

PRELIMINARY DESIGN REPORT

FRY CREEK RESTORATION AND FLOOD REDUCTION PROJECT



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ACRONYMS AND ABBREVIATIONS

BMP	best management practice
CFR	Code of Federal Regulations
cfs	cubic feet per second
the City	City of Aberdeen
COE	U.S. Army Corps of Engineers
CSWGP	Construction Stormwater General Permit
CWA	Clean Water Act
DAHP	Washington State Department of Archaeology and Historic Preservation
DMMP	Dredged Material Management Program
DNR	Washington State Department of Natural Resources
DNS	determination of non-significance
Ecology	Washington State Department of Ecology
ESA	environmental site assessment
fps	feet per second
FWQC	federal water quality criteria
HEC-RAS	Hydraulic Engineering Center River Analysis System
HPA	Hydraulic Project Approval
JARPA	Joint Aquatic Resources Permit Application
KPFF	KPFF Consulting Engineers
MFA	Maul Foster & Alongi, Inc.
NHPA	National Historic Preservation Act
NPDES	National Pollutant Discharge Elimination System
the Port	Port of Grays Harbor
PUD	Grays Harbor County Public Utility District
RCW	Revised Code of Washington
REC	recognized environmental condition
SAP	sampling and analysis plan
SEPA	State Environmental Policy Act
USC	U.S. Code
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WSE	Watershed Science & Engineering
WWHM	Western Washington Hydrology Model

1 INTRODUCTION

The Fry Creek Restoration and Flood Reduction project was identified as one of the highest priorities in the Timber Works Resiliency and Restoration Master Plan because of its significant potential to reduce flood risk while enhancing natural habitat and creating community benefit through open space and recreation opportunities.¹ In support of this project, Maul Foster & Alongi, Inc. (MFA) has prepared this preliminary design report for the restoration of segments of Fry Creek in Aberdeen, Washington (see Figure 1-1), on behalf of the City of Aberdeen (the City). Project partners include KPFF Consulting Engineers (KPFF), Watershed Science & Engineering (WSE), and Forterra.

This report describes the existing conditions of Fry Creek, specifically through the City of Aberdeen itself, and proposes a number of revisions to the current configuration that will allow the City to achieve the primary objectives of the project—i.e., to reduce flooding, restore and enhance riparian habitat, introduce a more natural flow regime in the tidally influenced creek, and provide a community benefit of enhanced open spaces.

This preliminary design report presents the current restoration design for Fry Creek, with options for addressing flood reduction throughout the system. As preferred options are selected based on flood reduction optimization, cost constraints, and sequencing of available grant monies, the design may undergo changes as the design process proceeds.

This report is also intended to support the City's application for construction and environmental permits from local, state, and federal agencies. The City plans to submit a Joint Aquatic Resources Permit Application (JARPA), based on the design elements presented in this report, to the U.S. Army Corps of Engineers (COE), the Washington Department of Fish and Wildlife (WDFW), the Washington State Department of Ecology (Ecology), and the Washington State Department of Natural Resources (DNR), and the City's community development department. Design changes that are developed as part of the permitting process, in addition to other design refinements, will be incorporated into the final design.

1.1 Hydrologic and Ecological Setting

Fry Creek is an approximately 3-mile-long, tidally influenced stream that flows from the forested hills above the cities of Aberdeen and Hoquiam down into a low-lying, flat, and highly developed area before discharging into the Grays Harbor Estuary, at the mouth of the Chehalis River (see Figure 1-2). Soils in this area are predominantly unconsolidated sandy or silty loam. These soils are highly erodible on steep slopes. Before the development of the cities, the lower Fry Creek watershed was an active floodplain dominated by shrub-scrub wetlands, with Fry Creek flowing from the foothills to

¹ MFA. Timberworks resiliency and restoration master plan. Maul Foster & Alongi, Inc., Seattle, Washington, December, 2016.

the Chehalis River. The historical floodplain and wetlands associated with Fry Creek have largely been filled as a result of development.

Currently, the upper portion of the Fry Creek watershed is forested and includes land that is managed for timber harvest. The lower portion of the watershed is intensively developed with commercial, residential, and institutional uses. The urbanized reach of Fry Creek is straightened and constrained by a series of seven culverts, which have been identified as flow constrictions and partial fish passage barriers. The lower reach of the stream is tidally influenced, but with low to no salinity. The stream corridor is narrow, with less than 50 feet of undeveloped land on either side of the creek in most locations. The stream corridor is characterized by mowed grass with patches of nonnative, invasive species such as Himalayan blackberry (*Rubus armeniacus*) and Japanese knotweed (*Polygonum cuspidatum*) and minimal tree canopy. For the distance of one city block (approximately 420 feet), Fry Creek has been routed through underground pipes. Although the cities of Aberdeen and Hoquiam are adjacent to extensive areas of high-quality, protected forests, mountains, wetlands, and estuarine habitats, the quality of fish habitat in urban streams such as Fry Creek is highly degraded and limited in its capacity to support native fisheries.

Salmon and trout species migrate through Grays Harbor and the Chehalis River and use tributary streams for foraging, rearing, and spawning habitat,² and field observations have confirmed the presence of juvenile salmon in Fry Creek. Salmon populations in the Chehalis River basin are not listed under the Endangered Species Act, but they are managed under the Magnuson-Stevens Act. The Chehalis River is designated under the Endangered Species Act as critical habitat for bull trout (75 Code of Federal Regulations [CFR] 63898). Bull trout are managed by the U.S. Fish and Wildlife Service (USFWS).

Chinook salmon, coho salmon, chum salmon, and steelhead trout all occur in the Chehalis River and have the potential to be present in tributary streams, including Fry Creek. All of the streams and estuarine waters that support Chinook or coho salmon are considered “essential fish habitat” protected by the Magnuson-Stevens Act.

USFWS Information for Planning and Consultation further identifies marbled murrelet, short-tailed albatross, streaked horned lark, and yellow-billed cuckoo as potentially affected by planned activities in the project area. However, there is no identified critical habitat for these species in the project area.

2 EXISTING CONDITIONS

2.1.1 Hydrologic Analysis

WSE used the Western Washington Hydrology Model (WWHM) to develop the 100-year design storm for the Fry Creek watershed. Rather than using a single-event design storm, the WWHM uses local,

² Washington State Conservation Commission. Salmon and steelhead limiting factors: Chehalis Basin and nearby drainages, Water Resource Inventory Areas 22 and 23, 2001.

continuous rainfall data collected over a long period of time (in this case 1955 through 2009). These data are applied to basin elements in the model; rainfall is converted to generated runoff by an implementation of the U.S. Environmental Protection Agency's (USEPA) Hydrological Simulation Program—FORTRAN model. The WSE memorandum in Appendix A describes the hydrologic model development in detail.

The design storm represents a combination of the 100-year precipitation event with a static mean higher high water tide elevation of 8.47 feet North American Vertical Datum of 1988 at the mouth of Fry Creek (at the Chehalis River).

2.2 Existing Hydraulics

WSE prepared a Hydraulic Engineering Center River Analysis System (HEC-RAS) model of the lower Fry Creek drainage (described in detail in Appendix A), from where Fry Creek enters the Chehalis River valley (near the terminus of Ash Street) to the mouth of Fry Creek (see Figure 3 of Appendix A).

The model identifies areas of flooding in the Fry Creek corridor, primarily between the Grays Harbor County Public Utility District (PUD) yard and the first railroad crossing, under varying flood conditions ranging from the ten-year event to the 100-year event (see WSE Figure 6 in Appendix A.)

Many of the flooding impacts are interrelated (i.e., undersized structures downstream causing flooding upstream); the following subsections explore the hydraulic properties of the individual existing channel segments and structures in the context of the 100-year design storm event.

2.2.1 Segment 1—Cherry Street Reach

The Cherry Street reach is defined as the portion of Fry Creek from the PUD yard bridge to Sumner Avenue (see Figure 1-1). The existing Cherry Street crossing is the first significant hydraulic obstruction encountered by Fry Creek as the creek enters the highly urbanized portion of the watershed. The creek leaves the upper watershed and flows first past and then through the PUD yard, where the channel becomes highly constrained. The channel immediately upstream of the Cherry Street crossing is approximately 25 feet wide. Fry Creek is conveyed under Cherry Street through two 5-foot-diameter corrugated metal pipes. A steel trash rack spans the entrance to these pipes.

The twin steel pipes discharge into a similarly constrained channel south of Cherry Street. An 8-inch-diameter sewer pipe spans the creek approximately halfway between Cherry Street and the culverts at Sumner Avenue to the south.

A concrete block floodwall is in place to the west of Fry Creek from the culvert headwall (north of Sumner Avenue) north to approximately halfway between Cherry Street and the PUD yard bridge (see Figure 1-1). This floodwall also extends a short distance to the east of Fry Creek from the culvert headwall north along the Hoquiam Licensing & Transportation Agency building.

The model predicts that, during the 100-year event, nearly 40 percent of the Fry Creek discharge entering the Cherry Street Reach will spill over this floodwall, with most of that fraction flowing “out of the system” to the west (toward Olympic Stadium).

2.2.2 Segment 2—Sumner Avenue to Simpson Avenue

Fry Creek enters two round concrete culverts at a concrete block headwall to the north of Sumner Avenue. These culverts extend beneath Sumner Avenue, through the existing parking lot between Sumner Avenue and Simpson Avenue. The culverts discharge into an open channel to the south of Simpson Avenue.

Together, these culverts constitute the most significant hydraulic obstruction in the design reach. As described above, the WSE model predicts significant flooding upstream of these culverts, with nearly 40 percent of the flow leaving the system. This corresponds well to the historical record of observed flooding at and around Cherry Street (see Appendix A). An inspection of the hydraulic profile for the 100-year event (see WSE Figure 6 in Appendix A) reveals that flooding at, and even upstream of, Cherry Street can be attributed to backwater effects from the Sumner/Simpson culverts.

2.2.3 Segment 3—Simpson Avenue to Pacific Avenue

2.2.3.1 Simpson Avenue to Aberdeen Avenue Reach

Fry Creek exits the two concrete culverts immediately south of Simpson Avenue and enters a highly constrained channel. The channel immediately turns to the southwest as it is routed around a tire storage area owned by Les Schwab Tire Centers. This tire storage area forms the eastern bank of Fry Creek for most of the reach between Simpson Avenue and Aberdeen Avenue. In this reach, Fry Creek is bounded to the west by residential properties. An 8-inch-diameter sewer pipe spans Fry Creek about midway between Simpson Avenue and Aberdeen Avenue.

At Aberdeen Avenue, Fry Creek enters a corrugated metal arch culvert approximately 9.5 feet wide and 6.4 feet high. The model predicts that, at the peak discharge of the 100-year event, the headloss through the culvert would be 0.6 foot. It is important to note that backwater effects from this culvert continue upstream to the discharge from the culverts at Simpson Avenue.

The WSE model includes a lateral structure that represents the roadway elevation of Myrtle Street, to the west of Fry Creek, approximately midway between Simpson Avenue and Aberdeen Avenue. The model predicts that, at the peak of the 100-year event, nearly 16 percent of the Fry Creek flow exiting the culverts at Simpson Avenue would flow to the west and exits the system at Myrtle Street.

2.2.3.2 Aberdeen Avenue to Pacific Avenue Reach

Fry Creek between Aberdeen Avenue and Pacific Avenue flows past residential properties to the east and west. This reach is still constrained and highly channelized, with little to no floodplain storage present. The model predicts the potential for minor flooding within these properties, especially in the northern half of this reach.

The culvert at Pacific Avenue is a concrete box culvert approximately 8 feet wide and 5 feet tall. The model predicts 0.76 foot of headloss across this culvert at the peak discharge of the 100-year event. Backwater effects from this culvert are predicted to reach the culvert discharge at Aberdeen Avenue. The model does not predict that flow will overtop Pacific Avenue.

2.2.4 Segment 4—Pacific Avenue to Railroad Crossing

This segment of Fry Creek continues in a nearly linear alignment to the south. In this segment, the Fry Creek channel is constrained between a large commercial development to the west and public housing tracts to the east. A ditch, which conveys flow from the east, enters Fry Creek just upstream of the railroad crossing and runs parallel to the railroad tracks, to the south of the Wes Peterson Playfield.

Two sewer pipelines span Fry Creek in this segment: an 8-inch-diameter cast iron pipe approximately midway between Pacific Avenue and the terminus of Bay Avenue; and a 12-inch-diameter ductile iron pipe that crosses at an oblique angle to Fry Creek approximately 100 feet north of the culverts at the railroad crossing.

The model predicts little flooding in this reach; flow is largely confined to the channel. The model does predict that water will fill the ditch to the north of the railroad line; floodwaters from this ditch may cause flooding in the neighborhood to the southeast of Wes Peterson Playfield.

2.2.5 Segment 5—Railroad Crossing to Port Industrial Road

The dominating feature of this reach is the pump station complex to the north of Port Industrial Road. This pump station contains a single vertical propeller pump with a rated capacity of 62.4 cubic feet per second (cfs). This pump is operated by float switches affixed to the pump station structure. The pump discharges into a 5.5-foot-diameter corrugated metal pipe that crosses under Port Industrial Road. Two 5.5-foot-diameter corrugated metal culverts extend in parallel with the pump discharge pipeline under Port Industrial Road; the outlets of these two culverts and the pump discharge pipeline are fitted with tide gates to prevent reverse flow.

Flooding is not predicted for this reach for the 100-year event. The Fry Creek restoration and flood reduction project does not currently identify restoration elements in this segment.

2.2.6 Segment 6—Port Industrial Road to Grays Harbor

This lowest segment of Fry Creek is highly channelized, straightened, and armored. Fry Creek emerges on the south side of Port Industrial Road from two gravity pipelines (with tide gates) and one pump discharge pipeline. The channel initially flows to the northwest for approximately 300 feet, then it makes an abrupt turn to the southwest. The channel continues along this linear alignment for approximately 1,700 feet, at which point the creek enters a final culvert under the railroad bridge. This arch culvert is approximately 12 feet wide at the base and approximately 7.5 feet high. For the peak 100-year discharge, the model estimates 0.35 foot of headloss through this final culvert. Fry Creek

enters Grays Harbor immediately to the southwest of the railroad bridge arch culvert, which represents the downstream boundary condition in the model.

Flooding during the 100-year event is not predicted for this reach; the land surrounding Fry Creek has been filled by the Port of Grays Harbor (the Port) to raise the Port's property above the 100-year flood elevation. The Fry Creek restoration and flood reduction project does not currently identify restoration elements in this segment.

3 FLOOD CONTROL DESIGN

MFA used WSE's HEC-RAS model to evaluate design alternatives for reducing or eliminating flooding associated with the 100-year flood event in the Fry Creek corridor. The scenarios modeled by MFA are:

- Removal or modification of individual constrictions above the first railroad crossing, with no change to the existing hydraulic conditions downstream of this railroad crossing
- Removal or modification of individual constrictions above the first railroad crossing, with the addition of the proposed North Shore Levee pump station
- Removal or modification of all existing constrictions above the first railroad crossing, with the addition of the proposed levee pump station

The intent in evaluating hydraulic improvements individually as well as collectively is to provide a technical basis for the selection of alternatives to prioritize for initial construction, whether they be individual segments or a combination thereof. Understanding the degree to which certain improvements can alleviate 100-year flooding in the Fry Creek corridor is important and informs decision-making when coupled with other design considerations and constraints such as cost, ability to acquire needed parcels, and consideration of public input. Costs associated with modifications in each segment are presented in Section 4.

3.1 Hydraulic Improvements

Using WSE's existing-conditions HEC-RAS model, MFA developed a series of hydraulic models evaluating the removal or modification of each of the significant obstructions above the first railroad crossing (Cherry Street through Pacific Avenue). MFA also developed a similar series of hydraulic models assuming the installation of the new levee pump station immediately upstream of the first railroad crossing. KPFF's preliminary pump station design and associated tide gate options, expected to handle up to the 100-year design event, are discussed in Appendix B. These water surface elevations at the upstream and downstream bounding cross sections for each of the two series of model results are presented in Table 3-1. Table 3-1 also presents the cumulative flooding out of the system at each of the three lateral structures upstream of the railroad crossing (Cherry Street west, Cherry Street east, Myrtle Street) during the 100-year flood event for both series of hydraulic models.

Unless noted otherwise, the water surface elevation differences given in the following narrative subsections describe changes in the water surface elevation at the cross section immediately upstream of that particular obstruction.

3.1.1 Segment 1—Cherry Street Reach

As described in Section 2.2.1 above, the existing hydraulics at Cherry Street are highly influenced by backwater effects from the hydraulic constriction at Sumner Avenue. MFA evaluated the effects of removing the Cherry Street crossing independent of any other action in Fry Creek.

The removal or upgrading of the Cherry Street crossing and the relocation of the existing trash rack to the PUD yard bridge upstream, with no other modifications to the existing hydraulics, results in a minor reduction of the maximum water surface elevation during the 100-year event—approximately 0.3 foot. However, this reduction in maximum water surface elevation does not necessarily result in a significant overall decrease in flooding during the 100-year event; the existing-conditions model estimates that 8.67 acre-feet flows out of the system at Cherry Street, while the removal of the Cherry Street crossing is predicted to result in 8.46 acre-feet flowing out of the system at Cherry Street.

The removal or replacement of the Cherry Street crossing, with the addition of the levee pump station (see Appendix B), has little effect when compared to the addition of the levee pump station only. The maximum water surface elevations during the 100-year event upstream of the first railroad crossing are identical or slightly higher under the Cherry Street removal scenario when compared with the levee pump station only simulation. The model indicates that the overall flood volume leaving the system, under the removal or upgrading of the Cherry Street crossing and levee pump station scenario, would be reduced slightly relative to the levee pump station only scenario—from 7.01 acre-feet to 6.83 acre-feet.

3.1.2 Segment 2—Sumner Avenue to Simpson Avenue

The existing culverts between Sumner Avenue and Simpson Avenue represent the largest hydraulic constriction in the Fry Creek basin. MFA considered two options for reducing this constriction: (1) “daylighting” of Fry Creek between Sumner Avenue and Simpson Avenue through the existing parking lot, removal of the existing culverts and the installation of new box culverts at Sumner and Simpson Avenues; and (2) the addition of a third pipe to convey flood flows in parallel to the existing culverts.

3.1.2.1 Culvert Removal/Daylighting

This scenario considers the removal of the existing culverts between Sumner and Simpson Avenues and the construction of an open channel in the existing parking lot. Fry Creek would pass through two 20-feet-wide-by-6.5-feet-high culverts, one each at Sumner and Simpson Avenues.

MFA modeled this daylighting scenario with no additional modifications in Fry Creek basin. This scenario results in a significant reduction of the maximum water surface elevation upstream of Sumner Avenue during the 100-year event—nearly 1.4 feet immediately upstream of Sumner Avenue. The replacement of these existing culverts in isolation does not result in a large reduction in flooding

throughout the system during the 100-year event. Flooding above Cherry Street is reduced from 8.67 acre-feet to 1.33 acre-feet. However, flooding at Myrtle Street is dramatically increased from 2.11 acre-feet to 8.76 acre-feet. Essentially, the removal of the hydraulic restriction imposed by these culverts moves the flooding problem downstream. This daylighting scenario also involves significant challenges for constructing the new crossings with adequate freeboard. The backwater effects from the remaining downstream obstructions lead to a maximum water surface elevation of 11.81 feet downstream of Simpson Avenue during the 100-year event; for comparison, the existing centerline elevation of Simpson Avenue in the vicinity of the Fry Creek crossing varies between 11.35 feet and 11.64 feet. Upstream of Sumner Avenue, the maximum water surface elevation during the 100-year event is predicted to be 11.93 feet, while the centerline elevation of Sumner Avenue in the vicinity of the Fry Creek crossing varies between 11.43 feet and 11.73 feet.

MFA also modeled this daylighting scenario with the levee pump station installed. This scenario did result in a nearly 1.6-foot reduction in the water surface elevation upstream of Sumner Avenue during the 100-year event relative to the levee-pump-station-only scenario. Overall flooding out of the system was significantly reduced from 7.01 acre-feet to 3.00 acre-feet. Of note, however, flooding at Myrtle Street increased from 0 acre-feet to 2.23 acre-feet under this scenario. As with the existing-conditions and daylighting scenario described above, the daylighting scenario with the levee pump station also involves significant challenges for constructing the new crossings with adequate freeboard. The backwater effects from the remaining downstream obstructions lead to a maximum water surface elevation of 11.41 feet downstream of Simpson Avenue during the 100-year event and a maximum water surface elevation of 11.63 feet upstream of Sumner Avenue. This is an improvement over the existing-conditions daylighting scenario, but implementation likely would still prove very challenging, given the grade constraints of the adjacent roadways and properties.

3.1.2.2 Installation of Third Pipe

To provide the City with an alternative design that would achieve the same hydraulic goals as the daylighting scenario described above at potentially lower cost, MFA evaluated the installation of a third pipe between Sumner Avenue and Simpson Avenue. MFA modeled the additional pipe as an 84-inch-diameter concrete pipe. This additional pipe would result in a water surface elevation above Sumner Avenue similar to that of the daylighting scenario. Maximum velocity through this additional pipe during the 100-year-event would be approximately 6 feet per second (fps).

It is important to note that, while this pipe would achieve favorable hydraulic results, it likely would be difficult to permit through the natural resource agencies, especially given that the pipeline would be nearly 500 feet long and would likely be viewed as a barrier to fish.

3.1.3 Segment 3—Simpson Avenue to Pacific Avenue

This reach presents an opportunity to alleviate localized flooding, especially in the neighborhood between Simpson Avenue and Aberdeen Avenue. The removal of the Aberdeen Avenue crossing, with no other modifications to the existing hydraulic conditions, results in a minor reduction of the maximum water surface elevation of approximately 0.2 foot during the 100-year event. Flooding out of the system at Myrtle Street would be reduced from 2.11 acre-feet to 0.69 acre-feet over the course

of the 100-year event. Flooding out of the system at Cherry Street would be reduced slightly—from 8.67 acre-feet to 7.97 acre-feet.

The removal of the Aberdeen Avenue crossing, with the installation of the levee pump station, brings dramatic reductions in the maximum water surface elevation at Aberdeen Avenue during the 100-year event—over 1.1 feet. The model predicts that no flow would leave the system at Myrtle Street under this configuration. Flooding out of the system at Cherry Street would be reduced from 8.67 acre-feet (existing conditions) to 5.69 acre-feet.

3.1.4 Segment 4—Pacific Avenue to Railroad Crossing

The MFA model includes a replacement of the existing culvert at Pacific Avenue with a much larger box culvert, 20-feet-wide-by-6.5-feet-tall. The model predicts that, with no other modifications to the existing-conditions hydraulics, this larger culvert would result in a minor reduction of the maximum water surface elevation of approximately 0.4 foot during the 100-year event. As the existing-conditions model does not predict significant flooding in this reach, replacement of this culvert with no further hydraulic modifications would have impacts mostly upstream. The model predicts that the flow out of the system at Myrtle Street (in the Simpson Avenue to Aberdeen Avenue reach) would be reduced from 2.11 acre-feet to 0.55 acre-foot—this is a greater reduction in this section than simply removing the Aberdeen Avenue crossing itself.

The replacement of the existing culvert at Pacific Avenue also provides even greater benefit upstream with the installation of the levee pump station. Under this scenario, the model predicts that flooding would be eliminated at Myrtle Street, and flow leaving the system at Cherry Street would be reduced from 8.67 acre-feet (existing conditions) to 5.28 acre-feet.

3.1.4.1 Modification of Aberdeen and Pacific Avenue Crossings

Together, the removal of the Aberdeen Avenue crossing and the replacement of the existing culvert at Pacific Avenue yield significant flooding reductions (see Appendix B). The modification of these two crossings, with no other modifications to the existing hydraulic conditions, results in a reduction of flooding volume at Cherry Street from 8.67 acre-feet to 6.78 acre-feet. The model predicts that no flow would leave the system at Myrtle Street. This is a total reduction of 4 acre-feet in overland flooding in the Fry Creek system due just to these two modifications.

The removal of the Aberdeen Avenue crossing and the replacement of the existing culvert at Pacific Avenue, with the installation of the levee pump station, yields additional benefits: flooding at Cherry Street is reduced from 8.67 acre-feet to 3.59 acre-feet. Not surprisingly, the model predicts that no flow would leave the system at Myrtle Street.

3.1.5 All Segments—Cherry Street to Railroad Crossing

The model indicates that the removal or modification of all constrictions in the Fry Creek corridor, in conjunction with the levee pump station, will result in alleviation of nearly all flooding associated with the 100-year event. These post-modification water surface elevations are shown on Table 3-2.

The maximum velocities in the proposed culverts under this scenario are 2.96 fps, 2.95 fps, and 3.08 fps at Sumner, Simpson, and Pacific Avenues respectively; these velocities are compatible with WDFW water crossing design guidelines.³ The peak discharge to the proposed levee pump station during the 100-year event is approximately 400 cfs.

4 DESIGN CONSIDERATIONS AND ELEMENTS

4.1 Segment 1—Public Utility District Yard to Cherry Street

The proposed improvements at Cherry Street include relocation of the existing trash rack to the PUD yard bridge and elimination or increased conveyance capacity of the Cherry Street crossing (see Appendix B, Drawings C1.4 through C1.6 for crossing and roadway closure options). In this reach, Fry Creek is highly constrained by existing development that offers limited opportunities for significant habitat/floodplain restoration.

As the design process advances, consideration of tsunami evacuation routes will be fully considered. The DNR evacuation map for Aberdeen identifies Simpson Avenue east to Oak Street north, with an assembly area at the top of Basich Boulevard, as the designated evacuation route for this area. While not in conflict with the potential removal of the Cherry Street crossing, it is a design variable that should be considered as the process progresses.

The estimated cost of the proposed improvements in this segment varies, depending on whether traffic signals are required to accommodate road closure if the Cherry Street crossing is removed. The estimated cost of replacing the culvert, with contingency, is \$298,000. The estimated cost of providing traffic signals, with contingency, is \$325,000. See Appendix B for detailed cost estimates for all road closure options. Property acquisition costs are not included and will be determined as the design process advances.

4.2 Segment 2—Sumner Avenue to Simpson Avenue

As described in Section 3.1.2 above, MFA evaluated two options for reducing the hydraulic restriction imposed by the existing culverts between Sumner and Simpson Avenues: (1) removal of the existing culverts daylighting the creek through the existing parking lot, and the installation of new box culverts at Sumner and Simpson Avenues, respectively; and (2) the installation of a third pipe in parallel with the two existing culverts.

4.2.1 Culvert Removal/Daylighting

The culvert removal/daylighting scenario includes the removal of the existing culverts, construction of new three-sided 20-foot-wide-by-6.5-foot-tall box culverts (see Drawings C1.7 and C1.8 in Appendix B) at Sumner and Simpson Avenues, respectively, and reestablishing an open channel in the existing

³ WDFW. Water Crossing Design Guidelines. Washington Department of Fish and Wildlife, 2013.

parking lot. The daylighting concept is shown in detail on Exhibit C1. A typical section of this segment under the daylighting scenario is shown on Exhibit C6. These improvements would provide approximately 0.6 additional acre-foot of storage during the 100-year event.

In addition to these hydraulic benefits, the proposed work would provide ecological benefits and would include increased opportunities for pedestrians and visitors to the parking lot to interact with Fry Creek. A pedestrian bridge midway between the crossings is proposed to maintain the functionality of the existing parking lot and preserve pedestrian circulation. The reconfigured parking lot would provide 160 parking spaces as compared to the existing 168. An additional six spaces can be incorporated along Simpson Avenue, as shown on Exhibit C1.

The estimated cost of the proposed improvements in this segment, including contingency, is \$3,188,000. See Appendices B and C for detailed cost estimates. Property acquisition costs are not included and will be determined as the design process advances.

4.2.2 Installation of Third Pipe

The third-pipe scenario is shown on Exhibit C2. Aside from the additional pipe itself, there would be few permanent changes to the Sumner to Simpson Avenue segment under this scenario. The pipeline construction would require temporary partial or full closures of Sumner and Simpson Avenues and temporary access restrictions to portions of the existing parking lot.

Minor channel reconfigurations at the entrance to and outlet from the additional pipe would be required to ensure that flow is routed appropriately to the pipe and to reduce scour.

The estimated cost to install this third pipe between Sumner and Simpson Avenues, including contingency, is \$1,584,000. See Appendix C for detailed cost estimates. Property acquisition costs are not included and will be determined as the design process advances.

4.3 Segment 3—Simpson Avenue to Pacific Avenue

The proposed configuration of the Simpson Avenue to Pacific Avenue segment is depicted on Exhibits C3 and C4.

In the northern half of this segment, between Simpson Avenue and Aberdeen Avenue, the proposed changes include: elimination of the existing tire storage facility on the east bank of the creek; installation of a sidewalk and observation platform, the demolition of the existing concrete slab (former house foundation) immediately downstream of the Simpson Avenue crossing; and the reestablishment of floodplain storage on both sides of the channel. Landscape elements would be included along the sidewalk alignment to provide both upland riparian habitat, as well as screening to somewhat isolate the user experience from the commercial developments on the east side of Ash Street.

Exhibit C7 provides a cross section of the proposed Fry Creek channel adjacent to the proposed observation platform, with expanded floodplain storage along the western bank of the creek. These

modifications would provide approximately 0.5 acre-foot of additional flood storage during the 100-year event (assuming construction of the levee pump station).

It is proposed that the existing crossing at Aberdeen be removed and the creek channel restored. Refer to KPFF Drawing C1.9 in Appendix B for additional detail regarding the termination of Aberdeen Avenue on the west side of Fry Creek. The existing crossing would be replaced by a pedestrian crossing, which would be elevated above the 100-year flood elevation. As shown on Exhibit C3, Aberdeen Avenue to the east of Fry Creek would be terminated, with traffic redirected onto Ash Street.

As the design process advances, tsunami evacuation routes will be fully considered. The DNR evacuation map for Aberdeen identifies Port Industrial Road east/southeast, north to Maple and Oak Streets, with an assembly area at the top of Basich Boulevard, as the designated evacuation route for this area. While not in conflict with the potential removal of the Cherry Street crossing, it is a design variable that should be considered as the process progresses.

The estimated cost of the proposed improvements in this segment, including contingency, is \$1,311,000. See Appendices B and C for detailed cost estimates. Property acquisition costs are not included and will be determined as the design process advances.

4.4 Segment 4—Pacific Avenue to First Railroad Crossing

As depicted on Exhibit C5, changes to Fry Creek in this section focus mostly on the Pacific Avenue crossing itself and the eastern side of the channel. The western side of the channel abuts existing commercial property; the channel is particularly impinged upon from the west in the southern portion of the segment.

