway

RCC @ -25% slope

Dam not Raised

Feasibility Level Cost:
$ 25,383,000

Bylin Dam
Option 6

Broad Crested 720-feet located near existing spillway

Reinforced Concrete @ -25% slope

Dam not Raised

Feasibility Level Cost:
$ 54,224,000

PRELIMINARY
NOT FOR CONSTRUCTION

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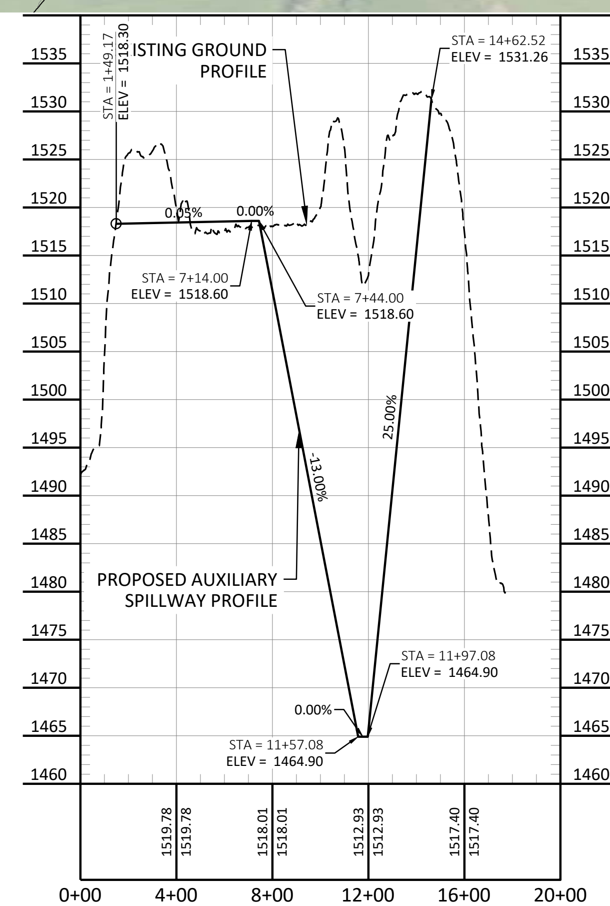

FIGURE D-3-6
Bylin Dam
Option 7

Broad Crested 3,200-feet located near existing spillway

Earthen @ -13% slope

Modify principal spillway to pass PSH without activating auxiliary spillway

Dam not Raised

Feasibility Level Cost:
$ 32,182,000

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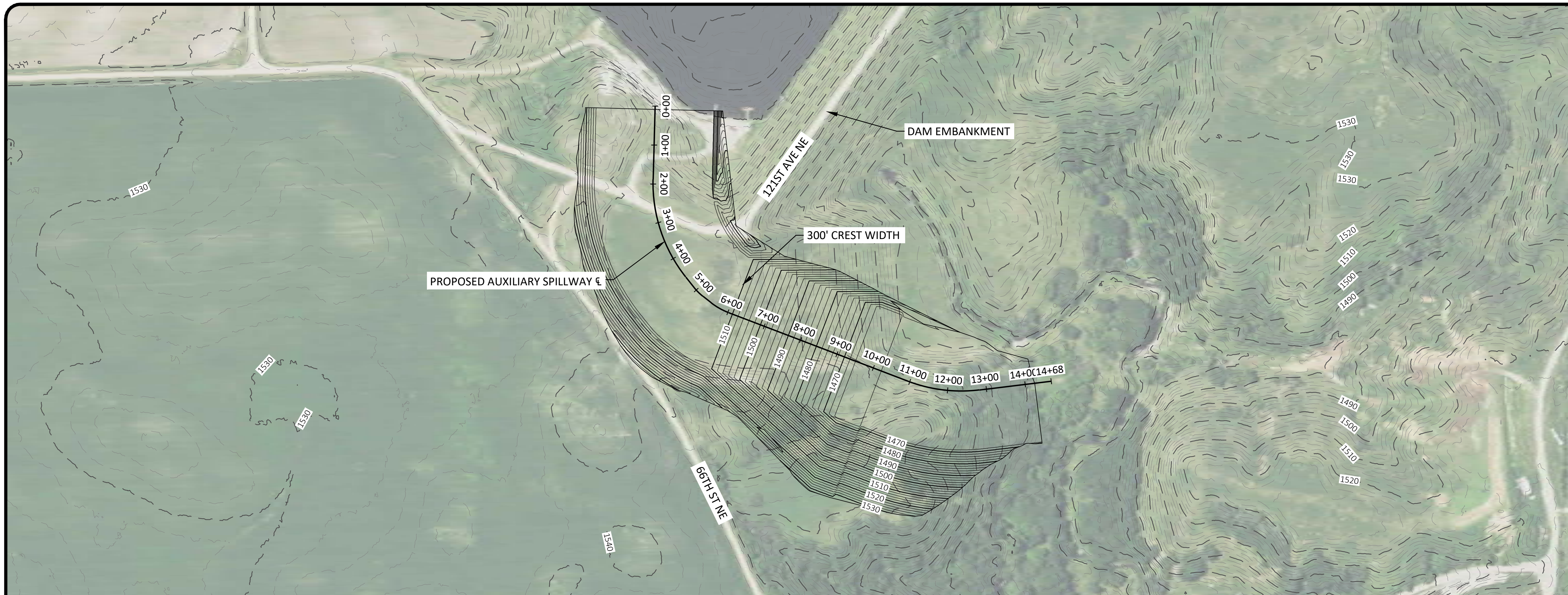

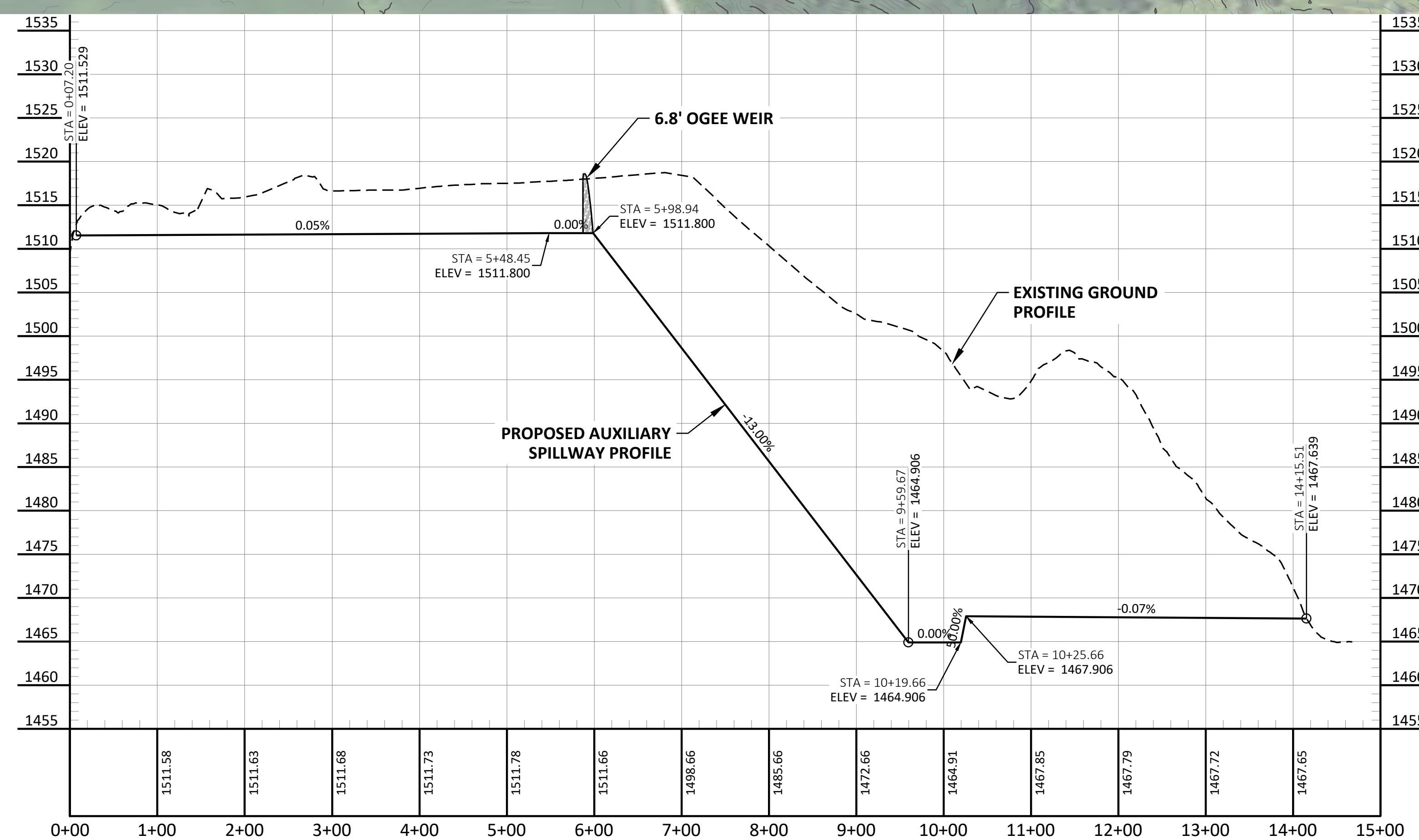

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FIGURE D-3-7

Bylin Dam

Option 8

Ogee Weir 300-feet located near existing spillway

ACBs @ -13% slope (EPEC SD 900 OCT)

Modify principal spillway to pass PSH without activating auxiliary spillway

Dam Raised 1.5'

Feasibility Level Cost:
$ 10,754,000

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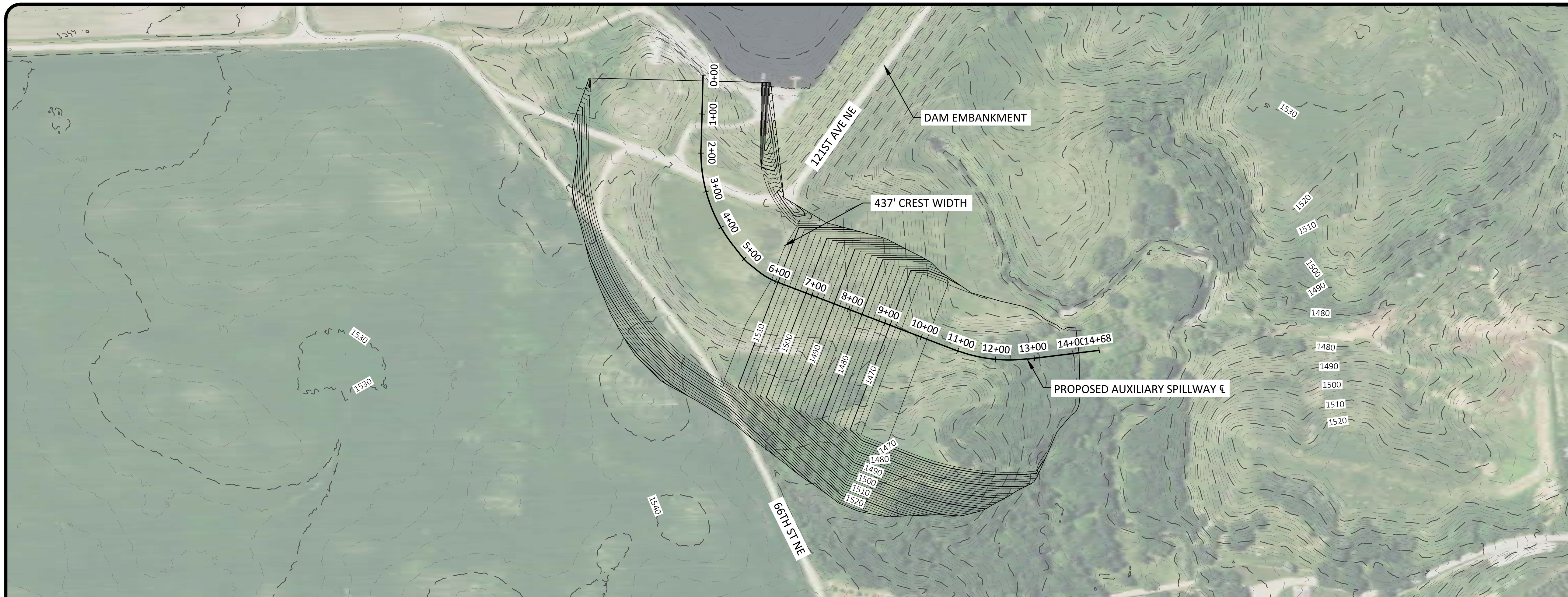

