Post-Disaster Guidance for Repair, Replacement, and Clean-up Projects in Streams and Waterways of Puerto Rico from Hurricane María

In Puerto Rico, flooding caused by heavy rainfall events, tropical storms, and hurricanes can damage stream crossings (bridges, culverts, low-water crossings, etc.) and in-stream structures (piers, docks, etc.), and create debris jams. Many streams in Puerto Rico support an array of aquatic species, including anadromous and catadromous fishes. Repair and clean-up activities in streams have the potential to adversely affect these species and their habitat, causing sedimentation in areas downstream of the project and disruption of sediment transport leading to channel instability.

Following the response to Hurricane María, Federal Emergency Management Agency (FEMA) requested assistance from U.S. Fish and Wildlife Service (USFWS) to coordinate project planning and mitigation within the transportation sector. This guidance is provided to FEMA for regulatory review by permitting agencies, protect damaged structures, reduce future damages, and prevent or minimize damage to natural resources.

This guidance applies to post-disaster repair, replacement, and clean-up projects related to storm damage incurred by Hurricane María. The guidance applies to creeks, rivers, and tidally-influenced waters. All projects in aquatic habitats should be considered with the following conditions below. If the recommended methods are implemented and appropriate conditions are included in the project approval, the USFWS would request that FEMA or any other authorizing agency (e.g. Corps of Engineers) send a summary of the work performed at each project to document alternatives on existing structures and methods utilized for successful projects. These summaries will assist in future design and construction methodologies following post disaster relief efforts.

General Guidance for Road Crossing Structures

Road-Stream Crossing Removal and Associated Channel Restoration

If a crossing structure will be removed, the affected area should be restored to a natural state. Following structure removal, the stream channel should be reconstructed to match natural bankfull (i.e., channel shape from effective discharge or channel forming discharge [Figure 1]) width, channel slope and active floodplain dimensions, which exist upstream and downstream of the structure being removed. This activity should occur to restore physical and biological aquatic habitat connectivity, most notably, passage for aquatic and terrestrial organisms. All structure removal projects should occur in association with a closed or decommissioned road and not a low-water ford stream crossing.

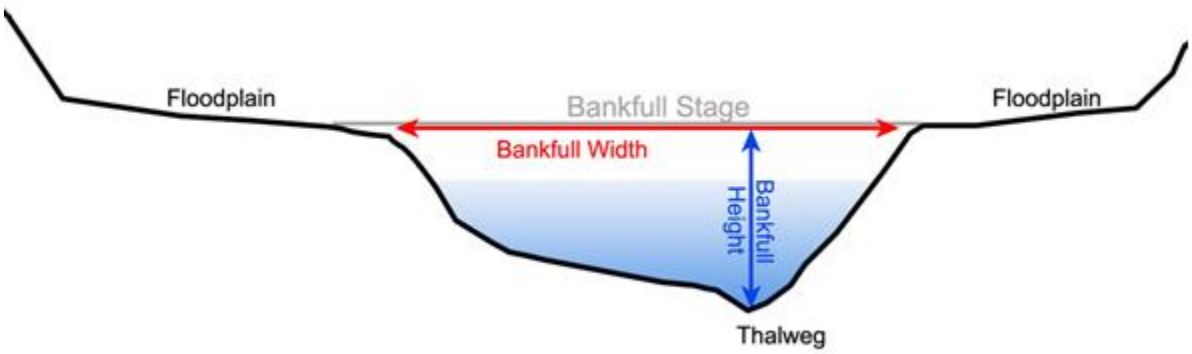

Figure 1. Bankfull Cross Section.

Road-Stream Crossing Replacement Structure

A crossing structure will be removed and replaced with a culvert or open-bottomed structure. Culvert refers to a variety of closed-bottomed metal and concrete structures. Open-bottomed structures include arches, three-sided boxes and bridges. Structure widths should be at least 1.2 times bankfull width with stable bank rocks on both sides. Structures should be constructed in a manner that accommodates 100-year flows (Figures 2 and 3) and allows for natural stream processes including sediment and wood transport to the greatest degree possible given the structure dimensions. Flood relief culverts (Figure 4) on unconfined floodplains may be used. Crossings with large unconfined floodplains may require additional capacity or may include floodplain relief structures.

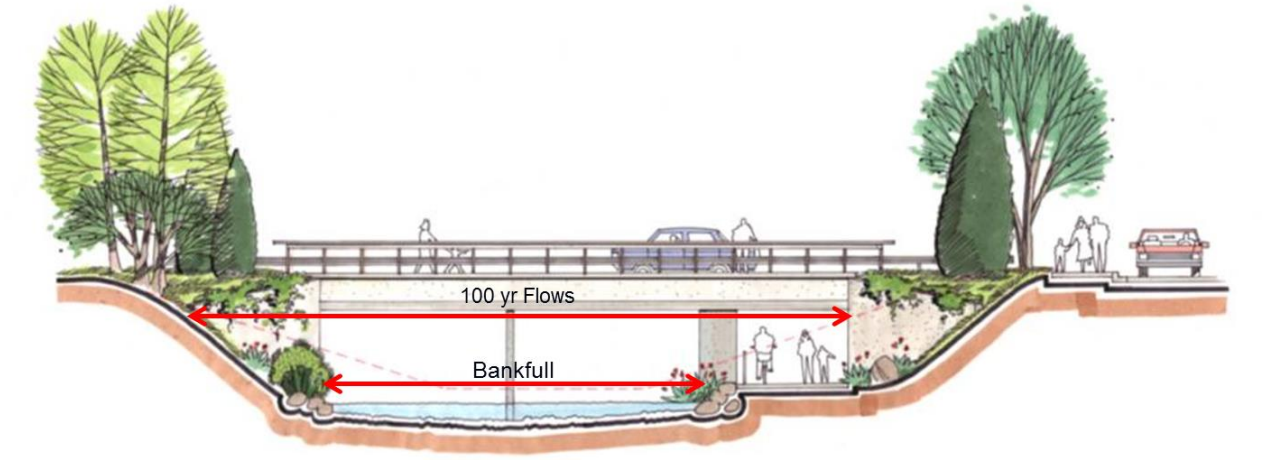

Figure 2. 100 yr Flow Design.