Proposed changes to the channel itself include laying back the slope of the eastern bank and regrading to provide a floodplain bench (as shown on Exhibit C8). These modifications would provide an additional 0.5 acre-foot of storage during the 100-year event (assuming construction of the levee pump station).

There are no significant hydraulic obstructions between Pacific Avenue and the first railroad crossing; upon installation of the levee pump station, the water surface elevation in this segment during flood events will be controlled largely by the levee pump station.

As shown on KPFF Drawing C1.10 (see Appendix B), it is proposed that the existing culvert at Pacific Avenue be replaced by a 20-foot-wide-by-6.5-foot-tall, concrete, three-sided culvert. No additional changes to the Pacific Avenue right-of-way are proposed.

The estimated cost of the proposed improvements in this segment, including contingency, is \$1,228,000. See Appendices B and C for detailed cost estimates. Property acquisition costs are not included and will be determined as the design process advances.

4.5 Pump Station and Tide Gate—North Shore Levee

Design considerations associated with the levee pump station and tide gate, including gate options and pump types, configurations, and controls, are described in detail in the KPFF report provided in Appendix B, particularly Drawings C1.0, C1.1, and C1.2.

The estimated cost of proposed improvements in this segment, including contingency, is \$7,477,600. See Appendix B for detailed cost estimates.

5 PHASING

Restoring the entire Fry Creek corridor as one contiguous project would be ideal and would allow the City to achieve all of the project objectives at one time. However, MFA understands that funding constraints will dictate a phased and segmented approach, requiring deferred construction of some segments. With those considerations in mind, this section considers two overarching scenarios—one with and one without the levee pump station—and is intended to guide the City in determining which segments to prioritize, given the need to balance project objectives with currently available funding and other decision variables.

5.1 No Levee Pump Station

As described in Section 3 and as shown on Table 3-1, the options for providing an overall reduction in flooding upstream of the first railroad crossing will be limited until the levee pump station is installed. The combination of the elimination of the existing Aberdeen Avenue crossing and the replacement of the existing culvert at Pacific Avenue (Segments 3 and 4) yields significant benefits in overall flood volume reduction without increasing flooding in any other portion of the creek.

While the daylighting of Fry Creek between Sumner and Simpson Avenues (Segment 2) would decrease the overall flood volume at Cherry Street, this action in isolation would pass most of this flood volume farther down the basin (see Section 3.1.2.1.). The construction of the new crossings at Sumner and Simpson Avenues, without the levee pump station, likely would be difficult to implement and/or permit, given the backwater conditions.

Without the levee pump station, MFA recommends the proposed work in Segments 3 and 4—Simpson Avenue to Bay Avenue—including the floodplain improvements. Because the proposed pump station and potential storage area are currently planned for the area south of Bay Avenue, MFA would recommend that the City delay construction of the remainder of Segment 4 floodplain improvements (from Bay Avenue to the railroad) so that it coincides with installation of the pump station. MFA also recommends that the existing trash rack at Cherry Street be relocated or replaced upstream at the PUD yard bridge.

5.2 Levee Pump Station

The installation of the levee pump station would offer hydraulic benefits by itself and provides for a wider range of phasing options without increasing flooding elsewhere. As shown on Table 3-1, the maximum water surface elevation during the 100-year event at all of the current obstructions would be lowered by the installation of the levee pump station (see Appendix B). The overall flooding volume during the 100-year event would be reduced from the current 10.78 acre-feet to 7.01 acre-feet, notably with no flooding at Myrtle Street.

If the levee pump station is installed first, MFA would still recommend that the first phase of the Fry Creek project include the combination of the removal of the crossing at Aberdeen Avenue and the replacement of the existing culvert at Pacific Avenue (Segments 3 and 4), including all floodplain improvements down to the first railroad crossing. The model indicates that these improvements, in combination with the levee pump station, would provide overall flood volume reduction during the 100-year event—from 7.01 acre-feet (levee pump station only) to 3.59 acre-feet.

The reduction of these downstream constrictions would then allow for future segmenting and the installation of the new crossings at Sumner and Simpson Avenues (Segment 2) with appropriate freeboard. As described in Section 3.1.2.1 above, the daylighting of Fry Creek between Sumner and Simpson Avenues, with the installation of the levee pump station, would be difficult to implement while maintaining adequate freeboard at the new crossings. Improving the downstream constrictions at Aberdeen and Pacific Avenues first would allow construction of the new crossings at Sumner and Simpson Avenues at existing grade while maintaining adequate freeboard.

Additional improvements at Cherry Street (Segment 1), beyond the relocation or replacement of the existing trash rack upstream at the PUD yard bridge, might be best considered following the improvements in Segments 3 through 5. The model indicates that the maximum flood elevation upstream of Cherry Street during the 100-year event will be slightly below the elevation of the existing floodwall if the levee pump station and improvements in Segments 3 through 5 are installed.

5.3 Advancing Alternatives

Advancing alternatives will depend on a number of variables, including timing and availability of grant monies associated with both the Fry Creek Restoration and Flood Reduction project and the North Shore Levee project. Ideally, funds would be available under the North Shore Levee project to advance the design and construction of the levee pump station and tide gate in conjunction with the proposed Fry Creek improvements. If the two projects must be constructed out of sequence (i.e., Fry Creek segments proceed first), the hydraulic impacts, as presented in Section 3, must be carefully considered during the decision process.

At this time, MFA recommends prioritizing construction of the proposed work in Segments 3 and 4—Simpson Avenue to Bay Avenue—including the floodplain and enhanced open space improvements. MFA also recommends that the existing trash rack at Cherry Street be relocated or replaced upstream at the PUD yard bridge. Construction of these two segments will provide a net

benefit to flood reduction, improvement to habitat quality, and enhanced open space without transferring flooding concerns elsewhere.

Construction costs associated with Segments 3 and 4, including contingency, are estimated at \$2,539,000, and are within range of currently earmarked Washington Coast Restoration Initiative grant monies of approximately \$2,000,000 to \$2,500,000. Property acquisition costs are not included and will be determined at a later date. As the Fry Creek design process advances, the levee pump station and tide gate design will advance toward optimization under the North Shore Levee project. The two projects will require close coordination as the design process advances to the next phase.

6 REGULATORY CONSIDERATIONS

The Fry Creek restoration project will be subject to a variety of federal, state, and local laws and regulations. This section presents anticipated requirements of the permitting process.

6.1 Joint Aquatic Resources Permit Application

The JARPA is administered by the State of Washington to facilitate application for a number of federal, state, and local permits. Those relevant to the Fry Creek restoration and flood reduction project include the following.

6.1.1 COE Section 404 and Section 10 Permit

The COE requires that a dredge/fill permit be obtained consistent with Section 404 of the Clean Water Act (CWA). The permit also requires that the state issue a certification of the project under CWA Section 401. Section 404 requires that a permit be obtained to perform dredge and fill operations in U.S. waterways and wetlands. Discharges of dredged or fill materials are not permitted unless there is no practicable alternative that will have less adverse impact on the aquatic ecosystem.

Section 10 of the Rivers and Harbors Act of 1899 (33 U.S. Code [USC] 403) prohibits the unauthorized obstruction or alteration of any navigable waters of the United States. This section states that any other work affecting the course, location, condition, or physical capacity of U.S. waterways is unlawful unless the work has been permitted by the COE.

COE permitting to fulfill the requirements of CWA Section 404 and Section 10 of the Rivers and Harbors Act will be included as part of the JARPA process.

6.1.1.1 Sediment Evaluation

The Dredged Material Management Program (DMMP) establishes a framework for the evaluation of sediment to be dredged and the disposal of dredged sediment. The DDMP is an interagency program led by the Seattle District COE; it includes the USEPA, Ecology, and DNR.

Sediment to be removed as part of the Fry Creek project, as well as sediment that may be newly exposed as a result of Fry Creek project work, will be subject to evaluation by the DMMP. The Fry Creek project likely will require completion of a sampling and analysis plan (SAP) that includes the following components:

- Project overview
- Tier 1 Evaluation (includes a review of any known sources of contamination (past and present), adjacent historical and current land use, and a summary of any relevant analytical data)
- Characterization Plan (includes proposed project rank and justification and calculation of dredged material management units sampling and analysis requirements based on proposed volumes)
- Sampling Program (includes proposed sampling equipment, sample locations and depths, relevant horizontal datum, sample acceptance criteria)
- Chemical Analysis (includes table of current chemicals of concern, relevant regulatory limits, proposed analytical methods and reporting limits, quality assurance and data validation procedures)

Following approval of the SAP by the DMMP and collection of the samples, the project proponent will prepare a sediment sampling report. The DMMP uses this sediment sampling report to prepare a dredged material suitability determination memorandum, which outlines any restrictions on the disposal of dredged material and identifies requirements for additional dredging to avoid exposing sediment that does not meet the antidegradation standard.

6.1.2 Ecology: 401 Water Quality Certification

The CWA sets forth a number of provisions that require the development of regulations to protect the quality of the nation's waters. Section 401 requires that applicants for a federal license or permit to conduct work that may result in discharges into navigable U.S. waters provide the licensing or permitting agency a certification from the state that the discharge will comply with the applicable provisions of Sections 301, 302, 303, 306, and 307 of the CWA. Section 402 of the CWA requires the development of comprehensive programs for preventing, reducing, or eliminating pollution in the nation's waterways. National Pollutant Discharge Elimination System (NPDES) requirements are specified in Section 402. This program has been delegated to the State of Washington. Section 404 regulates the discharge of dredged or fill materials into waters of the U.S.

Section 401 requests every applicant for a federal permit for any activity that may result in a discharge to a water body to obtain a certification from the state that the proposed activity will comply with state water quality standards. The objective of the CWA (33 USC 1251-1376 and 40 CFR 129 and 131) is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. Sections 303 and 304 of the CWA require the USEPA to issue ambient surface-water quality criteria for the protection of aquatic life and human health. The federal water quality criteria (FWQC), as specified in 40 CFR 131, are nonenforceable guidelines to be used by states to set water-quality

standards for surface water. FWQC, based on chronic and acute effects to aquatic life, have been developed for 120 priority toxic pollutants and 45 nonpriority pollutants for marine waters and freshwaters.

The Fry Creek project design will incorporate best management practices (BMPs) to limit water quality impacts. These BMPs may include temporarily isolating the work area(s) and limiting the types and placement of construction equipment used to perform the work. Upland construction activities will be required to comply with the requirements of the Construction Stormwater General Permit (CSWGP) as described in Section 6.4 below.

6.1.3 DNR: Use Authorizations for State-Owned Aquatic Lands

DNR requires that an authorization be obtained to perform any work over state-owned aquatic lands. A DNR authorization is different from other regulatory permits in that it is a legal contract in which DNR outlines the terms and conditions of the use, as well as conveying property rights to the user in exchange for rent.

DNR suggests contacting them early in the design process to avoid delays in receiving authorization. The consultation will help to ensure that land is available, to determine if the proposed use is appropriate, and to avoid or minimize impacts to aquatic resources. DNR will be contacted early in the permitting process to ensure a timely consult.

6.1.4 WDFW: Hydraulic Project Approvals

The Washington State Legislature developed the Hydraulic Project Approval (HPA) process to establish requirements for the protection of fish and fish habitat from the impacts of hydraulic projects (Chapter 77.55 Revised Code of Washington [RCW]). These projects are considered to be any work that would use, divert, obstruct, or change the natural flow or bed of any river or stream or utilize any waters of the state.

The Hydraulic Code requires any person or agency that desires to undertake a hydraulic project to obtain approval from the WDFW, in the form of a permit, before beginning work. It is expected that the Fry Creek project will apply for an HPA by submitting the JARPA. The project will be designed to protect and improve fish and fish habitat. All prescribed work windows will be observed.

6.1.5 City Shoreline Master Program

Any “substantial development” performed along any shoreline of statewide significance in the city is regulated under the Shoreline Management Master Program (Chapter 16.20 of the City Code). A substantial development permit is required for such an action. The City adopted an updated Shoreline Management Master Program in 2016.

It is expected that the Fry Creek project will apply for a Substantial Development Permit by submitting the JARPA. The requirements of the Substantial Development Permit will be met as part of the design process.

6.2 State Environmental Policy Act

The State Environmental Policy Act (SEPA) is intended to ensure that environmental values are considered during decision-making by state and local agencies. SEPA's environmental review process includes the preparation of a SEPA checklist that is used to obtain information about a proposal. The SEPA checklist includes questions about the proposal, possible future activities, and potential impacts of the proposal on the environment.

Review of the SEPA checklist is delegated to a lead agency. For the Fry Creek project, the lead agency would be the project proponent—the City. The lead agency is tasked with determining whether or not the proposal will have a significant environmental impact. If the lead agency determines that it will, then an environmental impact statement is required to formally quantify these impacts. If the lead agency determines that the proposal is unlikely to have significant adverse environmental impacts, or that mitigation has been identified that will reduce impacts to a non-significant level, then that agency publishes a determination of non-significance (DNS). Typically, a DNS is subject to a 14-day public comment period prior to lead agency action. It is expected that the environmental benefits of the proposed Fry Creek project will far outweigh any temporary adverse environmental impacts and that the project will receive a DNS.

6.3 Cultural Resources

The National Historic Preservation Act (NHPA), passed in 1966 (16 USC 470 et seq.), established a national policy for the protection of important historic buildings and archeological sites and outlined responsibilities for federal and state governments. Under Section 106 of the NHPA, each agency must consult with the Washington State Department of Archaeology and Historic Preservation (DAHP) to assure that cultural resources are identified, and to obtain the formal opinion of the office on each site's significance and the impact of its action on the site. The responsibilities of all parties in the Section 106 review process are set forth in federal regulations developed by the Advisory Council on Historic Preservation as 36 CFR 800. Section 106 compliance is required, as state funds are being used to facilitate a portion of the remedial action and activities requiring a permit from the COE are being conducted.

Under the Washington State Governor's Executive Order 05-05, archeological and cultural resources must be evaluated to satisfy federal regulations of 36 CFR 800. RCW 27.44 (Indian Graves and Records) addresses the need to protect graves, cairns, and glyptic marks, and establishes associated penalties, civil actions, and procedures. RCW 27.53 (Archaeological Sites and Resources) lays out the state's interest in protecting archaeological resources and establishes and empowers DAHP to complete an inventory and study, make National Register of Historic Places nominations, and identify and excavate the "state's archeological resources" (RCW 27.53.020). Washington Administrative Code (WAC) 25-48 establishes procedures for implementing the permit sections of RCW 27.53. WAC 25-46 establishes regulation procedures for historic archaeological resources on, in, or under aquatic lands owned by the state; RCW 79.105.600 deals with "archaeological activities" on state aquatic lands, and addresses shoreline management (via RCW 79.105). RCW 42.56.300 exempts disclosure of the location of archaeological sites.

The Fry Creek restoration and flood reduction project will be conducted under a cultural resources monitoring plan consistent with the regulations and laws described above. The monitoring plan will be developed by a professional archaeologist licensed in the State of Washington, in coordination with DAHP and affected tribes.

6.4 National Pollutant Discharge Elimination System Construction Stormwater Permit

The NPDES CSWGP is administered by Ecology to regulate construction activities that disturb 1 or more acres of land through clearing, grading, excavating, or stockpiling of fill materials and that pose a risk of stormwater running off the site into surface waters or conveyance systems leading to surface waters of the state during construction. Smaller sites may also require coverage if they are included as part of an overall plan of development that will ultimately disturb at least 1 acre or if construction activities have the potential to disturb known contaminated soil. To receive coverage under the CSWGP, the applicant must first file a notice of intent application form with Ecology and then publish a public notice at least once a week for two consecutive weeks, with at least seven days between publications, in a newspaper of general circulation in the county in which the construction is to take place.

As part of the permit process, applicants must prepare a stormwater pollution prevention plan and incorporate BMPs into their land-disturbing construction work. If the construction work has the potential to disturb contaminated soils, Ecology will require additional information about the nature of the contamination and specific BMPs that will be in place to ensure that contaminated stormwater and/or construction dewatering water does not enter waters of the state. An administrative order may be required to allow Ecology to temporarily regulate, as part of the CSWGP, the discharge to surface water of potentially contaminated stormwater and/or construction dewatering water (the CSWGP itself regulates only turbidity and pH).

6.5 Local Permits

6.5.1 Critical Areas

Section 14.100 of City code regulates development within critical areas, critical area buffers, and sites immediately adjoining critical areas. Critical areas include the following: critical aquifer recharge areas; wetlands; frequently flooded areas; geologically hazardous areas; and fish and wildlife habitat conservation areas. The City publishes maps and inventory lists of the approximate location of critical areas.

The City's critical areas maps indicate that the Fry Creek restoration and flood reduction project elements would be constructed in both frequently flooded areas and geologic hazard areas (liquefaction). Compliance with the critical areas code will be ensured as part of the review for other local permits (e.g., shoreline substantial development permit, floodplain development permit application).

6.5.2 Hydrodynamic/Flood Analysis

The proposed work will be in compliance with the City's Flood Hazard Protection Code (Chapter 15.55 of the Aberdeen Municipal Code). As one of the main objectives of the Fry Creek project is to reduce flooding, it is not expected that this permitting effort will pose serious challenges.

All work will also be coordinated with KPFF's North Shore Levee project as that design advances.

6.6 Phase I and Phase II Environmental Site Assessments

Under state and federal law, the acquisition of land carries with it the potential for environmental liability, but with appropriate due diligence, these same laws allow the liability to be maintained by the prior owners and operators. As part of the property acquisition process for targeted parcels, a Phase I environmental site assessment (ESA) will be conducted to allow the City to satisfy one of the requirements to qualify for the bona fide prospective purchaser, innocent landowner, and/or contiguous property owner limitations on Comprehensive Environmental Response, Compensation and Liability Act liabilities. The purpose of the Phase I ESA is to identify "recognized environmental conditions" (RECs). RECs are defined in the American Society for Testing and Materials Standard Practice E1527-13 as the presence or likely presence of any hazardous substances or petroleum products on a property under conditions that indicate an existing release, a past release, or a material threat of a release of any hazardous substances or petroleum products into structures on the property, or into the ground, groundwater, or surface water of a property. RECs and/or data gaps identified in the Phase I ESA are then assessed in a Phase II ESA, which typically includes the collection and analysis of representative media (e.g., soil, groundwater, soil vapor). The results of the Phase II activities will also provide information necessary to plan for and address contamination before or during construction.

Grays Harbor County was recently awarded USEPA brownfield assessment grant funds that may support Phase I and Phase II ESAs for properties along the Fry Creek corridor. The cities of Aberdeen and Hoquiam are coordinating with the Grays Harbor Council of Governments to identify early opportunity sites for assessment. If funding is available, it will help expedite the acquisition of key parcels currently under consideration as part of this project.

LIMITATIONS

The services undertaken in completing this report were performed consistent with generally accepted professional consulting principles and practices. No other warranty, express or implied, is made. These services were performed consistent with our agreement with our client. This report is solely for the use and information of our client unless otherwise noted. Any reliance on this report by a third party is at such party's sole risk.

Opinions and recommendations contained in this report apply to conditions existing when services were performed and are intended only for the client, purposes, locations, time frames, and project parameters indicated. We are not responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services. We do not warrant the accuracy of information supplied by others, or the use of segregated portions of this report.

TABLES



Table 3-1
Fry Creek Water Surface Elevations and Flood Volumes
Fry Creek Restoration and Flood Reduction Project
Aberdeen, Washington

Station	Existing Conditions—Water Surface Elevation (feet NAVD)						Levee Pump Station—Water Surface Elevation (feet NAVD)					
	Baseline	Cherry Only	Sumner Simpson Only	Aberdeen Only	Aberdeen & Pacific	Pacific Only	Baseline	Cherry Only	Sumner Simpson Only	Aberdeen Only	Aberdeen & Pacific	Pacific Only
Above Cherry	13.34	13.35	12.63	13.31	13.24	13.31	13.24	13.24	12.55	13.19	12.99	13.14
Below Cherry	13.31	13.32	12.00	13.28	13.21	13.28	13.22	13.22	11.72	13.17	12.92	13.10
Above Sumner	13.29	13.30	11.93	13.26	13.19	13.26	13.19	13.19	11.63	13.14	12.87	13.07
Below Simpson	11.29	11.30	11.81	11.10	10.73	11.08	10.81	10.81	11.41	10.29	9.27	10.13
Above Aberdeen	11.27	11.28	11.81	11.07	10.66	11.04	10.72	10.73	11.34	10.13	8.92	9.96
Below Aberdeen	10.67	10.67	11.24	11.05	10.65	10.31	9.75	9.76	10.13	10.09	8.86	8.76
Above Pacific	10.65	10.66	11.22	11.05	10.63	10.29	9.67	9.67	10.06	10.02	8.60	8.52
Below Pacific	9.89	9.90	10.44	10.15	10.58	10.26	8.42	8.42	8.51	8.50	8.58	8.51

Flooding Location	Existing Conditions—Flooding "out of system" (acre-feet)						Levee Pump Station—Flooding "out of system" (acre-feet)					
	No Change	Baseline	Sumner Simpson Only	Aberdeen Only	Aberdeen & Pacific Only	Pacific Only	Baseline	Cherry Only	Sumner Simpson Only	Aberdeen Only	Aberdeen & Pacific Only	Pacific Only
Cherry West	8.16	7.96	1.23	7.5	6.38	7.44	6.59	6.42	0.71	5.35	3.37	4.96
Cherry East	0.51	0.50	0.10	0.47	0.40	0.47	0.42	0.41	0.06	0.34	0.22	0.32
Myrtle	2.11	2.22	8.76	0.69	0	0.55	0	0	2.23	0	0	0
Sum	10.78	10.68	10.09	8.66	6.78	8.46	7.01	6.83	3.00	5.69	3.59	5.28

NOTES:
Shaded cells indicate the portion of the Fry Creek channel where improvements have been included in that model.
NAVD = National Geodetic Vertical Datum 1983.

Table 3-2
Fry Creek Water Surface Elevations Baseline and All Segments Modified
Fry Creek Restoration and Flood Reduction Project
Aberdeen, Washington

Station	Water Surface Elevations (feet NAVD)	
	Baseline	All Segments
Above Cherry	13.34	10.59
Below Cherry	13.31	10.62
Above Sumner	13.29	10.32
Below Simpson	11.29	9.89
Above Aberdeen	11.27	9.38
Below Aberdeen	10.67	9.23
Above Pacific	10.65	8.92
Below Pacific	9.89	8.90
NOTE: NAVD = National Geodetic Vertical Datum 1983.		

FIGURES



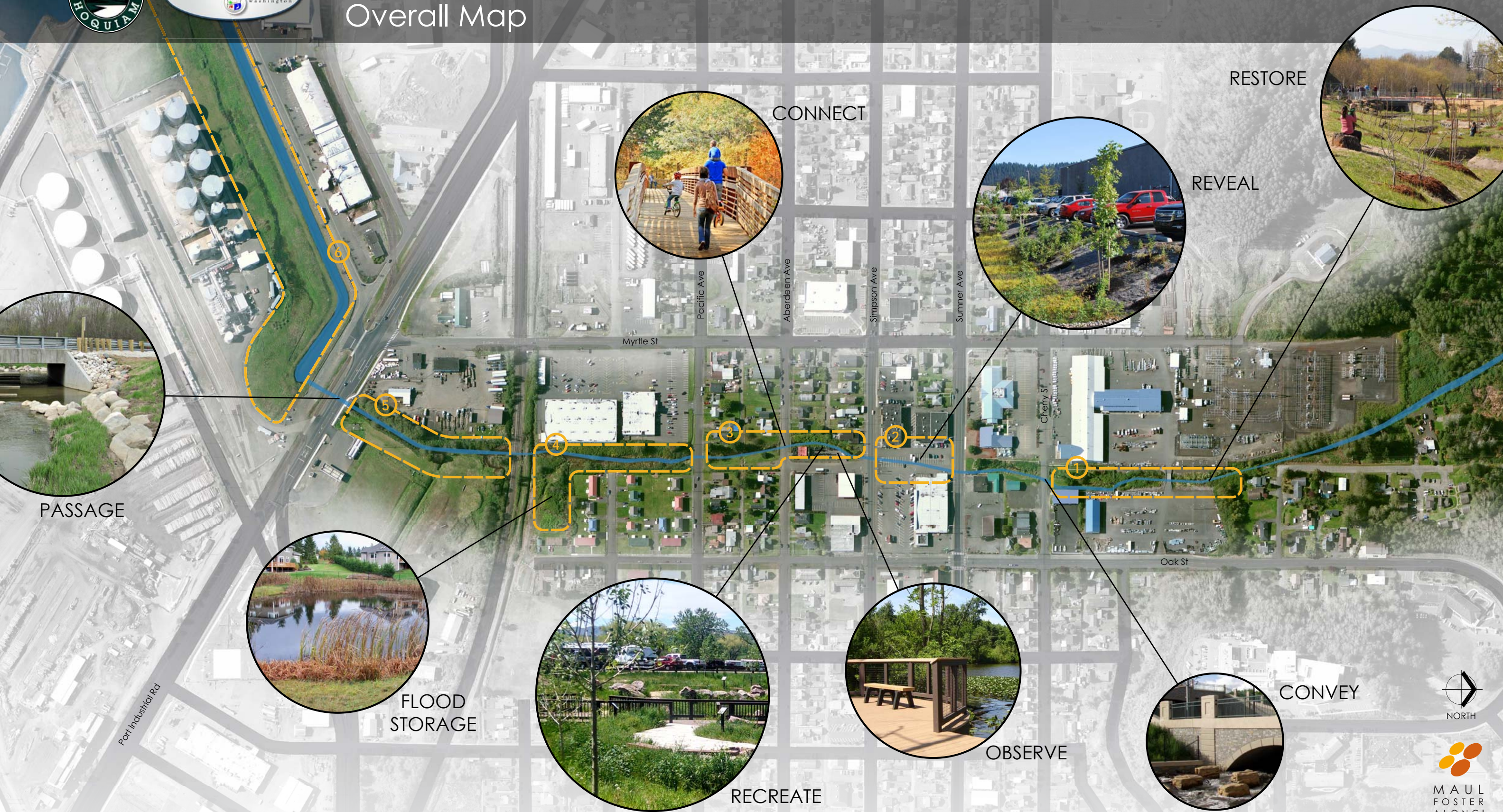
FIGURE 1-1

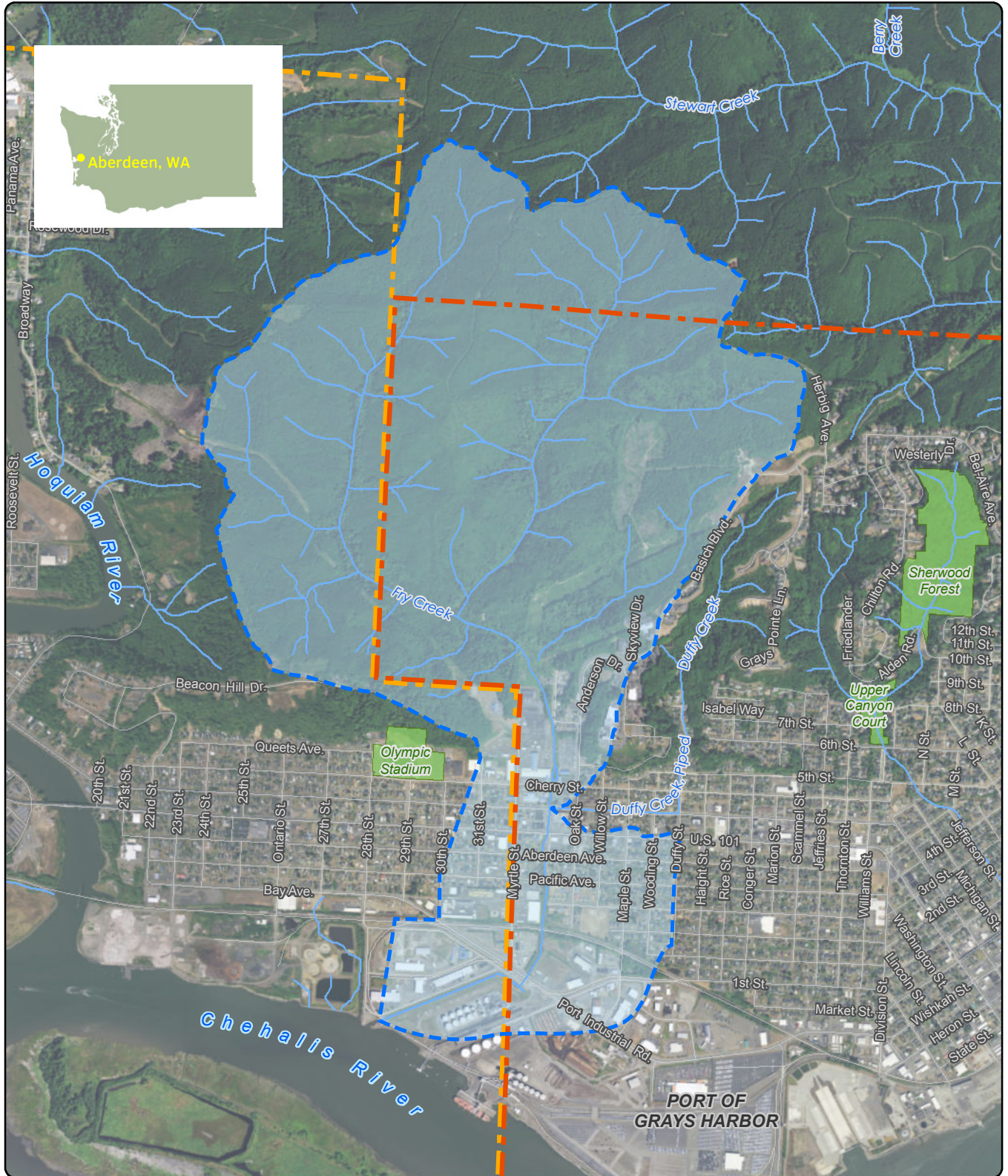


FRY CREEK RESTORATION & FLOOD REDUCTION

Overall Map

PRELIMINARY





Source: Aerial photograph obtained from Esri ArcGIS Online



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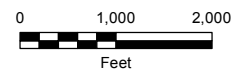
This product is for informational purposes and may not have been prepared for, or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information.