FIGURE D-3-8

Bylin Dam

Option 9

Ogee Weir 437-feet located near existing spillway

ACBs @ -13% slope (EPEC SD 900 OCT)

Modify principal spillway to pass PSH without activating auxiliary spillway

Dam not Raised

Feasibility Level Cost:
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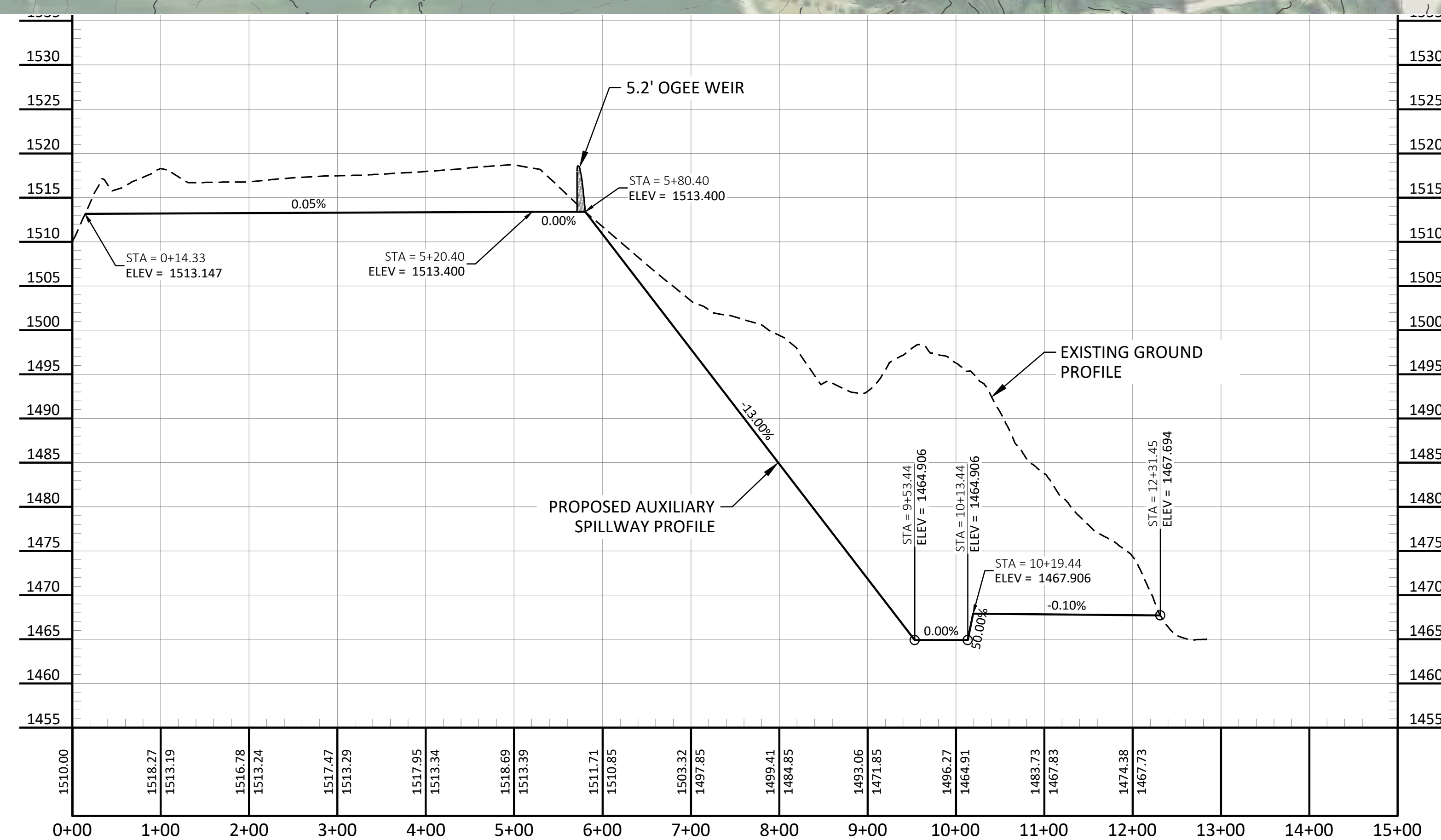

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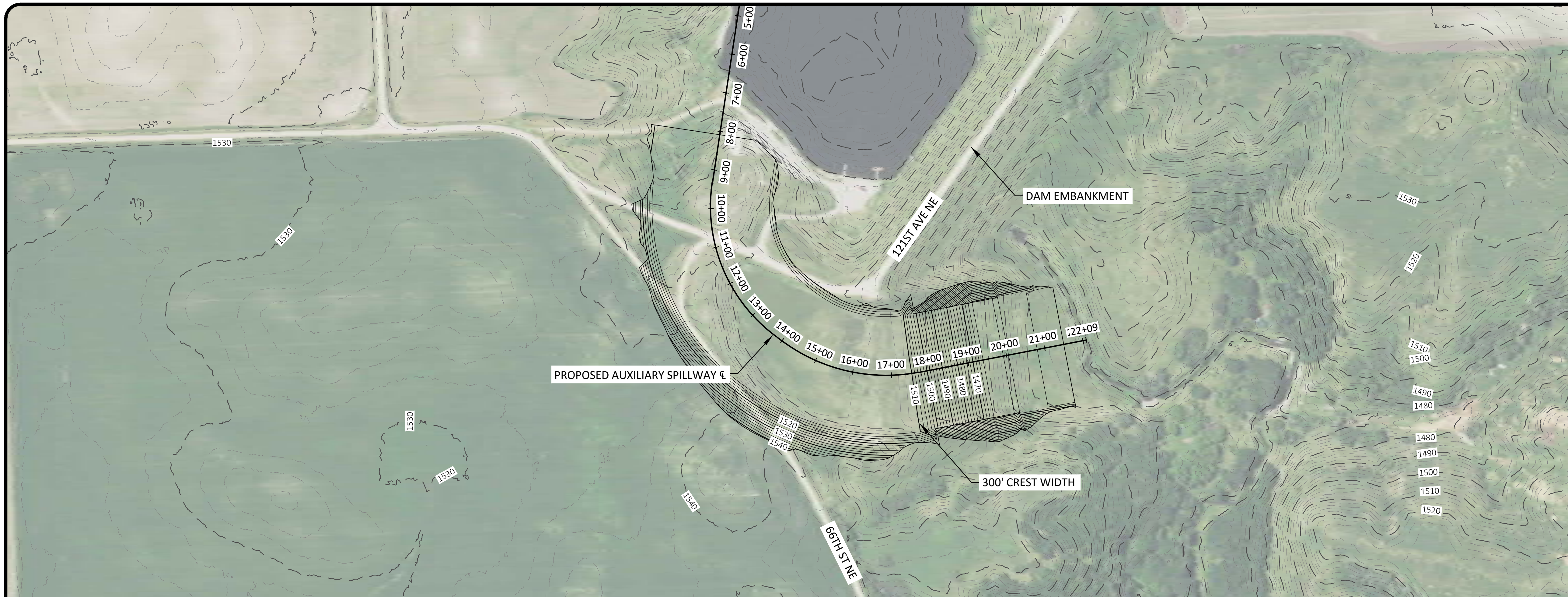

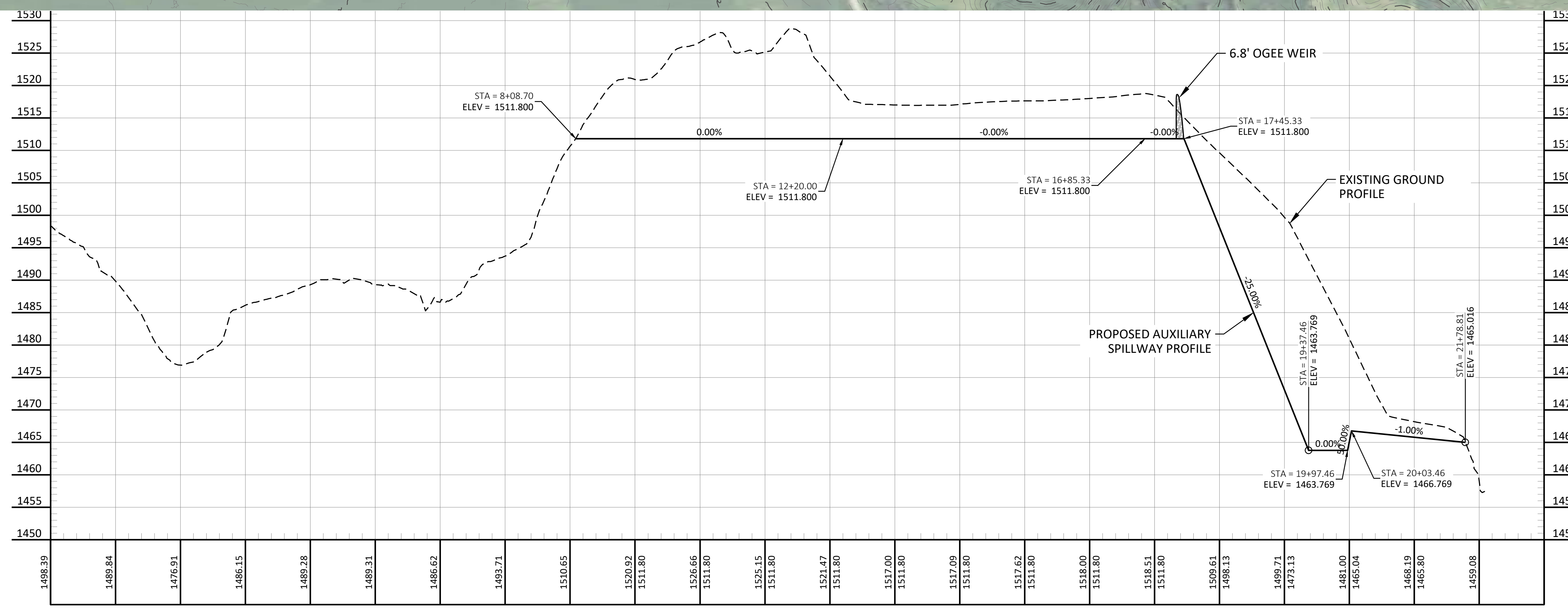

FIGURE D-3-9

Bylin Dam
Option 10

Ogee Weir 300-feet located near existing spillway

RCC @ -25% slope

Dam Raised 1.5'

Feasibility Level Cost:
$ 10,370,000

Bylin Dam
Option 12

Ogee Weir 300-feet located near existing spillway

Reinforced Concrete @ -25% slope

Dam Raised 1.5'

