Appendix L
Structural Engineering

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1 OAKWOOD BOTTOMS GREENTREE RESERVOIR EXISTING WATER CONTROL STRUCTURES

1.1 General

The Oakwood Bottoms HREP focuses on the 4,700 acres of the Oakwood Bottoms Greentree Reservoir (OBGTR). Currently, the OBGTR consists of 33 management units that are managed with various types of water control structures. There are a total of 115 existing structures including 47 stop log structures, 11 open flow culverts, 25 slide gates, 11 flap gates, 9 gatewells/gravity drains and 12 well pumps. Well pumps are discussed in detail in Appendix B – Civil Engineering. Photos included in this section are all from existing water control structures in the OBGTR inventory.

This appendix provides information on the structural engineering aspects of the water control structures including design considerations and assumptions for reinforced concrete stop log risers, headwalls, flared end walls (or wingwalls) and pump station.

1.1.1 Stop Log Structures

Stop log structures are designed to manage and control the water depths between management units. Stop logs are typically long rectangular beams or boards that are placed on top of each other into a frame or recess slots. The process of adding and removing stop logs is currently done manually by reservoir personnel. Existing stop log structures vary in type from corrugated metal pipes and risers with aluminum boards to concrete headwalls and end walls with timber boards. Pipe risers also vary in size, but the majority are 2 to 3-foot diameter pipes. Photos 1-5 show existing stop log structures.

Photo 1 Stop log risers with wood planks cap

Photo 2 Stop log riser with metal cap

Photo 3 Stop log-slide gate combination water control structure

Photo 4 Concrete stop log headwall structure

Photo 5 Concrete stop log headwall structure with metal mesh and wood boards in place

1.1.2 Open Flow Culverts

Existing open flow culverts include corrugated metal pipes (CMP) (Photo 6) and reinforced concrete box culverts. Problems with beavers have led the sponsors to build improvised mesh guards in the inlets/outlets to avoid beaver dams and the accumulation of trash and debris in the culverts. The addition of removable steel trash racks in the inlet/outlet headwalls will be considered during PED to mitigate this issue.

Photo 6 Open corrugated metal pipe culvert with mesh guard box

Photo 7 Damaged corrugated metal pipe

Open CMP culverts like the one shown in Photo 7, are prone to damage during regular maintenance operations. The Forest Service has reported issues with the ends of them being collapsed due to mowers and other maintenance equipment running over the ends. Design considerations to reduce potential damage during operation and maintenance include, but are not limited to marking the end of the pipe so they do not get run over during routine maintenance mowing, use of round concrete pipe, the addition of a concrete headwall and wingwall structures (inlet/outlet structures) attached to the pipe opening, and properly compacted soil and rip rap surrounding the top of pipe and inlet/outlet structures.

1.1.3 Slide Gate Structures

Slide gate structures are also used to control water flows from one management unit to the other. They are typically installed either directly on the culvert inlet opening or bolted to a concrete headwall. Many of the slide gates in the OBGTR are installed directly on the inlet openings or on the face of wooden access walkway bridges as shown in Photos 8-10.

Photo 8 Walkway bridge access to slide gate control structure

Photo 9 Slide gate mounted directly on pipe

Photo 10 Slide gate valve

1.1.4 Flap Gates

Flap gates permit the free flow of water from a pipe or structure while preventing and sealing against backflow. They are typically installed on the outlet side of concrete or corrugated metal pipes or headwalls. Some of the existing flap gates are shown in Photos 11 and 12.

Photo 11 Closed flap gate

Photo 12 Fully-open flap gate showing underside of leaf

1.1.5 Gatewells or Gravity Drains

Gatewells or gravity drains are water control structures in which a manually operated sluice gate installed on the inlet tower allows flow of water from the river to the leveed protected area and vice versa. The inlet tower can be just a headwall or a vertical box structure. In the case of the OBGTR, the gatewells and gated headwalls are found along the Grand Tower Levee and are operated by the Grand Tower Levee District. No actions are being considered for these structures. Photos 13-15 show some of the existing gatewell structures.

Photo 13 Concrete gatewell on the adjacent Levee

Photo 14 Concrete headwall structure on the Grand Tower Levee

Photo 15 Slide gates installed on concrete headwall structure on the existing adjacent levee

1.1.6 Well Pumps

There are 11 existing well pumps which provide water input to the management units. Additional well pumps will be constructed to provide the needed water supply to fill the management units in an acceptable time frame. See the Civil, Mechanical and Electrical Appendices for more details.

2 NEW PROPOSED WATER CONTROL STRUCTURES

2.1 General

One of the main objectives of this project is to improve the input and removal of water within the water management subunits. New proposed water control structures will add the proper infrastructure to help achieve this objective. Modifications to the water control structures include three planned actions: complete removal, removal and replacement and new installations. Structures to be completely removed were deemed no longer needed due to berm modifications and subunits layout changes. Undersized structures will be removed and replaced with bigger structures and new structures will be installed in various locations to increase capacity or due to berm modifications and subunits layout changes.

Out of the 115 existing water control structures, there are planned actions on 79 structures. These actions include removing 20 stop log structures and replacing 18 of them with new stop log structures, removing and replacing 9 slide gate structures and removing 6 flap gates. Out of the 8 existing open flow culverts, some will be replaced in the same locations and others will be installed in new locations for a total of 7 new culverts. Actions also include the installation of 1 new pump station and 4 new well pumps. Refer to Appendix B – *Civil Engineering* for more details.