Legend

- Fry Creek Watershed
- Streams
- Parks
- Aberdeen Boundary
- Hoquiam Boundary

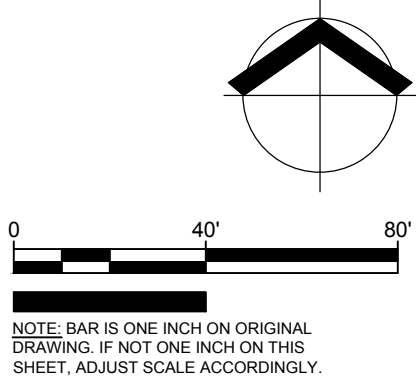
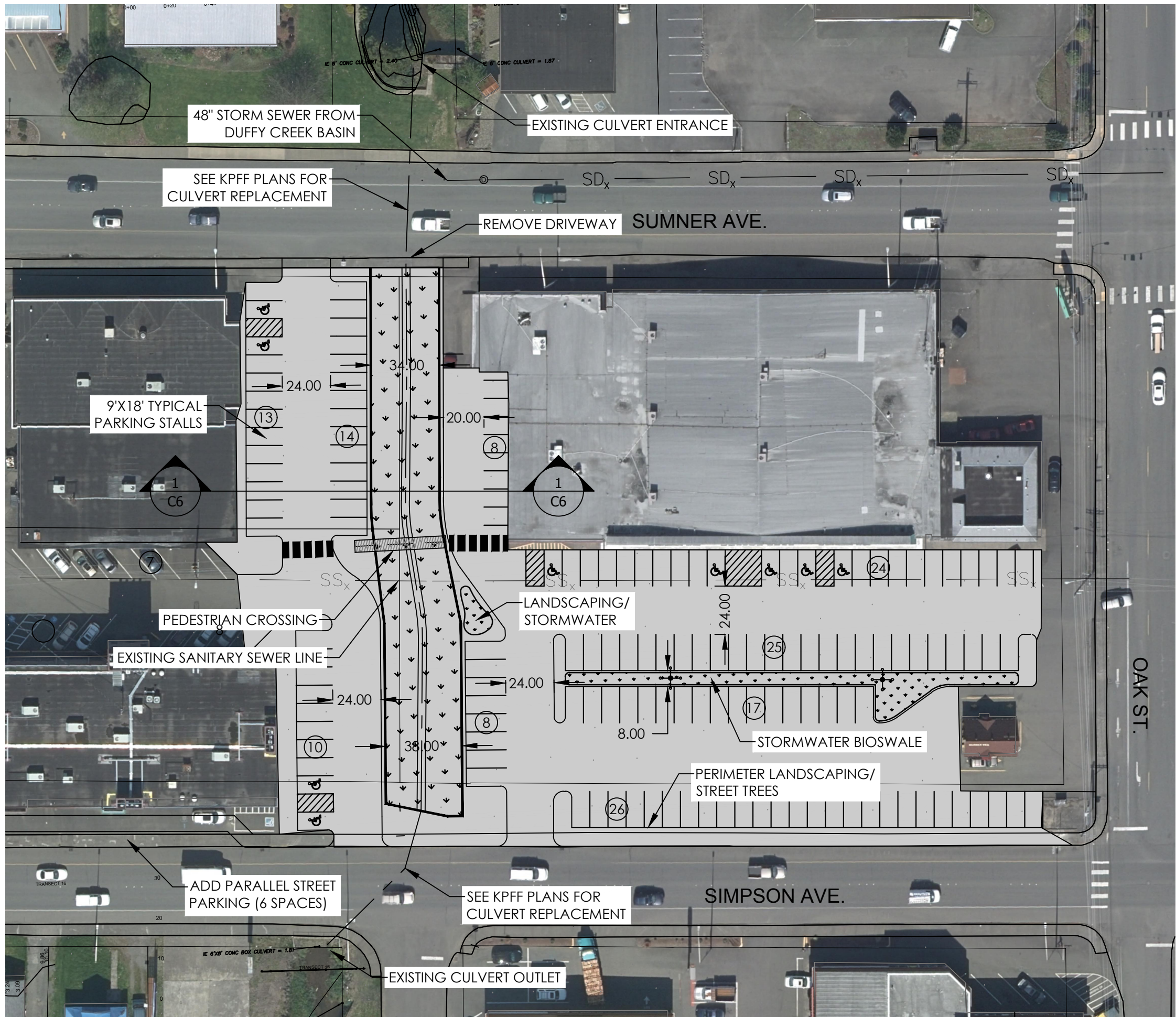
Figure 1-2 Fry Creek Watershed

Fry Creek Restoration and Flood
Reduction Project
Aberdeen, Washington



EXHIBITS

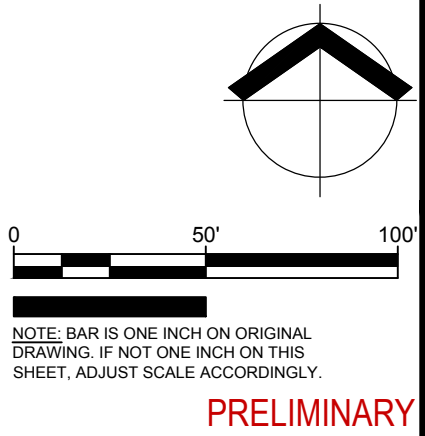





PRELIMINARY

SUMNER TO SIMPSON DAYLIGHTING CONCEPT
FRY CREEK RESTORATION & FLOOD REDUCTION
CITY OF ABERDEEN
ABERDEEN, WASHINGTON

EXHIBIT
C1



MFA JOB #:	0922.01.01
ISSUE DATE:	07/18/2017
CHECKED:	K. LOMBARDI
DRAWN:	J. ELLIOTT



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SUMNER TO SIMPSON THIRD PIPE CONCEPT

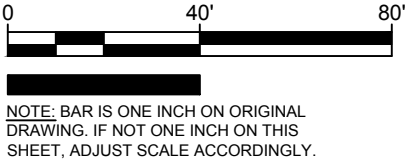
FRY CREEK RESTORATION & FLOOD REDUCTION

CITY OF ABERDEEN
ABERDEEN, WASHINGTON

EXHIBIT
C2

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NOTE: BAR IS ONE INCH ON ORIGINAL DRAWING. IF NOT ONE INCH ON THIS SHEET, ADJUST SCALE ACCORDINGLY.

PRELIMINARY

MFA JOB #:	0922.01.01
ISSUE DATE:	07/18/2017
CHECKED:	K. LOMBARDI
DRAWN:	J. ELLIOTT, C. RILEY



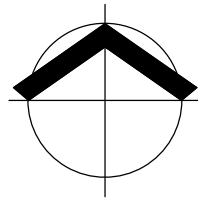
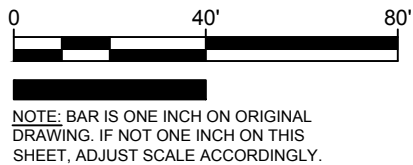
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ABERDEEN, WASHINGTON

EXHIBIT
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PRELIMINARY


ABERDEEN TO PACIFIC RESTORATION CONCEPT

FRY CREEK RESTORATION & FLOOD REDUCTION

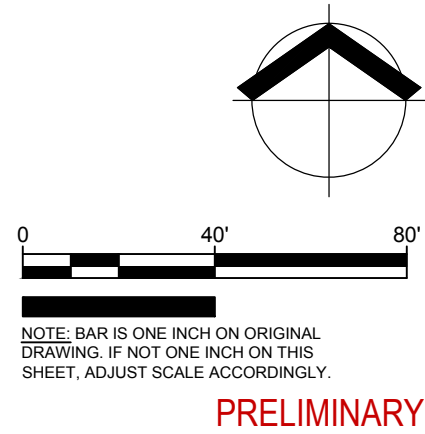
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ABERDEEN, WASHINGTON

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MFA JOB #:	0922.01.01
ISSUE DATE:	07/18/2017
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PRELIMINARY

PACIFIC TO RAILROAD RESTORATION CONCEPT
FRY CREEK RESTORATION & FLOOD REDUCTION

CITY OF ABERDEEN
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C5

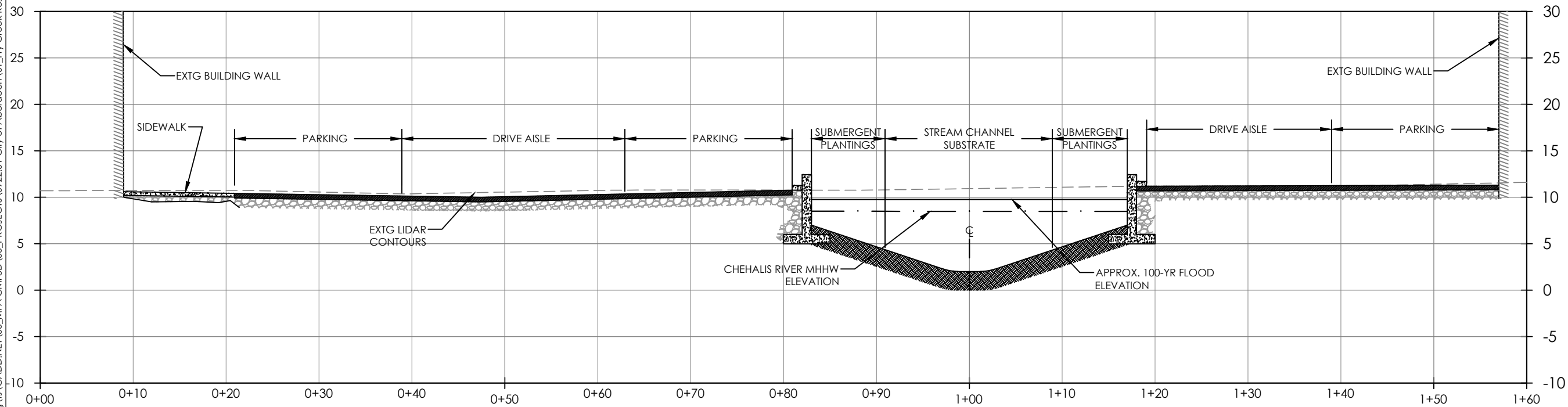
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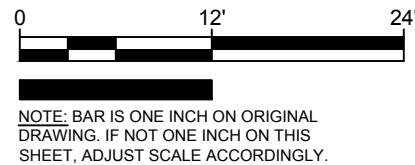
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C1
TYPICAL SECTION - SUMNER TO SIMPSON
HORIZ. 1" = 12'; VERT. 1" = 12'



PRELIMINARY

MFA JOB #:	0922.01.01
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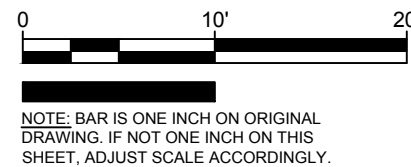
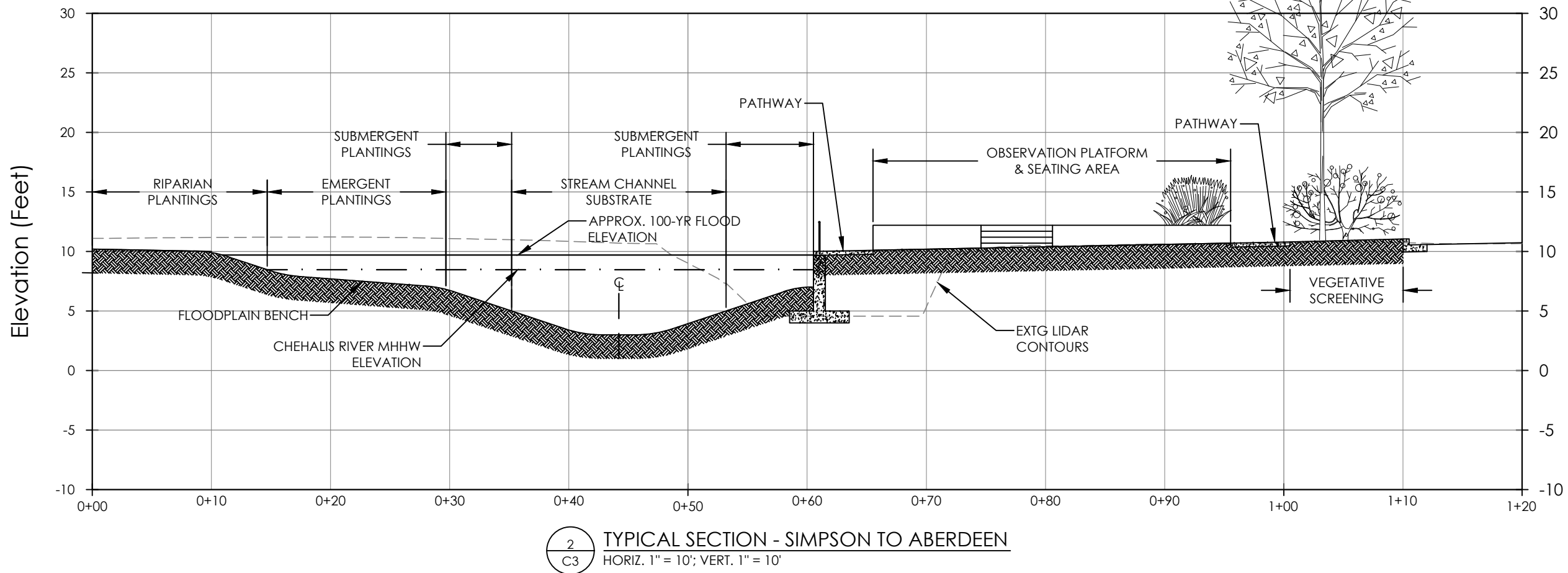
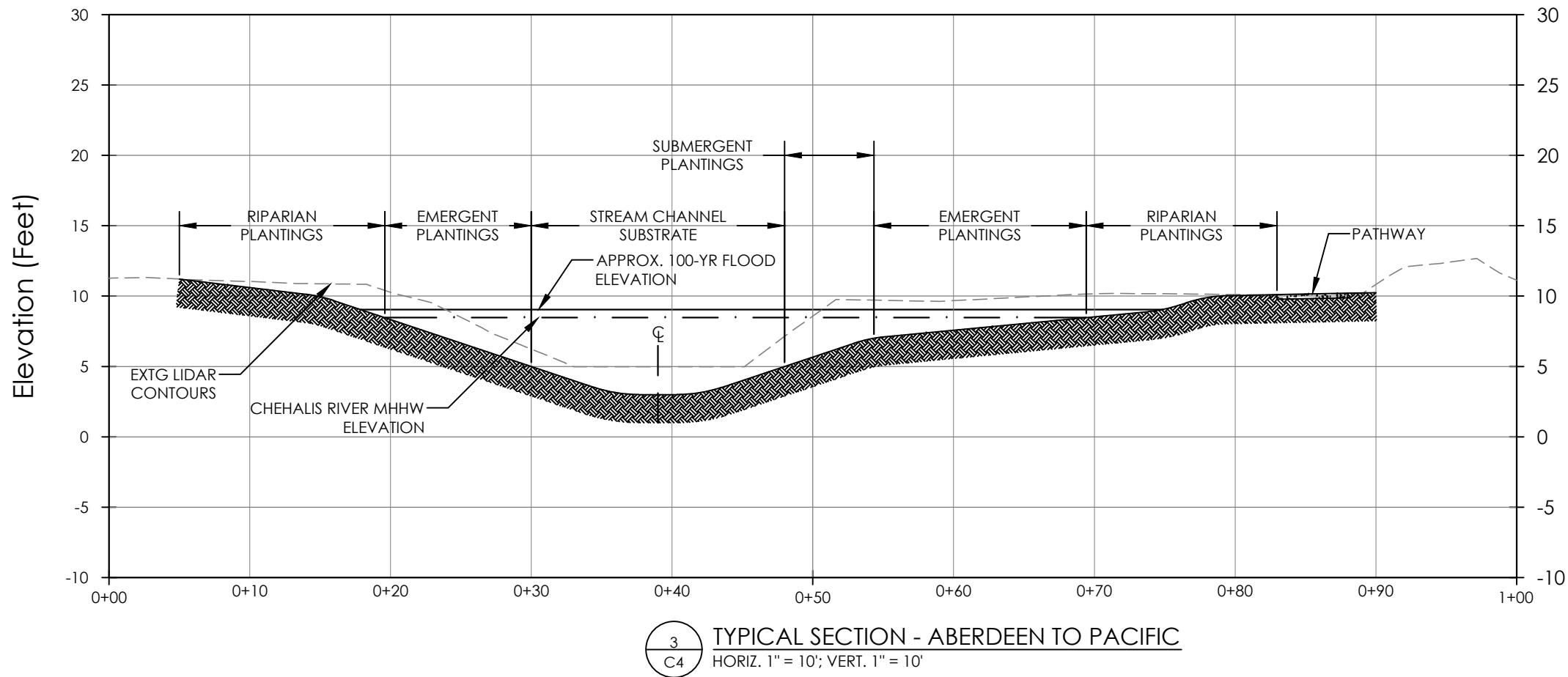


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TYPICAL SECTION 1
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EXHIBIT
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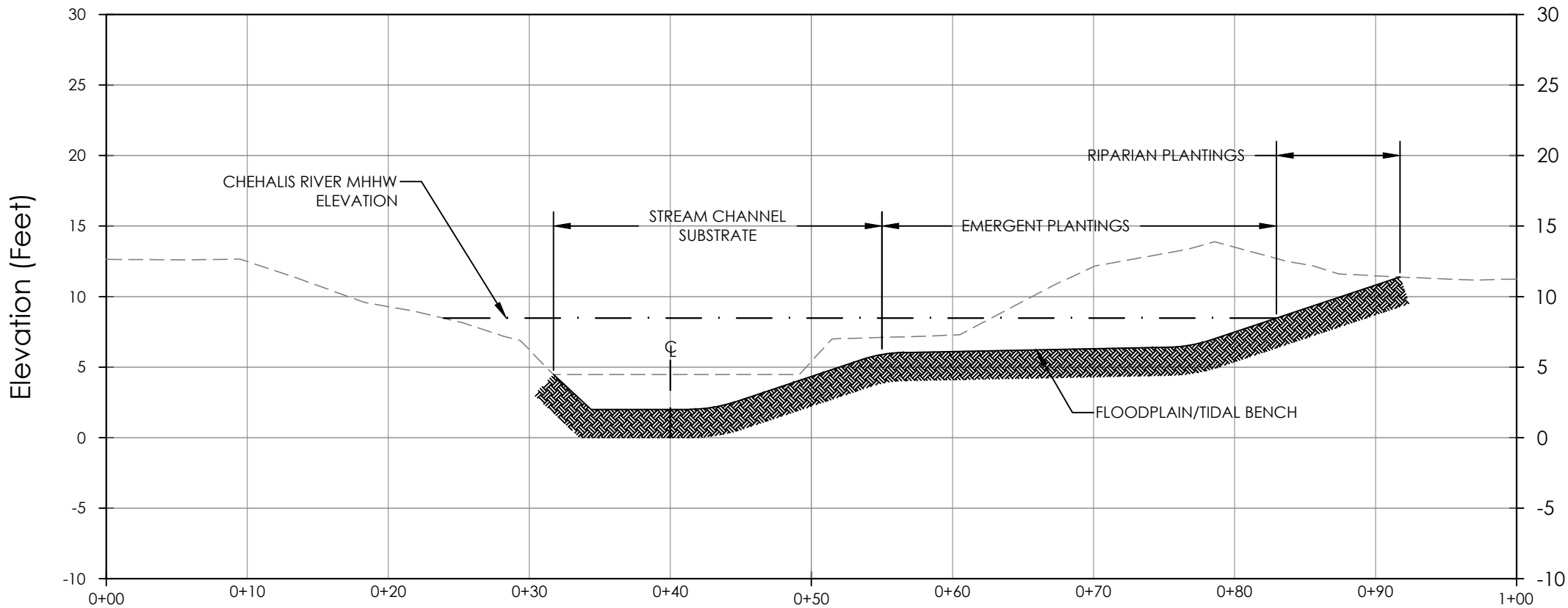


PRELIMINARY

TYPICAL SECTIONS 2 & 3
FRY CREEK RESTORATION & FLOOD REDUCTION
CITY OF ABERDEEN
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EXHIBIT
C7

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4
C5

TYPICAL SECTION - PACIFIC TO RAILROAD
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NOTE: BAR IS ONE INCH ON ORIGINAL
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SHEET, ADJUST SCALE ACCORDINGLY.


PRELIMINARY

TYPICAL SECTION 4

FRY CREEK RESTORATION & FLOOD REDUCTION

CITY OF ABERDEEN
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C8

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APPENDIX A

WSE MEMORANDUM



Memorandum

To: Kathy Lombardi, Maul Foster & Alongi
From: Larry Karpack, P.E. and Tim Tschetter, E.I.T.
Date: July 27, 2017
Re: Fry Creek Hydrologic and Hydraulic Model Development

INTRODUCTION

The following technical memorandum documents the development and calibration of hydrologic and hydraulic models by Watershed Science and Engineering (WSE) for the Fry Creek Rehabilitation and Restoration Project. Fry Creek is a small tidally influenced creek (Figure 1) that flows through the City of Aberdeen, WA. The purpose of this memo is to document data sources and model development, assumptions, and calibration. The Western Washington Hydrologic Model (WWHM) was used to simulate runoff into Fry Creek, and HEC-RAS was used to simulate hydraulic conditions within the creek. The baseline hydraulic model will be used to investigate design alternatives to restore aquatic habitat and reduce the potential for flooding.

MODEL DEVELOPMENT

DATA SOURCES

Data for Fry Creek were obtained from multiple sources. The City of Aberdeen provided GIS layers of the existing stormwater drainage network and design plans for the culverts beneath Cherry Street, Sumner and Simpson Avenues, and Aberdeen Avenue. KPFF Consulting Engineers (KPFF) surveyed channel cross sections, culvert lengths and invert elevations, and other points of interest in early 2017. Additional topographic information was obtained from a 3-foot by 3-foot gridded ground surface elevation model of the North Shore Levee project area provided by KPFF (created using aerial surveys collected in December 2014 and April 2016 by David C. Smith & Associates). Observations of the project site were made by WSE personnel during a site visit to Fry Creek on February 24th, 2017.

The default precipitation data used by WWHM for the Fry Creek basin comes from a gage in Montesano, WA, covering the period from October 1955 to September 2009. The precipitation time series record was extended to the present time using data from the Washington State University AgWeatherNet Station in Montesano, WA. Additional precipitation data from Bowerman Airport in Hoquiam, WA was acquired from NOAA's National Climatic Data Center (NCDC, 2017). Hydrologic soil classification maps were acquired from the National Resource Conservation Service Soil Survey Geographic Database (SSURGO) (NRCS, 2016). Land use in the watershed was determined from available aerial imagery.

Tidal water levels used as the model downstream boundary condition for this project were obtained from published levels for the NOAA tide station at Aberdeen (Station 9441187).

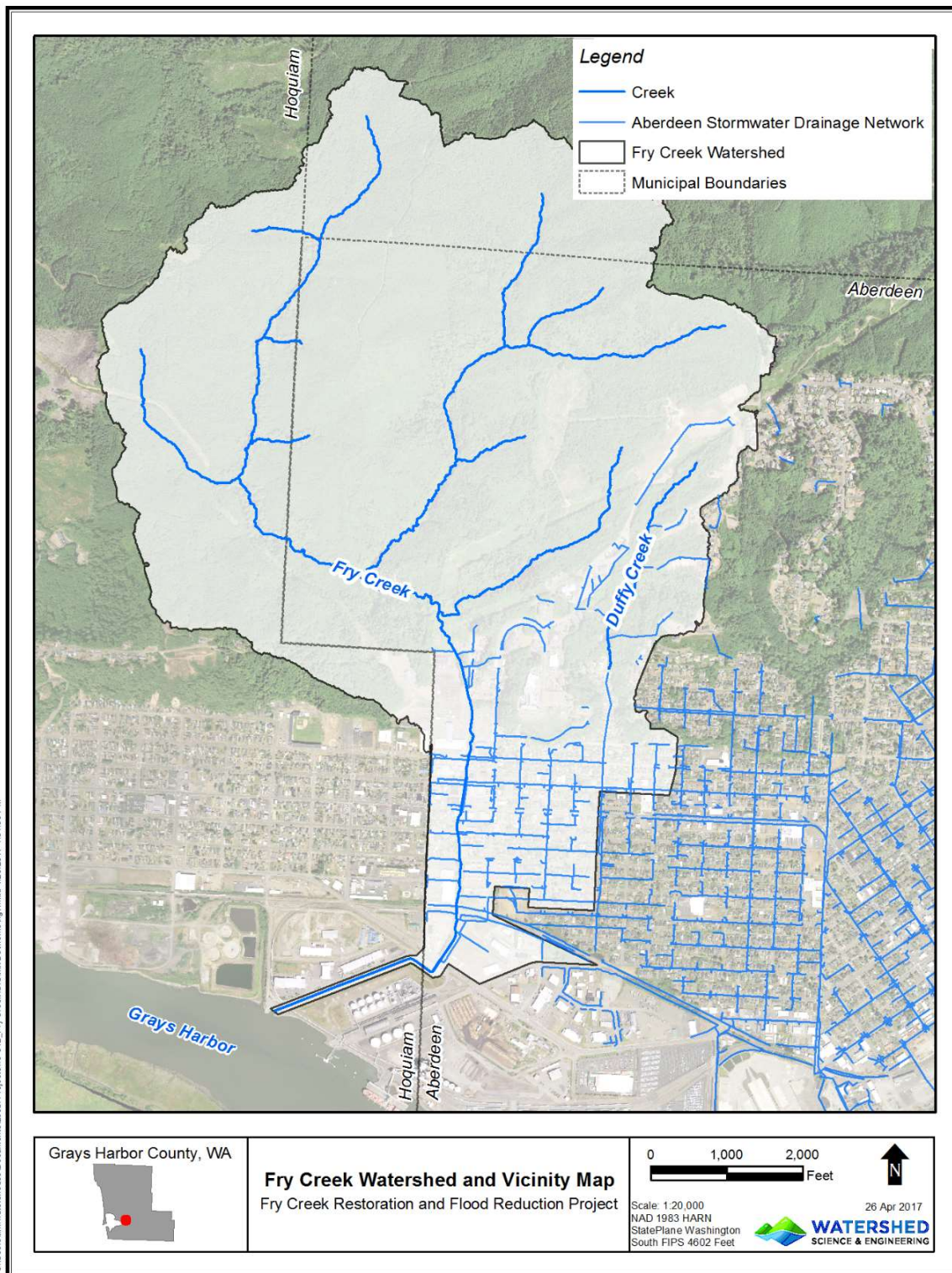


Figure 1 – Fry Creek Watershed and Vicinity Map.

There are no observed discharge or stage data or high water mark information available for Fry Creek. Anecdotal observations of historical flooding were made by Aberdeen city staff and community members. Those observations are summarized here. Kris Koski observed that Cherry Street had overtopped during Thanksgiving 2012 and January 2015. Larry Davis, the Facilities Maintenance Foreman at Grays Harbor PUD, noted that the culvert at Cherry Street had overtopped during January 2015 and one or two other times in the 11 years he has worked for the PUD. He also commented that the PUD yard bridge has not overtopped to his knowledge, and that during high flow events water leaves Fry Creek downstream of the PUD Bridge and flows southeast towards the PUD buildings.

HYDROLOGIC MODEL DEVELOPMENT

WWHM2012 is a continuous simulation hydrologic model produced for the Washington State Department of Ecology that uses the Hydrologic Simulation Program – Fortran (HSPF) computational engine. WWHM accesses a database of long term precipitation and pan evaporation time series and uses these data to simulate runoff based on user defined subbasin, land use, and soil type information.

The Fry Creek watershed was divided into fifteen subbasins (Figure 2). Subbasins in the undeveloped upper portion of the watershed were delineated based on topographic data from the digital elevation model. The lower developed portion of the watershed was delineated based on topographic data and maps of the stormwater drainage network provided by the City of Aberdeen.

SSURGO hydrologic soil groups were reclassified based on Table 1 for use in WWHM. SSURGO soil maps indicate that the predominant hydrologic soil type in the upper watershed is type B. During initial modeling runs this area was modeled as type A/B (outwash), but during model calibration this area was changed to type C (till). Geologic mapping indicates that most of the upper watershed consists of pre-Quaternary marine sedimentary rocks (Rau, 1986). The hilltops are mapped as Quaternary outwash deposits, but Rau (1986) notes that outwash deposits on hilltops (like in Fry Creek) are generally thin. Infiltration in the thin outwash deposits in the upper Fry Creek watershed is restricted by the underlying bedrock, and are therefore acts more like a type C (till) soil. The soil type distribution modeled in WWHM is shown in Figure 2.

Table 1. Table showing soil types in SSURGO dataset and as used in WWHM.

Mapped SSURGO Hydrologic Soil Group	Modeled Soil Type in WWHM
A	A/B (outwash)
B	C(till)
C	C (till)
C/D	Saturated

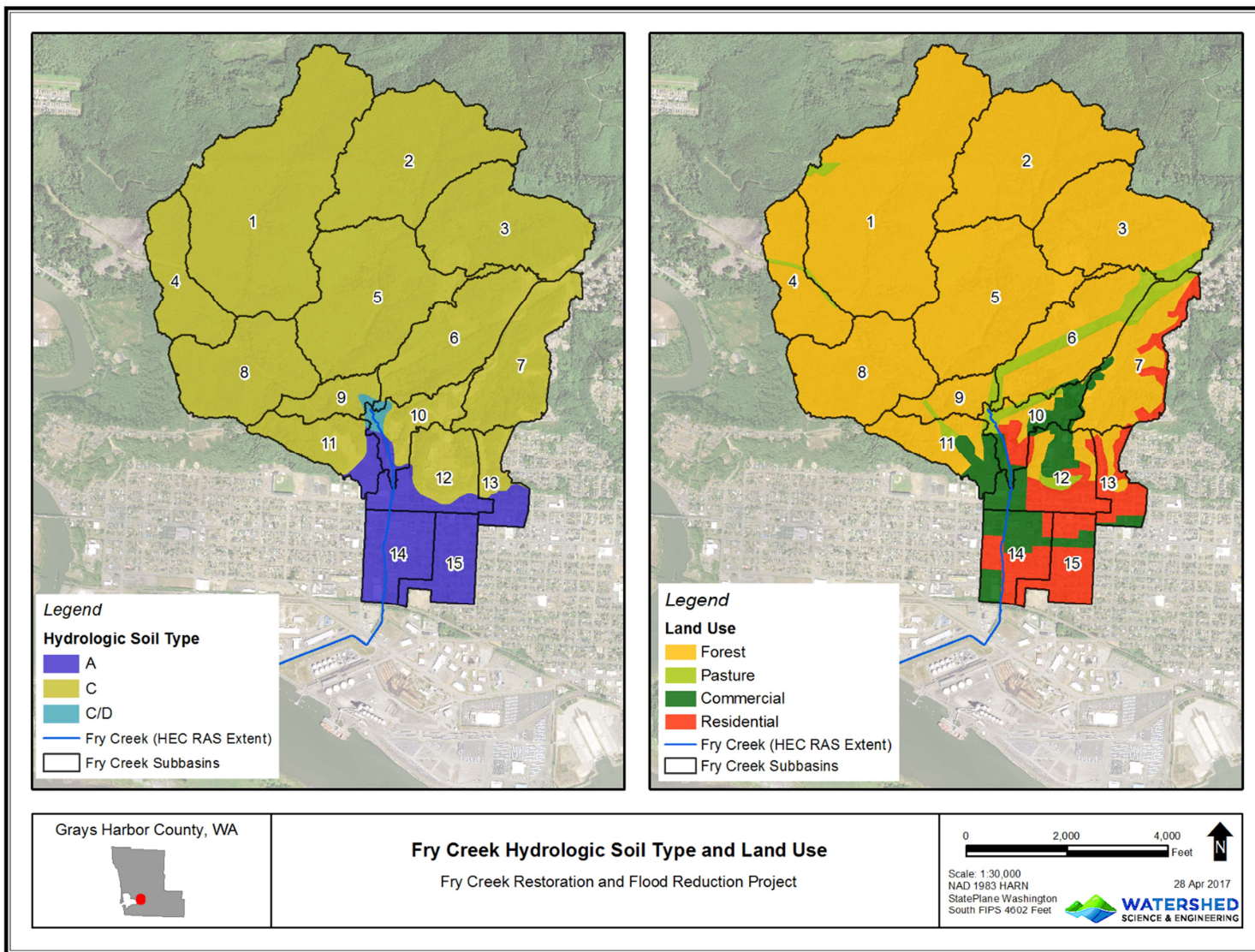


Figure 2

Figure 2 – Fry Creek hydrologic soil type and land use.