Feasibility Level Cost:
$ 32,852,000

PRELIMINARY
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GRAFTON, ND

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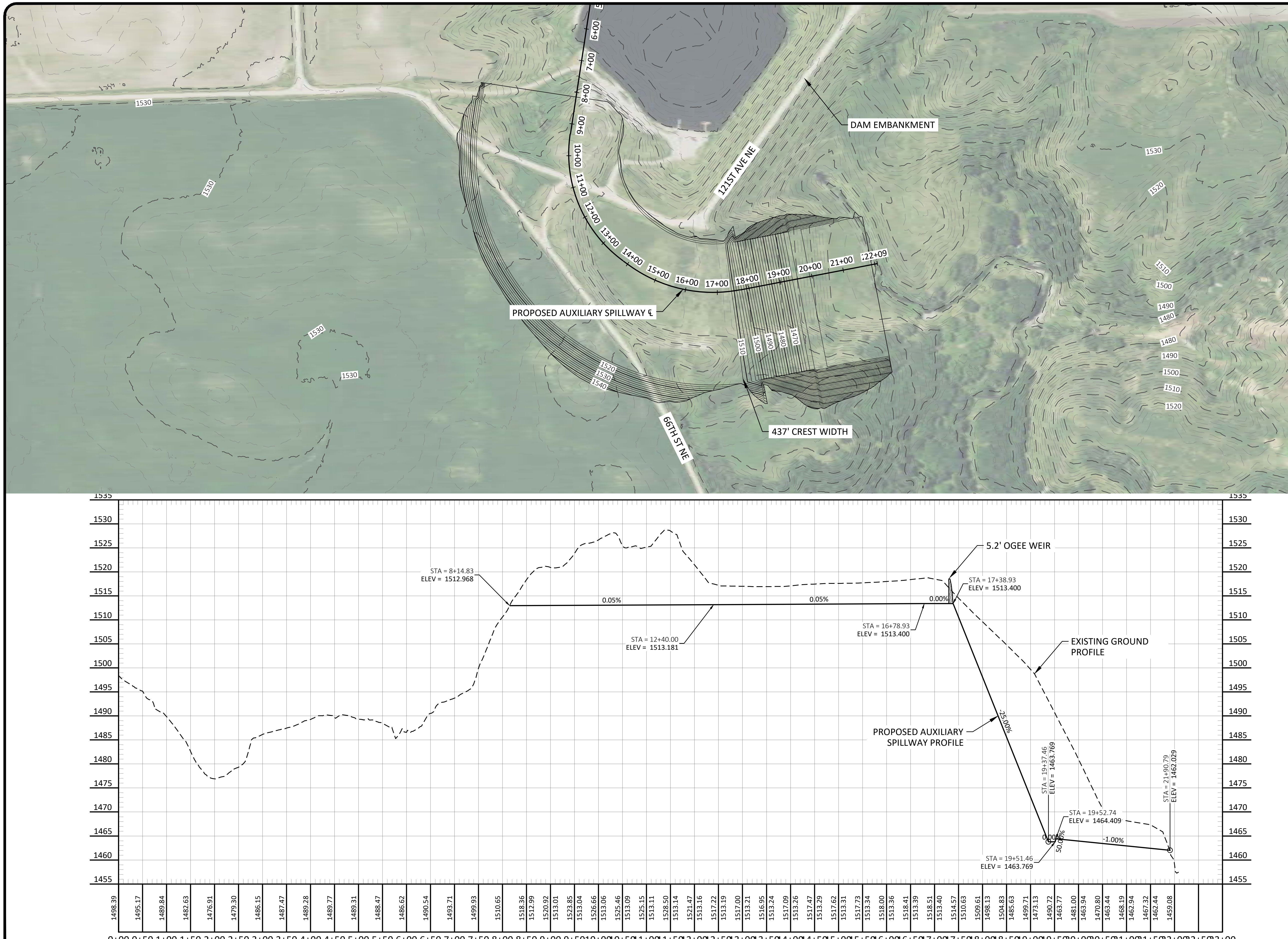

FIGURE D-3-10

Bylin Dam

Option 11

Ogee Weir 437-feet located near existing spillway

RCC @ -25% slope

Dam not Raised

Feasibility Level Cost:
$ 14,418,000

Bylin Dam

Option 13

Ogee Weir 437-feet located near existing spillway

Reinforced Concrete @ -25% slope

Dam not Raised

Feasibility Level Cost:
$ 32,535,000

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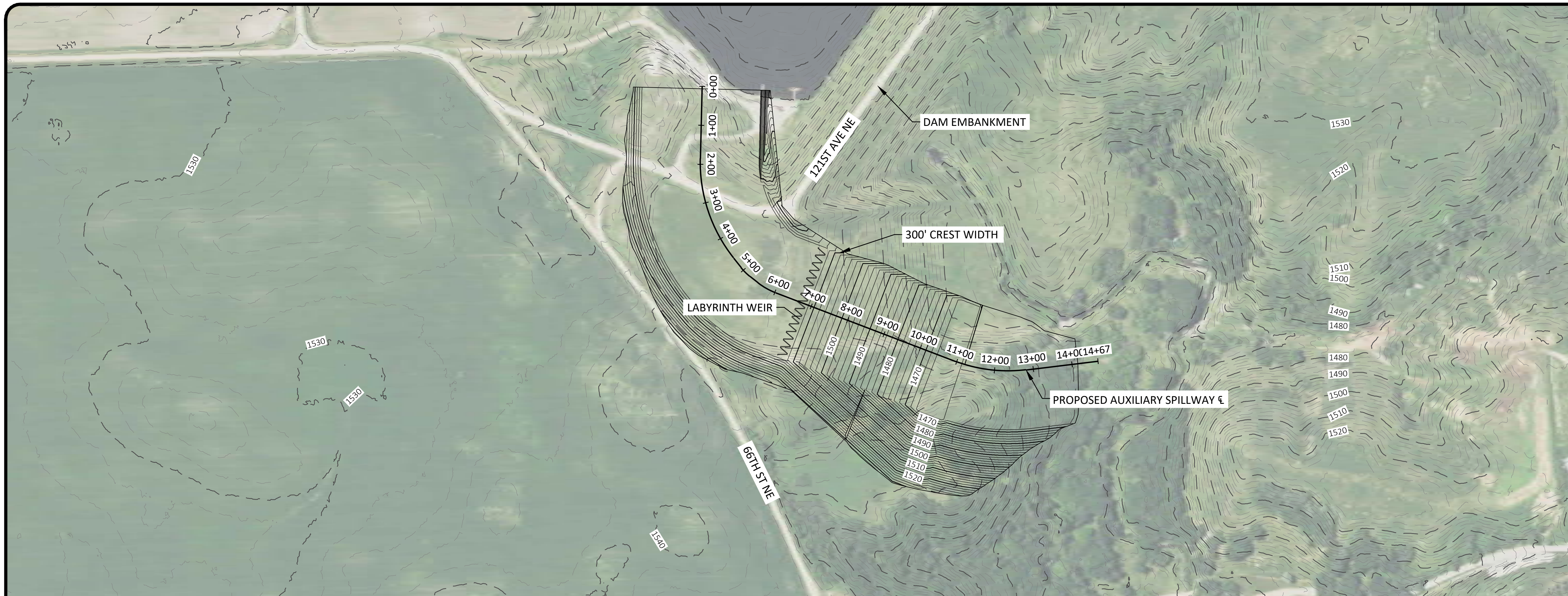

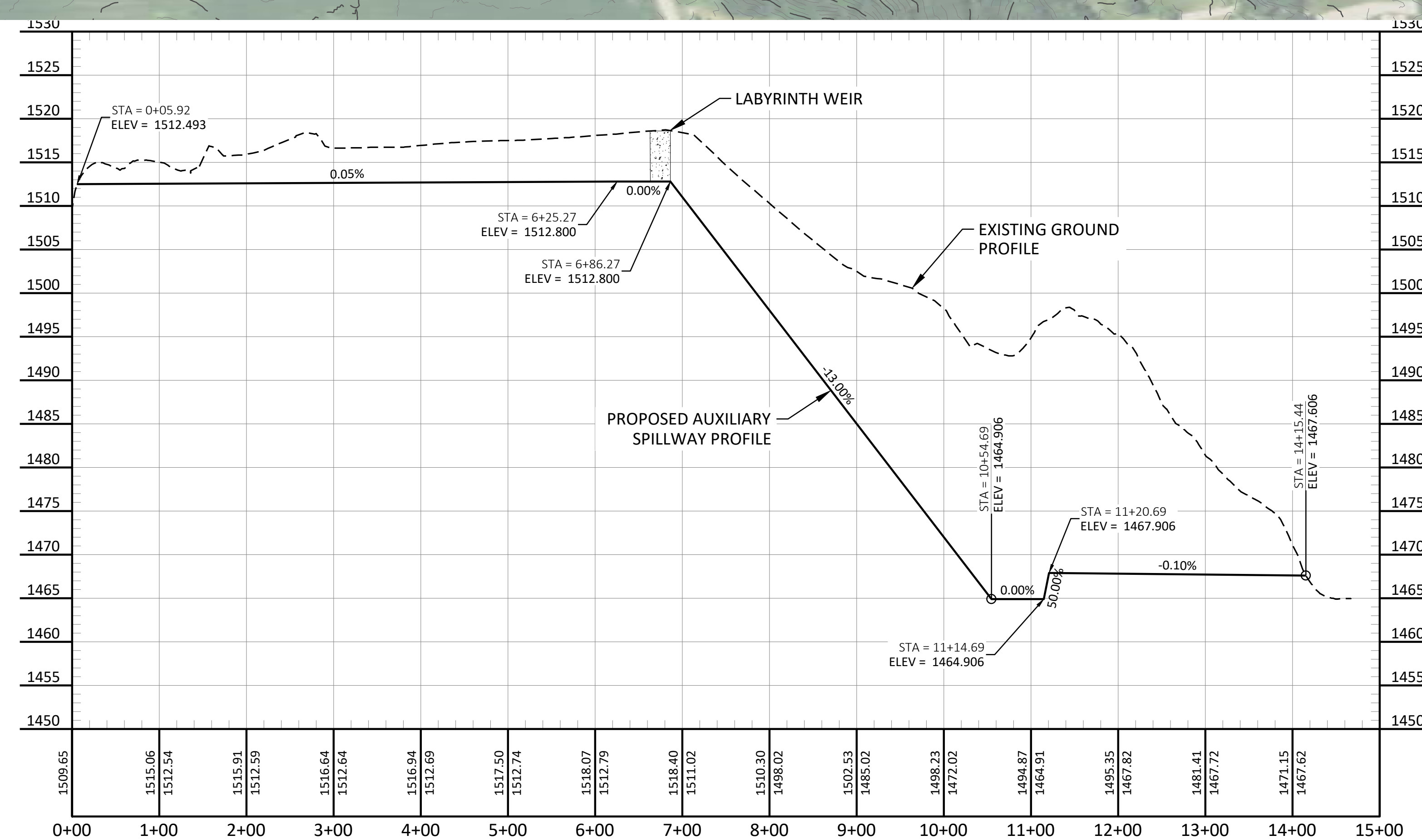

Scale: 100 0 100 200 Feet

FIGURE D-3-11

Bylin Dam

Option 14

Labyrinth Weir with 300' wide footprint. Effective weir length = 722 feet. Located in existing spillway

ACBs @ -13% slope (EPEC SD 900 OCT)