Figure 3. Bridge with Floodplain and Height Capacity for 100 yr Flows.

Figure 4. Bankfull Channel Culvert with Flood Relief Culverts at Floodplain Elevation.

Design Criteria

Stream designs are intended to replicate the natural stream processes at a road-stream crossing within and immediately adjacent to a culvert or opened-bottom structure. Aquatic organism passage, sediment transport and flood and wood conveyance within the structure are intended to imitate the stream conditions upstream and downstream of the crossing, as close to natural conditions as the structure type allows (Figures 5 and 6). Culverts and open-bottomed structures, when properly sized and designed, can accomplish these natural stream processes. Culverts should be partially filled with

material that simulates the natural streambed. Open-bottomed structures should contain substrate that matches the natural stream channel.

Figure 5. Scour and Degradation below Culvert and Obstruction to Fish Passage.

Figure 6. Bankfull Bottomless Arch Culvert with Floodplain Relief Drain.

Implementation of a replacement project requires a high level of information and site-specific data regarding stream hydrology and geomorphology, as well as engineering and construction expertise. Project design criteria include several components as described below.

Structure Width

The width of structures (at bankfull or top of bank elevation) should be equal to or greater than 1.2 times bankfull channel width. A single structure span of the width is preferred but multiple culverts are allowed, and should be accompanied with flood relief drains. The minimum structure width of a culvert should be five feet to allow placement of substrate material. The width of the structures within the vertical adjustment potential should be equal to or greater than 1.2 times bankfull channel width. No piers, footers, piles, or abutments should be within 1.2 times bankfull width, unless there are constraints in placement and design criteria which then should allow for a minimum amount of structures.

Structure Alignment

The structure should achieve optimal orientation relative to both the road and stream channel. Replacement structures are sometimes shifted to achieve better alignment with the natural stream channel pattern at the crossing location. Skew angle should be in line with stream channel orientation.

Structure Capacity

The structure should accommodate a 100-year flood flow without significant change in substrate size and composition. To meet this requirement, unconstrained channel types may require structures wider than 1.2 times bankfull or additional flood relief structures. The headwater depth to structure height ratio should not exceed 0.8:1 for 100-year flows in order to allow for additional vertical clearance for wood and sediment transport.

Channel Slope

The structure slope should match an appropriate reference reach of the natural stream (assessed at a minimum of approximately 20-30 times the channel width upstream and 20-30 times the channel width downstream of the site, though a suitable reference reach could be located further upstream or downstream). The maximum slope should not exceed 3.5 percent because of difficulties in retaining substrate within the structure at higher gradients, increasing both costs and design complexity. Bridges do not have a maximum slope range.

Embedment

If a culvert is used, the bottom of the culvert should be buried into the streambed not less than 2 feet or 20 percent of the culvert height beyond 2 feet.

Elevation

For open-bottomed structures, the footings or foundation should be designed to be stable for the maximum scour depth. The structure should also provide a low flow channel.

Substrate

Material in structures should match the natural stream channel. Bed materials should match natural stream bed mobility characteristics. Bank and other key bed structural elements (e.g. steps, weirs, ribs, etc.) should be stable at the 100-year flow.

Geotechnical analysis

Structure design and construction methods may be influenced by soil composition and subsurface conditions including, but not limited to, the presence of bedrock and clay. The need for geotechnical analysis is determined on a project-specific basis and is not always necessary.

These recommendations promote the use of the U.S. Forest Service's Stream Simulation approach for designing road-stream crossings, an approach which our agencies have successfully used on previous projects to support recovery of anadromous and catadromous fishes by restoring stream habitat.

***Specific Conditions for Road-Stream Crossings*:**

A. Bridge and Culvert Repair, Replacement, or Upgrade to a Higher Preference Order

All bridge and culvert projects should follow the guidelines below and the General Conditions in D. General design drawings and recommendations are shown in Appendix A. Stream crossing structures are listed in order of preference from 1 (most preferred) to 4 (least preferred). Bridges that fully span the stream and have no in-stream pilings are preferred over other crossing types and should be used whenever possible as they minimize impacts to listed species and critical habitat, and reduce the need for future repairs.