The soil type and land use distributions (Figure 2) were overlain in GIS to determine the area within each subbasin of each classification as required by WWHM. Commercial and residential land use areas were assumed to be 85% and 25% effective impervious, respectively. See Appendix A (WWHM model results) for additional details on subbasin characteristics. Within WWHM, subbasins are linked by channel elements. The length and slope of the channels and ditches were determined by GIS analysis of the digital elevation model. The bottom width of all channels was assumed to be 5 feet and the Manning's n coefficient was assumed to be equal to 0.03.

For the area around the Fry Creek Project site, WWHM uses observed 15-minute precipitation data from Montesano, WA. Data for that gage are available for the period October 1, 1955 to September 30, 2009. To account for differences in precipitation between the gage site and the project area, the model scales the precipitation by a multiplication factor based on the ratio of the 24-hour, 25-year rainfall intensities at the two locations from NOAA Atlas 2 (NOAA, 1973). For this project the scale factor was 1.1. The precipitation time series record in WWHM was extended through March 8, 2017 using 15-minute gage data from the Washington State University AgWeatherNet Station in Montesano, WA. Additionally, precipitation data for January 4-5, 2015 measured at the Bowerman Airport (USW00094225) in Hoquiam was used in place of the Montesano data for that time period. There was a large flood in Aberdeen on January 4-5, 2015 and it was felt that the data for Bowerman airport did a better job of representing the precipitation depths and intensities for that particular event than data from the Montesano gage.

DESIGN STORM DEVELOPMENT

Modeled discharges were extracted from WWHM at four locations (Figure 3) corresponding to the inflow points into Fry Creek in the HEC-RAS model. The catchments defined by the four inflow points are referred to as subbasin groups for the remainder of this report. Flow frequencies for the four subbasin groups were calculated by WWHM as shown in Table 2. Inflow hydrographs for HEC-RAS for the 2-, 10-, 25-, 100-, and 500- year design storms were developed using the following procedure:

1. The WWHM modeled discharge for the Upper Fry Creek subbasin group (inflow into the upstream end of the HEC-RAS model) were averaged over three durations, using moving time windows of 15-minutes, 1-hour, and 3-hours.
2. For each duration, the annual peak events were identified and ranked.
3. A flood frequency analysis was completed to determine the magnitude of the 10- and 100- year events for each duration.
4. The ranked annual peak events were then reviewed to determine historic flood events that approximately equaled the 10- and 100- year events at each of the three durations. Based on this analysis, the January 24, 1972 event was selected as the pattern hydrograph for the 100- year and 500- year event and the November 30, 1975 event was selected as the pattern for the 2-, 10-, and 25- year events.
5. The 100- and 500- year inflow hydrographs were developed by scaling the WWHM simulated hydrograph from the 1972 event. The scaling factor was determined as the ratio of the flow frequency quantile to the simulated maximum discharge for the event in the Upper Fry Creek subbasin group. This ensured that the peak inflow to the model matched the corresponding flow frequency value. The scaling factor from the Upper Fry Creek subbasin group was then applied to

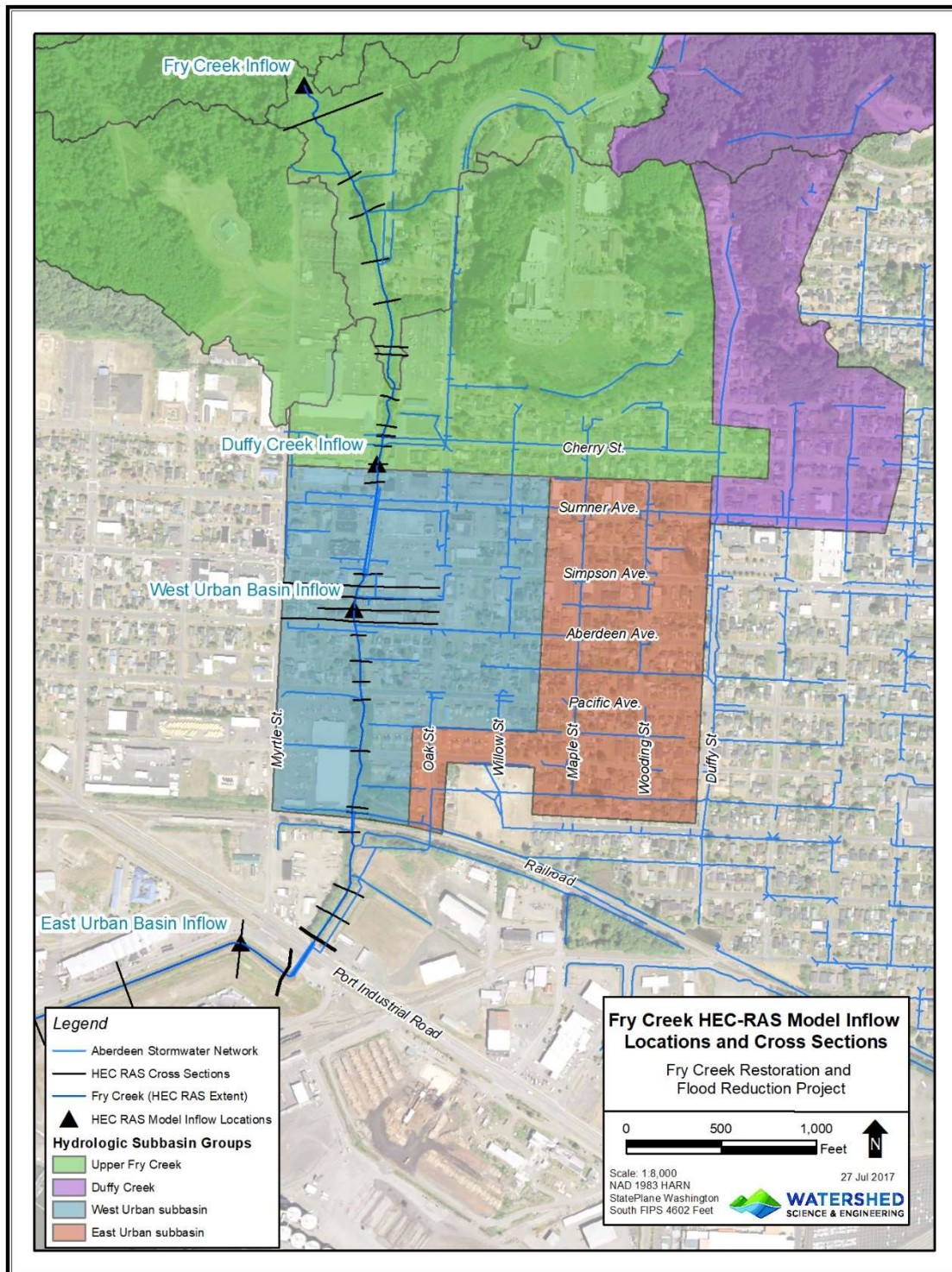


Figure 3

Figure 3 – Fry Creek model inflow locations, HEC-RAS cross sections, and subbasin groups.

the other three subbasin groups. This approach ensures that the storm is realistic as it is based on an observed storm scaled up uniformly over the watershed. It should be noted that this approach does not result in a 100-year inflow for each of the tributaries as it is unlikely that all of the tributaries, with varying sizes and levels of urbanization, would experience 100-year flows during the same event. The 100- year design synthetic hydrographs for the four HEC-RAS input locations are shown in Figure 4.

6. The above process, steps 1 through 5, was then completed for the 2-, 10-, and 25- year events using the 1975 event as the pattern hydrograph.

Table 2. WWHM modeled flow frequency for the Fry Creek subbasin groups.

Subbasin Group	2- year Discharge (cfs)	10- year Discharge (cfs)	25- year Discharge (cfs)	100- year Discharge (cfs)	500- year Discharge (cfs)
Upper Fry Creek	151	250	297	363	439
Duffy Creek	31	48	56	67	78
Urban Basin West	32	44	49	56	62
Urban Basin East	22	31	35	40	45

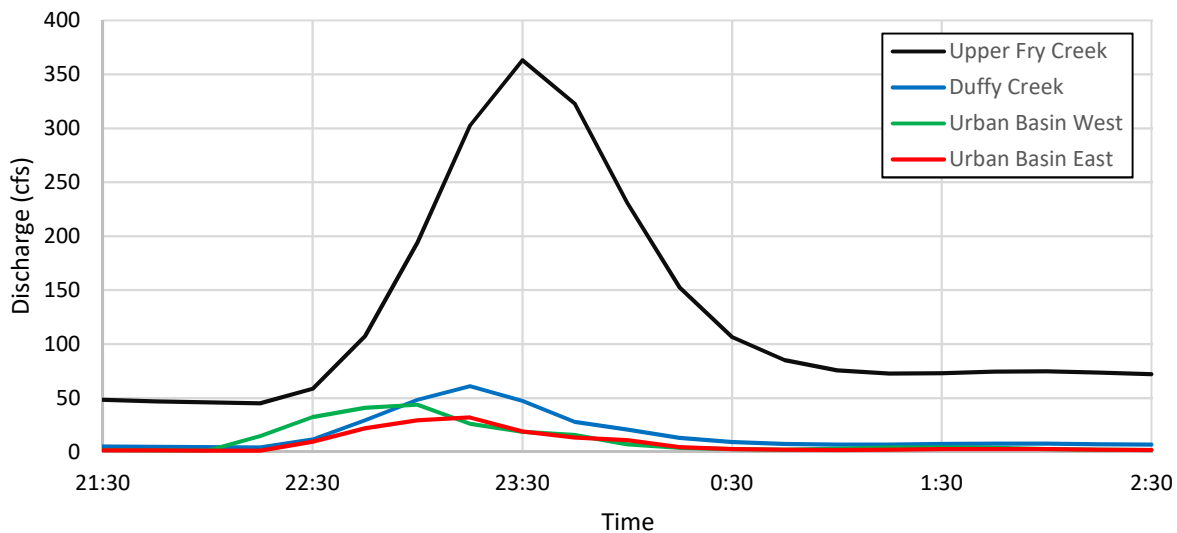


Figure 4 – 100-yr design synthetic hydrographs used for inflow into HEC-RAS hydraulic model.

HYDRAULIC MODEL DEVELOPMENT

A HEC-RAS one-dimensional unsteady hydraulic model of Fry Creek was developed to support hydraulic design of restoration and flood reduction alternatives. The initial model configuration was prepared using HEC-GeoRAS, an ArcGIS extension that processes GIS data for import into HEC-RAS. Cross section locations were specified based on the location of KPFF’s surveyed cross sections. Bank station positions were digitized in ArcGIS based on observed channel extents in aerial photographs. Land cover polygons within the cross-section extents were digitized based on aerial photographs, and corresponding Manning’s *n* values (Table 3) were selected based on Chow (1959). After importing the geometric data into HEC-RAS,

the cross sections were updated with station and elevation data from KPFF's survey data. Manning's n value for the Fry Creek channel was set to 0.035.

Culvert parameters (length, size, shape, material, invert elevations) were specified using design plans provided by the City of Aberdeen. Where design plans were not available, culvert parameters were input based on the KPFF survey data. Culvert entrance loss coefficients were set based on guidance in the HEC-RAS Reference Manual (USACE, 2016) and field observations by WSE personnel. Several of the culverts had sediment accumulation present. If the surveyed culvert invert elevation was higher than the invert elevation specified on the design plans, then the culvert was assumed blocked to that depth in HEC-RAS. Manning's n within all culverts was set to 0.024. The entrance of the Cherry Street culverts is protected by a trash rack (Figure 5), which was included in the model as a series of vertical obstructions that block 20% of the culvert entrance. The blocked percentage was assumed greater than the physical blockage by the vertical bars to account for additional hydraulic losses and blockage by debris during high flow events.

Table 3. Manning's n values by surface type within the HEC-RAS cross sections.

Channel/Overbank Surface	Manning's n
Channel	0.035
Grass	0.04
Brush	0.06
Thick Brush	0.08
Paved	0.02



Figure 5 – The entrance to the Cherry Street culverts is protected by a trash rack.

Lateral structures were placed at two locations in the model to account for off-channel storage and at two locations to simulate flow diversions out of the basin. The lateral structures were included where low overbank elevations near to the channel would allow flow out of the channel. The off-channel storage areas are on the east side of the channel near Cherry Street and in a drainage ditch north of the railroad.

The lateral structures that let flow leave Fry Creek are at the west side of the Cherry Street crossing and on Myrtle Street between Aberdeen and Simpson Avenues. Flow that leaves the channel at these locations flows west toward Hoquiam. The flow diversion at Cherry Street has been observed and reported by several sources whereas flooding at Myrtle Street has not been reported to WSE by anyone. However, a lateral structure was included in the model at that location because Myrtle Street is the lowest elevation on the block bounded by Myrtle, Aberdeen, Simpson, and Oak Streets and the model simulates flooding in this area under certain conditions.

The Fry Creek pump station at Port Industrial Road was modeled as a single pump outlet in parallel with twin 5.5-foot diameter culverts with flap gates. A single large pump at the pump house (Cascade 36P 250HP) is controlled by a float switch that turns the pump on at a water level of 6.92 feet and off at a water level of 5.42 feet. A pump curve is not available for the current pump configuration, so the modeled pump rate was set to a constant rate 62.4 cfs (28,000 gpm) regardless of head difference across the pump. A second smaller pump (Flygt 3201 30HP - 4,000 gpm/8.9 cfs) at a nearby (possibly linked) pump station was not included in the model.

The upstream boundary condition in the HEC-RAS model was defined by the WWHM based synthetic inflow hydrograph from the upper Fry Creek subbasin group. Additional lateral inflow hydrographs were specified at three locations as shown in Figure 3. See flow routing section below for discussion of inflow placements. The downstream boundary condition for the model was defined as the estimated mean higher high water (MHHW) or mean sea level (MSL) in Grays Harbor shown in Table 4. MHHW is the recommended downstream boundary condition for FEMA mapping and also a logical condition for two independent conditions (such as high tides and high creek flows) (FEMA, 2009).

Table 4. Tide and corresponding elevations used for the downstream boundary conditions. Tide elevations are published values from NOAA's Aberdeen tide gage (station ID 9441187).

Tide	Elevation (ft NAVD88)
MHHW	8.47
MSL	3.96

FLOW ROUTING

Flow routing through the Aberdeen stormwater drainage network is highly dependent on downstream tide levels and pumping rates. This makes it difficult to determine where and how much of the modeled stormwater runoff enters Fry Creek at specific locations. Developing a complete stormwater drainage network model is beyond the scope of this project, so some simplifying assumptions were made as follows:

1. All runoff generated within the upper Fry Creek subbasin area (Figure 3) was routed into the upstream end of the Fry Creek hydraulic model.
2. All runoff generated in Duffy Creek was added to Fry Creek hydraulic model between Cherry Street and Sumner Avenue (Figure 3). Diagrams of the Aberdeen stormwater drainage network indicate discharge from Duffy Creek may follow multiple flow paths to Fry Creek, or flow south then east and not join the Fry Creek watershed. The most likely route for Duffy Creek discharge is west via

the storm drain beneath Sumner Avenue, which flows into the culvert beneath Sumner and Simpson Avenues. Drainage to the south along Duffy Street is limited by smaller diameter piping and a higher invert elevation in the manhole vault beneath the intersection at Duffy Street and Sumner Avenue. Assuming all discharge from Duffy Creek enters Fry Creek between Cherry and Sumner is the most conservative routing estimate possible regarding flooding in the Cherry Street area.

3. All runoff generated within the Urban West subbasin (Figure 3) was added to the Fry Creek hydraulic model immediately upstream of the Aberdeen Avenue culvert. This location was chosen because it is the center of the catchment and the outflow of a stormwater drain beneath Aberdeen Avenue.
4. Runoff generated by the Urban East subbasin was added to Fry Creek downstream of the pump station at Port Industrial Road. The stormwater drainage network maps indicate runoff from this area may flow beneath the railroad to the second smaller pump at the Fry Creek Pump Station, or flow east and exit the Fry Creek watershed.

MODEL CALIBRATION

The only calibration data available for either the hydrologic or hydraulic model was the anecdotal observation that Fry Creek has flooded upstream of the Cherry Street culvert twice within the last ten years. The lack of calibration and validation data results in considerable uncertainty in the model results. Given the lack of detailed data for calibration the singular objective of model calibration was to simulate overtopping at Cherry Street during a 10-year flood event.

MODEL RESULTS AND DISCUSSION

Modeled maximum water surface elevation profiles are shown in Figure 6. While the model predicts overtopping at Cherry Street during the 10-year event, the model does not predict overtopping during the two observed historical floods (Thanksgiving 2012 and January 4-5, 2015). Flooding in Aberdeen on January 4-5, 2015 was some of the most severe flooding observed in the last 100 years although some reports indicate that flooding may have been exacerbated by sediment or debris entering the storm drain system. The WWHM simulated discharges for these events seems low because they do not overtop Cherry Street, but there is no way to verify the accuracy of the modeled discharges without observed flow data.

Review of the hydrologic model results suggest the predicted discharge is highly sensitive to short duration (i.e. 15 minute) intensities in precipitation. The measured precipitation data from the Bowerman Airport in Hoquiam was used to simulate the 2015 event because more total precipitation and greater precipitation intensity was measured at Hoquiam during this event than at Montesano. However, the Hoquiam gage only reports data in hourly increments, and therefore it is impossible to know what the peak 15-minute intensity was during this event; and the resulting simulated discharge is likely lower than if 15-minute precipitation data were available.

As noted previously reports indicate that on at least two recent occasions flow has been observed leaving Fry Creek and flowing west along Cherry Street towards Hoquiam. A lateral structure was included in the hydraulic model at Cherry Street to simulate this flow diversion. The modeled diversion towards Hoquiam

is shown in Table 5 but without measured flow data, the accuracy of the modeled diversion rates is impossible to assess. Irrespective of model accuracy, any modification to Fry Creek that reduces the stage immediately upstream of Cherry Street will reduce the amount of diverted flow and effectively increase the downstream discharge in Fry Creek.

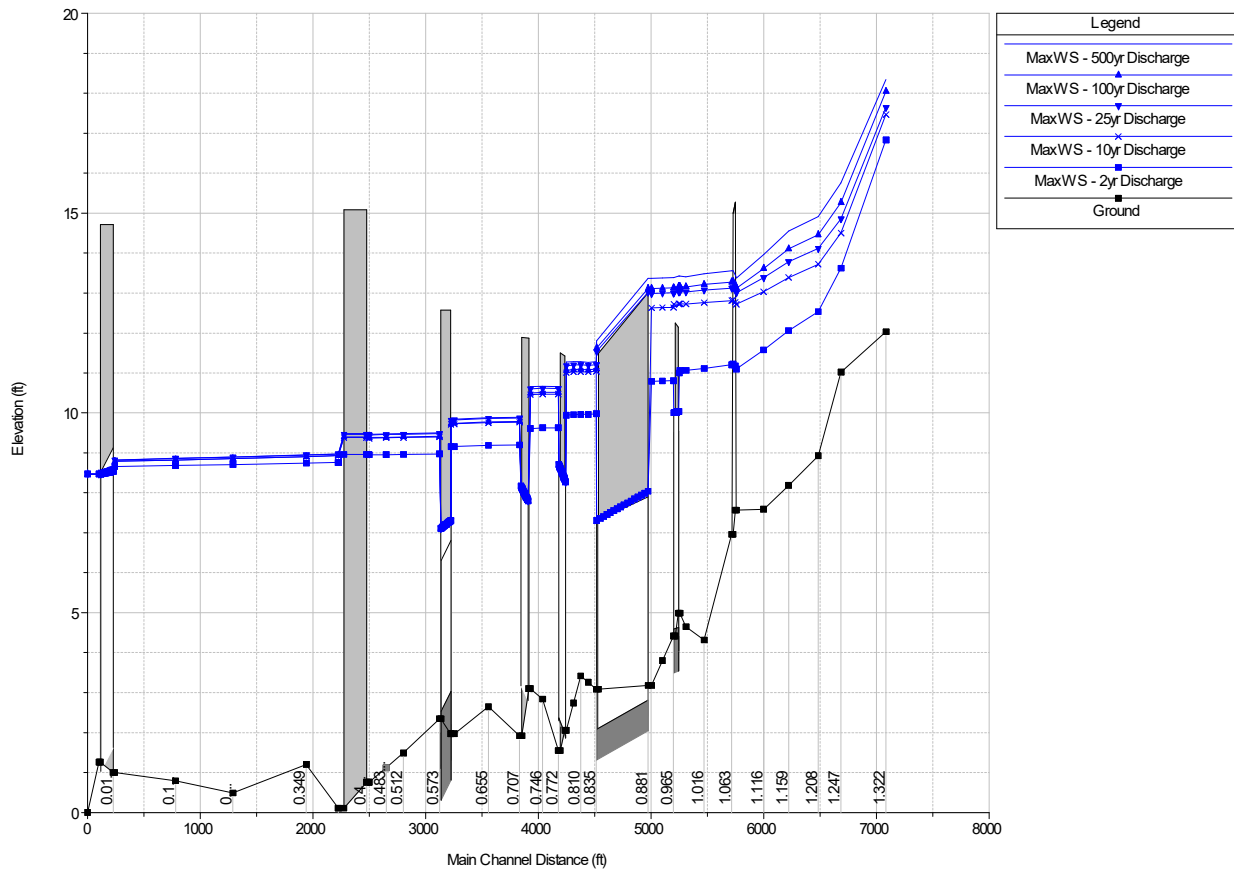


Figure 6. Maximum modeled water surface elevations for 2-, 10-, 25-, 100-, and 500-year discharge in Fry Creek. The tidal boundary condition used for all runs was mean higher high water (MHHW).

Table 5. Modeled flow diverted at Cherry Street toward Hoquiam.

Return Period (year)	Max. Discharge upstream of Cherry St. (cfs)	Max. Discharge Diverted at Cherry St. (cfs)
2	136	0
10	244	76
25	292	128
100	355	177
500	429	250

CLIMATE CHANGE EVALUATION

CLIMATE CHANGE SCENARIO PREDICTIONS

Climate change is predicted to increase the magnitude of extreme precipitation events in Western Washington and cause a rise in sea levels. The impact of future climate change on the Fry Creek watershed was assessed by scaling the discharge hydrographs for the five design flow events (2-, 10-, 25-, 100-, and 500-year) and increasing the tidal water level boundary condition based on climate change predictions for the second half of the 21st century. Design flows were increased using the scaling factors shown in Table 6. These represent the average increases seen in flow quantiles based on modeling and analysis done by the University of Washington Climate Impacts Group (UW CIG, 2016). These same scaling factors are also being applied to other work done for the Chehalis Basin Strategy (WSE, 2017).

Table 6. Climate change discharge scaling factors for the lower Chehalis Basin.

Return Period (year)	Climate Change Discharge Scaling Factor
2	+16%
10	+35%
25	+47%
100	+66%
500	+94%

For the tidal boundary, Kopp et al. (2014) predicted a water level increase of 1.25 feet by 2075 in Willapa Bay for the RCP 8.5 scenario. This prediction is the closest available to Grays Harbor and was recommended by the UW CIG. The tidal water level increase was added to the current MHHW tide level (8.47 ft NAVD88), meaning the downstream boundary condition used in the climate change scenario modeling was 9.72 ft NAVD88.

CLIMATE CHANGE MODELING RESULTS

Table 7 shows the modeled water surface elevation increase for the 2- and 10- year discharges for the climate change scenario over the current hydrologic conditions. Modeled water surface elevations rise by 0.81 to 1.47 feet when the predicted climate change effects are included in the analysis. The water surface elevations predicted for the 10- year climate change scenario are equal to or higher than the water surface elevations predicted for the current 100-year event. With the higher simulated water levels near Cherry Street and Aberdeen Avenue, a larger percentage of flow would leave the Fry Creek watershed at these locations and flow towards Hoquiam.

Downstream of Simpson Avenue, water surface elevations predicted by the model for the 10-year with climate change scenario should be regarded as approximate because water surface elevations at some model cross sections are higher than the ground at the edge of the sections and in reality water might leave Fry Creek (although in HEC-RAS it cannot do so). Extending the cross-sections to higher ground is not feasible because the ground surface is level or decreases as one moves away from the creek. The 100- and 500- year with climate change scenarios yielded water surface elevations well above the cross-section topography and are therefore not reported here.

Overall, the future climate change scenarios would result in deeper and more frequent flooding in Hoquiam and Aberdeen. Note, however, that these events cannot be modeled accurately using the one-dimensional HEC-RAS model as the overbank flows become very two-dimensional at these higher discharges.

Table 7. Predicted water surface elevation increase for the 2- and 10- year discharges for the climate change scenario over the current hydrologic conditions.

Event	XS	Location	Predicted Increase in Water Surface Elevation (ft)
2-yr	0.976	Cherry St.	1.1
2-yr	0.928	Sumner Ave.	1.19
2-yr	0.786	Aberdeen Ave.	1.02
2-yr	0.725	Pacific Ave.	1.06
2-yr	0.592	Railroad #1	1.12
2-yr	0.454	Port Industrial	1.14
2-yr	0.027	Railroad #2	1.24
10-yr	0.976	Cherry St.	0.81
10-yr	0.928	Sumner Ave.	0.94
10-yr	0.786	Aberdeen Ave.	1.01
10-yr	0.725	Pacific Ave.	1.24
10-yr	0.592	Railroad #1	1.41
10-yr	0.454	Port Industrial	1.47
10-yr	0.027	Railroad #2	1.22

SUMMARY AND CONCLUSION

A WWHM hydrologic model and HEC-RAS hydraulic model were developed and used to characterize baseline conditions in Fry Creek. The hydrologic model utilized precipitation records from Montesano and Hoquiam to simulate runoff within the Fry Creek watershed. The hydraulic model utilized survey data, available digital elevation models, and design plans from the City of Aberdeen to represent the physical configuration of the drainage system. The models were validated to anecdotal observations of historical flooding and then used to simulate the 2-, 5-, 10-, 100-, and 500- year flood events. Additional climate changed scenarios were also simulated to provide information on how flooding along Fry Creek might change in the future.

The models developed here will be used to inform the design of restoration and flood damage reduction projects along Fry Creek. Although there is considerable uncertainty in the modeling due to the lack of any calibration data the models are considered reasonable for the intended purpose. As time and budget allow, streamflow gaging along the creek could allow refined model calibration and improved accuracy. Unless and until such data become available the models developed for this study provide the best available tools for characterizing flows and water levels along Fry Creek.