2.1.1 Stop Log Structures

New stop log structures are intended to provide better infrastructure design, easier operations and easier access for maintenance. Stop log units can be made of different materials including wood, aluminum, steel and concrete or a combination of various materials. Stop logs can be manually placed or stacked with a logs lifter (See Figure 1). Stop logs are require to be stored when not in use to avoid weather exposure damage and loss due to theft.

Photos 16 and 17 show two sets of stop logs made of different materials, aluminum and composite fiberglass, respectively. Figure 1 shows a system of stop logs, log lifter and embedded metals for guiding and sealing the logs.

Photo 16 Aluminum stop logs

Photo 17 Composite fiberglass stop logs

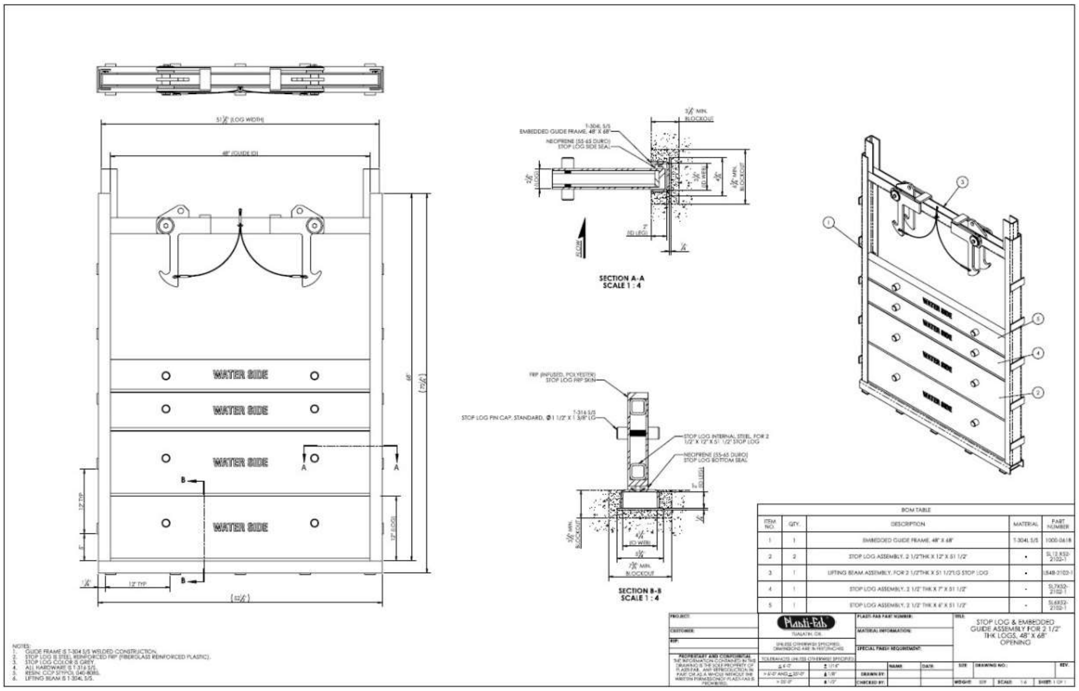

Figure 1 Plastifab® stop log, embedded guide assembly and stop log lifter sample drawing

The recess frames can be installed either on circular riser pipes or box culvert risers as shown in the figures below (Figures 2-5).

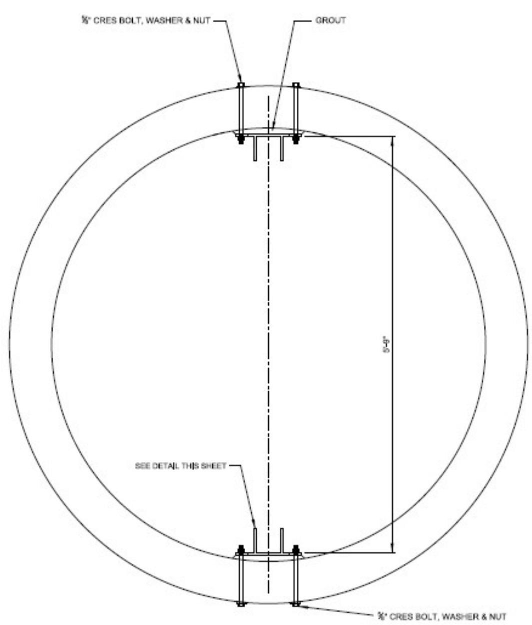

Figure 2 Top view drawing of stop log recesses installation on circular RCP riser