Modify principal spillway to pass PSH without activating auxiliary spillway

Dam not Raised

Feasibility Level Cost:
$ 9,072,000

PRELIMINARY
NOT FOR CONSTRUCTION

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GRAFTON, ND

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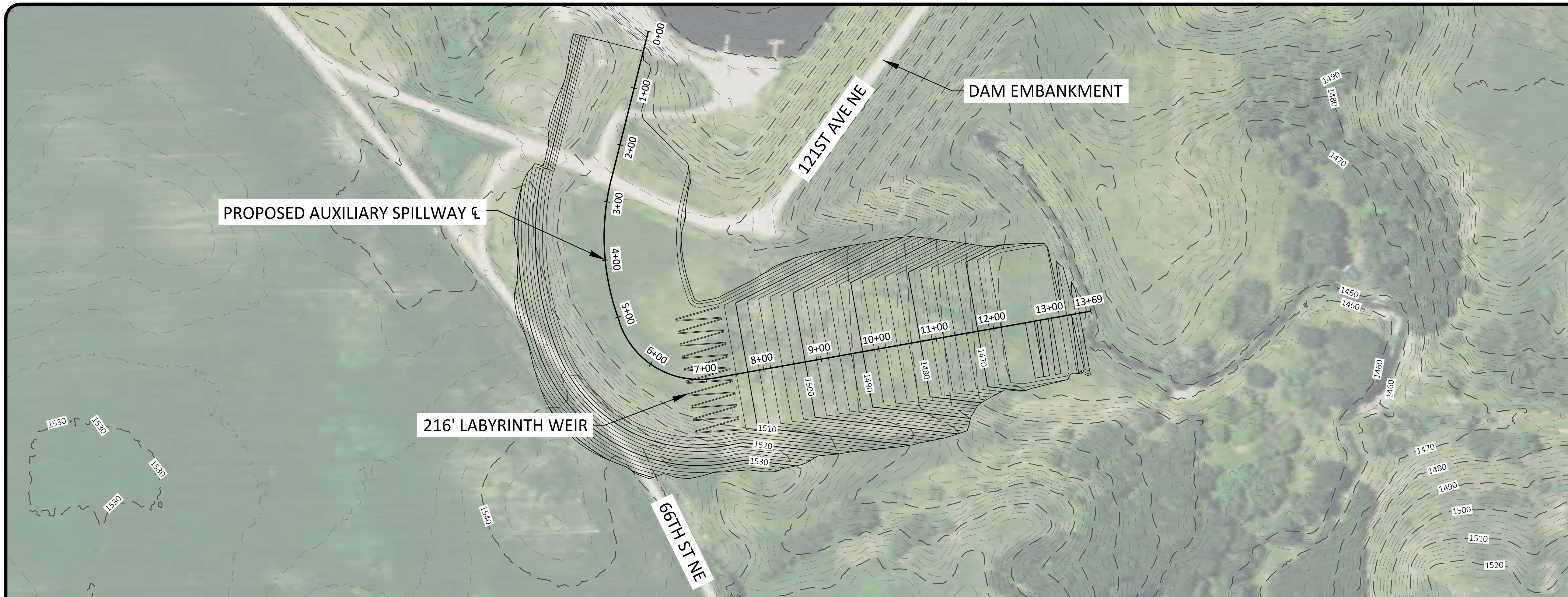


FIGURE D-3-12

Bylin Dam
Option 14A

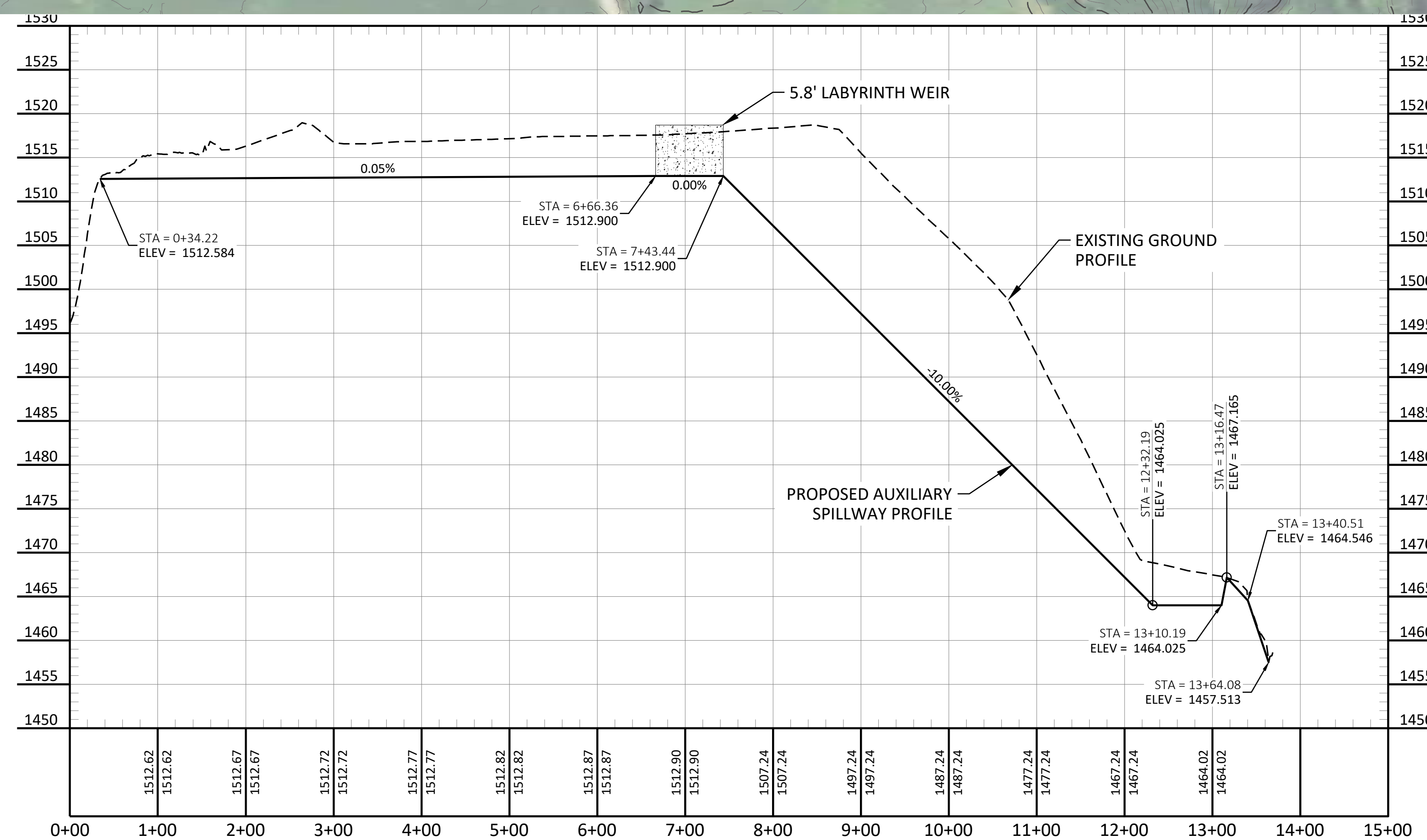
Labyrinth Weir width 216' wide footprint. Effective weir length = 1577 feet. Located in existing spillway

ACBs @ -10% slope (EPEC SD 900 OCT)

Modify principal spillway to pass PSH without activating auxiliary spillway

Dam not Raised

Feasibility Level Cost:
$ 10,395,000



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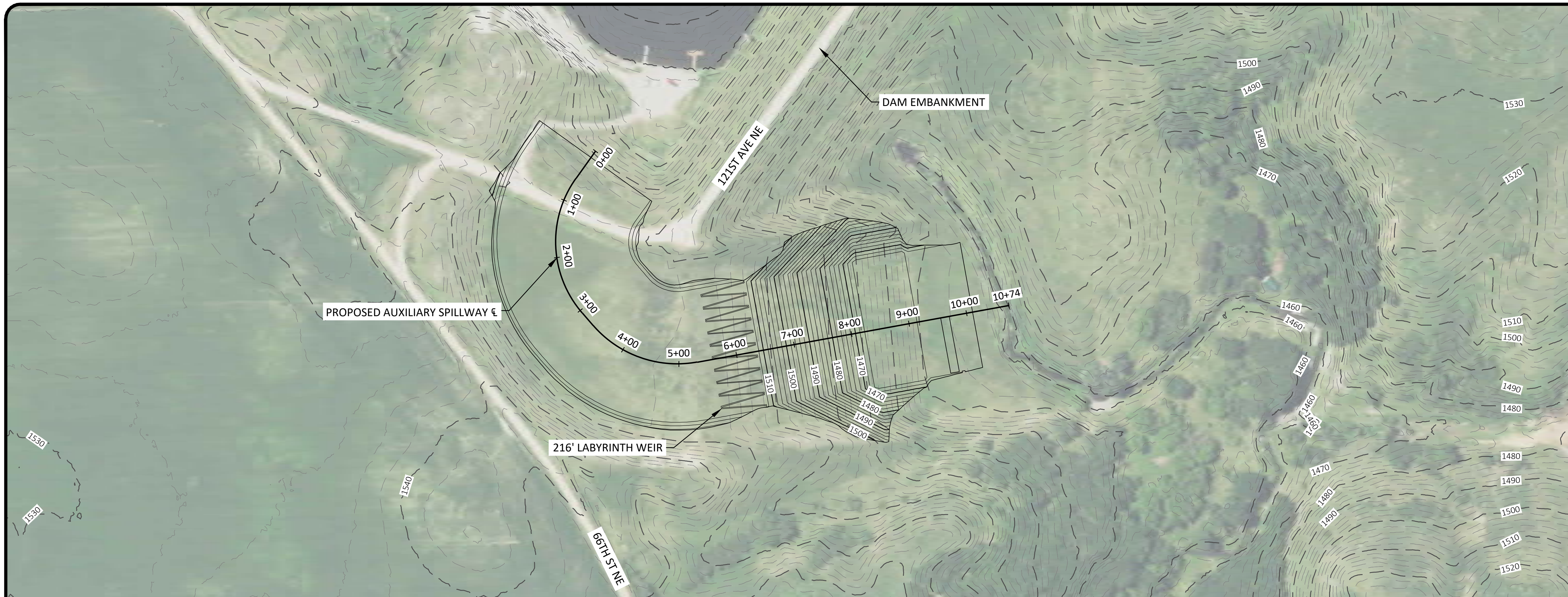