REFERENCES

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Appendix A – WWHM Project Report

WWHM2012 PROJECT REPORT

General Model Information

Project Name: FryCreek_FINAL
 Site Name:
 Site Address:
 City:
 Report Date: 5/8/2017
 Gage: Montesano
 Data Start: 1955/10/01 00:00
 Data End: 2017/03/06 00:00
 Timestep: 15 Minute
 Precip Scale: 0.00 (adjusted)
 Version Date: 2016/02/25
 Version: 4.2.12

POC Thresholds

Low Flow Threshold for POC1:	50 Percent of the 2 Year
High Flow Threshold for POC1:	50 Year
Low Flow Threshold for POC2:	50 Percent of the 2 Year
High Flow Threshold for POC2:	50 Year
Low Flow Threshold for POC3:	50 Percent of the 2 Year
High Flow Threshold for POC3:	50 Year
Low Flow Threshold for POC4:	50 Percent of the 2 Year
High Flow Threshold for POC4:	50 Year
Low Flow Threshold for POC5:	50 Percent of the 2 Year
High Flow Threshold for POC5:	50 Year
Low Flow Threshold for POC6:	50 Percent of the 2 Year
High Flow Threshold for POC6:	50 Year

Landuse Basin Data Predeveloped Land Use

Basin 3
 Bypass: No
 GroundWater: No
 Pervious Land Use acre
 C, Forest, Mod 119
 C, Pasture, Mod 6
 Pervious Total 125
 Impervious Land Use acre
 Impervious Total 0
 Basin Total 125

Element Flows To:
 Surface Interflow Groundwater
 Channel 5 Channel 5 Channel 5

Basin 2
 Bypass: No
 GroundWater: No
 Pervious Land Use acre
 C, Forest, Mod 156.9
 Pervious Total 156.9
 Impervious Land Use acre
 Impervious Total 0
 Basin Total 156.9

Element Flows To:
 Surface Interflow Groundwater
 Channel 5 Channel 5 Channel 5

Basin 1
 Bypass: No
 GroundWater: No
 Pervious Land Use acre
 C, Pasture, Mod 3.7
 C, Forest, Mod 263.6
 Pervious Total 267.3
 Impervious Land Use acre
 Impervious Total 0
 Basin Total 267.3

Element Flows To:
 Surface Interflow Groundwater
 Channel 8 Channel 8 Channel 8

Basin 4
 Bypass: No
 GroundWater: No
 Pervious Land Use acre
 C, Forest, Mod 61.1
 C, Pasture, Mod 2.5
 Pervious Total 63.6
 Impervious Land Use acre
 Impervious Total 0
 Basin Total 63.6

Element Flows To:
 Surface Interflow Groundwater
 Channel 8 Channel 8 Channel 8

Basin 8
 Bypass: No
 GroundWater: No
 Pervious Land Use acre
 C, Forest, Mod 101
 Pervious Total 101
 Impervious Land Use acre
 Impervious Total 0
 Basin Total 101

Element Flows To:
 Surface Interflow Groundwater
 Channel 9 Channel 9 Channel 9

Basin 6
 Bypass: No
 GroundWater: No
 Pervious Land Use acre
 C, Pasture, Mod 24.3
 C, Forest, Mod 71.3
 C, Lawn, Mod 0.1
 Pervious Total 95.7
 Impervious Land Use acre
 ROADS MOD 0.5
 Impervious Total 0.5
 Basin Total 96.2

Element Flows To:
 Surface Interflow Groundwater
 Channel 10 Channel 10 Channel 10

Basin 5
 Bypass: No
 GroundWater: No
 Pervious Land Use acre
 C, Forest, Mod 157.1
 Pervious Total 157.1
 Impervious Land Use acre
 Impervious Total 0
 Basin Total 157.1

Element Flows To:
 Surface Interflow Groundwater
 Channel 9 Channel 9 Channel 9

Basin 9
 Bypass: No
 GroundWater: No
 Pervious Land Use acre
 SAT, Forest, Mod 1
 SAT, Pasture, Mod 0.4
 C, Forest, Mod 23.8
 C, Pasture, Mod 2.7
 Pervious Total 27.9
 Impervious Land Use acre
 Impervious Total 0
 Basin Total 27.9

Element Flows To:
 Surface Interflow Groundwater
 Channel 10 Channel 10 Channel 10

Basin 10
 Bypass: No
 GroundWater: No
 Pervious Land Use acre
 SAT, Forest, Mod 0.8
 SAT, Pasture, Mod 3.3
 SAT, Lawn, Mod 0.2
 C, Forest, Mod 6.7
 C, Pasture, Mod 3.8
 C, Lawn, Mod 8.7
 Pervious Total 23.5
 Impervious Land Use acre
 ROADS MOD 18
 Impervious Total 18
 Basin Total 41.5

Element Flows To:
 Surface Interflow Groundwater
 Channel 14 Channel 14 Channel 14

Basin 13
 Bypass: No
 GroundWater: No
 Pervious Land Use acre
 C, Forest, Mod 58.5
 C, Pasture, Mod 8.3
 C, Lawn, Mod 12.3
 Pervious Total 79.1
 Impervious Land Use acre
 ROADS MOD 7.1
 Impervious Total 7.1
 Basin Total 86.2

Element Flows To:
 Surface Interflow Groundwater
 Channel 15 Channel 15 Channel 15

Basin 15		
Bypass:	No	
GroundWater:	No	
Pervious Land Use	acre	
C, Forest, Mod	7.2	
C, Lawn, Mod	16.5	
Pervious Total	23.7	
Impervious Land Use	acre	
ROADS MOD	8.1	
Impervious Total	8.1	
Basin Total	31.8	
Element Flows To:		
Surface	Interflow	Groundwater
Simpson Drainage	Simpson Drainage	Simpson Drainage

Basin 11		
Bypass:	No	
GroundWater:	No	
Pervious Land Use	acre	
SAT, Pasture, Mod	0.3	
SAT, Forest, Mod	0.1	
C, Forest, Mod	33.9	
C, Pasture, Mod	2.2	
C, Lawn, Mod	2.2	
Pervious Total	38.7	
Impervious Land Use	acre	
ROADS MOD	12.3	
Impervious Total	12.3	
Basin Total	51	
Element Flows To:		
Surface	Interflow	Groundwater
Channel 14	Channel 14	Channel 14

Basin 14	
Bypass:	No
GroundWater:	No
Pervious Land Use	acre
C, Lawn, Mod	22.6
Pervious Total	22.6
Impervious Land Use	acre
ROADS MOD	27.9
Impervious Total	27.9
Basin Total	50.5

Element Flows To:		
Surface	Interflow	Groundwater
Fry Creek	Fry Creek	Fry Creek

Basin 15	
Bypass:	No
GroundWater:	No
Pervious Land Use	acre
C, Lawn, Mod	26.7
Pervious Total	26.7
Impervious Land Use	acre
ROADS MOD	12.6
Impervious Total	12.6
Basin Total	39.3

Element Flows To:		
Surface	Interflow	Groundwater
OUTFLOW	OUTFLOW	OUTFLOW

Basin 12
 Bypass: No
 GroundWater: No
 Pervious Land Use acre
 C, Lawn, Mod 22.3
 C, Pasture, Mod 4.2
 C, Forest, Mod 12
 Pervious Total 38.5
 Impervious Land Use acre
 ROADS MOD 27.1
 Impervious Total 27.1
 Basin Total 65.6

Mitigated Land Use

Element Flows To:
 Surface Interflow Groundwater
 Channel 14 Channel 14 Channel 14

Routing Elements

Predeveloped Routing

Channel 5
 Bottom Length: 4552.00 ft.
 Bottom Width: 5.00 ft.
 Manning's n: 0.03
 Channel bottom slope 1: 0.015 To 1
 Channel Left side slope 0: 0 To 1
 Channel right side slope 2: 0 To 1
 Discharge Structure
 Riser Height: 0 ft.
 Riser Diameter: 0 in.
 Element Flows To:
 Outlet 1 Outlet 2
 Channel 9

Channel Hydraulic Table

Stage(feet)	Area(ac.)	Volume(ac-ft.)	Discharge(cfs)	Infiltr(cfs)
0.0000	0.522	0.000	0.000	0.000
0.1111	0.522	0.058	0.758	0.000
0.2222	0.522	0.116	2.342	0.000
0.3333	0.522	0.174	4.483	0.000
0.4444	0.522	0.232	7.058	0.000
0.5556	0.522	0.290	9.989	0.000
0.6667	0.522	0.348	13.21	0.000
0.7778	0.522	0.406	16.70	0.000
0.8889	0.522	0.464	20.40	0.000
1.0000	0.522	0.522	24.30	0.000
1.1111	0.522	0.580	28.37	0.000
1.2222	0.522	0.638	32.59	0.000
1.3333	0.522	0.696	36.94	0.000
1.4444	0.522	0.754	41.42	0.000
1.5556	0.522	0.812	46.00	0.000
1.6667	0.522	0.870	50.69	0.000
1.7778	0.522	0.928	55.46	0.000
1.8889	0.522	0.986	60.32	0.000
2.0000	0.522	1.045	65.25	0.000
2.1111	0.522	1.103	70.25	0.000
2.2222	0.522	1.161	75.32	0.000
2.3333	0.522	1.219	80.44	0.000
2.4444	0.522	1.277	85.62	0.000
2.5556	0.522	1.335	90.85	0.000
2.6667	0.522	1.393	96.12	0.000
2.7778	0.522	1.451	101.4	0.000
2.8889	0.522	1.509	106.8	0.000
3.0000	0.522	1.567	112.2	0.000
3.1111	0.522	1.625	117.6	0.000
3.2222	0.522	1.683	123.1	0.000
3.3333	0.522	1.741	128.6	0.000
3.4444	0.522	1.799	134.1	0.000
3.5556	0.522	1.857	139.6	0.000
3.6667	0.522	1.915	145.2	0.000
3.7778	0.522	1.973	150.8	0.000
3.8889	0.522	2.032	156.4	0.000

4.0000	0.522	2.090	162.1	0.000
4.1111	0.522	2.148	167.8	0.000
4.2222	0.522	2.206	173.4	0.000
4.3333	0.522	2.264	179.1	0.000
4.4444	0.522	2.322	184.9	0.000
4.5556	0.522	2.380	190.6	0.000
4.6667	0.522	2.438	196.4	0.000
4.7778	0.522	2.496	202.1	0.000
4.8889	0.522	2.554	207.9	0.000
5.0000	0.522	2.612	213.7	0.000
5.1111	0.522	2.670	219.5	0.000
5.2222	0.522	2.728	225.4	0.000
5.3333	0.522	2.786	231.2	0.000
5.4444	0.522	2.844	237.0	0.000
5.5556	0.522	2.902	242.9	0.000
5.6667	0.522	2.960	248.8	0.000
5.7778	0.522	3.018	254.7	0.000
5.8889	0.522	3.077	260.5	0.000
6.0000	0.522	3.135	266.4	0.000
6.1111	0.522	3.193	272.4	0.000
6.2222	0.522	3.251	278.3	0.000
6.3333	0.522	3.309	284.2	0.000
6.4444	0.522	3.367	290.1	0.000
6.5556	0.522	3.425	296.1	0.000
6.6667	0.522	3.483	302.0	0.000
6.7778	0.522	3.541	308.0	0.000
6.8889	0.522	3.599	313.9	0.000
7.0000	0.522	3.657	319.9	0.000
7.1111	0.522	3.715	325.9	0.000
7.2222	0.522	3.773	331.8	0.000
7.3333	0.522	3.831	337.8	0.000
7.4444	0.522	3.889	343.8	0.000
7.5556	0.522	3.947	349.8	0.000
7.6667	0.522	4.005	355.8	0.000
7.7778	0.522	4.064	361.8	0.000
7.8889	0.522	4.122	367.8	0.000
8.0000	0.522	4.180	373.8	0.000
8.1111	0.522	4.238	379.9	0.000
8.2222	0.522	4.296	385.9	0.000
8.3333	0.522	4.354	391.9	0.000
8.4444	0.522	4.412	397.9	0.000
8.5556	0.522	4.470	404.0	0.000
8.6667	0.522	4.528	410.0	0.000
8.7778	0.522	4.586	416.1	0.000
8.8889	0.522	4.644	422.1	0.000
9.0000	0.522	4.702	428.2	0.000
9.1111	0.522	4.760	434.2	0.000
9.2222	0.522	4.818	440.3	0.000
9.3333	0.522	4.876	446.3	0.000
9.4444	0.522	4.934	452.4	0.000
9.5556	0.522	4.992	458.5	0.000
9.6667	0.522	5.051	464.5	0.000
9.7778	0.522	5.109	470.6	0.000
9.8889	0.522	5.167	476.7	0.000
10.000	0.522	5.225	482.8	0.000
10.111	0.522	5.283	488.8	0.000

Channel 9
Bottom Length: 1407.00 ft.
Bottom Width: 5.00 ft.
Manning's n: 0.03
Channel bottom slope 1: 0.0083 To 1
Channel Left side slope 0: 0 To 1
Channel right side slope 2: 0 To 1
Discharge Structure
Riser Height: 0 ft.
Riser Diameter: 0 in.
Element Flows To:
Outlet 1 Outlet 2
Channel 10

Channel Hydraulic Table

Stage(feet)	Area(ac.)	Volume(ac-ft.)	Discharge(cfs)	Infilt(cfs)
0.0000	0.161	0.000	0.000	0.000
0.1111	0.161	0.017	0.564	0.000
0.2222	0.161	0.035	1.742	0.000
0.3333	0.161	0.053	3.335	0.000
0.4444	0.161	0.071	5.250	0.000
0.5556	0.161	0.089	7.430	0.000
0.6667	0.161	0.107	9.832	0.000
0.7778	0.161	0.125	12.42	0.000
0.8889	0.161	0.143	15.17	0.000
1.0000	0.161	0.161	18.07	0.000
1.1111	0.161	0.179	21.10	0.000
1.2222	0.161	0.197	24.24	0.000
1.3333	0.161	0.215	27.48	0.000
1.4444	0.161	0.233	30.81	0.000
1.5556	0.161	0.251	34.22	0.000
1.6667	0.161	0.269	37.70	0.000
1.7778	0.161	0.287	41.25	0.000
1.8889	0.161	0.305	44.87	0.000
2.0000	0.161	0.323	48.54	0.000
2.1111	0.161	0.341	52.26	0.000
2.2222	0.161	0.358	56.02	0.000
2.3333	0.161	0.376	59.84	0.000
2.4444	0.161	0.394	63.69	0.000
2.5556	0.161	0.412	67.58	0.000
2.6667	0.161	0.430	71.50	0.000
2.7778	0.161	0.448	75.46	0.000
2.8889	0.161	0.466	79.44	0.000
3.0000	0.161	0.484	83.46	0.000
3.1111	0.161	0.502	87.50	0.000
3.2222	0.161	0.520	91.56	0.000
3.3333	0.161	0.538	95.65	0.000
3.4444	0.161	0.556	99.76	0.000
3.5556	0.161	0.574	103.9	0.000
3.6667	0.161	0.592	108.0	0.000
3.7778	0.161	0.610	112.2	0.000
3.8889	0.161	0.628	116.4	0.000
4.0000	0.161	0.646	120.6	0.000
4.1111	0.161	0.664	124.8	0.000
4.2222	0.161	0.681	129.0	0.000
4.3333	0.161	0.699	133.3	0.000

Channel 8
Bottom Length: 2730.00 ft.
Bottom Width: 5.00 ft.
Manning's n: 0.03
Channel bottom slope 1: 0.011 To 1
Channel Left side slope 0: 0 To 1
Channel right side slope 2: 0 To 1
Discharge Structure
Riser Height: 0 ft.
Riser Diameter: 0 in.
Element Flows To:
Outlet 1 Outlet 2
Channel 9

Channel Hydraulic Table

Stage(feet)	Area(ac.)	Volume(ac-ft.)	Discharge(cfs)	Infilt(cfs)
0.0000	0.313	0.000	0.000	0.000
0.1111	0.313	0.034	0.649	0.000
0.2222	0.313	0.069	2.006	0.000
0.3333	0.313	0.104	3.839	0.000
0.4444	0.313	0.139	6.044	0.000
0.5556	0.313	0.174	8.554	0.000
0.6667	0.313	0.208	11.31	0.000
0.7778	0.313	0.243	14.30	0.000
0.8889	0.313	0.278	17.47	0.000
1.0000	0.313	0.313	20.81	0.000
1.1111	0.313	0.348	24.29	0.000
1.2222	0.313	0.383	27.90	0.000
1.3333	0.313	0.417	31.63	0.000
1.4444	0.313	0.452	35.47	0.000
1.5556	0.313	0.487	39.39	0.000
1.6667	0.313	0.522	43.40	0.000
1.7778	0.313	0.557	47.49	0.000
1.8889	0.313	0.591	51.65	0.000
2.0000	0.313	0.626	55.88	0.000
2.1111	0.313	0.661	60.16	0.000
2.2222	0.313	0.696	64.50	0.000
2.3333	0.313	0.731	68.89	0.000
2.4444	0.313	0.766	73.32	0.000
2.5556	0.313	0.800	77.80	0.000
2.6667	0.313	0.835	82.31	0.000
2.7778	0.313	0.870	86.87	0.000
2.8889	0.313	0.905	91.46	0.000
3.0000	0.313	0.940	96.08	0.000
3.1111	0.313	0.974	100.7	0.000
3.2222	0.313	1.009	105.4	0.000
3.3333	0.313	1.044	110.1	0.000
3.4444	0.313	1.079	114.8	0.000
3.5556	0.313	1.114	119.6	0.000
3.6667	0.313	1.149	124.3	0.000
3.7778	0.313	1.183	129.1	0.000
3.8889	0.313	1.218	134.0	0.000
4.0000	0.313	1.253	138.8	0.000
4.1111	0.313	1.288	143.6	0.000
4.2222	0.313	1.323	148.5	0.000
4.3333	0.313	1.357	153.4	0.000

4.4444	0.161	0.717	137.5	0.000
4.5556	0.161	0.735	141.8	0.000
4.6667	0.161	0.753	146.1	0.000
4.7778	0.161	0.771	150.4	0.000
4.8889	0.161	0.789	154.7	0.000
5.0000	0.161	0.807	159.0	0.000
5.1111	0.161	0.825	163.3	0.000
5.2222	0.161	0.843	167.6	0.000
5.3333	0.161	0.861	172.0	0.000
5.4444	0.161	0.879	176.3	0.000
5.5556	0.161	0.897	180.7	0.000
5.6667	0.161	0.915	185.0	0.000
5.7778	0.161	0.933	189.4	0.000
5.8889	0.161	0.951	193.8	0.000
6.0000	0.161	0.969	198.2	0.000
6.1111	0.161	0.987	202.6	0.000
6.2222	0.161	1.004	207.0	0.000
6.3333	0.161	1.022	211.4	0.000
6.4444	0.161	1.040	215.8	0.000
6.5556	0.161	1.058	220.2	0.000
6.6667	0.161	1.076	224.6	0.000
6.7778	0.161	1.094	229.1	0.000
6.8889	0.161	1.112	233.5	0.000
7.0000	0.161	1.130	237.9	0.000
7.1111	0.161	1.148	242.4	0.000
7.2222	0.161	1.166	246.8	0.000
7.3333	0.161	1.184	251.3	0.000
7.4444	0.161	1.202	255.7	0.000
7.5556	0.161	1.220	260.2	0.000
7.6667	0.161	1.238	264.7	0.000
7.7778	0.161	1.256	269.1	0.000
7.8889	0.161	1.274	273.6	0.000
8.0000	0.161	1.292	278.1	0.000
8.1111	0.161	1.310	282.5	0.000
8.2222	0.161	1.328	287.0	0.000
8.3333	0.161	1.345	291.5	0.000
8.4444	0.161	1.363	296.0	0.000
8.5556	0.161	1.381	300.5	0.000
8.6667	0.161	1.399	305.0	0.000
8.7778	0.161	1.417	309.5	0.000
8.8889	0.161	1.435	314.0	0.000
9.0000	0.161	1.453	318.5	0.000
9.1111	0.161	1.471	323.0	0.000
9.2222	0.161	1.489	327.5	0.000
9.3333	0.161	1.507	332.0	0.000
9.4444	0.161	1.525	336.5	0.000
9.5556	0.161	1.543	341.0	0.000
9.6667	0.161	1.561	345.5	0.000
9.7778	0.161	1.579	350.1	0.000
9.8889	0.161	1.597	354.6	0.000
10.000	0.161	1.615	359.1	0.000
10.111	0.161	1.633	363.6	0.000

4.4444	0.313	1.392	158.3	0.000
4.5556	0.313	1.427	163.2	0.000
4.6667	0.313	1.462	168.2	0.000
4.7778	0.313	1.497	173.1	0.000
4.8889	0.313	1.532	178.1	0.000
5.0000	0.313	1.566	183.0	0.000
5.1111	0.313	1.601	188.0	0.000
5.2222	0.313	1.636	193.0	0.000
5.3333	0.313	1.671	198.0	0.000
5.4444	0.313	1.706	203.0	0.000
5.5556	0.313	1.740	208.0	0.000
5.6667	0.313	1.775	213.0	0.000
5.7778	0.313	1.810	218.1	0.000
5.8889	0.313	1.845	223.1	0.000
6.0000	0.313	1.880	228.2	0.000
6.1111	0.313	1.915	233.2	0.000
6.2222	0.313	1.949	238.3	0.000
6.3333	0.313	1.984	243.4	0.000
6.4444	0.313	2.019	248.4	0.000
6.5556	0.313	2.054	253.5	0.000
6.6667	0.313	2.089	258.6	0.000
6.7778	0.313	2.123	263.7	0.000
6.8889	0.313	2.158	268.8	0.000
7.0000	0.313	2.193	273.9	0.000
7.1111	0.313	2.228	279.0	0.000
7.2222	0.313	2.263	284.2	0.000
7.3333	0.313	2.298	289.3	0.000
7.4444	0.313	2.332	294.4	0.000
7.5556	0.313	2.367	299.5	0.000
7.6667	0.313	2.402	304.7	0.000
7.7778	0.313	2.437	309.8	0.000
7.8889	0.313	2.472	315.0	0.000
8.0000	0.313	2.507	320.1	0.000
8.1111	0.313	2.541	325.3	0.000
8.2222	0.313	2.576	330.4	0.000
8.3333	0.313	2.611	335.6	0.000
8.4444	0.313	2.646	340.8	0.000
8.5556	0.313	2.681	345.9	0.000
8.6667	0.313	2.715	351.1	0.000
8.7778	0.313	2.750	356.3	0.000
8.8889	0.313	2.785	361.5	0.000
9.0000	0.313	2.820	366.6	0.000
9.1111	0.313	2.855	371.8	0.000
9.2222	0.313	2.890	377.0	0.000
9.3333	0.313	2.924	382.2	0.000
9.4444	0.313	2.959	387.4	0.000
9.5556	0.313	2.994	392.6	0.000
9.6667	0.313	3.029	397.8	0.000
9.7778	0.313	3.064	403.0	0.000
9.8889	0.313	3.098	408.2	0.000
10.000	0.313	3.133	413.4	0.000
10.111	0.313	3.168	418.6	0.000

Channel 10
 Bottom Length: 1849.00 ft.
 Bottom Width: 5.00 ft.
 Manning's n: 0.03
 Channel bottom slope 1: 0.0029 To 1
 Channel Left side slope 0: 0 To 1
 Channel right side slope 2: 0 To 1
 Discharge Structure
 Riser Height: 0 ft.
 Riser Diameter: 0 in.
 Element Flows To:
 Outlet 1 Outlet 2
 Channel 14

Channel Hydraulic Table

Stage(feet)	Area(ac.)	Volume(ac-ft.)	Discharge(cfs)	Infilt(cfs)
0.0000	0.212	0.000	0.000	0.000
0.2778	0.212	0.059	1.474	0.000
0.5556	0.212	0.117	4.392	0.000
0.8333	0.212	0.176	8.146	0.000
1.1111	0.212	0.235	12.47	0.000
1.3889	0.212	0.294	17.22	0.000
1.6667	0.212	0.353	22.28	0.000
1.9444	0.212	0.412	27.60	0.000
2.2222	0.212	0.471	33.11	0.000
2.5000	0.212	0.530	38.79	0.000
2.7778	0.212	0.589	44.60	0.000
3.0556	0.212	0.648	50.52	0.000
3.3333	0.212	0.707	56.54	0.000
3.6111	0.212	0.766	62.64	0.000
3.8889	0.212	0.825	68.80	0.000
4.1667	0.212	0.884	75.03	0.000
4.4444	0.212	0.943	81.30	0.000
4.7222	0.212	1.002	87.63	0.000
5.0000	0.212	1.061	93.99	0.000
5.2778	0.212	1.120	100.3	0.000
5.5556	0.212	1.179	106.8	0.000
5.8333	0.212	1.238	113.2	0.000
6.1111	0.212	1.297	119.7	0.000
6.3889	0.212	1.356	126.2	0.000
6.6667	0.212	1.414	132.8	0.000
6.9444	0.212	1.473	139.3	0.000
7.2222	0.212	1.532	145.9	0.000
7.5000	0.212	1.591	152.5	0.000
7.7778	0.212	1.650	159.1	0.000
8.0556	0.212	1.709	165.7	0.000
8.3333	0.212	1.768	172.3	0.000
8.6111	0.212	1.827	178.9	0.000
8.8889	0.212	1.886	185.6	0.000
9.1667	0.212	1.945	192.2	0.000
9.4444	0.212	2.004	198.9	0.000
9.7222	0.212	2.063	205.6	0.000
10.000	0.212	2.122	212.2	0.000
10.278	0.212	2.181	218.9	0.000
10.556	0.212	2.240	225.6	0.000
10.833	0.212	2.299	232.3	0.000

11.111	0.212	2.358	239.0	0.000
11.389	0.212	2.417	245.7	0.000
11.667	0.212	2.476	252.5	0.000
11.944	0.212	2.535	259.2	0.000
12.222	0.212	2.594	265.9	0.000
12.500	0.212	2.653	272.6	0.000
12.778	0.212	2.712	279.4	0.000
13.056	0.212	2.770	286.1	0.000
13.333	0.212	2.829	292.8	0.000
13.611	0.212	2.888	299.6	0.000
13.889	0.212	2.947	306.3	0.000
14.167	0.212	3.006	313.1	0.000
14.444	0.212	3.065	319.9	0.000
14.722	0.212	3.124	326.6	0.000
15.000	0.212	3.183	333.4	0.000
15.278	0.212	3.242	340.1	0.000
15.556	0.212	3.301	346.9	0.000
15.833	0.212	3.360	353.7	0.000
16.111	0.212	3.419	360.4	0.000
16.389	0.212	3.478	367.2	0.000
16.667	0.212	3.537	374.0	0.000
16.944	0.212	3.596	380.8	0.000
17.222	0.212	3.655	387.5	0.000
17.500	0.212	3.714	394.3	0.000
17.778	0.212	3.773	401.1	0.000
18.056	0.212	3.832	407.9	0.000
18.333	0.212	3.891	414.7	0.000
18.611	0.212	3.950	421.5	0.000
18.889	0.212	4.009	428.3	0.000
19.167	0.212	4.068	435.0	0.000
19.444	0.212	4.126	441.8	0.000
19.722	0.212	4.185	448.6	0.000
20.000	0.212	4.244	455.4	0.000
20.278	0.212	4.303	462.2	0.000
20.556	0.212	4.362	469.0	0.000
20.833	0.212	4.421	475.8	0.000
21.111	0.212	4.480	482.6	0.000
21.389	0.212	4.539	489.4	0.000
21.667	0.212	4.598	496.2	0.000
21.944	0.212	4.657	503.0	0.000
22.222	0.212	4.716	509.8	0.000
22.500	0.212	4.775	516.6	0.000
22.778	0.212	4.834	523.4	0.000
23.056	0.212	4.893	530.2	0.000
23.333	0.212	4.952	537.0	0.000
23.611	0.212	5.011	543.8	0.000
23.889	0.212	5.070	550.6	0.000
24.167	0.212	5.129	557.5	0.000
24.444	0.212	5.188	564.3	0.000
24.722	0.212	5.247	571.1	0.000
25.000	0.212	5.306	577.9	0.000

Channel 14
 Bottom Length: 2300.00 ft.
 Bottom Width: 5.00 ft.
 Manning's n: 0.03
 Channel bottom slope 1: 0.001 To 1
 Channel Left side slope 0: 0 To 1
 Channel right side slope 2: 0 To 1
 Discharge Structure
 Riser Height: 0 ft.
 Riser Diameter: 0 in.
 Element Flows To:
 Outlet 1 Outlet 2
 Fry Creek

Channel Hydraulic Table

Stage(feet)	Area(ac.)	Volume(ac-ft.)	Discharge(cfs)	Infilt(cfs)
0.0000	0.264	0.000	0.000	0.000
0.3889	0.264	0.102	1.477	0.000
0.7778	0.264	0.205	4.312	0.000
1.1667	0.264	0.308	7.865	0.000
1.5556	0.264	0.410	11.87	0.000
1.9444	0.264	0.513	16.21	0.000
2.3333	0.264	0.616	20.77	0.000
2.7222	0.264	0.718	25.50	0.000
3.1111	0.264	0.821	30.37	0.000
3.5000	0.264	0.924	35.34	0.000
3.8889	0.264	1.026	40.40	0.000
4.2778	0.264	1.129	45.53	0.000
4.6667	0.264	1.232	50.71	0.000
5.0556	0.264	1.334	55.94	0.000
5.4444	0.264	1.437	61.21	0.000
5.8333	0.264	1.540	66.52	0.000
6.2222	0.264	1.642	71.86	0.000
6.6111	0.264	1.745	77.22	0.000
7.0000	0.264	1.848	82.60	0.000
7.3889	0.264	1.950	88.00	0.000
7.7778	0.264	2.053	93.43	0.000
8.1667	0.264	2.156	98.86	0.000
8.5556	0.264	2.258	104.3	0.000
8.9444	0.264	2.361	109.7	0.000
9.3333	0.264	2.464	115.2	0.000
9.7222	0.264	2.566	120.7	0.000
10.1111	0.264	2.669	126.2	0.000
10.500	0.264	2.772	131.7	0.000
10.889	0.264	2.874	137.2	0.000
11.278	0.264	2.977	142.7	0.000
11.667	0.264	3.080	148.2	0.000
12.056	0.264	3.182	153.8	0.000
12.444	0.264	3.285	159.3	0.000
12.833	0.264	3.388	164.8	0.000
13.222	0.264	3.490	170.4	0.000
13.611	0.264	3.593	175.9	0.000
14.000	0.264	3.696	181.5	0.000
14.389	0.264	3.798	187.0	0.000
14.778	0.264	3.901	192.6	0.000
15.167	0.264	4.004	198.1	0.000

15.556	0.264	4.106	203.7	0.000
15.944	0.264	4.209	209.3	0.000
16.333	0.264	4.312	214.8	0.000
16.722	0.264	4.414	220.4	0.000
17.111	0.264	4.517	226.0	0.000
17.500	0.264	4.620	231.5	0.000
17.889	0.264	4.722	237.1	0.000
18.278	0.264	4.825	242.7	0.000
18.667	0.264	4.928	248.3	0.000
19.056	0.264	5.030	253.9	0.000
19.444	0.264	5.133	259.4	0.000
19.833	0.264	5.236	265.0	0.000
20.222	0.264	5.338	270.6	0.000
20.611	0.264	5.441	276.2	0.000
21.000	0.264	5.544	281.8	0.000
21.389	0.264	5.646	287.4	0.000
21.778	0.264	5.749	293.0	0.000
22.167	0.264	5.852	298.6	0.000
22.556	0.264	5.954	304.1	0.000
22.944	0.264	6.057	309.7	0.000
23.333	0.264	6.160	315.3	0.000
23.722	0.264	6.262	320.9	0.000
24.111	0.264	6.365	326.5	0.000
24.500	0.264	6.468	332.1	0.000
24.889	0.264	6.570	337.7	0.000
25.278	0.264	6.673	343.3	0.000
25.667	0.264	6.776	348.9	0.000
26.056	0.264	6.878	354.5	0.000
26.444	0.264	6.981	360.1	0.000
26.833	0.264	7.084	365.7	0.000
27.222	0.264	7.186	371.3	0.000
27.611	0.264	7.289	376.9	0.000
28.000	0.264	7.392	382.5	0.000
28.389	0.264	7.494	388.1	0.000
28.778	0.264	7.597	393.7	0.000
29.167	0.264	7.700	399.4	0.000
29.556	0.264	7.802	405.0	0.000
29.944	0.264	7.905	410.6	0.000
30.333	0.264	8.008	416.2	0.000
30.722	0.264	8.110	421.8	0.000
31.111	0.264	8.213	427.4	0.000
31.500	0.264	8.316	433.0	0.000
31.889	0.264	8.418	438.6	0.000
32.278	0.264	8.521	444.2	0.000
32.667	0.264	8.624	449.8	0.000
33.056	0.264	8.726	455.4	0.000
33.444	0.264	8.829	461.0	0.000
33.833	0.264	8.932	466.6	0.000
34.222	0.264	9.034	472.3	0.000
34.611	0.264	9.137	477.9	0.000
35.000	0.264	9.240	483.5	0.000

Channel 15
Bottom Length: 2900.00 ft.
Bottom Width: 5.00 ft.
Manning's n: 0.03
Channel bottom slope 1: 0.0096 To 1
Channel Left side slope 0: 0 To 1
Channel right side slope 2: 0 To 1
Discharge Structure
Riser Height: 0 ft.
Riser Diameter: 0 in.
Element Flows To:
Outlet 1 Outlet 2
Simpson Drainage