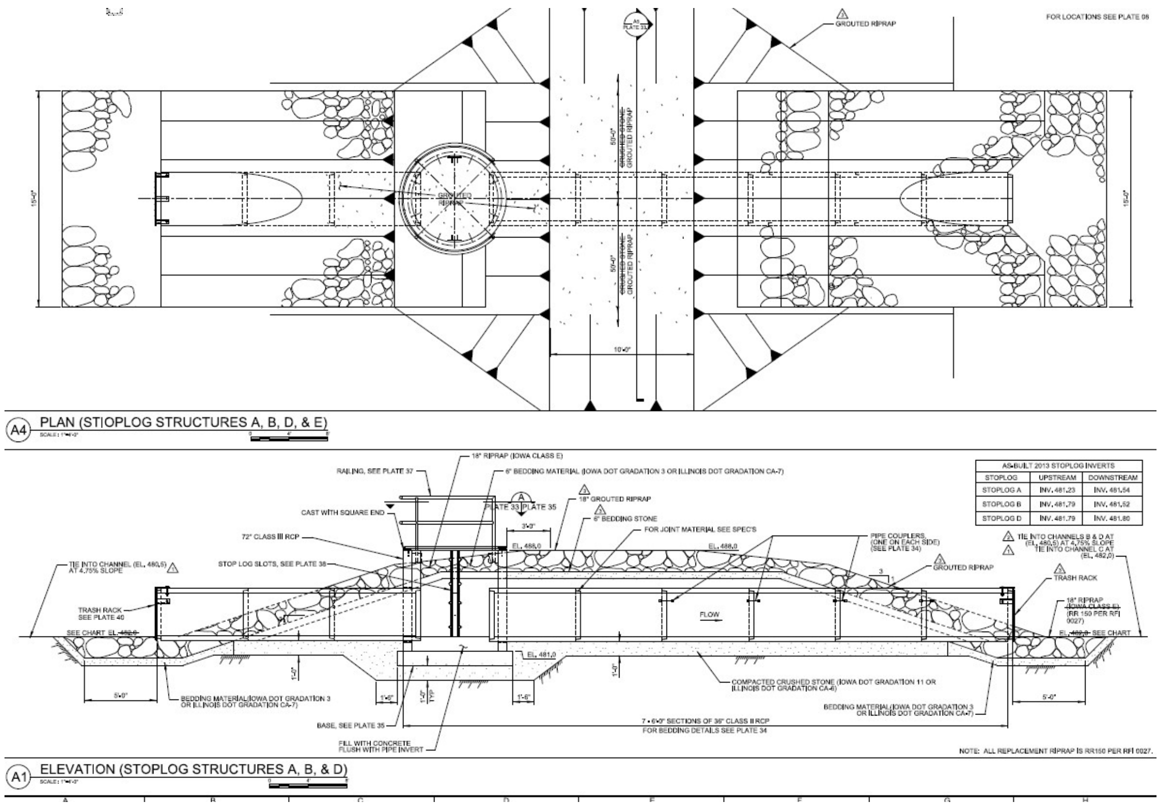

Figure 3 Sample drawing of circular RCP culvert with circular concrete stop log riser

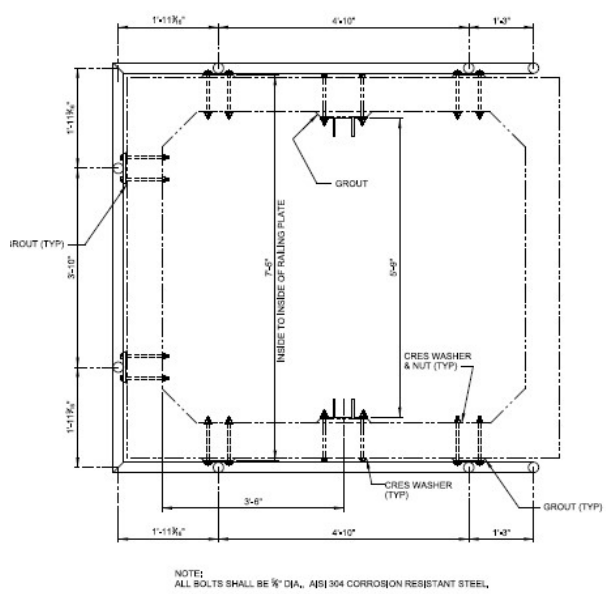

Figure 4 Top view drawing of stop log recesses installation on reinforced concrete box riser