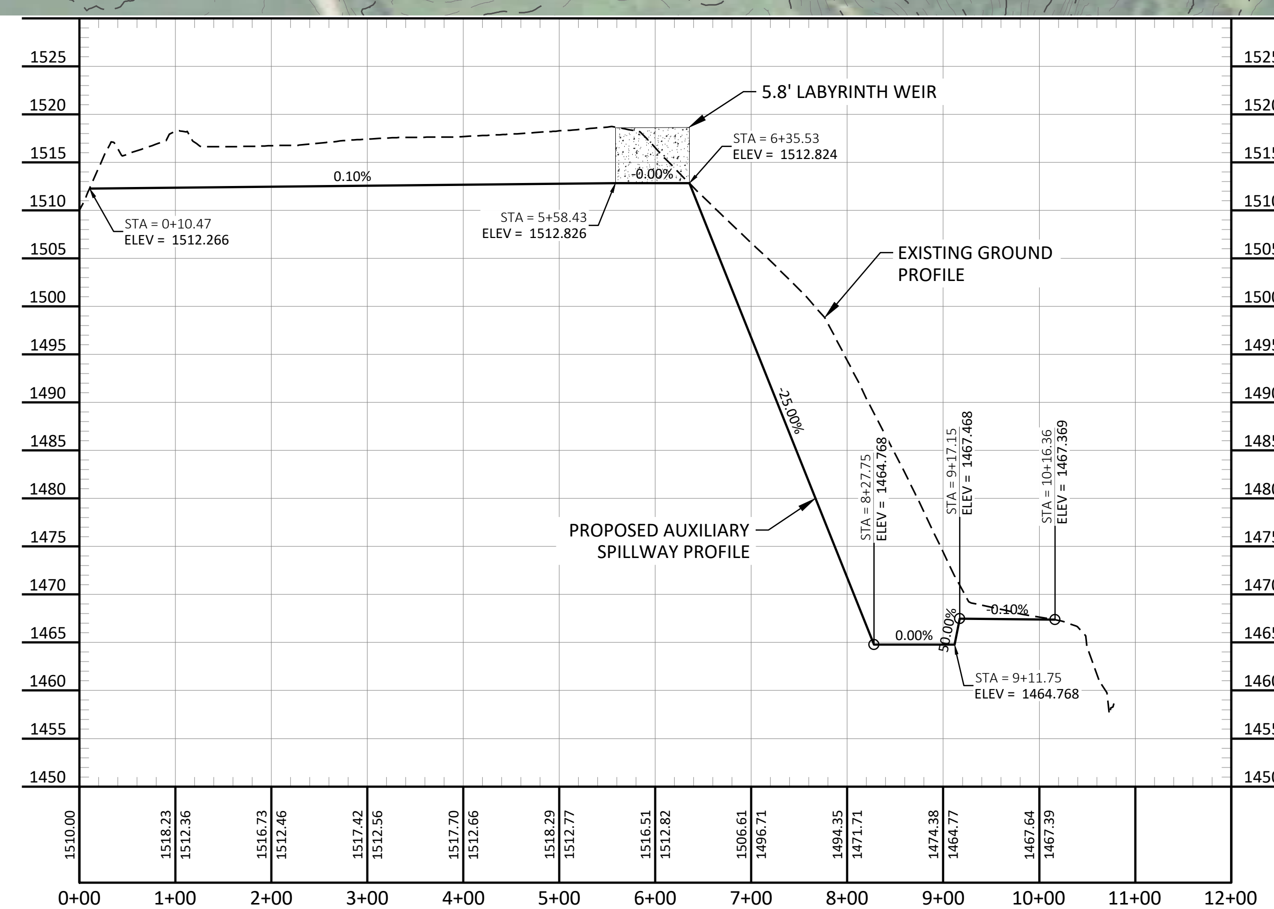

FIGURE D-3-13

Bylin Dam

Option 15

Labyrinth Weir with 216' wide footprint. Effective weir length = 1577 feet. Located in existing spillway

RCC @ -25% slope

Modify principal spillway to pass PSH without activating auxiliary spillway

Dam not Raised

Feasibility Level Cost:
$ 8,933,000

PRELIMINARY
NOT FOR CONSTRUCTION

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WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, ND

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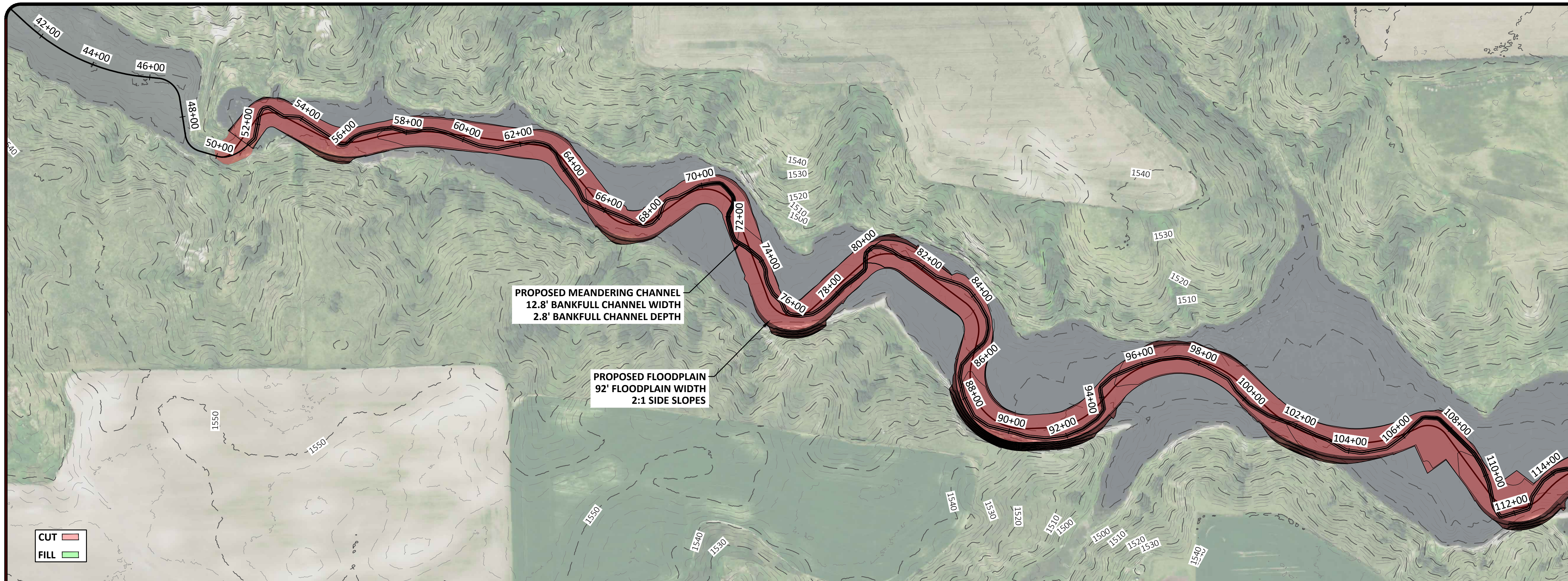

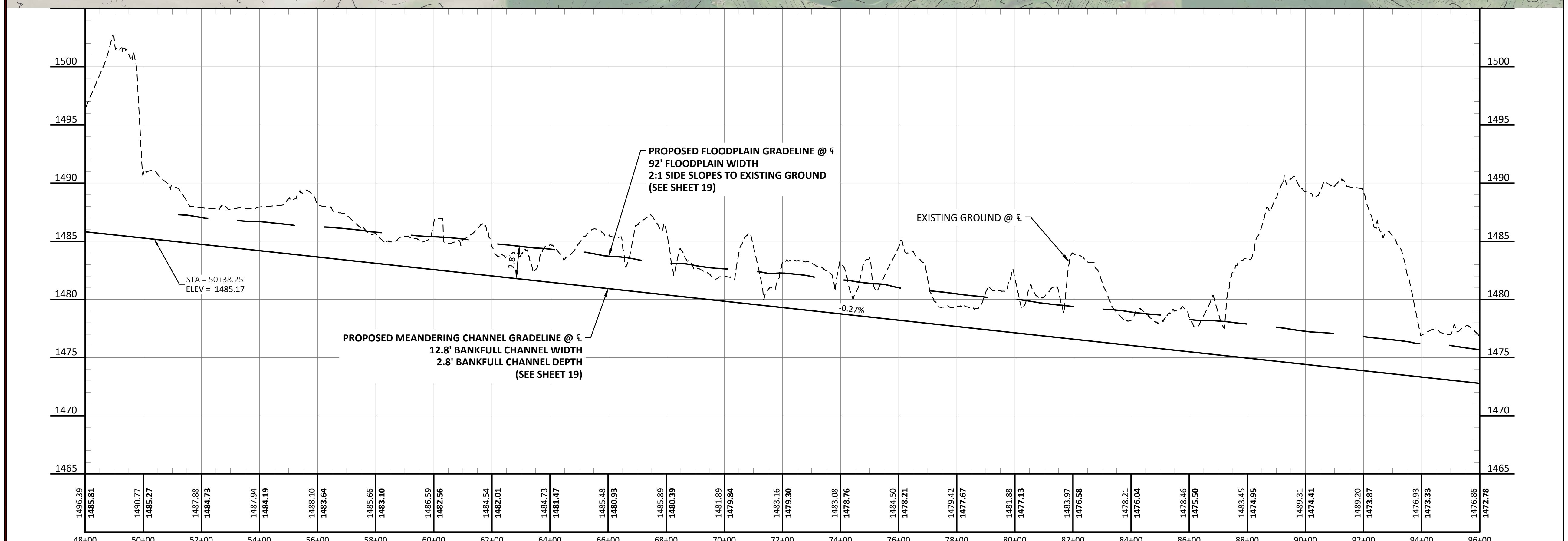

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FIGURE D-3-14

Bylin Dam

Non Structural Decommissioning (1)

Proposed channel alignment approximately follows historic channel alignment

Bankfull Width (W/bkf):	12.8 ft
Bankfull Depth (d/max):	2.80 ft
Average Slope (S):	0.0027 ft/ft
Channel Sinuosity (k):	1.46 ft/ft
Floodplain Width (7.2xW/bkf):	92 ft

Cost Includes earthwork to reestablish meandering channel through the existing reservoir, installing grade stabilization measures, construction of ring dikes to protect habitable structures, construction of setback levees to protect agricultural land, and the purchase of land within the setback levees.

Note:
1. Proposed grade line represents riffle to riffle profile. Runs, glides, and pools would be constructed throughout the meandering channel.

Feasibility Level Cost:
$ 37,414,750

PRELIMINARY
NOT FOR CONSTRUCTION

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PROJECT NO. 7135-0037

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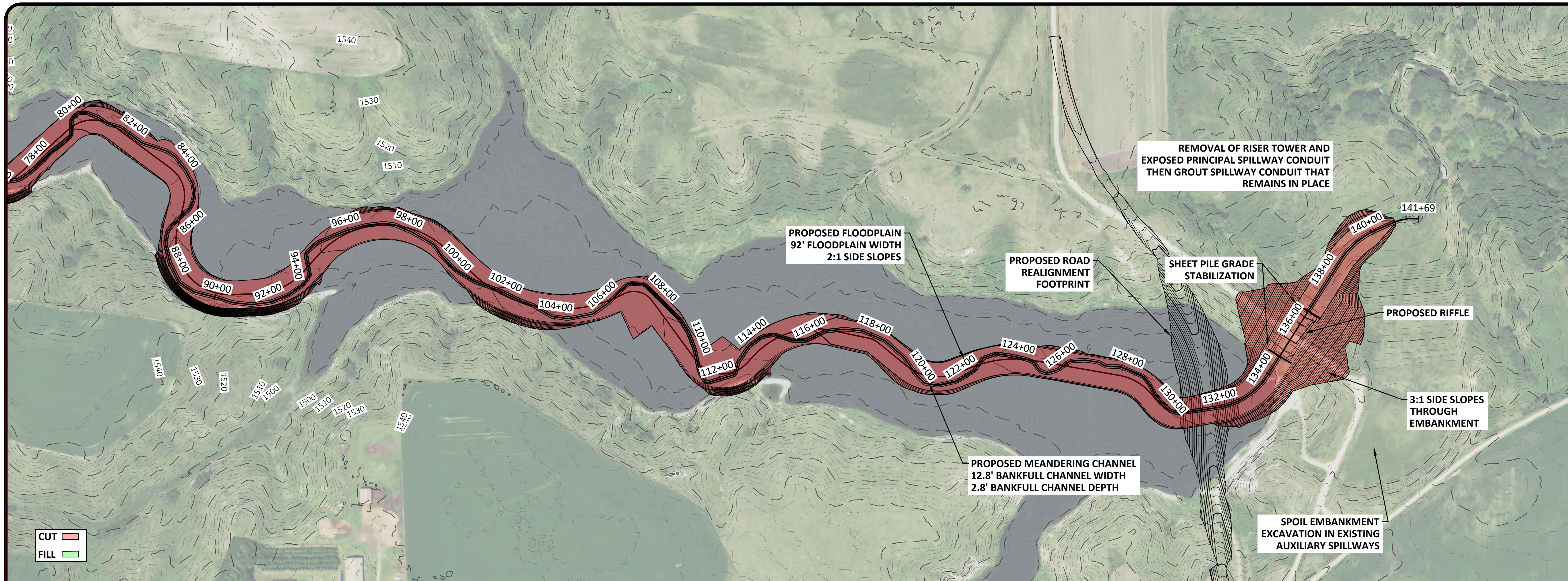