Order of Preference	Structure	Project Description	Conditions
N/A	Bridge	Repair/ reinforcement	Follow the General Conditions listed in D. below.
		Repair/reinforcement with new rip rap	*Placement of new rip rap in-stream should be consulted on with the Service on a case-by-case basis for specific recommendations.*
1	Bridge – no in-stream pilings	Replacement or upgrade	1) Remove all remnants of the damaged structure from the stream channel and dispose of in an off-site disposal area. 2) Follow the General Conditions listed in D. below.
2	Bridge – with in-stream pilings	Replacement or upgrade	*All bridge replacements and upgrades that require in-stream supports should be consulted on with the Service on a case- by-case basis for specific recommendations.*
3	Culvert – bottomless	Replacement or upgrade	1) Culvert width should be 1.2 times bankfull width. 2) Multiple culverts are needed when the maximum culvert width available is reached, but bankfull width has not been reached. 3) Culvert slope should match channel grade. 4) It is recommended that floodplain relief drains be installed in road approaches.
4	Culvert – box, elliptical or round (in order of preference for minimization of impacts)	Replacement	1) Culvert width should be 1.2 times bankfull width. 2) Culvert should be counter sunk below substrate to a depth of 20% of the culvert diameter (round) or rise (elliptical, box). 3) Multiple culverts are needed when the maximum culvert width available is reached, but bankfull width has not been reached. 4) Culvert slope should match channel grade. 5) It is recommended that floodplain relief drains be installed in road approaches.

B. Demolition and Removal of Damaged Structures

- Conduct activities in a manner that minimizes disturbance to the stream bottom and banks.
- The structure should be lifted or floated out of the stream, not dragged on the bottom.
- Wooden pilings should be cut or pinched off at the substrate level.

- Remove all remnants of the damaged structure from the stream channel and dispose of in an off-site disposal area.
- In addition, follow the General Conditions listed in D. below.

C. Debris Removal

- When feasible and safe, natural woody debris should remain in the stream.
- Conduct activities in a manner that minimizes disturbance to the stream bottom and banks.
- Debris should be lifted or floated out of the stream, not dragged on the bottom.
- In addition, follow the General Conditions listed in D. below.

D. General Conditions for all Projects

1. Keep in-stream work to a minimum.

2. Conduct work activities from atop a stable streambank or reinforced platform, when feasible, and in a manner that does not degrade or destabilize the streambank.

3. Install erosion and sediment control devices before any work is performed, and closely monitor and maintain for the life of the construction project. Implement the appropriate best management practices for preventing and minimizing erosion and sediment outlined in the following manuals: *Florida Stormwater, Erosion, and Sediment Control Inspector's Manual* (July 2008), and *State of Florida Erosion and Sediment Control Designer and Reviewer Manual* (July 2007).

4. Keep land clearing to the minimum level necessary for project completion. Stream bank vegetation should be left intact to the extent practicable. Cutting vegetation is preferred to root grubbing near streams.

5. Cover disturbed areas with erosion controls mats and revegetated promptly with native grasses.

6. Locate debris collection sites, borrow sites, fill dirt stockpiles, and equipment staging areas at least 200 feet from stream channels to minimize the potential of sediments and contaminants entering the waterway.

E. Low Water Crossings-Fords

1. All recommendations for Low Water Crossings-Fords can be found in the U.S. Forest Service Publications Number 0625 1808—SDTDC Titled "Low-Water Crossings: Geomorphic, Biological, and Engineering Design Considerations".

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Appendix A
General Design Drawings for Fish Passage Structures

BID SET No. _____

PROJECT OWNER

CONTRACT DRAWINGS FOR

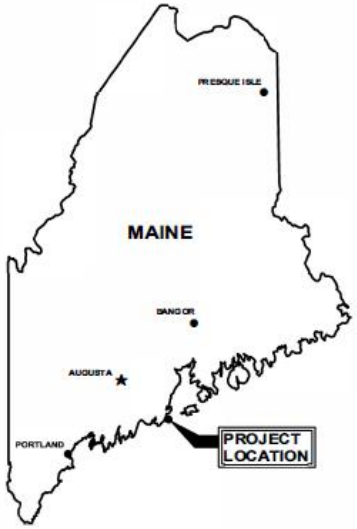
PROJECT NAME

ANYTOWN, ME

MONTH YEAR

NOTE

This set of plans is meant to portray an example of final construction drawings only, and must be accompanied by sufficient additional documentation of site conditioins to satisfy the need for the Programmatic Notification Form. That documentation would include elements such as stream profile, cross-section(s), substrate characterization, hydrology and hydaulics analysis.



DRAWING NO.	TITLE
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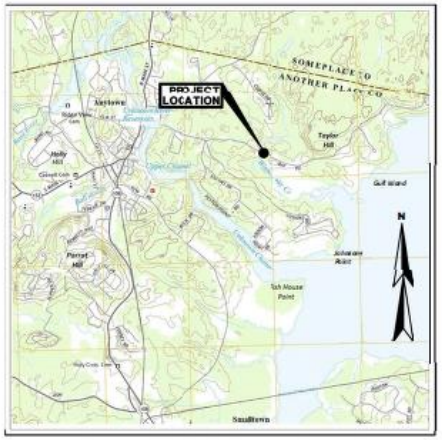
C-1 A & B	EXISTING AND PROPOSED PLANS AND SECTIONS
C-2	ROADWAY PLAN AND PROFILE
C-3	TEMPORARY WATER CONTROL PLAN