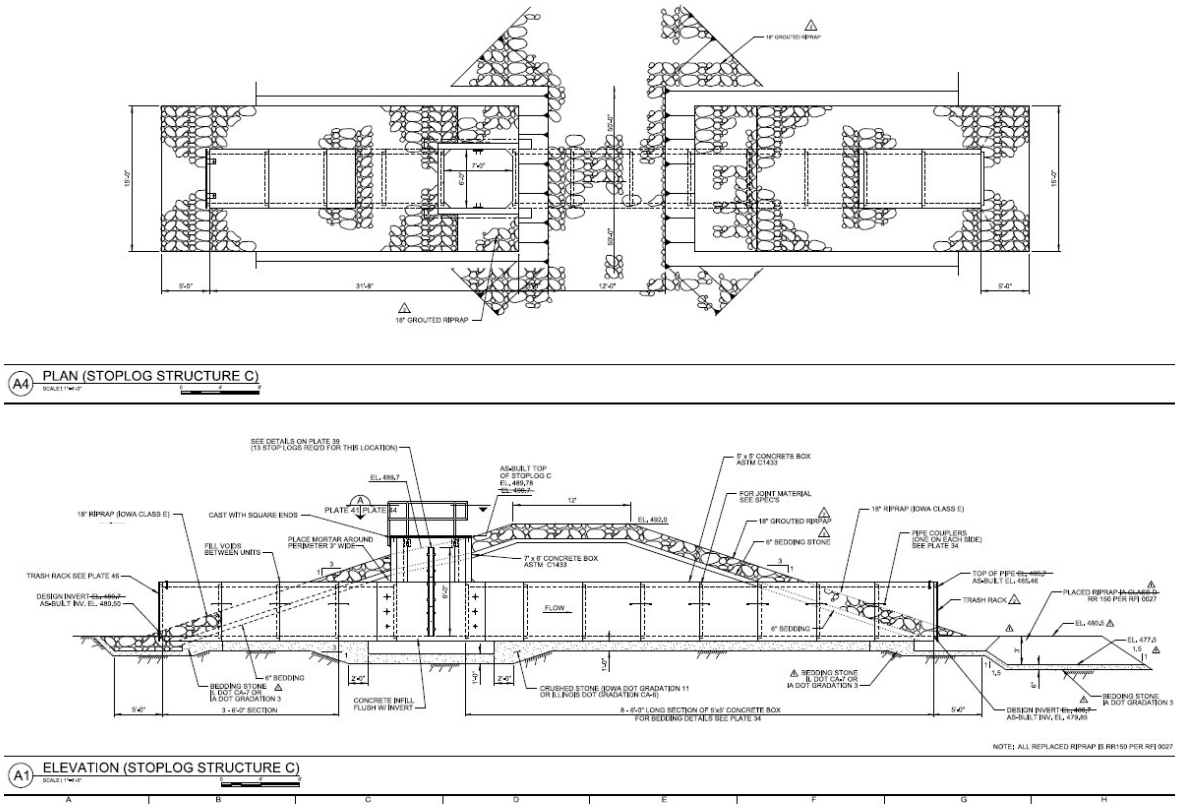

Figure 5 Sample drawing of reinforced concrete box culvert with reinforced concrete box stop log riser

2.1.2 Overshot Gates

An overshot gate provides for water movement and water depth control between two management units. They are known to be an effective replacement to stop logs. These types of gates stay in place after installation and can be manually or automatically controlled with a cable drum hoist. They are typically more expensive than stop log configurations and can require a larger reinforced concrete footprint. However, operational advantages include less travel between storage spaces and structures because the gates remain in place, and potentially less manpower for operation. Sample drawings are shown in Figures 6 and 7.