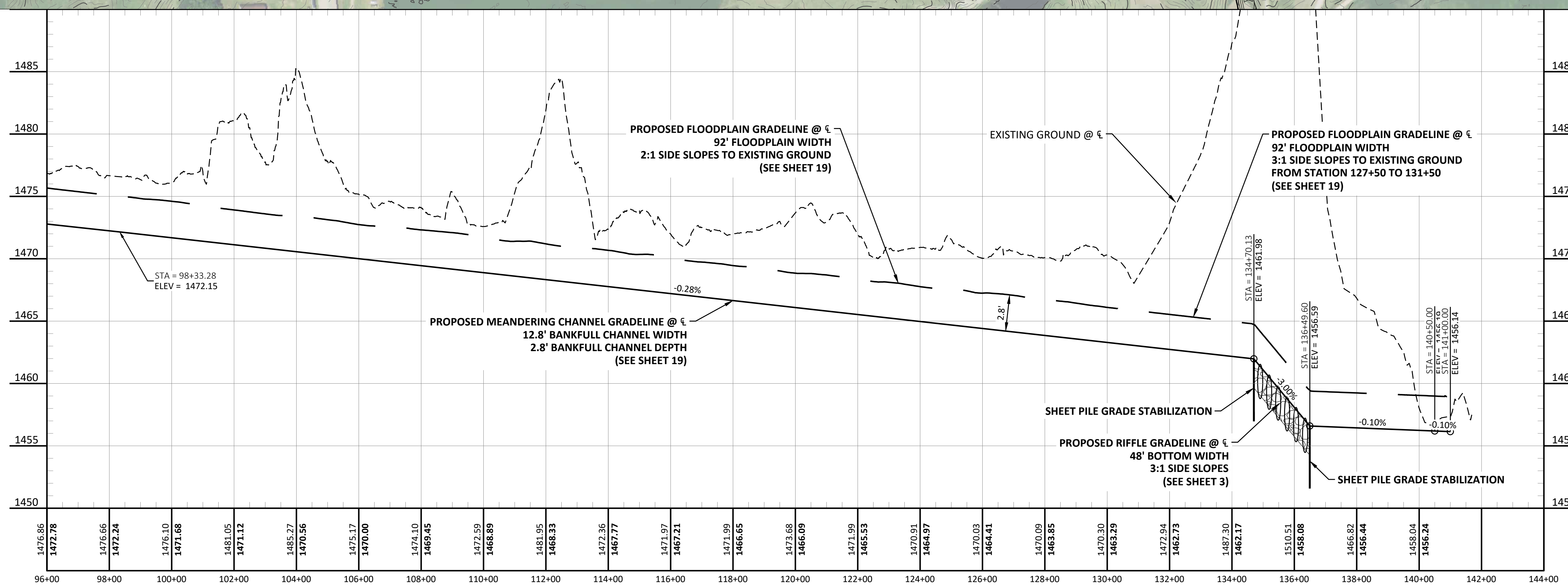

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FIGURE D-3-15

Bylin Dam

Non Structural Decommissioning (2)

Proposed channel alignment approximately follows historic channel alignment

Bankfull Width (W/bkf):	12.8 ft
Bankfull Depth (d/max):	2.80 ft
Average Slope (S):	0.0027 ft/ft
Channel Sinuosity (k):	1.46 ft/ft
Floodplain Width (7.2xW/bkf):	92 ft

Cost Includes earthwork to reestablish meandering channel through the existing reservoir, installing grade stabilization measures, construction of ring dikes to protect habitable structures, construction of setback levees to protect agricultural land, and the purchase of land within the setback levees.

Note:
1. Proposed grade line represents riffle to riffle profile. Runs, glides, and pools would be constructed throughout the meandering channel.

Feasibility Level Cost:
$ 37,414,750

PRELIMINARY
NOT FOR CONSTRUCTION

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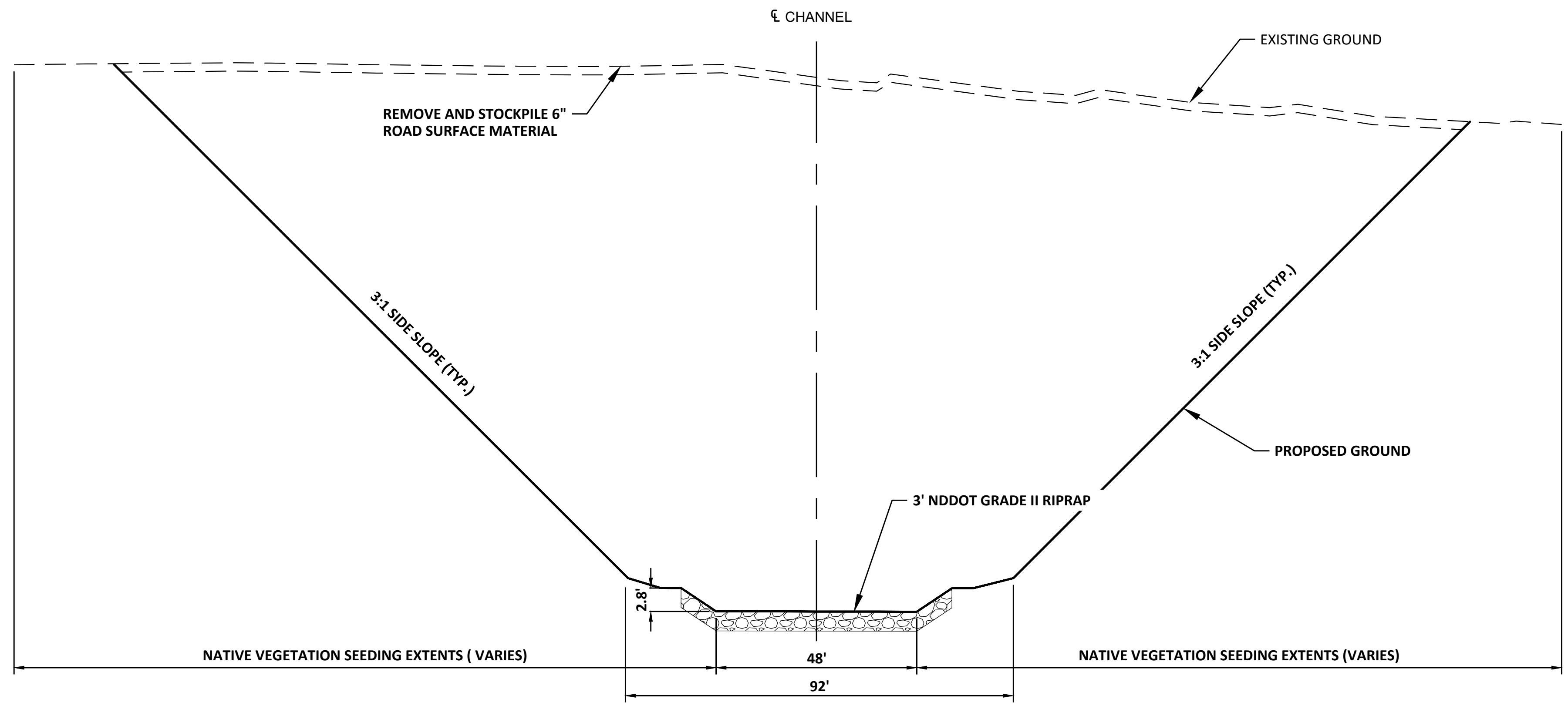
FOREST RIVER BYLIN DAM - REVIEW POINT 3
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

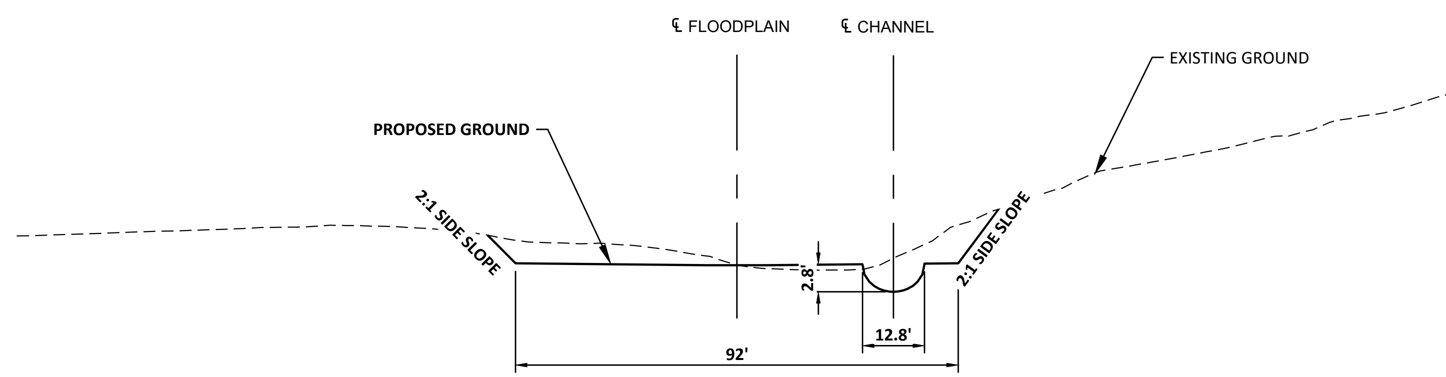
PLAN AND PROFILE - DECOMMISSIONING
PROJECT NO. 7135-0037

SHEET
18



TYPICAL SECTION - DAM CUT AND RIFFLE SECTION

NOT TO SCALE



TYPICAL SECTION - FLOODPLAIN

NOT TO SCALE

NOTES:

1. DIMENSIONS OF MEANDERING CHANNEL AND FLOODPLAIN ARE DETERMINED FROM ROSGEN SURVEY DATA (2020).
2. STRIPPING SHALL BE REQUIRED AS NECESSARY UPSTREAM AND DOWNSTREAM OF EXISTING EMBANKMENT.
3. ALL DISTURBED AREAS WITHIN THE CONSTRUCTION EASEMENT SHALL BE SEEDED EXCEPT CHANNEL BOTTOM.
4. SEEDING WITHIN THE FLOODPLAIN AND FLOODPLAIN SPOIL EXTENTS SHALL BE OF NATIVE VEGETATION SEED MIXTURE.

FIGURE D-3-16

Bylin Dam

Non Structural Decommissioning (3)

Proposed channel alignment approximately follows historic channel alignment

Bankfull Width (W/bkf):	12.8 ft
Bankfull Depth (d/max):	2.80 ft
Average Slope (S):	0.0027 ft/ft
Channel Sinuosity (k):	1.46 ft/ft
Floodplain Width (7.2xW/bkf):	92 ft

Cost Includes earthwork to reestablish meandering channel through the existing reservoir, installing grade stabilization measures, construction of ring dikes to protect habitable structures, construction of setback levees to protect agricultural land, and the purchase of land within the setback levees.