LOCATION PLAN
SCALE: NTS

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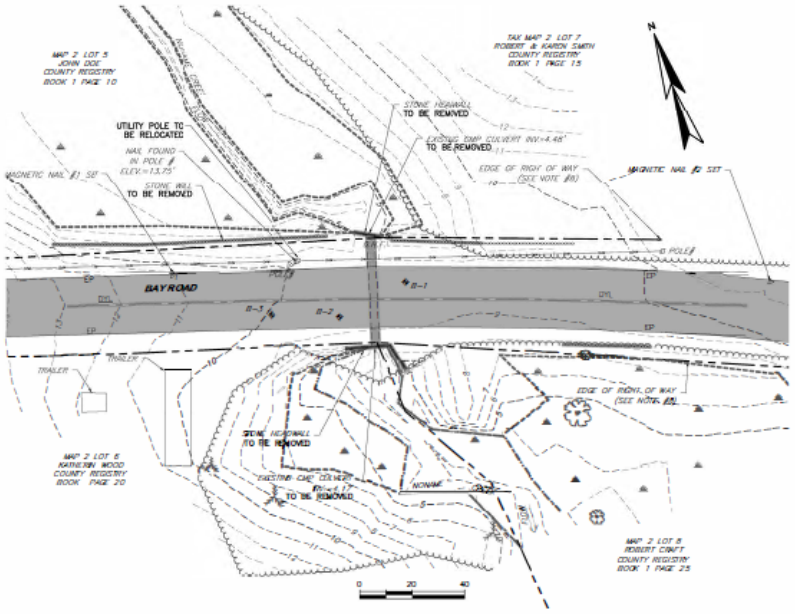
FOR REVIEW _____

FOR BIDDING _____

WP PROJECT NO. XXXXX



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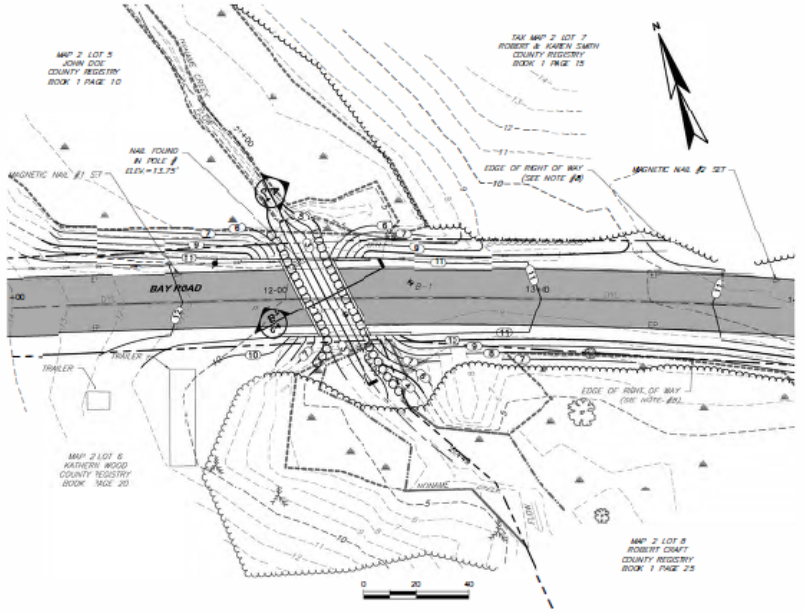

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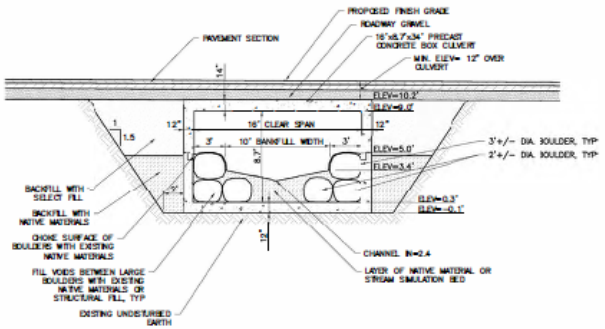

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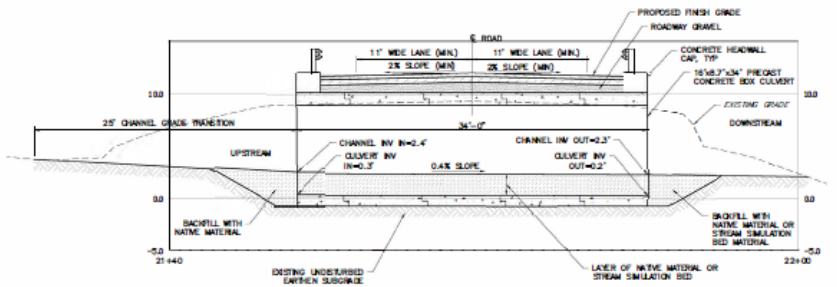

SECTION A-A
SCALES:
VERT: 1"=5'
HORIZ:1"=5'

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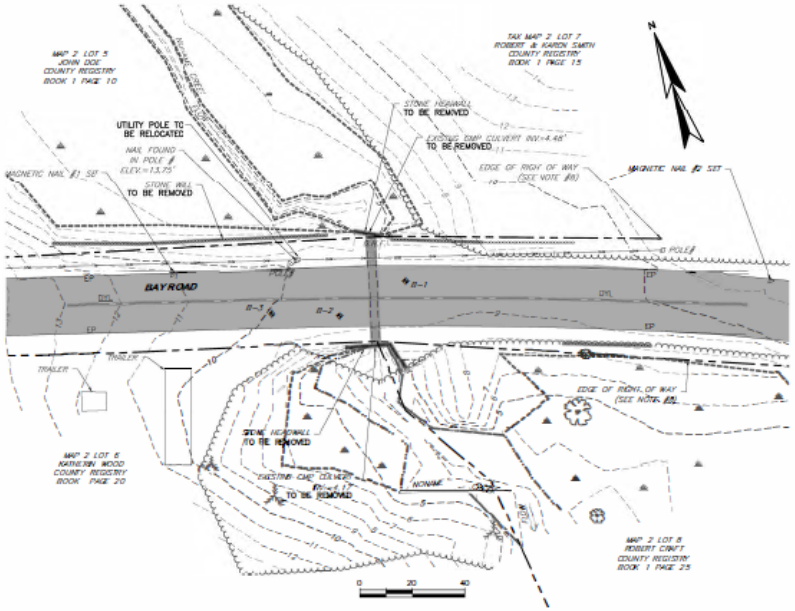
PROJECT OWNER
PROJECT NAME
PROJECT LOCATION
OPTION A