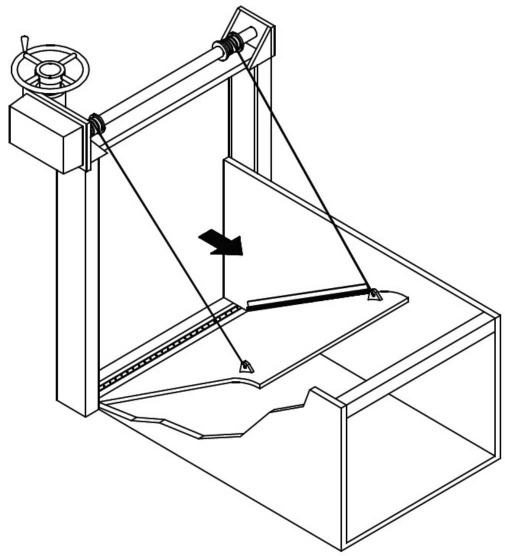

Figure 6 Overshot or tilting weir gate

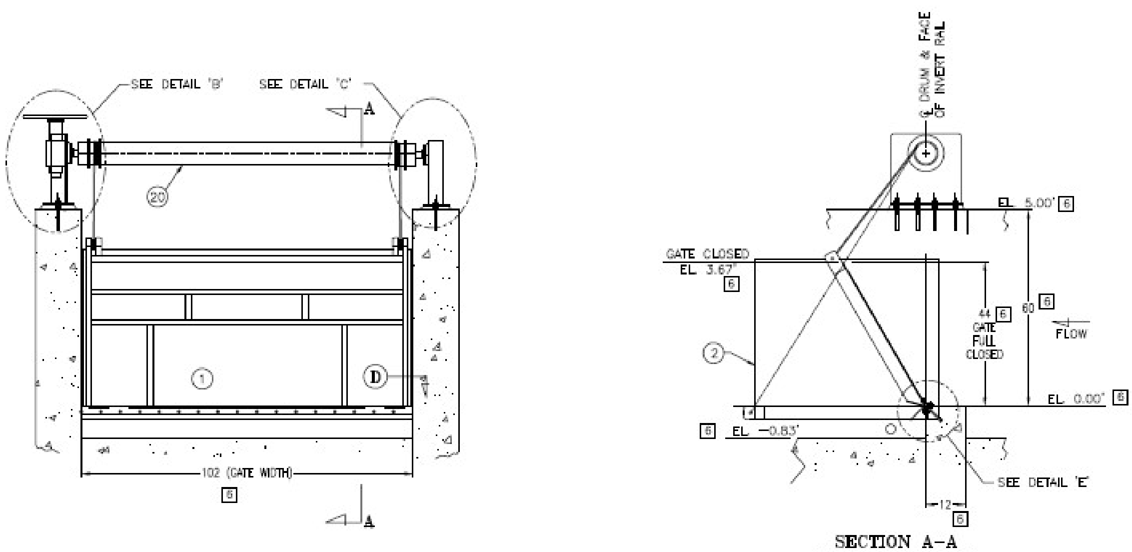

Figure 7 Sample drawing of overshot gate installation

2.1.3 Open Culverts

Open culvert water control structures consist of RCP and flared end sections (Photo 18) with gates, if needed, to control water within the management units. For this report it was assumed concrete pipe would be used due to O&M considerations, unknown soil conditions, and other considerations. All of the existing pipes are corrugated metal and the Forest Service has reported issues with the ends of them being collapsed due to mowers and other maintenance equipment running over the ends. This damage was observed during site visits and it reduces the capacity of the pipes. Reinforced concrete pipes would limit the damage caused by mowers and other equipment. Corrosion of the existing corrugated metal pipes was observed during the site visit which impacts the life span of corrugated metal pipes without the proper coatings. Reinforced concrete pipes are not subject to corrosion and will ensure the pipes last the life of the project if corrosive soils are present. Soil tests can be conducted during PED to determine the corrosiveness of the soil and to determine the appropriate coating to use for corrugated metal pipes. Costs, sponsor preference, soil conditions, and O&M considerations of the pipe materials will be considered during PED. Plastic pipe such as high-density polyethylene (HDPE) will not be utilized due to the controlled burns that are utilized by the Forest Service, given they could potentially melt. The water control structures will be constructed by excavating down to the required grades, placing the pipe and structures, backfilling, and seeding the disturbed areas. Since the reservoir is fairly flat and the berms are not very tall, multiple pipes or the height of the embankment may need to be increased over the top of the pipes to prevent live loads from crushing the pipes. This will be evaluated further during PED.

Hydraulic and soil information is needed to analyze for strength and stability and confirm adequate reinforcement in RCP or reinforced concrete box culverts (Photo 19) as well as foundation requirements to prevent undesirable movement of the elements. If needed, customized RCP or box culvert designs can be calculated.

Photo 18 RCP and headwall/wingwall assembly during construction

Photo 19 Reinforced concrete circular pipe and box culvert

To protect the structures from beaver activity and to alleviate maintenance issues, removable “trash racks” or metal guards can be installed in the culverts’ openings (Photos 20 A & B).

Photo 20 Different removable trash racks installations (A & B)

2.1.4 Slide Gates

Slides gates are typically installed on reinforced concrete headwalls or on monoliths with flared end walls. They can also be installed on the face of a RCP or box culvert, with safe access to the gate operator provided by either by a walkway bridge or a grating platform. There are many types of slide gates that come in different shapes, but all are operated with upward/downward movements. Sluice-type slide gates allow flow through the opening when the leaf is lifted. Weir-type slide gates allow flow through the opening when the leaf is lowered. Only sluice-type gates are being considered for this project. Slide gates can be manually or automatically operated. Structural portions of gate design include details associated with the installation hardware (e.g. blockouts for guide recesses and seal plates, anchorage or support of operators) and design of the reinforced concrete headwalls and flared end walls. Examples of slide gates and their installations are shown in Photos 21 through 24.

Photo 21 Single metal slide gate and frame

Photo 22 Metal slide gate installed on headwall face

Photo 23 Automatic slide gate installed on box culvert opening

Photo 24 Slide gate installed on reinforced concrete headwall structure

2.1.5 Pump Station

A pump station design involves the coordination of many disciplines and can take numerous forms. Pump station infrastructure can consist of a reinforced concrete monolith, a structural steel framework supporting an operating platform, or a sheet pile supported culvert inlet-outlet landing area. Depending on the infrastructure, pumps can be fixed within the station structure or brought to the station as needed. Pumps can be electric or diesel operated. In some cases diesel engines can be brought to the stations as needed to operate the pumps. For stations built within embankments, water can be conveyed into and out of the station by RCPs, concrete box culverts, or mortar-lined steel pipes.

Two primary aspects of the structural design of at pump station are strength and stability. The strength aspect considers the capacity of the structure's individual elements to withstand the loads applied and the stability aspect considers the capability of the structural system as a whole to resist undesirable movement like sliding, overturning, flotation and bearing. For a reinforced concrete station, the strength aspect is covered in the reinforced concrete design of the plant building or platform, depending on the layout, and the inlet and outlet structures. The plant building includes chamber and sump walls, beams, etc. The design of inlet and outlet structures include forebay, headwalls and flared end walls. The stability aspect of the design is analyzed using the weight of the structure versus the load combinations applied and the limits of the bearing capacity of the foundation materials.

Other designs include trash racks and miscellaneous metals (see section 2.1.6).

Reinforced concrete designs are dependent on hydraulic needs and soil information obtained from the area, as well as operation and maintenance considerations.

Sample pump station and inlet/outlet structures section drawings are shown in Figures 8 through 11.