Channel Hydraulic Table

Stage(feet)	Area(ac.)	Volume(ac-ft.)	Discharge(cfs)	Infiltr(cfs)
0.0000	0.332	0.000	0.000	0.000
0.0556	0.332	0.018	0.193	0.000
0.1111	0.332	0.037	0.607	0.000
0.1667	0.332	0.055	1.176	0.000
0.2222	0.332	0.074	1.874	0.000
0.2778	0.332	0.092	2.682	0.000
0.3333	0.332	0.111	3.587	0.000
0.3889	0.332	0.129	4.578	0.000
0.4444	0.332	0.147	5.647	0.000
0.5000	0.332	0.166	6.786	0.000
0.5556	0.332	0.184	7.991	0.000
0.6111	0.332	0.203	9.255	0.000
0.6667	0.332	0.221	10.57	0.000
0.7222	0.332	0.240	11.94	0.000
0.7778	0.332	0.258	13.36	0.000
0.8333	0.332	0.277	14.82	0.000
0.8889	0.332	0.295	16.32	0.000
0.9444	0.332	0.314	17.86	0.000
1.0000	0.332	0.332	19.44	0.000
1.0556	0.332	0.351	21.05	0.000
1.1111	0.332	0.369	22.69	0.000
1.1667	0.332	0.388	24.37	0.000
1.2222	0.332	0.406	26.07	0.000
1.2778	0.332	0.425	27.80	0.000
1.3333	0.332	0.443	29.55	0.000
1.3889	0.332	0.462	31.33	0.000
1.4444	0.332	0.480	33.13	0.000
1.5000	0.332	0.499	34.96	0.000
1.5556	0.332	0.517	36.80	0.000
1.6111	0.332	0.536	38.66	0.000
1.6667	0.332	0.554	40.55	0.000
1.7222	0.332	0.573	42.45	0.000
1.7778	0.332	0.591	44.37	0.000
1.8333	0.332	0.610	46.30	0.000
1.8889	0.332	0.628	48.25	0.000
1.9444	0.332	0.647	50.22	0.000
2.0000	0.332	0.665	52.20	0.000
2.0556	0.332	0.684	54.19	0.000
2.1111	0.332	0.702	56.20	0.000
2.1667	0.332	0.721	58.22	0.000

OUTFLOW
Bottom Length: 100.00 ft.
Bottom Width: 50.00 ft.
Manning's n: 0.0001
Channel bottom slope 1: 0.01 To 1
Channel Left side slope 0: 0 To 1
Channel right side slope 2: 0 To 1
Discharge Structure
Riser Height: 0 ft.
Riser Diameter: 0 in.
Element Flows To:
Outlet 1 Outlet 2

Channel Hydraulic Table

Stage(feet)	Area(ac.)	Volume(ac-ft.)	Discharge(cfs)	Infiltr(cfs)
0.0000	0.114	0.000	0.000	0.000
0.5556	0.114	0.063	27563	0.000
1.1111	0.114	0.127	86263	0.000
1.6667	0.114	0.191	16719	0.000
2.2222	0.114	0.255	26636	0.000
2.7778	0.114	0.318	38119	0.000
3.3333	0.114	0.382	50977	0.000
3.8889	0.114	0.446	65063	0.000
4.4444	0.114	0.510	80255	0.000
5.0000	0.114	0.574	96453	0.000
5.5556	0.114	0.638	11357	0.000
6.1111	0.114	0.701	13153	0.000
6.6667	0.114	0.765	15027	0.000
7.2222	0.115	0.829	16974	0.000
7.7778	0.115	0.893	18988	0.000
8.3333	0.115	0.957	21065	0.000
8.8889	0.115	1.021	23200	0.000
9.4444	0.115	1.085	25390	0.000
10.000	0.115	1.149	27631	0.000
10.556	0.115	1.212	29921	0.000
11.111	0.115	1.276	32256	0.000
11.667	0.115	1.340	34634	0.000
12.222	0.115	1.404	37053	0.000
12.778	0.115	1.468	39510	0.000
13.333	0.115	1.532	42004	0.000
13.889	0.115	1.596	44532	0.000
14.444	0.115	1.660	47093	0.000
15.000	0.115	1.724	49685	0.000
15.556	0.115	1.788	52306	0.000
16.111	0.115	1.852	54956	0.000
16.667	0.115	1.916	57633	0.000
17.222	0.115	1.980	60335	0.000
17.778	0.115	2.044	63061	0.000
18.333	0.115	2.108	65811	0.000
18.889	0.115	2.172	68584	0.000
19.444	0.115	2.236	71377	0.000
20.000	0.115	2.300	74192	0.000
20.556	0.115	2.364	77026	0.000
21.111	0.115	2.428	79878	0.000
21.667	0.115	2.492	82749	0.000

2.2222	0.332	0.739	60.25	0.000
2.2778	0.332	0.758	62.30	0.000
2.3333	0.332	0.776	64.35	0.000
2.3889	0.332	0.795	66.42	0.000
2.4444	0.332	0.813	68.49	0.000
2.5000	0.332	0.832	70.58	0.000
2.5556	0.332	0.850	72.68	0.000
2.6111	0.332	0.869	74.78	0.000
2.6667	0.332	0.887	76.90	0.000
2.7222	0.332	0.906	79.02	0.000
2.7778	0.332	0.924	81.15	0.000
2.8333	0.332	0.943	83.29	0.000
2.8889	0.332	0.961	85.44	0.000
2.9444	0.332	0.980	87.59	0.000
3.0000	0.332	0.998	89.76	0.000
3.0556	0.332	1.017	91.93	0.000
3.1111	0.332	1.035	94.10	0.000
3.1667	0.332	1.054	96.29	0.000
3.2222	0.332	1.072	98.48	0.000
3.2778	0.332	1.091	100.6	0.000
3.3333	0.332	1.109	102.8	0.000
3.3889	0.332	1.128	105.0	0.000
3.4444	0.332	1.146	107.3	0.000
3.5000	0.332	1.165	109.5	0.000
3.5556	0.332	1.183	111.7	0.000
3.6111	0.332	1.202	113.9	0.000
3.6667	0.332	1.220	116.2	0.000
3.7222	0.332	1.239	118.4	0.000
3.7778	0.332	1.257	120.6	0.000
3.8333	0.332	1.276	122.9	0.000
3.8889	0.332	1.294	125.1	0.000
3.9444	0.332	1.313	127.4	0.000
4.0000	0.332	1.331	129.7	0.000
4.0556	0.332	1.350	131.9	0.000
4.1111	0.332	1.368	134.2	0.000
4.1667	0.332	1.387	136.5	0.000
4.2222	0.332	1.405	138.7	0.000
4.2778	0.332	1.424	141.0	0.000
4.3333	0.332	1.442	143.3	0.000
4.3889	0.332	1.461	145.6	0.000
4.4444	0.332	1.479	147.9	0.000
4.5000	0.332	1.498	150.2	0.000
4.5556	0.332	1.516	152.5	0.000
4.6111	0.332	1.534	154.8	0.000
4.6667	0.332	1.553	157.1	0.000
4.7222	0.332	1.571	159.4	0.000
4.7778	0.332	1.590	161.7	0.000
4.8333	0.332	1.608	164.0	0.000
4.8889	0.332	1.627	166.3	0.000
4.9444	0.332	1.645	168.7	0.000
5.0000	0.332	1.664	171.0	0.000
5.0556	0.332	1.682	173.3	0.000

22.222	0.115	2.556	85637	0.000
22.778	0.115	2.620	88542	0.000
23.333	0.115	2.684	91463	0.000
23.889	0.115	2.748	94399	0.000
24.444	0.115	2.812	97350	0.000
25.000	0.115	2.876	10031	0.000
25.556	0.115	2.940	10329	0.000
26.111	0.115	3.005	10628	0.000
26.667	0.115	3.069	10929	0.000
27.222	0.115	3.133	11231	0.000
27.778	0.115	3.197	11533	0.000
28.333	0.115	3.261	11838	0.000
28.889	0.115	3.325	12143	0.000
29.444	0.115	3.389	12449	0.000
30.000	0.115	3.453	12756	0.000
30.556	0.115	3.518	13065	0.000
31.111	0.115	3.582	13374	0.000
31.667	0.115	3.646	13684	0.000
32.222	0.115	3.710	13995	0.000
32.778	0.115	3.774	14307	0.000
33.333	0.115	3.838	14620	0.000
33.889	0.115	3.903	14934	0.000
34.444	0.115	3.967	15248	0.000
35.000	0.115	4.031	15564	0.000
35.556	0.115	4.095	15880	0.000
36.111	0.115	4.160	16197	0.000
36.667	0.115	4.224	16514	0.000
37.222	0.115	4.288	16832	0.000
37.778	0.115	4.352	17151	0.000
38.333	0.115	4.416	17471	0.000
38.889	0.115	4.481	17791	0.000
39.444	0.115	4.545	18112	0.000
40.000	0.115	4.609	18433	0.000
40.556	0.115	4.674	18755	0.000
41.111	0.115	4.738	19077	0.000
41.667	0.115	4.802	19401	0.000
42.222	0.115	4.866	19724	0.000
42.778	0.115	4.931	20048	0.000
43.333	0.115	4.995	20373	0.000
43.889	0.115	5.059	20698	0.000
44.444	0.115	5.124	21024	0.000
45.000	0.115	5.188	21350	0.000
45.556	0.115	5.252	21676	0.000
46.111	0.115	5.317	22003	0.000
46.667	0.115	5.381	22331	0.000
47.222	0.115	5.446	22659	0.000
47.778	0.115	5.510	22987	0.000
48.333	0.115	5.574	23316	0.000
48.889	0.115	5.639	23645	0.000
49.444	0.115	5.703	23974	0.000
50.000	0.115	5.767	24304	0.000

Fry Creek
Bottom Length: 100.00 ft.
Bottom Width: 20.00 ft.
Manning's n: 0.03
Channel bottom slope 1: 0.001 To 1
Channel Left side slope 0: 0 To 1
Channel right side slope 2: 0 To 1
Discharge Structure
Riser Height: 0 ft.
Riser Diameter: 0 in.
Element Flows To:
Outlet 1 Outlet 2
OUTFLOW

Channel Hydraulic Table

Stage(feet)	Area(ac.)	Volume(ac-ft.)	Discharge(cfs)	Infiltr(cfs)
0.0000	0.045	0.000	0.000	0.000
0.5556	0.045	0.025	11.37	0.000
1.1111	0.045	0.051	34.90	0.000
1.6667	0.045	0.076	66.40	0.000
2.2222	0.045	0.102	103.9	0.000
2.7778	0.045	0.127	146.4	0.000
3.3333	0.045	0.153	192.8	0.000
3.8889	0.045	0.178	242.6	0.000
4.4444	0.045	0.204	295.3	0.000
5.0000	0.045	0.229	350.4	0.000
5.5556	0.045	0.255	407.7	0.000
6.1111	0.045	0.280	466.8	0.000
6.6667	0.045	0.306	527.6	0.000
7.2222	0.045	0.331	589.9	0.000
7.7778	0.045	0.357	653.5	0.000
8.3333	0.045	0.382	718.2	0.000
8.8889	0.045	0.408	784.1	0.000
9.4444	0.045	0.433	850.8	0.000
10.000	0.045	0.459	918.4	0.000
10.556	0.045	0.484	986.9	0.000
11.111	0.045	0.510	1056.	0.000
11.667	0.045	0.535	1125.	0.000
12.222	0.045	0.561	1196.	0.000
12.778	0.045	0.586	1267.	0.000
13.333	0.045	0.612	1338.	0.000
13.889	0.045	0.637	1410.	0.000
14.444	0.045	0.663	1483.	0.000
15.000	0.045	0.688	1555.	0.000
15.556	0.045	0.714	1628.	0.000
16.111	0.045	0.739	1702.	0.000
16.667	0.045	0.765	1776.	0.000
17.222	0.045	0.790	1850.	0.000
17.778	0.045	0.816	1924.	0.000
18.333	0.045	0.841	1999.	0.000
18.889	0.045	0.867	2074.	0.000
19.444	0.045	0.892	2149.	0.000
20.000	0.045	0.918	2225.	0.000
20.556	0.045	0.944	2301.	0.000
21.111	0.045	0.969	2376.	0.000
21.667	0.045	0.995	2452.	0.000

22.222	0.045	1.020	2529.	0.000
22.778	0.045	1.046	2605.	0.000
23.333	0.045	1.071	2682.	0.000
23.889	0.045	1.097	2758.	0.000
24.444	0.045	1.122	2835.	0.000
25.000	0.045	1.148	2912.	0.000
25.556	0.045	1.173	2989.	0.000
26.111	0.045	1.199	3066.	0.000
26.667	0.045	1.224	3144.	0.000
27.222	0.045	1.250	3221.	0.000
27.778	0.045	1.275	3299.	0.000
28.333	0.045	1.301	3377.	0.000
28.889	0.045	1.326	3454.	0.000
29.444	0.045	1.352	3532.	0.000
30.000	0.045	1.377	3610.	0.000
30.556	0.045	1.403	3688.	0.000
31.111	0.045	1.428	3766.	0.000
31.667	0.045	1.454	3845.	0.000
32.222	0.045	1.479	3923.	0.000
32.778	0.045	1.505	4001.	0.000
33.333	0.045	1.531	4080.	0.000
33.889	0.045	1.556	4158.	0.000
34.444	0.045	1.582	4237.	0.000
35.000	0.045	1.607	4315.	0.000
35.556	0.045	1.633	4394.	0.000
36.111	0.045	1.658	4473.	0.000
36.667	0.045	1.684	4552.	0.000
37.222	0.045	1.709	4630.	0.000
37.778	0.045	1.735	4709.	0.000
38.333	0.045	1.760	4788.	0.000
38.889	0.045	1.786	4867.	0.000
39.444	0.045	1.811	4946.	0.000
40.000	0.046	1.837	5025.	0.000
40.556	0.046	1.862	5105.	0.000
41.111	0.046	1.888	5184.	0.000
41.667	0.046	1.913	5263.	0.000
42.222	0.046	1.939	5342.	0.000
42.778	0.046	1.964	5421.	0.000
43.333	0.046	1.990	5501.	0.000
43.889	0.046	2.016	5580.	0.000
44.444	0.046	2.041	5660.	0.000
45.000	0.046	2.067	5739.	0.000
45.556	0.046	2.092	5818.	0.000
46.111	0.046	2.118	5898.	0.000
46.667	0.046	2.143	5977.	0.000
47.222	0.046	2.169	6057.	0.000
47.778	0.046	2.194	6137.	0.000
48.333	0.046	2.220	6216.	0.000
48.889	0.046	2.245	6296.	0.000
49.444	0.046	2.271	6376.	0.000
50.000	0.046	2.296	6455.	0.000

Simpson Drainage
Bottom Length: 100.00 ft.
Bottom Width: 20.00 ft.
Manning's n: 0.03
Channel bottom slope 1: 0.001 To 1
Channel Left side slope 0: 0 To 1
Channel right side slope 2: 0 To 1
Discharge Structure
Riser Height: 0 ft.
Riser Diameter: 0 in.
Element Flows To:
Outlet 1 Outlet 2
OUTFLOW

Channel Hydraulic Table

Stage(feet)	Area(ac.)	Volume(ac-ft.)	Discharge(cfs)	Infiltr(cfs)
0.0000	0.045	0.000	0.000	0.000
0.0556	0.045	0.002	0.253	0.000
0.1111	0.045	0.005	0.800	0.000
0.1667	0.045	0.007	1.568	0.000
0.2222	0.045	0.010	2.523	0.000
0.2778	0.045	0.012	3.647	0.000
0.3333	0.045	0.015	4.924	0.000
0.3889	0.045	0.017	6.344	0.000
0.4444	0.045	0.020	7.898	0.000
0.5000	0.045	0.023	9.577	0.000
0.5556	0.045	0.025	11.37	0.000
0.6111	0.045	0.028	13.28	0.000
0.6667	0.045	0.030	15.30	0.000
0.7222	0.045	0.033	17.43	0.000
0.7778	0.045	0.035	19.65	0.000
0.8333	0.045	0.038	21.97	0.000
0.8889	0.045	0.040	24.38	0.000
0.9444	0.045	0.043	26.89	0.000
1.0000	0.045	0.045	29.47	0.000
1.0556	0.045	0.048	32.15	0.000
1.1111	0.045	0.051	34.90	0.000
1.1667	0.045	0.053	37.73	0.000
1.2222	0.045	0.056	40.64	0.000
1.2778	0.045	0.058	43.62	0.000
1.3333	0.045	0.061	46.67	0.000
1.3889	0.045	0.063	49.79	0.000
1.4444	0.045	0.066	52.99	0.000
1.5000	0.045	0.068	56.24	0.000
1.5556	0.045	0.071	59.57	0.000
1.6111	0.045	0.074	62.95	0.000
1.6667	0.045	0.076	66.40	0.000
1.7222	0.045	0.079	69.91	0.000
1.7778	0.045	0.081	73.48	0.000
1.8333	0.045	0.084	77.10	0.000
1.8889	0.045	0.086	80.78	0.000
1.9444	0.045	0.089	84.52	0.000
2.0000	0.045	0.091	88.31	0.000
2.0556	0.045	0.094	92.15	0.000
2.1111	0.045	0.096	96.04	0.000
2.1667	0.045	0.099	99.99	0.000

2.2222	0.045	0.102	103.9	0.000
2.2778	0.045	0.104	108.0	0.000
2.3333	0.045	0.107	112.1	0.000
2.3889	0.045	0.109	116.2	0.000
2.4444	0.045	0.112	120.4	0.000
2.5000	0.045	0.114	124.6	0.000
2.5556	0.045	0.117	128.9	0.000
2.6111	0.045	0.119	133.2	0.000
2.6667	0.045	0.122	137.5	0.000
2.7222	0.045	0.125	141.9	0.000
2.7778	0.045	0.127	146.4	0.000
2.8333	0.045	0.130	150.9	0.000
2.8889	0.045	0.132	155.4	0.000
2.9444	0.045	0.135	159.9	0.000
3.0000	0.045	0.137	164.5	0.000
3.0556	0.045	0.140	169.1	0.000
3.1111	0.045	0.142	173.8	0.000
3.1667	0.045	0.145	178.5	0.000
3.2222	0.045	0.147	183.3	0.000
3.2778	0.045	0.150	188.0	0.000
3.3333	0.045	0.153	192.8	0.000
3.3889	0.045	0.155	197.7	0.000
3.4444	0.045	0.158	202.5	0.000
3.5000	0.045	0.160	207.4	0.000
3.5556	0.045	0.163	212.4	0.000
3.6111	0.045	0.165	217.3	0.000
3.6667	0.045	0.168	222.3	0.000
3.7222	0.045	0.170	227.4	0.000
3.7778	0.045	0.173	232.4	0.000
3.8333	0.045	0.176	237.5	0.000
3.8889	0.045	0.178	242.6	0.000
3.9444	0.045	0.181	247.8	0.000
4.0000	0.045	0.183	252.9	0.000
4.0556	0.045	0.186	258.1	0.000
4.1111	0.045	0.188	263.4	0.000
4.1667	0.045	0.191	268.6	0.000
4.2222	0.045	0.193	273.9	0.000
4.2778	0.045	0.196	279.2	0.000
4.3333	0.045	0.199	284.6	0.000
4.3889	0.045	0.201	289.9	0.000
4.4444	0.045	0.204	295.3	0.000
4.5000	0.045	0.206	300.7	0.000
4.5556	0.045	0.209	306.1	0.000
4.6111	0.045	0.211	311.6	0.000
4.6667	0.045	0.214	317.1	0.000
4.7222	0.045	0.216	322.6	0.000
4.7778	0.045	0.219	328.1	0.000
4.8333	0.045	0.221	333.6	0.000
4.8889	0.045	0.224	339.2	0.000
4.9444	0.045	0.227	344.8	0.000
5.0000	0.045	0.229	350.4	0.000
5.0556	0.045	0.232	356.1	0.000

POC 1

POC #1 was not reported because POC must exist in both scenarios and both scenarios must have been run.

POC 2

POC #2 was not reported because POC must exist in both scenarios and both scenarios must have been run.

POC 3

POC #3 was not reported because POC must exist in both scenarios and both scenarios must have been run.

POC 4

POC #4 was not reported because POC must exist in both scenarios and both scenarios must have been run.

POC 5

POC #5 was not reported because POC must exist in both scenarios and both scenarios must have been run.

POC 6

POC #6 was not reported because POC must exist in both scenarios and both scenarios must have been run.

Model Default Modifications

Total of 0 changes have been made.

PERLND Changes

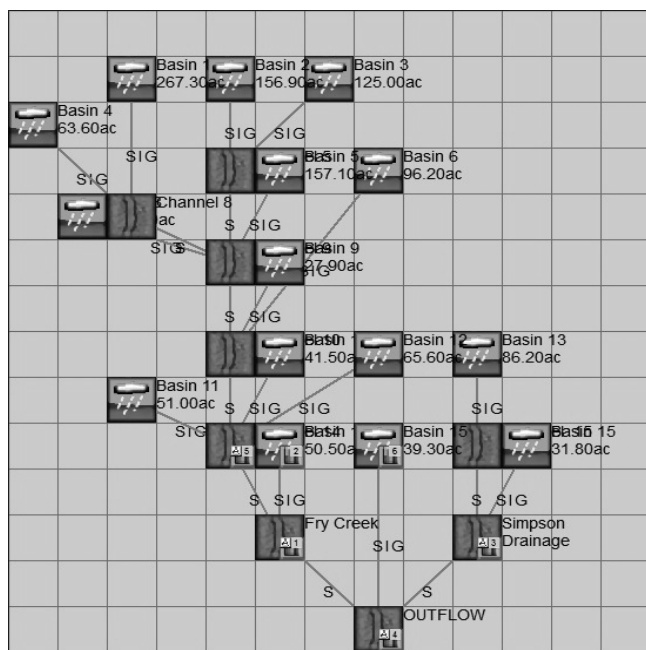
No PERLND changes have been made.

IMPLND Changes

No IMPLND changes have been made.

Appendix

Predeveloped Schematic

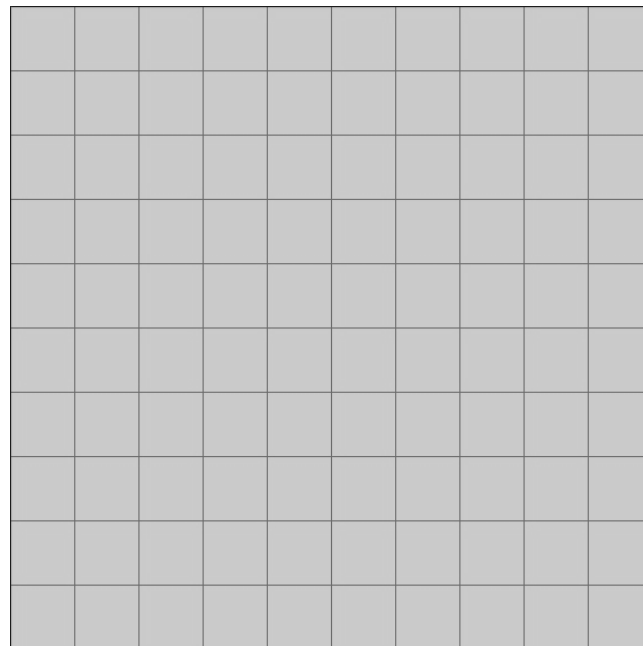


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Mitigated Schematic



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Predeveloped UCI File

```
RUN
GLOBAL
  WWHM4 model simulation
  START 1955 10 01
  RUN INTERP OUTPUT LEVEL 3 0
  RESUME 0 RUN 1
  UNIT SYSTEM 1
END GLOBAL

FILES
<File> <Un#> <-----File Name----->***
<-ID->
WDM 26 FryCreek_FINAL.wdm
MESSU 25 PreFryCreek_FINAL.MES
27 PreFryCreek_FINAL.L61
28 PreFryCreek_FINAL.L62
31 POCFryCreek_FINAL2.dat
35 POCFryCreek_FINAL6.dat
32 POCFryCreek_FINAL3.dat
34 POCFryCreek_FINAL5.dat
30 POCFryCreek_FINAL1.dat
33 POCFryCreek_FINAL4.dat
END FILES

OPN SEQUENCE
  INGRP INDELT 00:15
  PERLND 11
  PERLND 14
  PERLND 17
  IMPLND 2
  PERLND 20
  PERLND 23
  PERLND 26
  RCHRES 1
  RCHRES 2
  RCHRES 3
  RCHRES 4
  RCHRES 5
  RCHRES 6
  RCHRES 7
  RCHRES 8
  RCHRES 9
  COPY 502
  COPY 506
  COPY 503
  COPY 505
  COPY 501
  COPY 504
  DISPLY 2
  DISPLY 6
  DISPLY 3
  DISPLY 5
  DISPLY 1
  DISPLY 4
END INGRP
END OPN SEQUENCE
DISPLY
DISPLY-INFO1
# - #<-----Title----->***TRAN PIVL DIG1 FIL1 PYR DIG2 FIL2 YRND
2 Basin 14 MAX 1 2 31 9
6 Basin 15 MAX 1 2 35 9
3 Simpson Drainage MAX 1 2 32 9
5 Channel 14 MAX 1 2 34 9
1 Fry Creek MAX 1 2 30 9
4 OUTFLOW MAX 1 2 33 9
END DISPLY-INFO1
END DISPLY
COPY
```