EXISTING AND PROPOSED PLANS AND SECTIONS

DRAWING
C–1A



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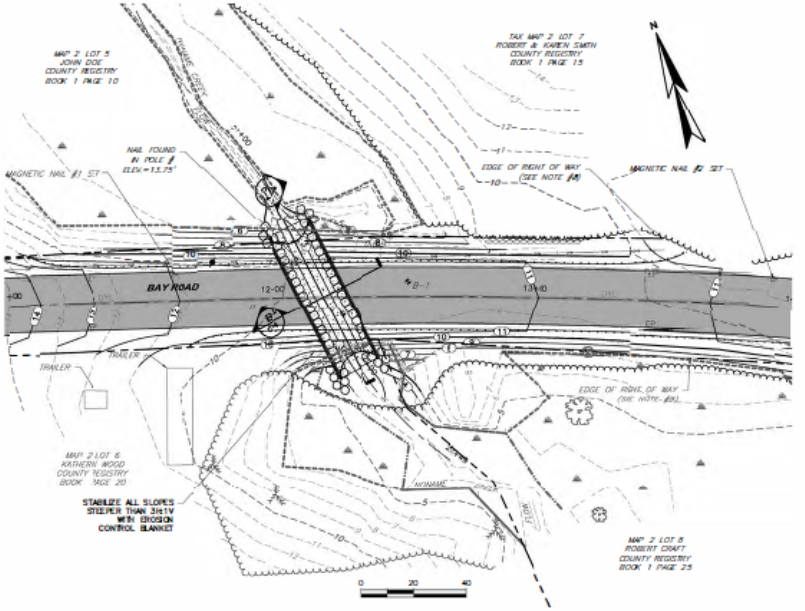

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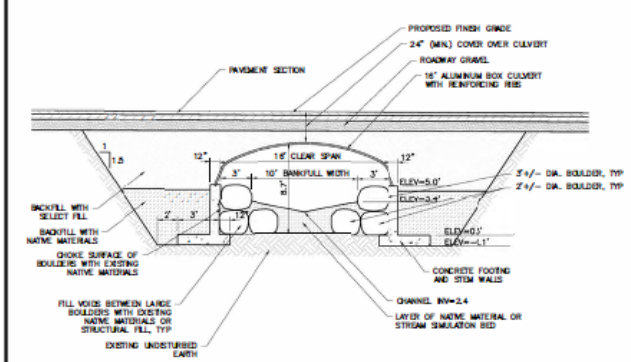

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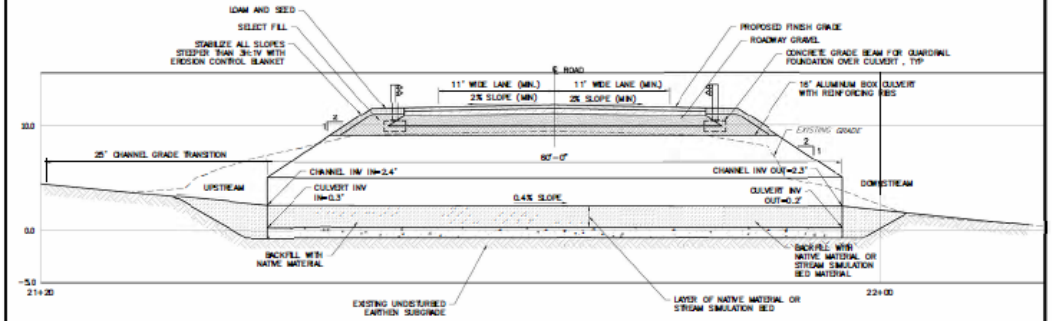

SECTION A-A
SCALES
VERT: 1"=5'
HORIZ:1"=5'