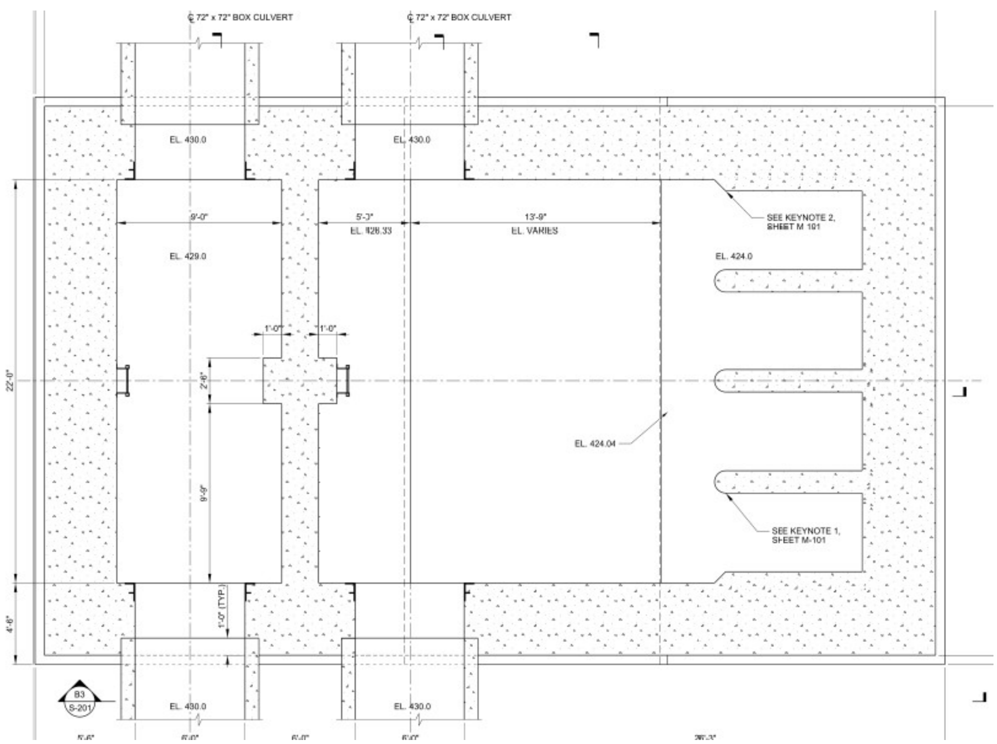

Figure 8 Sample drawing of section view of a pump station

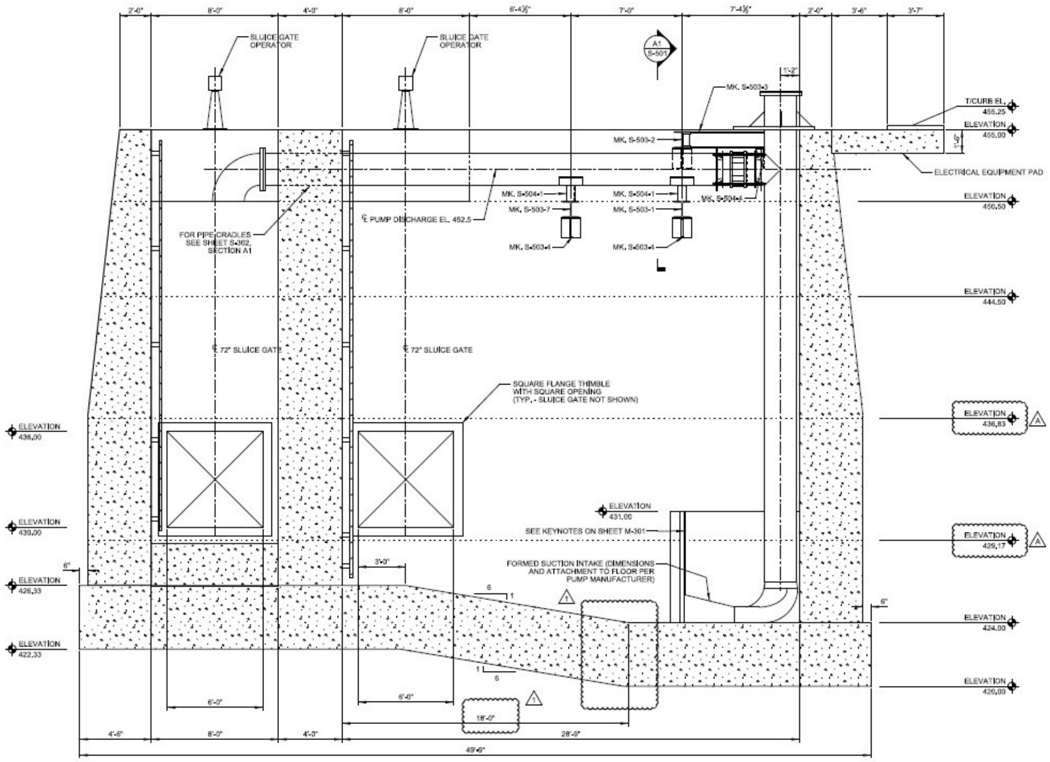

Figure 9 Sample drawing of section view of a pump station

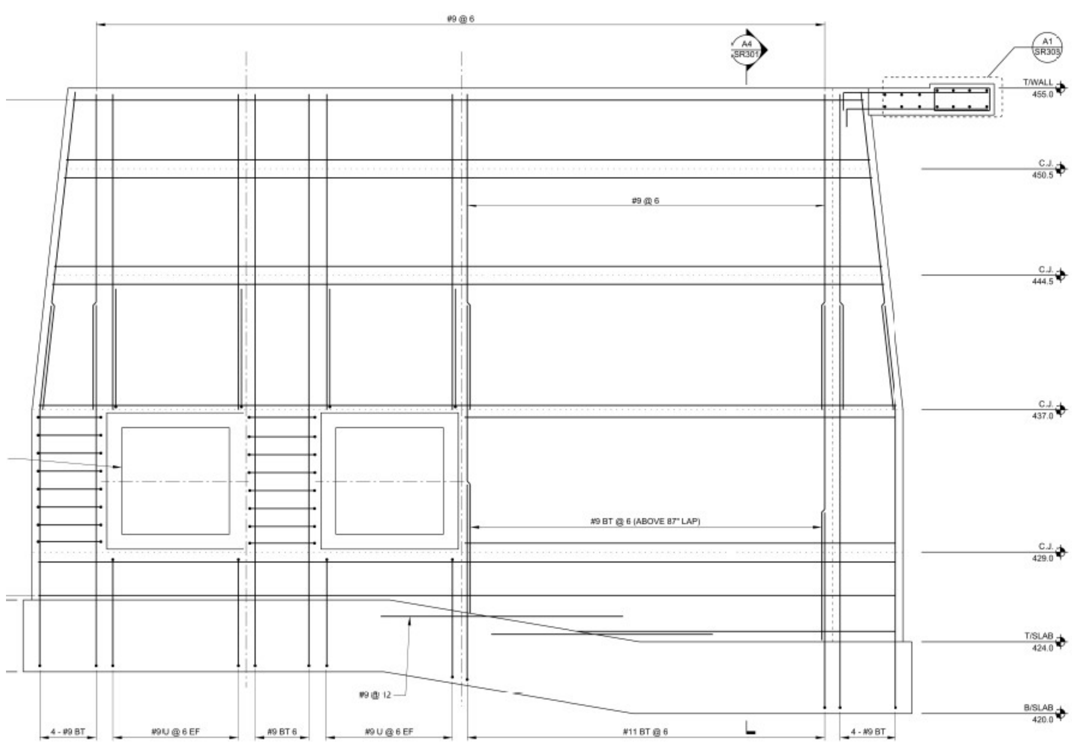

Figure 10 Sample drawing with reinforcement details of a pump station

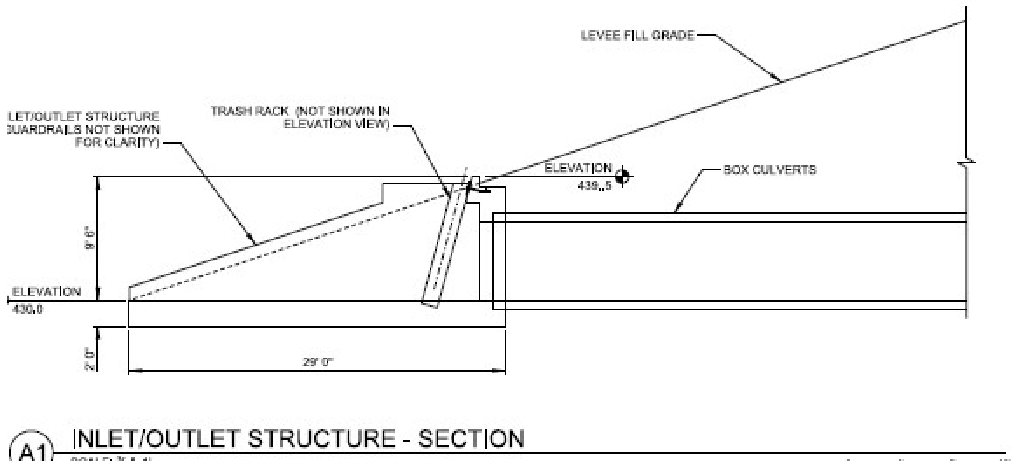

Figure 11 Sample drawing of inlet/outlet structure (applicable to pump station and gravity drains)

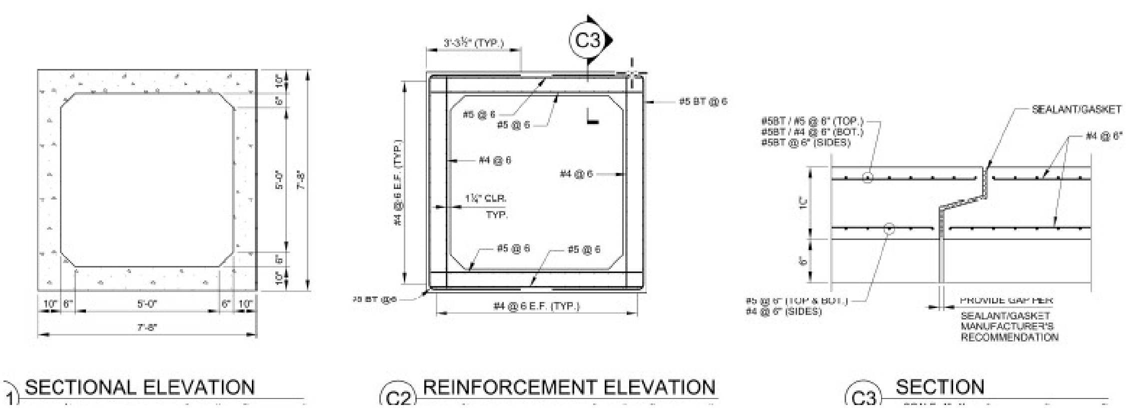

Figure 12 Sample drawings of different sections and details of a reinforced concrete box culvert

2.1.6 Miscellaneous Metals and FRP Items

The structural design of miscellaneous metals and fiberglass-reinforced plastic (FRP) includes guardrails, ladders, gratings, pump support beams, staff gages, installation hardware and others. Typical guardrail, rungs and grating installation are shown in Photos 25 through 27.

Photo 25 Typical guardrail on headwall structure

Photo 26 Typical guardrail and rungs on headwall structure

Photo 27 Example of metal grating on top of gatewell structure

2.2 Assumptions

The following assumptions were made in order to calculate the reinforced concrete quantity of the stop log risers. See Figure 13 for stop log riser sketch.