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```
TIMESERIES
# - # NPT NMN ***
1 1 1
502 1 1
506 1 1
503 1 1
505 1 1
501 1 1
504 1 1
END TIMESERIES
END COPY
GENER
OPCODE
# # OPCODE ***
END OPCODE
PARM
# # K ***
END PARM
END GENER
PERLND
GEN-INFO
<PLS> <-----Name----->NBLKS Unit-systems Printer ***
# - # User t-series Engr Metr ***
11 C, Forest, Mod 1 1 1 1 27 0
14 C, Pasture, Mod 1 1 1 1 27 0
17 C, Lawn, Mod 1 1 1 1 27 0
20 SAT, Forest, Mod 1 1 1 1 27 0
23 SAT, Pasture, Mod 1 1 1 1 27 0
26 SAT, Lawn, Mod 1 1 1 1 27 0
END GEN-INFO
*** Section PWATER***
ACTIVITY
<PLS> ***** Active Sections *****
# - # ATMP SNOW PWAT SED PST PWG PQAL MSTL PEST NITR PHOS TRAC ***
11 0 0 0 1 0 0 0 0 0 0 0 0 0
14 0 0 0 1 0 0 0 0 0 0 0 0 0
17 0 0 0 1 0 0 0 0 0 0 0 0 0
20 0 0 0 1 0 0 0 0 0 0 0 0 0
23 0 0 0 1 0 0 0 0 0 0 0 0 0
26 0 0 0 1 0 0 0 0 0 0 0 0 0
END ACTIVITY
PRINT-INFO
<PLS> ***** Print-flags ***** PIVL PYR
# - # ATMP SNOW PWAT SED PST PWG PQAL MSTL PEST NITR PHOS TRAC *****
11 0 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
14 0 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
17 0 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
20 0 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
23 0 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
26 0 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
END PRINT-INFO
PWAT-PARM1
<PLS> PWATER variable monthly parameter value flags ***
# - # CSNO RTOP UZFG VCS VUZ VNN VIPW VIRG VLE INFC HWT ***
11 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
14 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
17 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
20 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
23 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
26 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
END PWAT-PARM1
PWAT-PARM2
<PLS> PWATER input info: Part 2
# - # ***FOREST LZEN INFILT LSUR SLSUR KVAR AGWRC
11 0 4.5 0.08 400 0.1 0.5 0.996
```

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14 0 4.5 0.06 400 0.1 0.5 0.996
17 0 4.5 0.03 400 0.1 0.5 0.996
20 0 4 2 100 0.01 0.5 0.996
23 0 4 1.8 100 0.01 0.5 0.996
26 0 4 1 100 0.01 0.5 0.996
END PWAT-PARM2

PWAT-PARM3
<PLS> PWATER input info: Part 3 ***
- # ***PETMAX PETMIN INFEXP INFILD DEEPFR BASETP AGWETP
11 0 0 2 2 0 0 0
14 0 0 2 2 0 0 0
17 0 0 2 2 0 0 0
20 0 0 10 2 0 0 0.7
23 0 0 10 2 0 0 0.5
26 0 0 10 2 0 0 0.35
END PWAT-PARM3

PWAT-PARM4
<PLS> PWATER input info: Part 4 ***
- # CEPSC UZSN NSUR INTFW IRC LZETP ***
11 0.2 0.5 0.35 6 0.5 0.7
14 0.15 0.4 0.3 6 0.5 0.4
17 0.1 0.25 0.25 6 0.5 0.25
20 0.2 3 0.5 1 0.7 0.8
23 0.15 3 0.5 1 0.7 0.6
26 0.1 3 0.5 1 0.7 0.4
END PWAT-PARM4

PWAT-STATE1
<PLS> *** Initial conditions at start of simulation
ran from 1990 to end of 1992 (pat 1-11-95) RUN 21 ***
- # *** CEPS SURS UZS IPWS LZS AGWS GWVS
11 0 0 0 0 2.5 1 0
14 0 0 0 0 2.5 1 0
17 0 0 0 0 2.5 1 0
20 0 0 0 0 4.2 1 0
23 0 0 0 0 4.2 1 0
26 0 0 0 0 4.2 1 0
END PWAT-STATE1

END PERLND

IMPLND

GEN-INFO
<PLS> <-----Name-----> Unit-systems Printer ***
- # User T-series Engrl Metr ***
2 ROADS/MOD 1 1 1 27 0
END GEN-INFO
*** Section IWATER***

ACTIVITY
<PLS> ***** Active Sections *****
- # ATMP SNOW IWAT SLD IMG IQAL ***
2 0 0 1 0 0 0
END ACTIVITY

PRINT-INFO
<PLS> ***** Print-flags ***** PIVL PYR
- # ATMP SNOW IWAT SLD IMG IQAL *****
2 0 0 4 0 0 0 1 9
END PRINT-INFO

IWAT-PARM1
<PLS> IWATER variable monthly parameter value flags ***
- # CSNO RTOP VRS VNN RTLI ***
2 0 0 0 0 0
END IWAT-PARM1

IWAT-PARM2

<PLS> IWATER input info: Part 2 ***
- # *** LSUR SLUR NSUR RETSC
2 400 0.05 0.1 0.08
END IWAT-PARM2

IWAT-PARM3
<PLS> IWATER input info: Part 3 ***
- # ***PETMAX PETMIN
2 0 0
END IWAT-PARM3

IWAT-STATE1
<PLS> *** Initial conditions at start of simulation
- # *** RETS SURS
2 0 0
END IWAT-STATE1

END IMPLND

SCHEMATIC
<-Source-> <-Area-> <-Target-> MLBK ***
<Name> # <Name> # Tbl# ***
Basin 3***
PERLND 11 119 RCHRES 2 2
PERLND 11 119 RCHRES 2 3
PERLND 11 119 RCHRES 2 4
PERLND 14 6 RCHRES 2 2
PERLND 14 6 RCHRES 2 3
PERLND 14 6 RCHRES 2 4
Basin 2***
PERLND 11 156.9 RCHRES 2 2
PERLND 11 156.9 RCHRES 2 3
PERLND 11 156.9 RCHRES 2 4
Basin 13***
PERLND 11 58.5 RCHRES 1 2
PERLND 11 58.5 RCHRES 1 3
PERLND 11 58.5 RCHRES 1 4
PERLND 14 8.3 RCHRES 1 2
PERLND 14 8.3 RCHRES 1 3
PERLND 14 8.3 RCHRES 1 4
PERLND 17 12.3 RCHRES 1 2
PERLND 17 12.3 RCHRES 1 3
PERLND 17 12.3 RCHRES 1 4
IMPLND 2 7.1 RCHRES 1 5
Basin 14***
PERLND 14 3.7 RCHRES 3 2
PERLND 14 3.7 RCHRES 3 3
PERLND 14 3.7 RCHRES 3 4
PERLND 11 263.6 RCHRES 3 2
PERLND 11 263.6 RCHRES 3 3
PERLND 11 263.6 RCHRES 3 4
Basin 4***
PERLND 11 61.1 RCHRES 3 2
PERLND 11 61.1 RCHRES 3 3
PERLND 11 61.1 RCHRES 3 4
PERLND 14 2.5 RCHRES 3 2
PERLND 14 2.5 RCHRES 3 3
PERLND 14 2.5 RCHRES 3 4
Basin 8***
PERLND 11 101 RCHRES 5 2
PERLND 11 101 RCHRES 5 3
PERLND 11 101 RCHRES 5 4
Basin 6***
PERLND 14 24.3 RCHRES 6 2
PERLND 14 24.3 RCHRES 6 3
PERLND 14 24.3 RCHRES 6 4
PERLND 11 71.3 RCHRES 6 2
PERLND 11 71.3 RCHRES 6 3
PERLND 11 71.3 RCHRES 6 4
PERLND 17 0.1 RCHRES 6 2

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PERLND 17 0.1 RCHRES 6 3
PERLND 17 0.1 RCHRES 6 4
IMPLND 2 0.5 RCHRES 6 5
Basin 5***
PERLND 11 157.1 RCHRES 5 2
PERLND 11 157.1 RCHRES 5 3
PERLND 11 157.1 RCHRES 5 4
Basin 9***
PERLND 20 1 RCHRES 6 2
PERLND 20 1 RCHRES 6 3
PERLND 20 1 RCHRES 6 4
PERLND 23 0.4 RCHRES 6 2
PERLND 23 0.4 RCHRES 6 3
PERLND 23 0.4 RCHRES 6 4
PERLND 11 23.8 RCHRES 6 2
PERLND 11 23.8 RCHRES 6 3
PERLND 11 23.8 RCHRES 6 4
PERLND 14 2.7 RCHRES 6 2
PERLND 14 2.7 RCHRES 6 3
PERLND 14 2.7 RCHRES 6 4
Basin 14***
PERLND 17 22.6 RCHRES 8 2
PERLND 17 22.6 RCHRES 8 3
PERLND 17 22.6 RCHRES 8 4
IMPLND 2 27.9 RCHRES 8 5
Basin 10***
PERLND 20 0.8 RCHRES 7 2
PERLND 20 0.8 RCHRES 7 3
PERLND 20 0.8 RCHRES 7 4
PERLND 23 3.3 RCHRES 7 2
PERLND 23 3.3 RCHRES 7 3
PERLND 23 3.3 RCHRES 7 4
PERLND 26 0.2 RCHRES 7 2
PERLND 26 0.2 RCHRES 7 3
PERLND 26 0.2 RCHRES 7 4
PERLND 11 6.7 RCHRES 7 2
PERLND 11 6.7 RCHRES 7 3
PERLND 11 6.7 RCHRES 7 4
PERLND 14 3.8 RCHRES 7 2
PERLND 14 3.8 RCHRES 7 3
PERLND 14 3.8 RCHRES 7 4
PERLND 17 8.7 RCHRES 7 2
PERLND 17 8.7 RCHRES 7 3
PERLND 17 8.7 RCHRES 7 4
IMPLND 2 18 RCHRES 7 5
Basin 15***
PERLND 17 26.7 RCHRES 9 2
PERLND 17 26.7 RCHRES 9 3
PERLND 17 26.7 RCHRES 9 4
IMPLND 2 12.6 RCHRES 9 5
Basin 15***
PERLND 11 7.2 RCHRES 4 2
PERLND 11 7.2 RCHRES 4 3
PERLND 11 7.2 RCHRES 4 4
PERLND 17 16.5 RCHRES 4 2
PERLND 17 16.5 RCHRES 4 3
PERLND 17 16.5 RCHRES 4 4
IMPLND 2 8.1 RCHRES 4 5
Basin 11***
PERLND 23 0.3 RCHRES 7 2
PERLND 23 0.3 RCHRES 7 3
PERLND 23 0.3 RCHRES 7 4
PERLND 20 0.1 RCHRES 7 2
PERLND 20 0.1 RCHRES 7 3
PERLND 20 0.1 RCHRES 7 4
PERLND 11 33.9 RCHRES 7 2
PERLND 11 33.9 RCHRES 7 3
PERLND 11 33.9 RCHRES 7 4
PERLND 14 2.2 RCHRES 7 2
PERLND 14 2.2 RCHRES 7 3

PERLND 14 2.2 RCHRES 7 4
PERLND 17 2.2 RCHRES 7 2
PERLND 17 2.2 RCHRES 7 3
PERLND 17 2.2 RCHRES 7 4
IMPLND 2 12.3 RCHRES 7 5
Basin 12***
PERLND 17 22.3 RCHRES 7 2
PERLND 17 22.3 RCHRES 7 3
PERLND 17 22.3 RCHRES 7 4
PERLND 14 4.2 RCHRES 7 2
PERLND 14 4.2 RCHRES 7 3
PERLND 14 4.2 RCHRES 7 4
PERLND 11 12 RCHRES 7 2
PERLND 11 12 RCHRES 7 3
PERLND 11 12 RCHRES 7 4
IMPLND 2 27.1 RCHRES 7 5
Basin 14***
PERLND 17 22.6 COPY 502 12
PERLND 17 22.6 COPY 502 13
PERLND 17 22.6 COPY 502 14
IMPLND 2 27.9 COPY 502 15
Basin 15***
PERLND 17 26.7 COPY 506 12
PERLND 17 26.7 COPY 506 13
PERLND 17 26.7 COPY 506 14
IMPLND 2 12.6 COPY 506 15

*****Routing*****

RCHRES 2 1 RCHRES 5 6
RCHRES 5 1 RCHRES 6 6
RCHRES 3 1 RCHRES 5 6
RCHRES 6 1 RCHRES 7 6
RCHRES 7 1 RCHRES 8 6
RCHRES 1 1 RCHRES 4 6
RCHRES 8 1 RCHRES 9 6
RCHRES 4 1 RCHRES 9 6
RCHRES 7 1 COPY 505 16
RCHRES 9 1 COPY 504 16
RCHRES 8 1 COPY 501 16
RCHRES 4 1 COPY 503 16
END SCHEMATIC

NETWORK

<-Volume> <-Grp> <-Member><-Mult-->Tran <-Target vols> <-Grp> <-Member> ***
<Name> # <Name> # <-factor-->strg <Name> # # INPUT <Name> # # ***
COPY 502 OUTPUT MEAN 1 1 48.4 DISPLY 2 INPUT TIMSER 1
COPY 506 OUTPUT MEAN 1 1 48.4 DISPLY 6 INPUT TIMSER 1
COPY 503 OUTPUT MEAN 1 1 48.4 DISPLY 3 INPUT TIMSER 1
COPY 505 OUTPUT MEAN 1 1 48.4 DISPLY 5 INPUT TIMSER 1
COPY 501 OUTPUT MEAN 1 1 48.4 DISPLY 1 INPUT TIMSER 1
COPY 504 OUTPUT MEAN 1 1 48.4 DISPLY 4 INPUT TIMSER 1

<-Volume> <-Grp> <-Member><-Mult-->Tran <-Target vols> <-Grp> <-Member> ***
<Name> # <Name> # <-factor-->strg <Name> # # <Name> # # ***
END NETWORK

RCHRES

GEN-INFO
RCHRES Name Nexits Unit Systems Printer ***
- #<-----Name-----><---> User T-series Engrl Metr LKFG ***
1 Channel 15 1 1 1 1 28 0 1
2 Channel 5 1 1 1 1 28 0 1
3 Channel 8 1 1 1 1 28 0 1
4 Simpson Drainage-144 1 1 1 1 28 0 1
5 Channel 9 1 1 1 1 28 0 1
6 Channel 10 1 1 1 1 28 0 1
7 Channel 14 1 1 1 1 28 0 1

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Fry Creek          1 1 1 1 1 28 0 1
9 OUTFLOW          1 1 1 1 1 28 0 1
END GEN-INFO
*** Section RCHRES***

ACTIVITY
<PLS > ***** Active Sections *****
# - # HYPG ADPG CNFG HTFG SDPG GPGF OXPG NUPG PKPG PHFG ***
1 0 0 0 0 0 0 0 0 0 0
2 1 0 0 0 0 0 0 0 0 0
3 1 0 0 0 0 0 0 0 0 0
4 1 0 0 0 0 0 0 0 0 0
5 1 0 0 0 0 0 0 0 0 0
6 1 0 0 0 0 0 0 0 0 0
7 1 0 0 0 0 0 0 0 0 0
8 1 0 0 0 0 0 0 0 0 0
9 1 0 0 0 0 0 0 0 0 0

END ACTIVITY

PRINT-INFO
<PLS > ***** Print-flags *****
# - # HYDR ADCA CONS HEAT SED QGL OXRX NUTR PLNK PHCB PIVL PYR *****
1 4 0 0 0 0 0 0 0 0 0 0 1 9
2 4 0 0 0 0 0 0 0 0 0 0 1 9
3 4 0 0 0 0 0 0 0 0 0 0 1 9
4 4 0 0 0 0 0 0 0 0 0 0 1 9
5 4 0 0 0 0 0 0 0 0 0 0 1 9
6 4 0 0 0 0 0 0 0 0 0 0 1 9
7 4 0 0 0 0 0 0 0 0 0 0 1 9
8 4 0 0 0 0 0 0 0 0 0 0 1 9
9 4 0 0 0 0 0 0 0 0 0 0 1 9

END PRINT-INFO

HYDR-PARM1
RCHRES Flags for each HYDR Section
# - # VC A1 A2 A3 ODFVFG for each
FG FG FG FG possible exit *** ODGTFG for each
*** possible exit FUNCT for each
*** possible exit
1 0 0 0 0 4 0 0 0 0 0 0 0 0 2 2 2 2 2
2 0 1 0 0 4 0 0 0 0 0 0 0 0 2 2 2 2 2
3 0 1 0 0 4 0 0 0 0 0 0 0 0 2 2 2 2 2
4 0 1 0 0 4 0 0 0 0 0 0 0 0 2 2 2 2 2
5 1 1 0 0 0 0 0 0 0 0 0 0 0 2 2 2 2 2
6 0 1 0 0 4 0 0 0 0 0 0 0 0 2 2 2 2 2
7 0 1 0 0 4 0 0 0 0 0 0 0 0 2 2 2 2 2
8 0 1 0 0 4 0 0 0 0 0 0 0 0 2 2 2 2 2
9 0 1 0 0 4 0 0 0 0 0 0 0 0 2 2 2 2 2

END HYDR-PARM1

HYDR-PARM2
# - # FTABNO LEN DELTH STCOR KS DB50 ***
1 1 0.55 0.0 0.0 0.5 0.0
2 2 0.86 0.0 0.0 0.5 0.0
3 3 0.52 0.0 0.0 0.5 0.0
4 4 0.02 0.0 0.0 0.5 0.0
5 5 0.27 0.0 0.0 0.5 0.0
6 6 0.35 0.0 0.0 0.5 0.0
7 7 0.44 0.0 0.0 0.5 0.0
8 8 0.02 0.0 0.0 0.5 0.0
9 9 0.02 0.0 0.0 0.5 0.0

END HYDR-PARM2

HYDR-INIT
RCHRES Initial conditions for each HYDR section
# - # *** VOL Initial value of COLIND Initial value of OUTDGT
*** ac-ft for each possible exit *** for each possible exit
1 0 4.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
2 0 4.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
3 0 4.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

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6.000000 0.522518 3.135048 266.4895 3.111111 0.161507 0.502458 87.50389
6.111111 0.522519 3.193106 272.3965 3.222222 0.161508 0.520403 91.56394
6.222222 0.522519 3.251163 278.3119 3.333333 0.161508 0.538349 95.65789
6.333333 0.522520 3.309221 284.2354 3.444444 0.161508 0.556294 99.76814
6.444444 0.522520 3.367279 290.1667 3.555556 0.161508 0.574239 103.8988
6.555556 0.522520 3.425337 296.1055 3.666667 0.161508 0.592185 108.0487
6.666667 0.522521 3.483395 302.0519 3.777778 0.161509 0.610130 112.2167
6.777778 0.522521 3.541452 308.0044 3.888889 0.161509 0.628075 116.4018
6.888889 0.522521 3.599510 313.9640 4.000000 0.161509 0.646021 120.6031
7.000000 0.522522 3.657568 319.9300 4.111111 0.161509 0.663966 124.8197
7.111111 0.522522 3.715626 325.9023 4.222222 0.161509 0.681912 129.0508
7.222222 0.522523 3.773684 331.8800 4.333333 0.161510 0.699857 133.2956
7.333333 0.522523 3.831742 337.8645 4.444444 0.161510 0.717803 137.5535
7.444444 0.522523 3.889801 343.8540 4.555556 0.161510 0.735748 141.8237
7.555556 0.522524 3.947859 349.8490 4.666667 0.161510 0.753694 146.1057
7.666667 0.522524 4.005917 355.8491 4.777778 0.161510 0.771639 150.3989
7.777778 0.522524 4.063975 361.8543 4.888889 0.161511 0.789585 154.7028
7.888889 0.522525 4.122033 367.8643 5.000000 0.161511 0.807531 159.0169
8.000000 0.522525 4.180092 373.8790 5.111111 0.161511 0.825476 163.3406
8.111111 0.522526 4.238150 379.8983 5.222222 0.161511 0.843422 167.6736
8.222222 0.522526 4.296209 385.9219 5.333333 0.161512 0.861368 172.0165
8.333333 0.522526 4.354267 391.9499 5.444444 0.161512 0.879314 176.3658
8.444444 0.522527 4.412326 397.9819 5.555556 0.161512 0.897259 180.7242
8.555556 0.522527 4.470384 404.0179 5.666667 0.161512 0.915205 185.0903
8.666667 0.522528 4.528443 410.0578 5.777778 0.161512 0.933151 189.4638
8.777778 0.522528 4.586501 416.1019 5.888889 0.161513 0.951097 193.8445
8.888889 0.522528 4.644560 422.1488 6.000000 0.161513 0.969043 198.2319
9.000000 0.522529 4.702619 428.1996 6.111111 0.161513 0.986988 202.6259
9.111111 0.522529 4.760678 434.2539 6.222222 0.161513 1.004934 207.0261
9.222222 0.522529 4.818736 440.3115 6.333333 0.161513 1.022880 211.4324
9.333333 0.522530 4.876795 446.3721 6.444444 0.161514 1.040826 215.8455
9.444444 0.522530 4.934854 452.4362 6.555556 0.161514 1.058772 220.2621
9.555556 0.522531 4.992913 458.5032 6.666667 0.161514 1.076718 224.6851
9.666667 0.522531 5.050972 464.5732 6.777778 0.161514 1.094664 229.1133
9.777778 0.522531 5.109031 470.6460 6.888889 0.161515 1.112610 233.5464
9.888889 0.522532 5.167090 476.7217 7.000000 0.16
```

0.222222 0.313361 0.069636 2.006264
0.333333 0.313362 0.104454 3.839643
0.444444 0.313362 0.139272 6.044484
0.555556 0.313362 0.174090 8.554154
0.666667 0.313363 0.208908 11.31890
0.777778 0.313363 0.243726 14.30203
0.888889 0.313363 0.278544 17.47427
1.000000 0.313363 0.313362 20.81195
1.111111 0.313364 0.348180 24.29554
1.222222 0.313364 0.382999 27.90873
1.333333 0.313364 0.417817 31.63770
1.444444 0.313365 0.452635 35.47063
1.555556 0.313365 0.487453 39.37355
1.666667 0.313365 0.522272 43.40903
1.777778 0.313365 0.557090 47.49797
1.888889 0.313366 0.591908 51.65737
2.000000 0.313366 0.626727 55.88128
2.111111 0.313366 0.661545 60.16438
2.222222 0.313366 0.696364 64.50196
2.333333 0.313367 0.731182 68.89799
2.444444 0.313367 0.766001 73.32408
2.555556 0.313367 0.800819 77.80144
2.666667 0.313368 0.835638 82.31879
2.777778 0.313368 0.870457 86.87333
2.888889 0.313368 0.905275 91.46254
3.000000 0.313368 0.940094 96.08413
3.111111 0.313369 0.974913 100.7360
3.222222 0.313369 1.009732 105.4162
3.333333 0.313369 1.044550 110.1230
3.444444 0.313370 1.079369 114.8548
3.555556 0.313370 1.114188 119.6101
3.666667 0.313370 1.149007 124.3875
3.777778 0.313370 1.183826 129.1858
3.888889 0.313371 1.218645 134.0038
4.000000 0.313371 1.253464 138.8404
4.111111 0.313371 1.288283 143.6946
4.222222 0.313372 1.323102 148.5655
4.333333 0.313372 1.357921 153.4522
4.444444 0.313372 1.392740 158.3539
4.555556 0.313372 1.427559 163.2699
4.666667 0.313373 1.462378 168.1994
4.777778 0.313373 1.497197 173.1419
4.888889 0.313373 1.532017 178.0966
5.000000 0.313374 1.566836 183.0630
5.111111 0.313374 1.601655 188.0406
5.222222 0.313374 1.636475 193.0289
5.333333 0.313374 1.671294 198.0272
5.444444 0.313375 1.706113 203.0353
5.555556 0.313375 1.740933 208.0528
5.666667 0.313375 1.775752 213.0791
5.777778 0.313375 1.810572 218.1140
5.888889 0.313376 1.845391 223.1571
6.000000 0.313376 1.880211 228.2080
6.111111 0.313376 1.915030 233.2664
6.222222 0.313377 1.949850 238.3321
6.333333 0.313377 1.984670 243.4046
6.444444 0.313377 2.019489 248.4839
6.555556 0.313377 2.054309 253.5696
6.666667 0.313378 2.089129 258.6614
6.777778 0.313378 2.123948 263.7592
6.888889 0.313378 2.158768 268.8627
7.000000 0.313379 2.193588 273.9717
7.111111 0.313379 2.228408 279.0860
7.222222 0.313379 2.263228 284.2055
7.333333 0.313379 2.298048 289.3298
7.444444 0.313380 2.332868 294.4590
7.555556 0.313380 2.367688 299.5928
7.666667 0.313380 2.402508 304.7310
7.777778 0.313381 2.437328 309.8735
7.888889 0.313381 2.472148 315.0202

8.000000 0.313381 2.506968 320.1709
8.111111 0.313381 2.541788 325.3255
8.222222 0.313382 2.576608 330.4838
8.333333 0.313382 2.611428 335.6458
8.444444 0.313382 2.646249 340.8113
8.555556 0.313382 2.681069 345.9803
8.666667 0.313383 2.715889 351.1525
8.777778 0.313383 2.750709 356.3280
8.888889 0.313383 2.785530 361.5065
9.000000 0.313384 2.820350 366.6882
9.111111 0.313384 2.855171 371.8728
9.222222 0.313384 2.889991 377.0602
9.333333 0.313384 2.924812 382.2504
9.444444 0.313385 2.959632 387.4432
9.555556 0.313385 2.994453 392.6387
9.666667 0.313385 3.029273 397.8367
9.777778 0.313386 3.064094 403.0372
9.888889 0.313386 3.098914 408.2401
10.00000 0.313386 3.133735 413.4453
END FTABLE 3
FTABLE 6
90 4
Depth Area Volume Outflow Velocity Travel Time***
(ft) (acres) (acre-ft) (cfs) (ft/sec) (Minutes)***
0.000000 0.212236 0.000000 0.000000 0.000000 0.000000
0.277778 0.212236 0.058954 1.474206 0.555556 0.212236 1.17909 4.392176
0.833333 0.212237 0.176864 8.146532 1.111111 0.212237 0.235818 12.47468
1.388889 0.212237 0.294773 17.22223 1.666667 0.212237 0.353728 22.28860
1.944444 0.212237 0.412682 27.60419 2.222222 0.212237 0.471637 33.11887
2.500000 0.212238 0.530592 38.79544 2.777778 0.212238 0.589547 44.60557
3.055556 0.212238 0.648502 50.52729 3.333333 0.212238 0.707457 56.54325
3.611111 0.212238 0.766412 62.63955 3.888889 0.212239 0.825367 68.80409
4.166667 0.212239 0.884322 75.03020 4.444444 0.212239 0.943278 81.30766
4.722222 0.212239 1.002233 87.63094 5.000000 0.212239 1.061188 93.99466
5.277778 0.212240 1.120144 100.3942 5.555556 0.212240 1.179099 106.8258
5.833333 0.212240 1.238055 113.2860 6.111111 0.212240 1.297010 119.7719
6.388889 0.212240 1.355966 126.2810 6.666667 0.212240 1.414921 132.8111
6.944444 0.212241 1.473877 139.3603 7.222222 0.212241 1.532833 145.9268
7.500000 0.212241 1.591789 152.5092 7.777778 0.212241 1.650745 159.1062
8.055556 0.212241 1.709700 165.7165 8.333333 0.212242 1.768656 172.3391
8.611111 0.212242 1.827612 178.9731 8.888889 0.212242 1.886568 185.6175
9.166667 0.212242 1.945525 192.2716 9.444444 0.212242 2.004481 198.9348
9.722222 0.212242 2.063437 212.2857 10.00000 0.212243 2.122393 218.9723
10.27778 0.212243 2.181350 218.9723 10.55556 0.212243 2.240306 225.6657
10.83333 0.212243 2.299262 232.3655 11.11111 0.212243 2.358219 239.0713
11.38889 0.212244 2.417175 245.7827 11.66667 0.212244 2.476132 252.4993
11.94444 0.212244 2.535089 259.2209 12.22222 0.212244 2.594045 267.9472
12.50000 0.212244 2.653002 272.6779

12.77778 0.212245 2.711959 279.4127
13.05556 0.212245 2.770916 286.1514
13.33333 0.212245 2.829872 292.8939
13.61111 0.212245 2.888829 299.6399
13.88889 0.212245 2.947786 306.3892
14.16667 0.212245 3.006743 313.1418
14.44444 0.212246 3.065701 319.8973
14.72222 0.212246 3.124658 326.6557
15.00000 0.212246 3.183615 333.4158
15.27778 0.212246 3.242572 340.1805
15.55556 0.212246 3.301529 346.9466
15.83333 0.212247 3.360487 353.7151
16.11111 0.212247 3.419444 360.4859
16.38889 0.212247 3.478402 367.2588
16.66667 0.212247 3.537359 374.0338
16.94444 0.212247 3.596317 380.8108
17.22222 0.212247 3.655274 387.5896
17.50000 0.212248 3.714232 394.3702
17.77778 0.212248 3.773190 401.1526
18.05556 0.212248 3.832147 407.9366
18.33333 0.212248 3.891105 414.7222
18.61111 0.212248 3.950063 421.5093
18.88889 0.212249 4.009021 428.2978
19.16667 0.212249 4.067979 435.0878
19.44444 0.212249 4.126937 441.8792
19.72222 0.212249 4.185895 448.6718
20.00000 0.212249 4.244853 455.4657
20.27778 0.212249 4.303811 462.2608
20.55556 0.212250 4.362769 469.0570
20.83333 0.212250 4.421728 475.8544
21.11111 0.212250 4.480686 482.6529
21.38889 0.212250 4.539644 489.4524
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FTABLE 7
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(ft) (acres) (acre-ft) (cfs) (ft/sec) (Minutes)***
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MASS-LINK 6
RCHRES ROFLOW RCHRES INFLOW
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Mitigated UCI File

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APPENDIX B

KPFF REPORT



FRY CREEK RESTORATION AND FLOOD REDUCTION

Project # 41600607

Concept Design Narrative for Fry Creek Tidal Control Structure, Pump System, Fish Screening and Roadway Stream Crossing Alternatives Analysis Report

August 4, 2017

Prepared by:

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Executive Summary

The goal of the Fry Creek Restoration Project is to restore the stream channel for improved management of flood waters by increasing habitat quality and floodplain capacity. A seminal objective is to restore the natural intertidal flow regime to the maximum extent practicable via tide gate automation and flood control pumping. The following concept design narrative documents the alternative analyses, technical feasibility and some preliminary basis for design of the Fry Creek Tidal Control Structure, Pump Station, Fish Screening and Roadway Stream Crossing approaches in support of the Fry Creek Rehabilitation and Restoration Project. A new traffic signal is being considered due to a possible road closure on Cherry Street. The analysis proposes integrating the tidal control structure adjacent to and northward of the existing railroad grade (the North Shore Levee alignment).

Alternatives for the pump station and tidal control complex were evaluated based on:

- flood control requirements,
- baseline storage availability,
- likelihood of flood storage creation,
- constructability review,
- construction and operational costs, and
- fish resource protection.

The analysis determined a need for construction of a fully automated and programmable permanent sluice gate/radial gate with storage/pumping pond that serves as flood storage and pumping reservoir. The location is at the Fry Creek/North Shore levee intersection and off-channel pumps manage flood waters that are diverted from an upstream screened channel (See DWG C1.0).

These alternatives include sluice gate and radial gate structures with consideration for maintaining as much natural bi-directional flow as feasible while enhancing flood storage capacity.

Fish screening was evaluated comparing point of diversion screening, at pump screening or a combination of the two depending on flow requirements and potential exposure of fishes to entrainment.

Various pump manufacturer's equipment and applications were evaluated. Hydraulic demands during flood periods were the premise for pump sizing and location. General considerations are provided for pump house structure.

Roadway stream crossings and turnaround alternative concept designs are included for Cherry, Street, Sumner, Simpson, Aberdeen and Pacific Avenue crossings. Alternative designs include bridge options when culvert cover depth requirements are not compatible with existing road surface elevation and utilities.

The project location, its integration with the North Shore Levee, evolving national floodplain management principles, and the increasing importance of fish passage defined the pathway to help meet fish passage objectives, restore the habitat, and propose a dynamic flood control system in an area of limited floodwater storage. Ultimately, improved conveyance, storage, and high capacity pumps will drastically reduce flood risk. Off-channel pumping from constructed storage ponds will minimize fish exposure to pumping and stranding impacts.

The proposed structures and operations are consistent with the Timberworks Master Plan and coastal flood management goals and would meet local, state and federal guidelines for traffic management and stream crossings.

All flood events referenced, unless noted, refer to creek, stormwater or upland flooding. The tide gate and proposed North Shore Levee will manage all coastal flooding concerns.

I. Existing Conditions

A. Description

Lower Fry Creek channel is low gradient ($< \frac{1}{2}$ percent) with slough-like characteristics. In general the groundwater levels are near the surface helping year-round flows but there may be extremely low flow periods where stream segments do not have visible surface flow. Floodplain capacity has been drastically reduced over decades due to floodplain development. Regional flood risk planning identifies restoration and flood reduction measures that include the types of restoration actions that increase floodwater capacity and restore habitat. This is the premise for evaluating a tidal and flood control system that integrates with these goals.

Currently, a trio of top-hinged flap gates with tensioner cable modifications regulates tidal inflow (Image 1). Although the tensioners are adjustable for partial opening they still restrict tidal inflow and affect fish passage. Baseline hydraulic conditions are described in the project's hydraulic evaluation (WSE 2017). Fry Creek drainage and its associated stormwater system may be limited in managing high precipitation and runoff events as evidenced by instances of stormwater system surcharging and chronic localized low-level nuisance flooding.

B. Constraints

Lower Fry Creek is located in a heavily urbanized area. The following items contribute to constraints or special design considerations for the tide gate structure, pumping facility and roadway stream crossings:

- Confined channel width with limited floodplain storage.
- Rapid runoff into Fry Creek due to large areas of hydrologically immature forests.
- Storm drains system potential inability to manage 100-year flood event without surcharging.
- High groundwater table and low hydraulic and streambed gradient throughout project area.
- Habitable land elevation in some areas are similar to Mean High Water Elevation.
- Commercial district and residential housing limits land use potential for flood storage.
- Utility crossings: low street elevations may require extensive engineering to accommodate stream crossings structures for appropriate freeboard, stream simulation design or similar.
- Meeting federal standard of State Highway crossings (Sumner and Simpson).
- Private property ownership restricts opportunity for lateral expansion.

II. Design Criteria

A. Hydrologic and Hydraulic Modeling

The Western Washington Hydrologic Model was used to simulate runoff into Fry Creek and HEC-RAS was used to simulate conditions within the Creek (Figure 1).

Subbasin Group	2 - year Discharge (cfs)	10 - year Discharge (cfs)	25 - year Discharge (cfs)	100 - year Discharge (cfs)	500 - year Discharge (cfs)
Upper Fry Creek	151	250	297	363	439
Duffy Creek	31	48	56	67	78
Urban Basin West	32	44	49	56	62
Urban Basin East	22	31	35	40	45

Figure 1. Modeled flood frequency for the Fry Creek HEC-RAS model inflow calculations.

Source: WSE Fry Creek Hydrologic and Hydraulic Model Development Memo 2017.

In consideration of the different subbasins not having coincident peak flow discharges (Figure 2), the predicted 100-year event discharge for this analysis is 400 cfs. For this modeling exercise, tailwater condition at the tide gate/levee site was set at 8.0 ft and unrestricted flows through the Fry Creek channel were assumed.