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PROJECT OWNER
PROJECT NAME
PROJECT LOCATION
OPTION B

EXISTING AND PROPOSED PLANS AND SECTIONS

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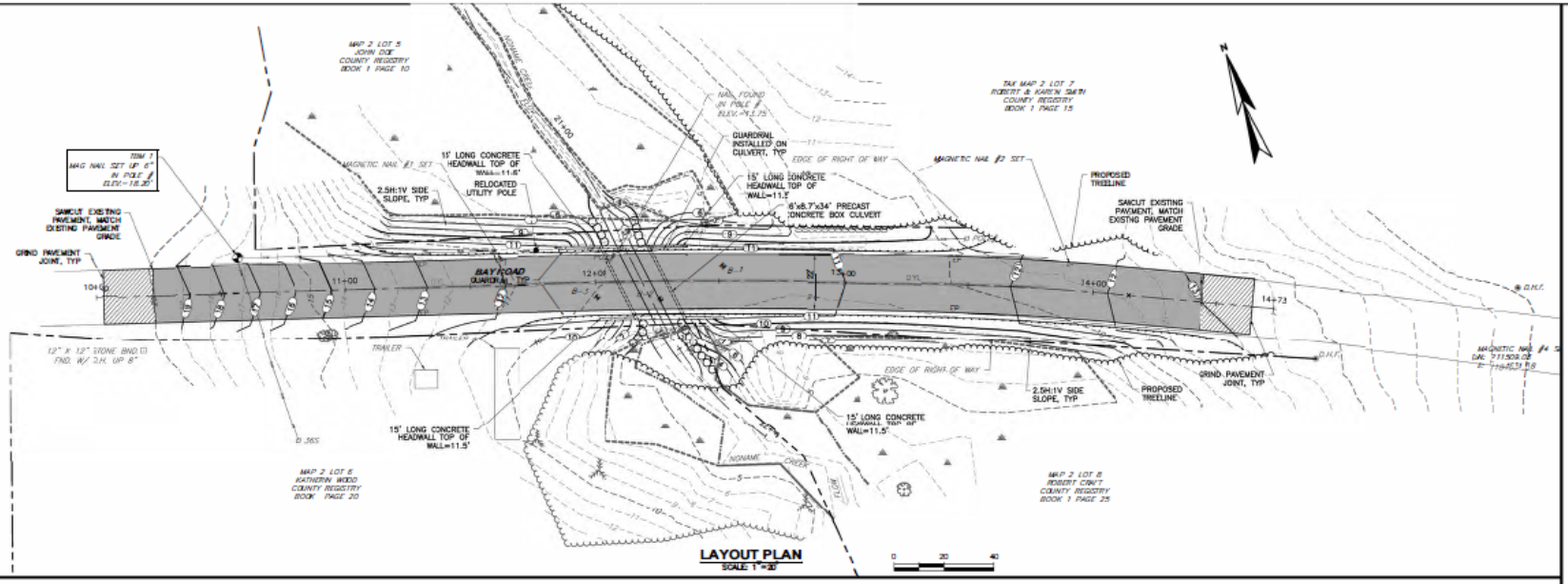
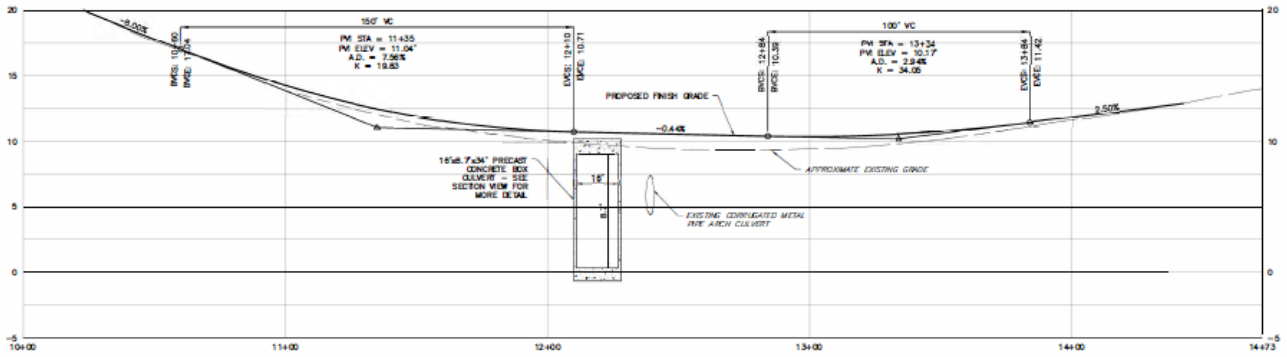
C-1B





BAY ROAD PROFILE

SCALES:
VERT: 1"=2'
HORIZ:1"=20'

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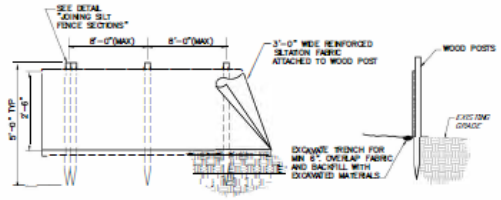
PROJECT OWNER
PROJECT NAME
PROJECT LOCATION

PLAN AND PROFILE

DRAWING
C–2



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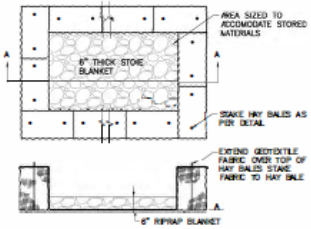

TEMPORARY HAY BALE SEDIMENT BASIN
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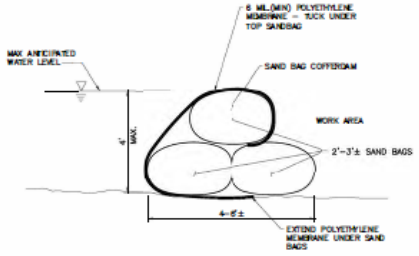


SAND BAG COFFER DAM
SCALE: "NTS"

CONSTRUCTION SEQUENCING:

1. INSTALL APPLICABLE UPLAND EROSION AND SEDIMENTATION CONTROLS AT THE SITE.
2. MOBILIZE APPLICABLE EQUIPMENT AND MATERIALS
3. COMMENCE TREE CLEARING, STUMPING AND GRUBBING. WORK MAY NOT OCCUR WITHIN THE WATERBODY UNTIL AFTER JULY 15 OR AS SPECIFIED IN THE PERMIT.
4. COORDINATE TRAFFIC CONTROL PLAN WITH THE ENGINEER AND APPLICABLE AUTHORITIES (PUBLIC WORKS, MDOT OR OTHERWISE).