Riser dimensions (H x W) = 5 ft x 5 ft

Wall thickness = 1 ft (conservative)

Top opening for Stop Logs access = 3 ft x 3 ft

Base dimensions (H x W) = 6 ft x 6 ft

Base thickness = 1 ft – 4 in

Wall openings for in/out RC box culvert pipes = 2 ft x 2 ft

Width from corner of wall to edge of culvert opening = 1 ft

Average fill above culvert pipes = 2 ft

“Freeboard” height between top of fill and top of riser = 1 ft

Out of the 34 new proposed control structures, 19 are stop log structures.

Riser walls = (1ft x 5ft x 5ft x 2) + (3ft x 5ft x 1ft x 2) = 80 cf.

Base = 1.33ft x 6ft x 6ft = 48 cf.

Culvert openings = -(2ft x 2ft x 1ft x 2) = -8 cf.

Net Volume of 1 riser structure = 120 cf.

Net Volume 19 risers = 120 cf. x 19 risers = 2,280 cf. of concrete

General quantities for RCPs, box culverts, headwalls, and flared end sections are included in Appendix B - Civil Engineering and costs have been assumed and accounted for.

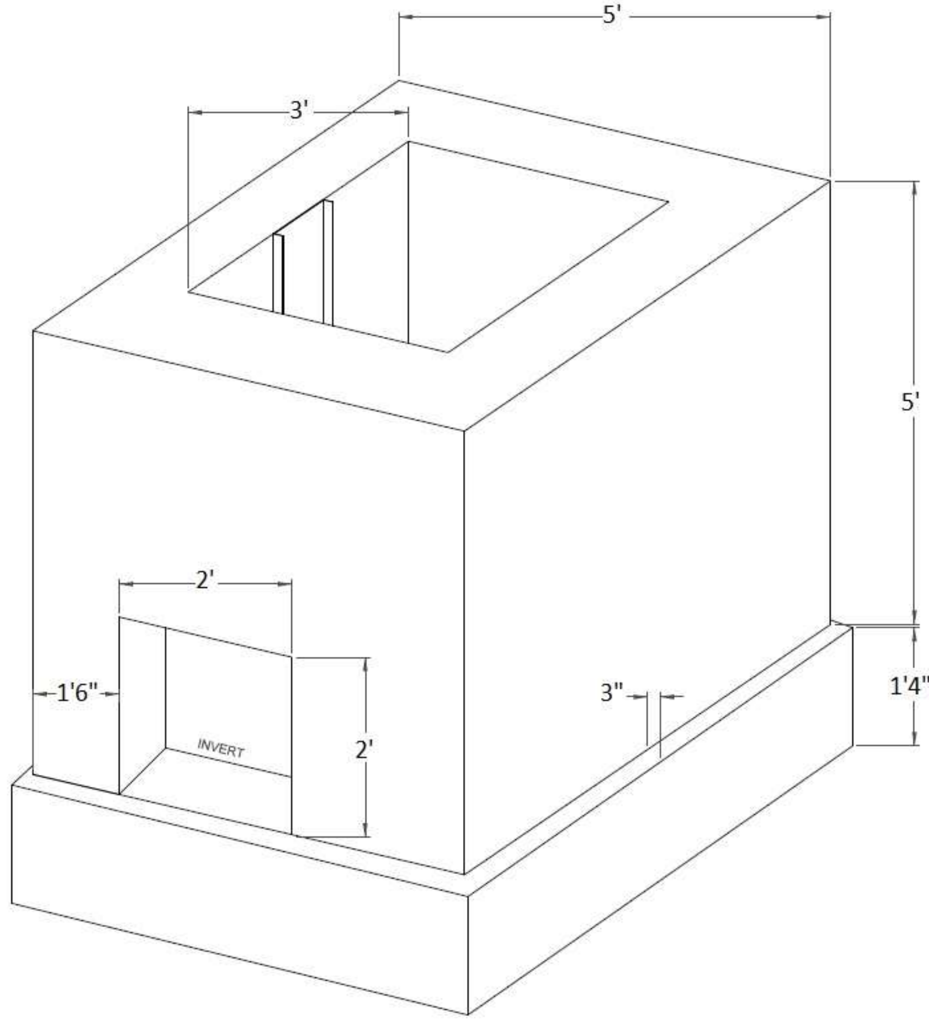

Figure 13 Sketch of new/proposed stop log riser design

2.3 Design Considerations

EM 1110-2-2100 Stability Analysis of Concrete Structures

EM 1110-2-2104 Strength Design for Reinforced Concrete Hydraulic Structures

EM 1110-2-2400 Structural Design and Evaluation of Outlet Works

EM 1110-2-2502 Retaining and Flood Walls

EM 1110-2-2504 Design of Sheet Pile Walls

EM 1110-2-2902 Conduits, Culverts and Pipes

EM 1110-2-2906 Design of Pile Foundations

EM 1110-2-3104 Structural and Architectural Design of Pumping Stations

EM 1110-2-6053 Earthquake Design and Evaluation of Concrete Hydraulic Structures

ACI 318-14

AISC Steel Construction Manual

MODOT/IDOT Culvert Design Guidelines

AASHTO Bridge Design

ASTM Standard Specifications