Feasibility Level Cost:
$ 37,414,750

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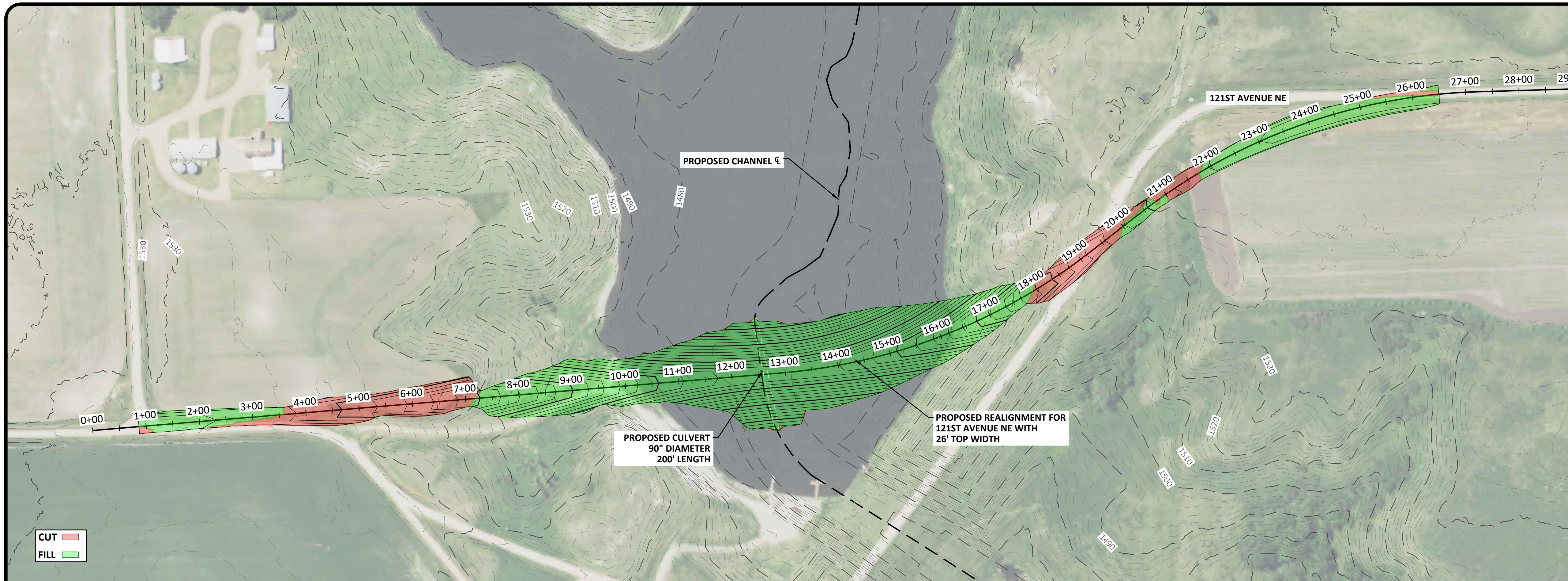
FOREST RIVER BYLIN DAM - REVIEW POINT 3
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

TYPICAL SECTION - DECOMISSIONING
PROJECT NO. 7135-0037



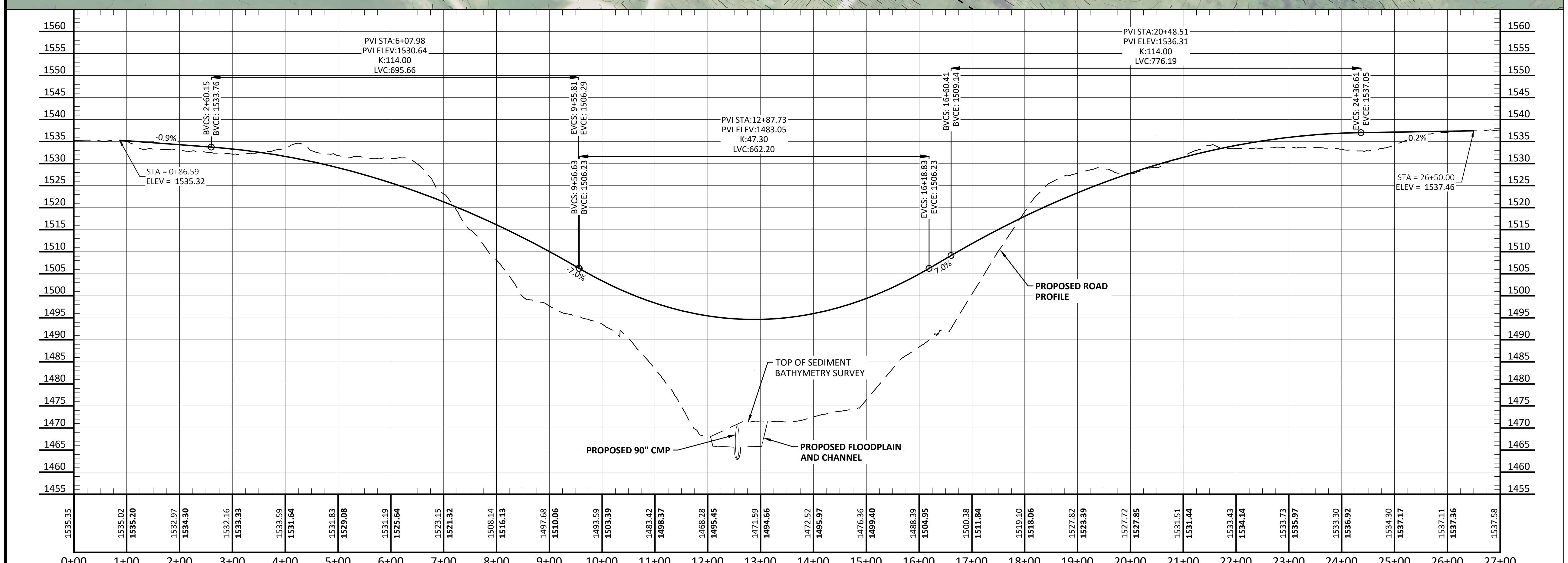


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FIGURE D-3-17

Bylin Dam

Non Structural Decommissioning (4)

Proposed road alignment approximately matches the road alignment prior to the construction of Bylin Dam.

Road Vertical and Horizontal Curves and slopes were designed using the AASHTO Green Book (2018 7th Edition).

Cost Includes earthwork to reestablish meandering channel through the existing reservoir, installing grade stabilization measures, construction of ring dikes to protect habitable structures, construction of setback levees to protect agricultural land, and the purchase of land within the setback levees.

Feasibility Level Cost:

$ 37,414,750

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FOREST RIVER BYLIN DAM - REVIEW POINT 3
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

PLAN AND PROFILE - DECOMISSIONING
PROJECT NO. 7135-0037

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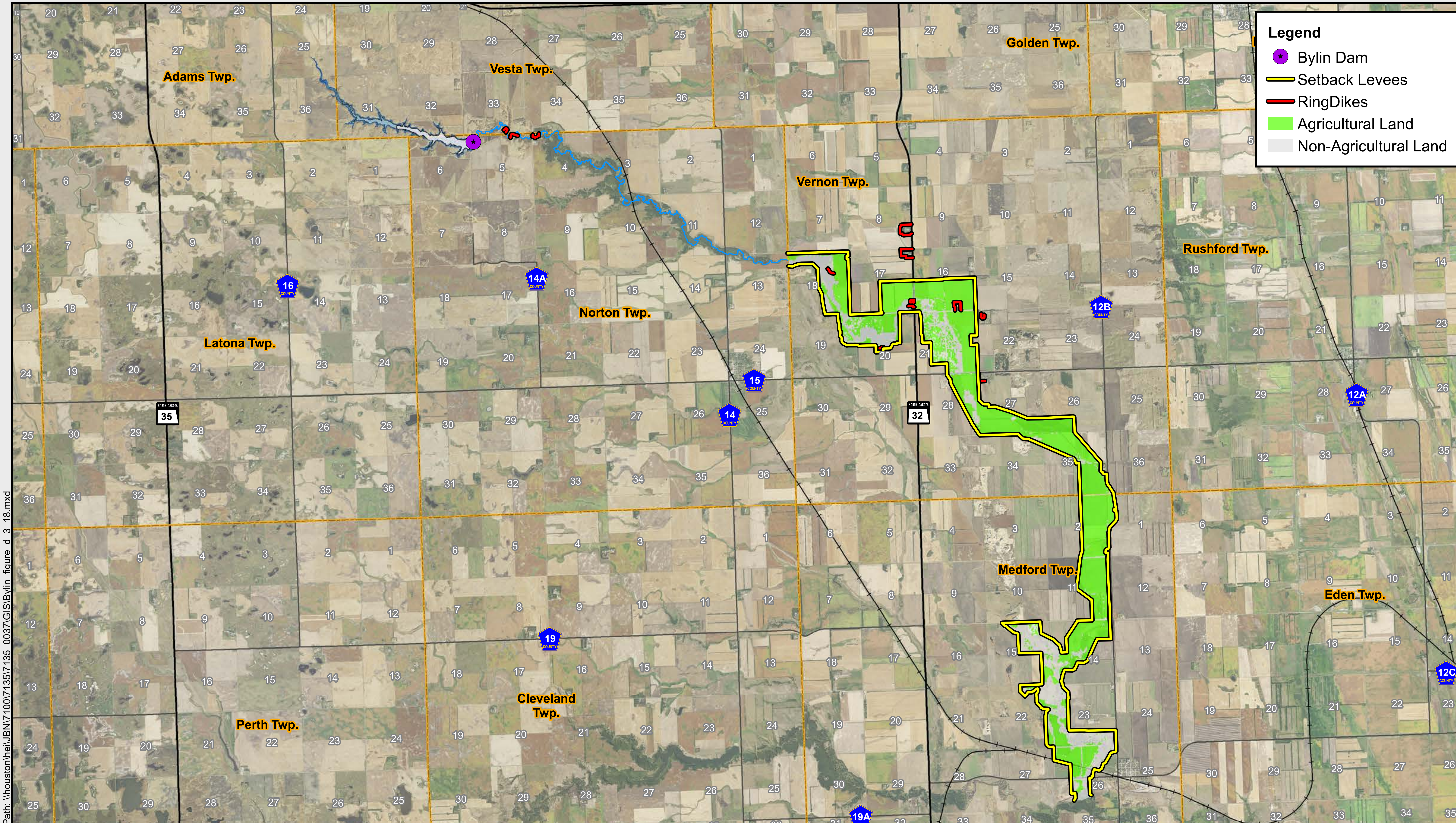

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F D-3-18

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AS SHOWN	ZCF	PDL	7135-0037	11/13/2023