PHASE "A" TO COMMENCE AFTER JULY 15:

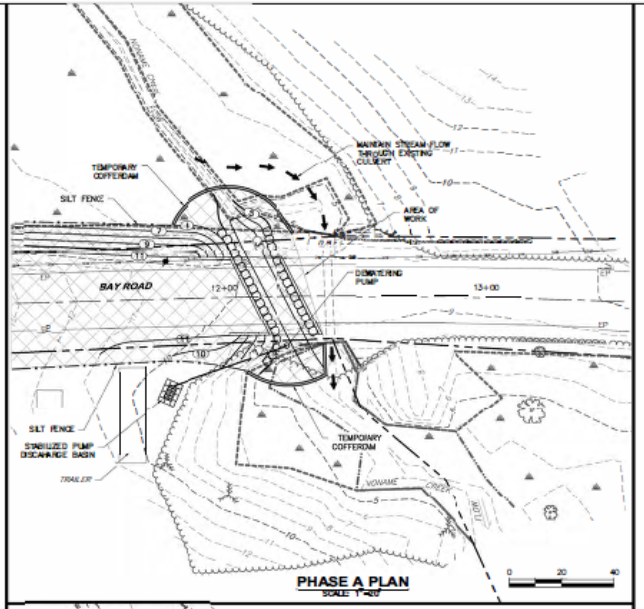
1. COMMENCE CLOSURE OF THE ROADWAY TO VEHICULAR TRAFFIC.
2. INSTALL UPSTREAM AND DOWNSTREAM COFFERDAMS.
3. MAINTAIN BYPASS FLOWS THROUGH THE EXISTING CULVERT. AT NO TIME DURING CONSTRUCTION SHALL FLOW BE BLOCKED COMPLETELY. A MINIMUM AQUATIC BASEFLOW SHALL BE BYPASSED AT ALL TIMES, AS DETERMINED BY THE PERMITTING AUTHORITIES AND AS DIRECTED BY THE ENGINEER.
4. INSTALL WORK ZONE DEWATERING SYSTEM. ENSURE THAT DEWATERING DISCHARGES ARE DIRECTED TO AN STABILIZED DISCHARGE AREA IN AN APPROVED UPLAND LOCATION. COORDINATE THE EXACT LOCATION AND BMPS TO BE UTILIZED WITH THE ENGINEER.
5. COMMENCE REMOVAL OF PAVEMENT AND EXCAVATION TO SUBGRADE FOR THE NEW CULVERT.
6. MAINTAIN THE DEWATERING SYSTEM AS NEEDED TO ENSURE THAT WORK OCCURS IN THE DRY. MAINTAIN ALL ASSOCIATED DEWATERING BMPS AS NEEDED TO MEET THE REQUIREMENTS OF THE PERMIT AS DIRECTED BY THE ENGINEER.
7. STOCKPILE NATIVE STREAM MATERIALS FOR REUSE AS BACKFILL. COORDINATE STOCKPILE LOCATION WITH THE ENGINEER AND PROVIDE APPROPRIATE EROSION AND SEDIMENTATION CONTROL BMPS AROUND THE STOCKPILE AREA.
8. PROOFROLL OR OTHERWISE PREPARE THE UNDISTURBED SUBGRADE FOR CULVERT PLACEMENT.
9. COMMENCE INSTALLATION OF LOWER BOX CULVERT SECTIONS.
10. COMMENCE INSTALLATION OF STREAM BANK BOULDERS TO THE LINES AND GRADES SHOWN ON THE PLANS.
11. FILL AREAS WITHIN THE CULVERT WITH NATIVE STREAM BED MATERIALS TO THE LINES AND GRADES SHOWN ON THE PLANS
12. FILL VOIDS WITHIN THE STREAM BANK BOULDERS BY CHOKING THE INTERSTITIAL SPACES WITH NATIVE STREAM BED MATERIAL.
13. COMPLETE INSTALLTION OF LOWER BOX CULVERT SECTIONS.
14. COMPLETE INSTALLATION OF STREAM BANK BOULDERS WITHIN THE PHASE A WORK AREA.
15. COMPLETE BACKFILLING OF CULVERT WITH NATIVE STREAM BANK MATERIAL.
16. COMMENCE INSTALLTION OF UPPER BOX CULVERT SECTIONS.
17. COMMENCE INSTALLATION OF HEADWALL AND WINGWALL STRUCTURES WITHIN THE PHASE A WORK AREA
18. COMMENCE FILLING AND BACKFILLING OF BOX CULVERT AND HADWALL/WINGWALLS STRUCTURES TO EMBANKMENT GRADES AND ROADWAY SUBGRADE.
19. MAINTAIN APPROPRIATE EROSION AND SEDIMENTATION CONTROLS, SUCH AS SILT FENCING AROUND THE PERIMETER OF ALL DISTURBED AREAS.
20. PERMANENTLY STABILIZE EMBANKMENT SLOPES WITHIN THE PHASE A WORK AREA.
21. COMMENCE REMOVAL OF PHASE A DEWATERING SYSTEM
22. COMMENCE REMOVAL OF PHASE A COFFER DAMS.
23. DIRECT STREAM FLOW THROUGH THE CONSTRUCTED STREAM BED AND BOX CULVERT
24. TEMPORARILY STABILIZE ANY OTHER REMAINING LOCATIONS WITHIN THE PHASE A WORK AREA.

PHASE "B" TO BE COMPLETED BEFORE SEPTEMBER 30:

1. MAINTAIN ROADWAY CLOSURE IN CONFORMANCE WITH THE TRAFFIC CONTROL PLAN.
2. INSTALL UPSTREAM AND DOWNSTREAM COFFERDAMS.
3. MAINTAIN FLOWS THROUGH THE NEW CULVERT. AT NO TIME DURING CONSTRUCTION SHALL FLOW BE BLOCKED COMPLETELY. A MINIMUM AQUATIC BASEFLOW SHALL BE BYPASSED AT ALL TIMES, AS DETERMINED BY THE PERMITTING AUTHORITIES AND AS DIRECTED BY THE ENGINEER.
4. INSTALL WORK ZONE DEWATERING SYSTEM. ENSURE THAT DEWATERING DISCHARGES ARE DIRECTED TO AN STABILIZED DISCHARGE AREA IN AN APPROVED UPLAND LOCATION. COORDINATE THE EXACT LOCATION AND BMPS TO BE UTILIZED WITH THE ENGINEER.
5. COMMENCE REMOVAL OF PAVEMENT AND EXCAVATION TO REMOVE THE EXISTING CULVERT.
6. COMPLETE REMOVAL OF THE EXITING CULVERT.
7. COMMENCE EXCAVATION TO SUBGRADE FOR REMAINING STREAM BANK BOULDERS
8. COMMENCE INSTALLATION OF REMAINING STREAM BANK BOULDERS.
9. COMPLETE STREAM BANK BOULDER INSTALLATION AND FILL VOIDS WITH BETWEEN THE STREAM BANK BOULDERS WITH NATIVE MATERIALS.
10. COMMENCE INSTALLTION OF REMAINING HEADWALL AND WINGWALL STRUCTURES
11. COMMENCE BACKFILL OF THE HEADWALL/WINGWALLS.
12. PLACE FILL AND BACKFILL TO EMBANKMENT GRADES AND ROADWAY SUBGRADE.
13. PERMENANTLY STABILIZE ALL EMBANKMENTS WITHIN THE PHASE B WORK AREA.
14. COMMENCE REMOVAL OF PHASE B DEWATERING SYSTEMS.
15. COMMENCE REMOVAL OF PHASE B COFFER DAMS.
16. COMPLETE PHASE B WORK AND ALL WORK WITHIN THE WATER OR WETLANDS.

WORK TO BE COMPLETED AFTE R PHASE B:

1. COMMENCE INSTALLATION OF ROADWAY GRAVELS
2. COMMENCE INSTALLATION OF BINDER PAVEMENT
3. COMMENCE INSTALLATION OF ROADWAY AND TRAFFIC CONTROL DEVICES, SUCH AS GUARDRAIL AS INDICATED ON THE PLANS.
4. COMPLETE PERMENANT STABILIZATION ON ALL AREAS DISTURBED BY CONSTRUCTION. ALL AREAS NOT RECEIVING STRUCTURAL STABILIZATION MEASURES SHALL BE PERMENENTLY STABILIZED WITH LOAM, SEED, AND MULCH. EROSION CONTROL BLANKETS MAY ALSO BE REQUIRED DEPENDING ON TIME OF YEAR AND
5. COMMENCE AND COMPLETE INSTALLATION OF FINAL PAVING
6. IN CONFORMANCE WITH THE TRAFFIC CONTROL PLAN, REPOEN THE ROADWAY TO VEHICULAR TRAFFIC. COORDINATE REOPENING WITH THE APPROPRIATE AUTHORITY (PUBLIC WORKS, MDOT, ETC.) AND THE ENGINEER.
7. COMPLETE ALL PERMENANT STABILIZATION.
8. DEMOBILIZE REMAINING EQUIPMENT AND MATERIALS FROM THE PROJECT AREA
9. REMOVE REMAINING EROSION AND SEDIMENTATION CONTROLS.



PHASE A PLAN
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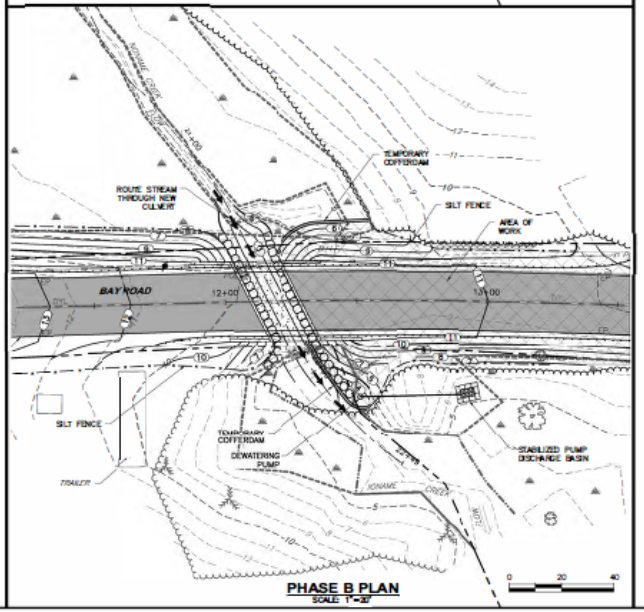

PHASE B PLAN
SCALE: 1"=20'

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PROJECT OWNER
PROJECT NAME
PROJECT LOCATION

TEMPORARY WATER CONTROL PLAN

DRAWING
C–3