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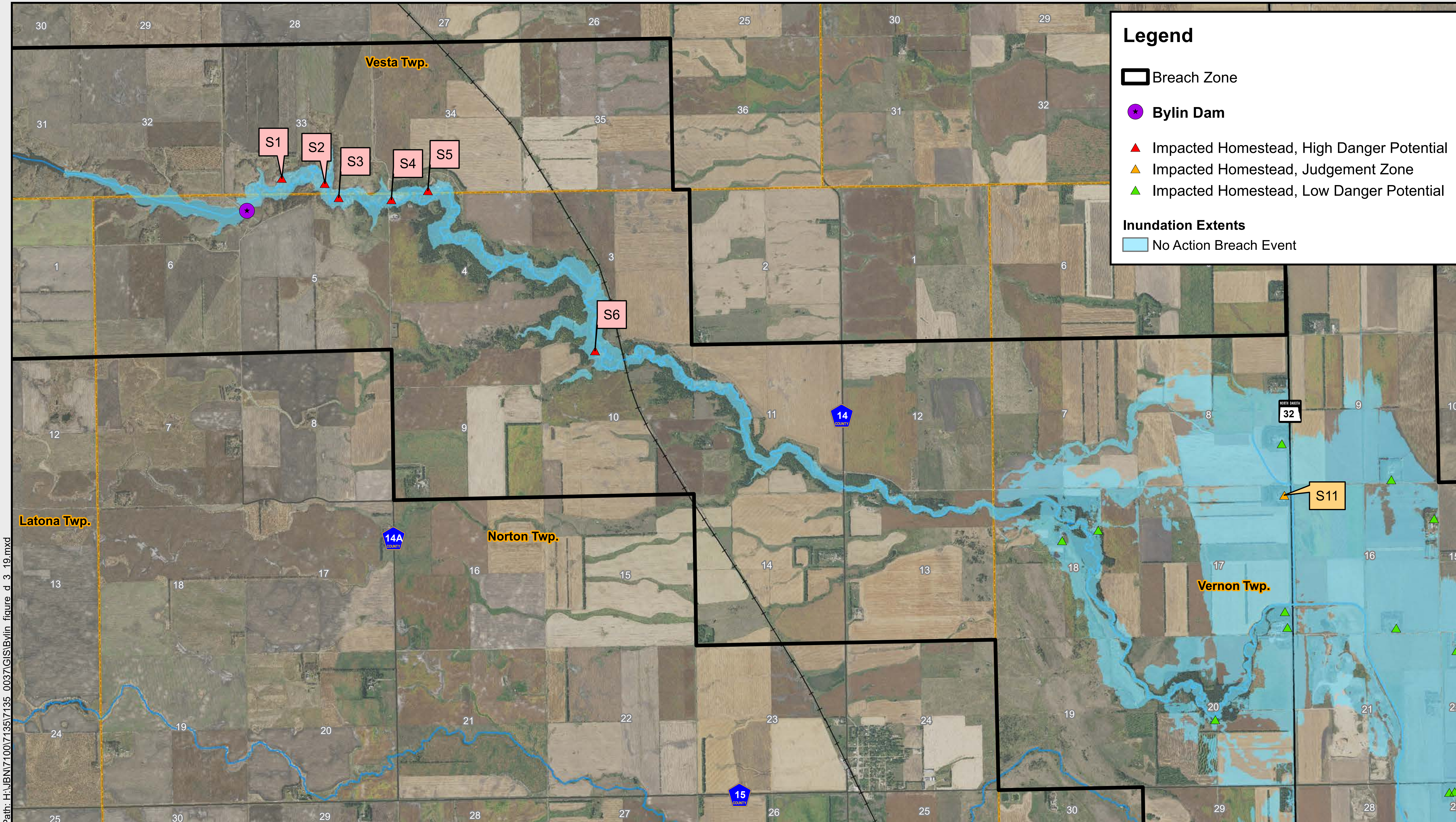
Figure D-3-18: Non Structural Decommissioning (5) - Downstream Flood Protection

North Branch Forest River Dam No. 1 (Bylin Dam)
Appendix D-4: Concept Design Report
Walsh County Water Resource District

0 1.5 3 Miles

N W E S



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AS SHOWN	PDL	PDL	7135-0037	2/15/2024

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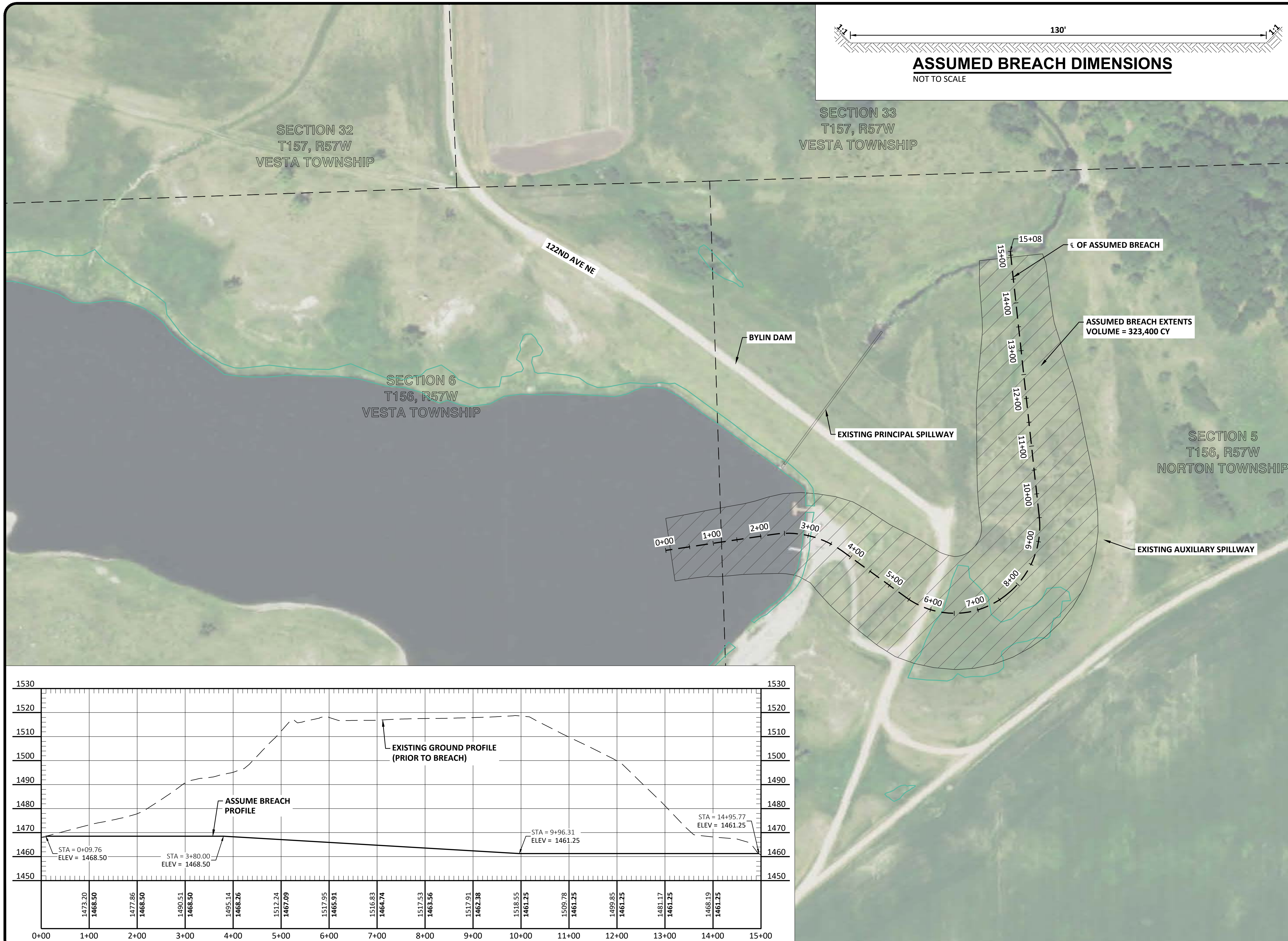
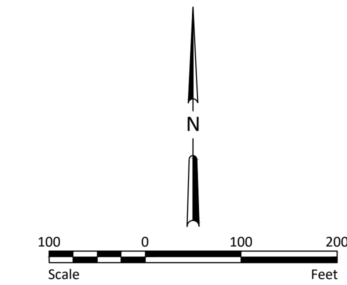
Figure D-3-19: No Action Breach Event - Impacted Residential Structures

North Branch Forest River Dam No. 1 (Bylin Dam)
Appendix D-3: Alternatives Evaluation Report
Walsh County Water Resource District





HEADCUT IMPACTED AREA

EXISTING WETLAND

FIGURE D-3-21

Bylin Dam

Non Structural

No Action Alternative

Alternative includes an assumed breach of the auxiliary spillway of the dam. Breach dimensions are assumed based on the Froehlich Equations and are as shown on this plan sheet.

PRELIMINARY
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BYLIN DAM
WALSH COUNTY WATER RESOURCE DISTRICT
GRAFTON, NORTH DAKOTA

BREACH - NO-ACTION
PLAN AND PROFILE
PROJECT NO. 7135-0037

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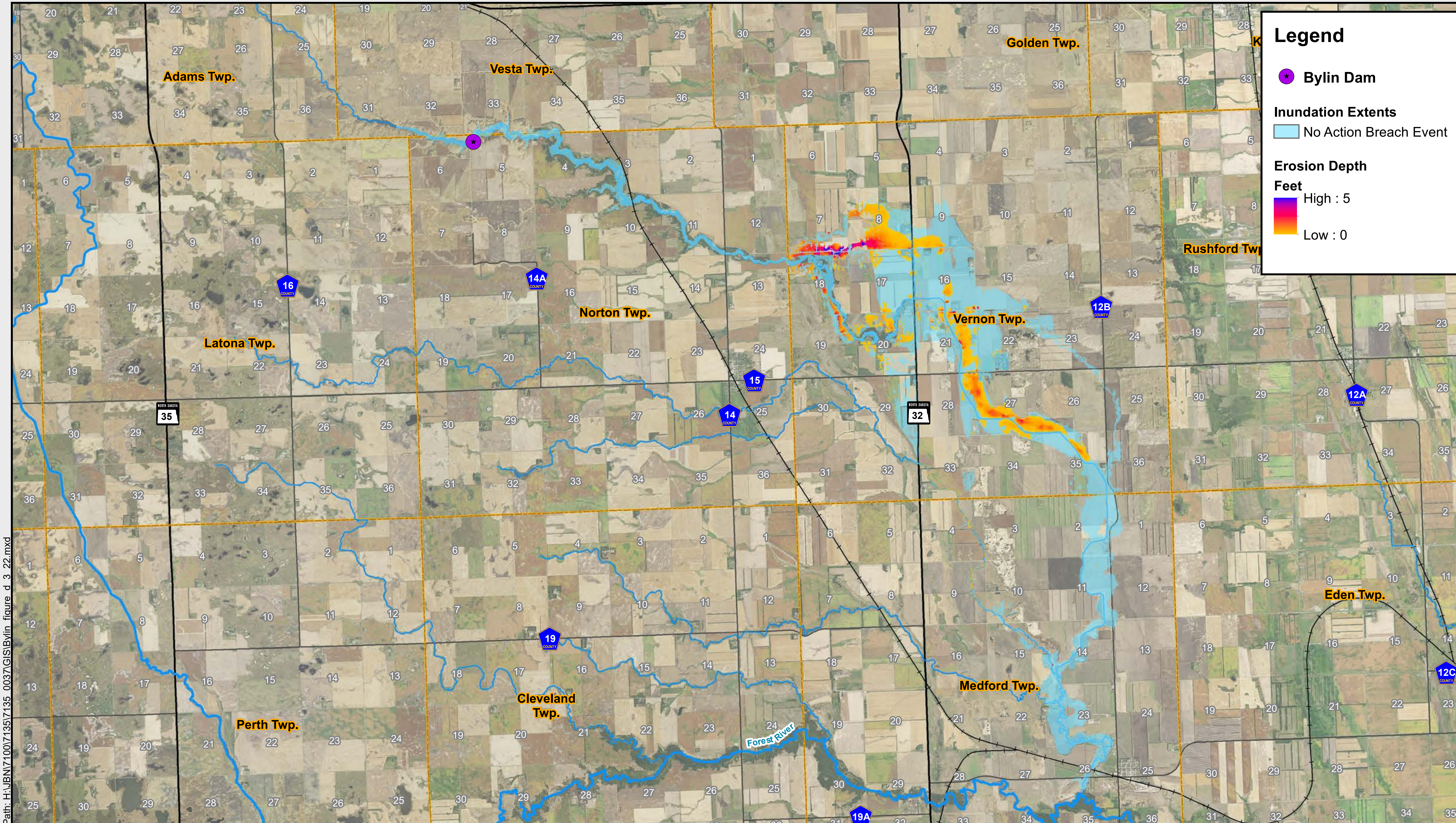

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AS SHOWN	PDL	PDL	7135-0037	12/21/2023

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Figure D-3-22: No Action Breach Event - Floodplain Erosion Depth

North Branch Forest River Dam No. 1 (Bylin Dam)
Appendix D-3: Alternatives Evaluation Report
Walsh County Water Resource District

0 1.5 3 Miles

N W E S