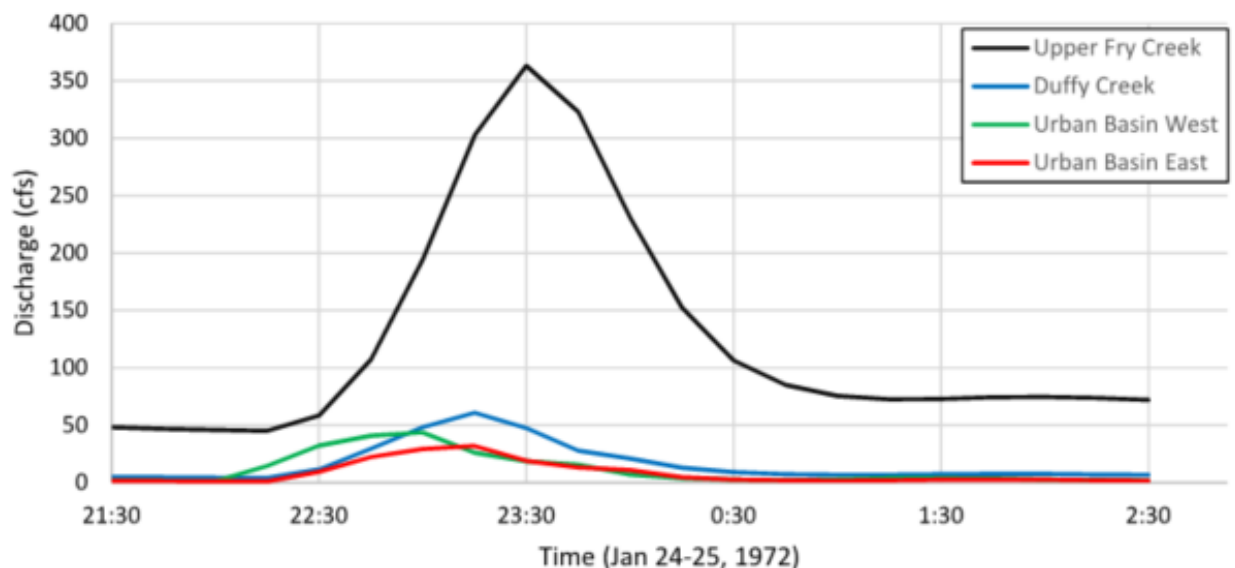


Figure 2. Synthetic 100-year hydrographs for the four (4) subbasin groups within the Fry Creek Watershed. Source: WSE Fry Creek Hydrologic and Hydraulic Model Development Memo 2017.

WSE analysts suggest hydrologic modeling in the basin lacks calibration and validation data.

Analysts were able to acquire peak 15-minute intensity precipitation data for the modeling exercise (WSE 2017) providing reasonable estimates based on basin size and the level of runoff one would expect in area drainages. The anomalies of upstream flooding based on channel constrictions and stormwater surging due to limits in stormwater system conveyance may be non-existent or secondary issues once the channel is restored with unrestricted conveyance and additional storage and increased pumping capacity is realized.

Additional hydrologic evaluations indicate that coastal flooding is the main driver for flooding at the 100-year flow event. This is based on the observation that the January 5, 2015 (Highest tide 11.3 ft) and November 19, 2012 (highest tide 9.8 ft) modeled flood events would not have caused overbank flooding although flooding occurred. This points towards the proposed tidal structure and levee components as the primary flood control mechanisms for the project once the channels and stormwater conveyance systems are unrestricted. The potential range of peak flows (350 cfs to 526 cfs) can be made more precise as the project moves forward with integrating the Fry Creek project with North Shore Levee stormwater conveyance management. Our alternatives analysis is not affected by the discharge range. Management of more or less flood flows relates to the number of pumps that would be recommended towards final design.

B. Basis of Design

Current pump capacity is estimated at 62.4 cfs (28,000 gpm) with an auxiliary 8.9 cfs (4,000 gpm) pump with float-triggered automation that manages the instream water level between 5.42 and 6.92 feet at tide gate closures (WSE 2017). The 100-year flood event estimated to be 400 cfs with unrestricted flows would quickly overwhelm the current pump capacity during tide gate closures. This may have not been observed to date since overland flooding occurs due to the constrictions of upstream culverts diverting floodwaters elsewhere.

The overall goal for water management is to restore the natural intertidal flow regime to the maximum extent practicable via tide gate automation and flood control pumping. The predominance of coastal flooding, which creates elevations far greater than instream 100-yr event flooding, validates the significance of a viable and reliable tidal structure. The project proposes a fully automated tide gate to maximize the restorative effect of estuarine inundation and also utilize it as a management tool (extended fish passage and sediment control).

Fry Creek pump design and operations intends to manage for a 100-year Fry Creek flood event. This may require the tide gate to be managed for prolonged openings or closures. All concept designs of structures assume there are unrestricted flows through Fry Creek and no headwater hydrologic restoration practices or hydrologic/wetland restoration other than stream protection required under Washington State's Forest and Fish Law. Default tide gate operations will manage all coastal flooding influences.

The design flood elevation for the project is the 100-year storm event which in the vicinity of the levee attains an elevation of 8.0 feet in unrestricted flow (absent tidal influence and upstream constrictions). In evaluating the tidal control structure, pump system, Fry Creek water level management and stream crossing needs we considered the following criteria:

- Infrastructure designed, located, and sufficiently protected to remain operational during flood emergencies, storm surges and power outages.

- Have long-term viability (remain functional despite potential increase in base flood elevations).
- Pump house secure and long-lasting with heavy duty construction materials.
- Maintain as much of the natural flow regime and close control over the depth or extent of inundation to avoid unacceptable increases in flood risk.
- Allow estuarine inundation within Fry Creek to balance flood control and habitat benefits.
- To the extent practical, incorporate fish screening design that maximizes protection of the life history stage and distribution of expected species.
- Minimize exposure to entrainment of all fish life stages by considering screen design, alignment, mesh sizes and maintenance needs.
- Constructed storage ponds must be able to be pumped completely or maintain one-way outflows following storm events to avoid fish entrapment.
- Promote natural stream simulation and tidal functions in consideration of structure design widths.
- Ensure tidal structure design is maintenance friendly in consideration of sediment and debris management.
- During low tidal periods flow characteristics should mimic what would otherwise be found absent any structures.

1. Tide Gate and Pump Station Operational Overview

Proposed operation of the tidal structure to manage tidal and storm events will be considerate of flood control and natural tidal inundation to the extent practical.

Essentially, during non-storm seasons the tide gates may stay open longer to allow tidal exchange into the channel. In the winter storm seasons, tide gates may be closed sooner to allow the channel and floodplain to maximize its storage for freshwater flows to utilize its storage before diverting to pumping area. Incoming tides will be met by an open tide gate creating estuarine inundation up to the 5-7 ft elevation prior to gate closing. Fry Creek flows will continue to fill the lower channel until the storage areas begin to be filled with diverted water. This inlet channel will be screened for fish protection at 7 ft. elevation¹. Pumps will manage the storage area surface water elevation as needed. The storage area can be variably managed depending on the season. During low flow periods, pumps may only be needed periodically since the water may drain from seepage through the water table during low tide cycles.

¹ The 7-ft. primary storage area inlet elevation serves as a surface water elevation control within Fry Creek. This design element may be influenced by North Shore Levee stormwater management planning. Additional evaluation is needed to determine the design elevation if stormwater is diverted into Fry Creek from the lowland areas.

During high flow and rainy periods, tide gate closure may occur much sooner, therefore requiring storage capacity within the Fry Creek mainstream prior to diverting into the storage area. Pumps would divert water through force main pipe to an outfall downstream of the proposed levee. The outfall is directed into a roughened channel or other style designed for energy dissipation (**Images 9-10**).

To ensure that fish screens do not prohibit flows from reaching pumps during flooding, a design height of 10 feet for the top of fish screen would allow unrestrained spillage into the storage pond.

2. Roadway Stream Crossings

Culverts along the corridor of Fry Creek are undersized for the 100-year flood. Therefore, a combination of culvert upgrades and culvert removals are proposed to eliminate constrictions in order to restore Fry Creek and reduce flooding. Road turnarounds have been schematically designed where culvert removals have been proposed. Criteria for road turnarounds included:

- Provide sufficient amount of room for channel restoration.
- Turnaround must be a fire apparatus access road if length of dead-end road exceeds 150 feet.
- Minimize private property impacts (work to remain in city ROW).

Turnaround designs have been proposed at Cherry Street and Aberdeen Avenue. Culvert upgrades have been proposed at Sumner Avenue, Simpson Avenue, Pacific Avenue, and Cherry Street as a second alternative.

C. Phasing

The concepts and information in this report are consistent with a 10% concept design and feasibility analyses. Fry Creek tide gate, pumps, culvert replacements and floodplain restoration are integrated into concurrent flood control efforts including channel restoration and North Shore Levee construction.

Further evaluation and prioritization of Fry Creek Restoration Project elements (culverts, storage areas) will develop phasing details. The following long term phasing elements are for consideration for the design and build sequence of all Fry Creek Restoration project elements:

- 1) Continued Project Development: preliminary and advanced engineering, preferred alternative cost refinement and scheduling, assure design standards, verify utilities and site constraints, preliminary codes and permitting requirements, secure suppliers.
- 2) Detailed Design: advanced topographic, boundary and locate surveys, refined project definition, finalize basis for design for each project element, schematic drawings, outline specifications, multiple drawing review (30%, 60%, 90%), owner's acceptance of final outline specifications and drawings, ascribe maximum price, constructability review.
- 3) Project implementation: procurement, cost control, long lead identification, quality assurance planning (during pre-construction), schedule and communication control, life cycle analysis, record drawings and operations/owner's manual.

- 4) Commissioning and Closing: mechanical systems start-up and training (tide gate and pump systems), final field inspections, punch list and manual handoff.

III. Alternatives

A. Tide Gate/Fish Screen/Pumps

Several tide gate structures, screen designs and materials, and pump technologies were evaluated to determine what would meet the design and operational criteria of a flood control system and to be compatible with stream restoration. The main function of traditional tide gates is to allow freshwater to flow into the estuaries and prevent the upstream movement of brackish estuarine waters. To be consistent with restoration concepts the alternatives evaluated will allow the upstream movement of brackish estuarine waters to the extent water level management goals are not compromised. We focused the in-depth analysis on automated tide gate systems to arrive at radial gate or sluice gate alternatives. This was due to a combination of ease of operation and maintenance and the ability to have flexibility for seasonal and flood water-level adaptability.

Fish screens were evaluated comparing point of diversion screening, at pump screening or a combination of the two depending on flow requirements and potential exposure of fishes to entrainment.

Pump selection criteria included exposure to saline environments, ability to design in series, proven durability, regional mechanical support, training in operation and maintenance.

B. Roadway Stream Crossings

Roadway stream crossings and turnaround alternative concept designs are included for Cherry Street, Sumner, Simpson, Aberdeen and Pacific Avenue crossings. Alternative designs include bridge options when required culvert cover depths are not compatible with existing road surface elevation and utilities.

IV. Concept Designs

A. Tide Gate/Pumps/Fish Screens

Non-automated self-regulating tide gates have widespread use in the Pacific Northwest. Although meeting many land management needs for agriculture and development, they fall short in ecological performance for fish passage and intertidal function. Top- and Side-hinged Flap Gates, Self-Regulating Tide Gates (SRT), Bottom-Hinged Pet Doors, Muted Tidal Regulator (MTR) systems, Manual Operation, and modifications such as “pet doors” were all considered in this alternatives assessment. Many of these gate styles are heavy and outdated and do not provide sufficient fish passage. Top-hinged tide gates with a mitigator fish passage device keep the tide gate open during part or all of the flood tide showing major improvements to juvenile fish passage.

These popular systems, although modifications to some have shown improvements in fish passage and estuarine connectivity than the traditional and basic styles, do not afford the operational flexibility that meet the project's flood control and habitat restoration criteria. Power availability at this site, which is typically a constraint for tidal structures, provides the opportunity for electric gates operated by a Supervisory Control and Data acquisition (SCADA)² system ensuring the proper timing of opening and closing the gate(s).

1. Tide Gate Alternatives

a) Radial (Tainter) Gates

Radial Gates are common in dam spillway scenarios but are becoming more popular in tide relief and regulation according to manufacturers. The radial gate is an electric powered, curved blade that remains completely out of the water in non-flood events. During a flood event the programmed SCADA system will lower the gate(s) to mitigate tidal flooding. After the flood event the SCADA system will lift the gate(s) completely out of the water and allow the creek and tide to function normally.

Benefits of Radial Gate(s)

- Rugged structure that can handle hard debris impact.
- Spans wide openings.
- Depending on gate layout, radial gates have less permanent structures always in the water (wing walls/mounting walls).

Disadvantages of Radial Gates(s)³

- Operational equipment can be complex (cranks, cables, and hoists).
- Increased visual obstruction when gate is not engaged.
- Debris build up along gate can cause sealing issues during flood events.
- Requires extra-sturdy concrete wing walls.
- Complex maintenance and replacement.
- Highest cost of all alternatives for materials and installation.
- Requires backup generator(s) in case of power outages.

b) Sluice Gates

Sluice Gates are the most widely used flood control gates. With correct maintenance and programming, sluice gates can provide effective flood control.

² SCADA packages are used to design an electrical control system to monitor and control the flow and level of water bodies. Gathered by pressure transducers the analogue water height information is converted to digital form. A tidal prediction program constantly informs the structure operation with predicted tide heights for deciding the position of the tide gate ensuring the required water levels are met.

³ Radial gate mechanical issues have been cited in large dam designs with high head dams where tremendous hydraulic pressures are involved. Smaller scale systems managing 5-10 foot hydraulic fluctuations may not experience the types of large-scale forces the technology has been most broadly applied in.

Sluice gates can be mounted to structures in a variety of ways. Commonly, sluice gates are mounted to the downstream end of the box culvert. Similar to radial gates, the closing and opening of the gates will be monitored and controlled by the SCADA system to prevent flooding and allow free flow in non-flood events.

Benefits of Sluice Gates

- Simple design allowing for simple operation and maintenance.
- Simple replacement when needed.
- Handle moderate debris impacts.
- Relatively lower cost (materials & installation) than other alternatives.

Disadvantages of Sluice Gates

- Most likely will have more permanent structures always in water than other alternatives.
- Shorter span/smaller openings (large openings will require multiple sluice gates).
- Requires backup generator(s) in case of power outages .

Multiple Gates

Regardless of the chosen alternative, multiple gates may be required. Based on span lengths, a single gate (radial or sluice) may not be wide enough. In this case, multiple of the chosen gate alternative will be used in parallel. The gates will continue to function identical as a single gate would.

Future Design for the Tide Gates will consist of:

1. Choosing tide gate alternative.
2. Further investigation and design of tide gate operating heights (opening/closing).
3. Design of connection of tide gate to the box culvert.
4. Design of wing wall & tide gate outlet channel.
5. Integration of SCADA system to tide gates and pump station.
6. Detailed cost estimate.

2. Pump Types, Configuration, and Controls

(Images 2-4 Tide gate and pump house area) The pump station will be designed to handle runoff from the Fry Creek Basin as delineated to the proposed levee location and to operate at multiple duty points to account for the variable creek flows and variable downstream creek levels. The pumps will be capable of pumping 50 cfs to 400 cfs to handle the base line creek flow and 100-year peak flow.

Pump Types: Axial flow pumps capable of high pump rates at low heads are proposed.

Number of Pumps: Multiple pumps are desired for a pump station of this size to provide 1) variable capacity and 2) a factor of safety in the event one pump faults. Four (4) pumps would be a typical number for a station of this capacity.

Pump Controls: Pump operation at low flows is anticipated to be accomplished by either multiple pump of the same size that are controlled with variable speed drives or constant speed pumps of different sizes with level controls that initiate the smaller pumps first and then the larger pumps as necessary. The variable speed pump option is assumed for this schematic design but will need to be evaluated as the project progresses. It is also assumed that a SCADA system connection to allow remote monitoring and/or operation of the pump station will be included.

Pump Intake and Sump Chamber: The inlet channel and pump sump chamber for a pump station of this type must be designed to reduce turbulence and velocity at the pump suction locations in order to promote pump reliable operation and longevity of the pumps. It is assumed that the inlet and sump chamber for this station would be cast in place concrete and would be the base for the proposed pump room building.

Pump Replacement: Recommended replacement frequency is from 10 to 20 years depending on use. Daily and Moderate use is expected for most pumps, so a replacement frequency of 13 years was chosen, requiring 3 replacements in 50 years. Some pumps will be periodically active in major flood events. The final design could consider pump use rotation to maximize life of all pumps.

3. Pump Station Housing Design Criteria

Pumps and controls are proposed to be housed in a concrete block building matching the architectural style of existing City owned facilities. Schematic design calls for a building of approximately 1,000 square feet that would house pumps, pump controls, and SCADA equipment. It is assumed at this time that a back-up generator will be located adjacent to the pump station building. Building layout and dimensions will be refined as pump configuration, inlet orientation, and outfall requirements are determined and based on city desires. A geotechnical evaluation of the site will be also necessary to determine the most appropriate building foundation. All elements of the pump station will be designed to allow full access and operation during major flood events. To facilitate this, the proposed structure would be located immediately adjacent to the levee with the building finished floor matching the top of levee elevation. Access to the pump house would be via the proposed top of levee maintenance road (see DWG C1.0).

4. Inlet Channel and Pump Fish Screening

(Images 5-8) Paneled fish screens will be installed at locations to minimize fish entrainment into storage area and avoid velocities created by pumps. The project contains two (2) screening elements 1) Point-of-diversion screening at entrance to the storage area, and 2) the pump site. **(See Drawing C 1.0).**

Effects on fish will be minimized if withdrawal does not occur right at the tidal structure, the backwatering of freshwater input during tide gate closures will be temporary rearing for outgoing fish. The ability to have saltwater inundation on a regular basis will keep freshwater fishes, or fishes in their freshwater life stage, from going too far down in the system reducing exposure to pump systems.

The point of diversion and storage pond separation screen will be multiple 6 ft x 3 ft stainless steel panels with ¼-inch mesh size with grades resilient to salinity. While providing substantial screening function for juvenile fish, the main objective of these panels are debris management and ability to move voluminous flows during flood periods. Alternatively, intake mounted cylindrical tee-screens (**Image 8**) are a means to provide very effective fish screening at the last point of pump exposure. These devices in combination with inlet screening will provide the highest level of fish protection. Area and volume constraints of the storage pond may make only one or two tee-screens feasible. For example, a tee screen could be placed on the pump(s) that are operating most frequently during regular operations and minor floods. During large flood events the operation would want to eliminate the risk of pumps not able to meet capacity due to potential clogging so some pumps may be unscreened relying on the point of diversion panel screening for resource protection.

B. Roadway Stream Crossings

1. Cherry Street Alternatives

(Exhibits C1.3 - C1.6) The two alternatives explored for Cherry Street includes a road turnaround design or upgrade the culvert. The road turnaround design will hinder PUD's accessibility to the highway (Sumner Avenue) at Oak Street, so proposed traffic signalization at Myrtle Street and Sumner Avenue is incorporated with the Cherry Street road turnaround designs. No traffic changes are necessary with the second alternative of culvert upgrades.

a) Road Turnaround Design/Culvert Removal

Two (2) road turnaround designs are proposed; a hammerhead turnaround and simply ending the road. The hammerhead design is proposed since the access road exceeds 150 feet. The fire apparatus turnaround impacts a small amount of PUD property. The second option is to end the road without a turnaround and to provide a fire truck route by an easement agreement with the property owner, as shown on the exhibit. This will allow the least amount of physical obstructions on private property since this option is contained within city right of way.

The culvert removal eliminates its Oak Street to Myrtle Street connection/segment as a thoroughfare (Exhibit CS-1). The effect of this traffic flow alteration will have an impact to the PUD. Currently, PUD vehicles travel east on Cherry Street to Oak Street to access the signal at Oak St/Sumner Ave (SR 101). The removal of the Cherry Street crossing eliminates the ability for PUD vehicles to access a traffic signal.

To alleviate this impact, the project proposes an alternative for a new traffic signal at the Myrtle Street/Sumner Avenue intersection. The new signal will have 3 mast arms:

1. One (1) to control the westbound Sumner Avenue (SR 101) traffic.
2. Two (2) controlling the 2-way northbound and southbound traffic of Myrtle Street.

Such a proposal will need to have early and detailed coordination discussions with WSDOT. Traffic signals have the ability to improve ingress/egress from lower volume roads to the higher volume roads, but also slow the overall Level-of-Service (LOS) to the higher volume road. Having two signals close to each other is known to have negative impacts to the LOS.

The proposal does not anticipate road widening for either Sumner or Myrtle Street, unless WSDOT feels the need.

b) Upgrade Culvert

The second design option is to upgrade the existing culvert and keep Cherry Street a continuous street. The water surface elevation for the 100-year flood at this location is 10.48 feet. The proposed box culvert is a 12' x 6' opening with a thickness of about 10 inches, giving the culvert a height of about 7 feet. Since the water surface elevation surpasses the height of the culvert as well as the road elevation (12.5') the road will need to be raised and graded out.

2. Upgrade Culvert at Sumner and Simpson Avenue

(Exhibit C1.7 and C1.8) Alternative designs include bridge options when culvert cover depth requirements are not compatible with existing road surface elevation and utilities. The water surface elevation for the 100-year flood at Sumner Avenue is 10.25 feet and the water surface elevation at Simpson Avenue is 9.87 feet. Both proposed culverts are 20' x 6.5' box culverts. These preliminary dimensions may increase laterally as design and hydraulic modeling advances in the next design phase. Streambed substrate movements during the 100-year event will be given further consideration.

3. Road Turnaround Design at Aberdeen Avenue

(Exhibits C1.9 to C1.11) Road termination is not an option as determined by emergency vehicle requirements since the length from the intersection to the end of the road is greater than 150 feet.

The existing culvert is proposed to be permanently removed and to open up the channel for restoration and flood reduction purposes. Cul-de-sac designs need to be suitable for a fire truck route, the biggest constraint was designing that space on the right bank of the creek. The options encroach on private property to varying degrees. To avoid encroachment onto private property on the left bank of the Creek, the Aberdeen Avenue and Ash Street intersection is converted to a corner. The first option for the road on the right bank of the Creek is to install a hammerhead turnaround. This option greatly impacts private properties. The second option is to install a 3-point Y turnaround. The Y-shape allows for less property to be impacted but still greatly affects home owners. The third option is a 3-point side turnaround and only impacts one private property.

4. Pacific Avenue 20' x 6.5' Box Culvert

(Exhibit C1.12) The water surface elevation at Pacific Avenue is 8.86 feet. The proposed culvert is a 20' x 6.5' box culvert. This size culvert manages the 100-year flood capacity but with the culvert flowing full. These preliminary dimensions may increase laterally as design and hydraulic modeling advances in the next design phase. Streambed substrate movements during the 100-year event will be given further consideration.

V. Next Steps: Advancing Alternatives/Preferred Alternative

Stream/intertidal flow dynamics, sediment management, upstream/downstream fish passage capability were the major considerations for analyzing structure type and operations. In addition, the ability to make seasonal adjustments to tide gates was deemed important to maximize fish passage effectiveness. The next steps in defining more detailed design criteria require a closer look at these considerations.

Stream/intertidal Flow Dynamics: The objective of improving the estuarine connectivity of the system via prolonged tide gate openings may cause some vertical and lateral channel adjustments. The new structure will operate differently than a self-regulating design and make allowances for estuarine waters to influence further upstream. For example, during seasons of low flooding likelihood tide gates can be open for extended periods of time during lower high tide events and allow brackish water inundation. This may contribute some changes to sediment deposition features in the channel allowing sediment from upstream to settle further upstream. These dynamics need to be evaluated in reference to the channel changes proposed in Fry Creek channel restoration.

Sediment Management: Fry Creek is in a somewhat steady state equilibrium in regards to its gradient and bed elevation. Channel reconfiguration during the restoration phases may allow some lateral channel movement but the gradient is generally fixed. The Fry Creek tide gate invert elevation will be established at a modeled equilibrium height and its associated box culvert at a gradient of what the natural channel determines. The creek's longitudinal profile was derived from the elevation inverts of the structures at Sumner Avenue and the current pump station. This .11% gradient is a reasonable representation of the bed profile and hydraulic gradient. Preliminary indications of channel conditions indicate that there is a very low sediment load moving through lower Fry Creek. Also, Fry Creek slough (the intertidal channel area below the proposed structure) is setback far enough from the main estuary that suspended sedimentation from incoming tides and storm surges will be minimal. Regardless, long term structures that are fixed in place in dynamic systems can cause varying geomorphic responses upon removal or changes.

The proposed structure types require a very good understanding of the sediment dynamics since their function relies on the ability to seal on uniform surfaces. Further understanding of structure maintenance level and longevity is brought forward when addressing sediment issues.

Fish Passage and Screening: Fish passage and ecological needs are met by providing the largest feasible width for the structure and its associated culvert that will maintain comparable flow depths and velocities observed in the natural channel. Velocities through structures will not exceed what would be found in the channel during periods that adult or juvenile salmon are migrating. Design outflow velocities should target about 3 - 4 ft./sec. maximum or not increase what is occurring in the natural channel. Preliminary modeling indicates that design velocities will not exceed 3 ft/sec. Some exceptions may occur during large storm events when channel change is occurring and fish are not typically migrating.

Roadway Stream Crossings: Standard schematics are presented in this report. Each site offers the potential to add variations. Potential variations can be discussed with additional information about the restored channel form. Bridge and culvert design and materials vary and can be further addressed as the project progresses.

VI. References

FEMA. 2011. Preliminary Flood Insurance Study. Grays Harbor County, WA and Incorporated Areas. Flood Insurance Study Number 53027CV000A.

FEMA 2014. Risk Report (DRAFT) For Grays Harbor County including the Cities of Aberdeen, Cosmopolis, Hoquiam, Ocean Shores, Westport, Montesano, McCleary, Elma, and Oakville. October 9, 2014

WSE. 2017. Fry Creek Hydrologic and Hydraulic Model Development" Technical Memorandum by Watershed Science and Engineering, Seattle, WA

VII. Cost Estimation Worksheets

Cost Estimate Index

Pump Station and Fish Screens

Tide Gates

Alternative 1: Radial Gate

Alternative 2: Sluice Gate

Box Culvert

Alternative 1: One Span

Alternative 2: Two Spans

Cherry Street

Alternative 1: Hammerhead turnaround

Alternative 2: End Road Design

Alternative 3: Culvert Replacement & Upgrade

Sumner Avenue Culvert Replacement & Upgrade

Simpson Avenue Culvert Replacement & Upgrade

Aberdeen Avenue 3-Point Y Turnaround

Pacific Avenue Culvert Replacement & Upgrade

VIII. Exhibits

Exhibit Drawing Index

- C1.0: Site Plan
- C1.1: Sections
- C1.2: Tide Gate Options
- C1.3: Culvert Alternates
- C1.4: Cherry Street Option 1
- C1.5: Cherry Street Option 2
- C1.6: Cherry Street Option 3
- C1.7: Sumner Avenue Plans & Sections
- C1.8: Simpson Avenue Plans & Sections
- C1.9: Aberdeen Avenue Option 1
- C1.10: Aberdeen Avenue Option 2
- C1.11: Aberdeen Avenue Option 3
- C1.12: Pacific Avenue Plan & Section

IX. Images



Image 1. Existing Fry Creek tide control structures include three (3) 6-ft diameter culverts whereby the far left culvert serves as the creek outflow during ebb tide after the other gates close. A flap-gate in the middle culvert and cables on the others allow adjustment to increase ebb tide (outgoing) conveyance.



Image 2. The proposed site of the tide gate structure and box culvert. This view is looking downstream at the culverts located under the railroad tracks. The two (2) culvert rounds and one (1) concrete box culvert (right of image next to piling) will be replaced by the culvert/tide gate system.



Image 3. View of Fry Creek looking upstream from proposed levee crossing. Arrow indicates general area of inflow channel to storage pond. The bottom of the utility pipe seen in the image is about 8.5 ft elevation. All managed and natural (below the 100-year flood event) water levels will occur below this pipe.



Image 4. View of Fry Creek looking downstream at the area of tide gate structure. Arrow indicates the outlet channel of the pumps' drainage culvert.



Image 5. Panel fish screens similar to what would be in place at the diversion channel. Design would include catwalk for maintenance and angle to 20 degrees to help with debris and leaf litter removal. Proposed length is about ½ of what is pictured here.



Image 6. Inclined screens allow easier cleaning from atop and push floating debris up and over screening adding a self-cleaning element. In this example the screen mesh size is very small. For Fry Creek the screens at the storage pond inlet channel will be removable horizontal panels with width designed to divert the 100- yr flood event.

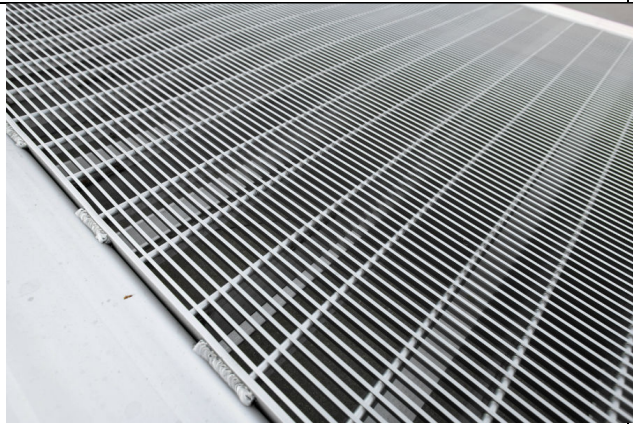


Image 7. Wedge Wire Screens can manage small debris and provide larger-size fish deterrence and lower maintenance effort than tee-screen intake mounts. This could be a style of screen that could be located near the pumps if cylindrical tee-screens are not used.

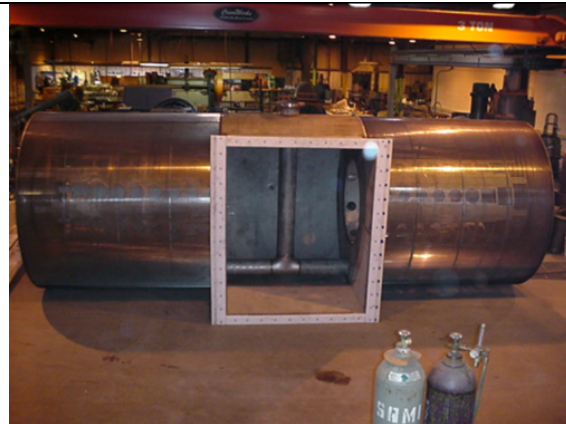


Figure 8. A cylindrical tee screen that is typically used for intake mount. This size of screen is rated for 106 cfs and an intake velocity of .5 feet/sec. Depth requirements may limit its utility.



Image 9. A concrete baffle drop is positioned at the pump's drainage culvert and serves to dissipate the energy as pumped water is introduced to the estuary.



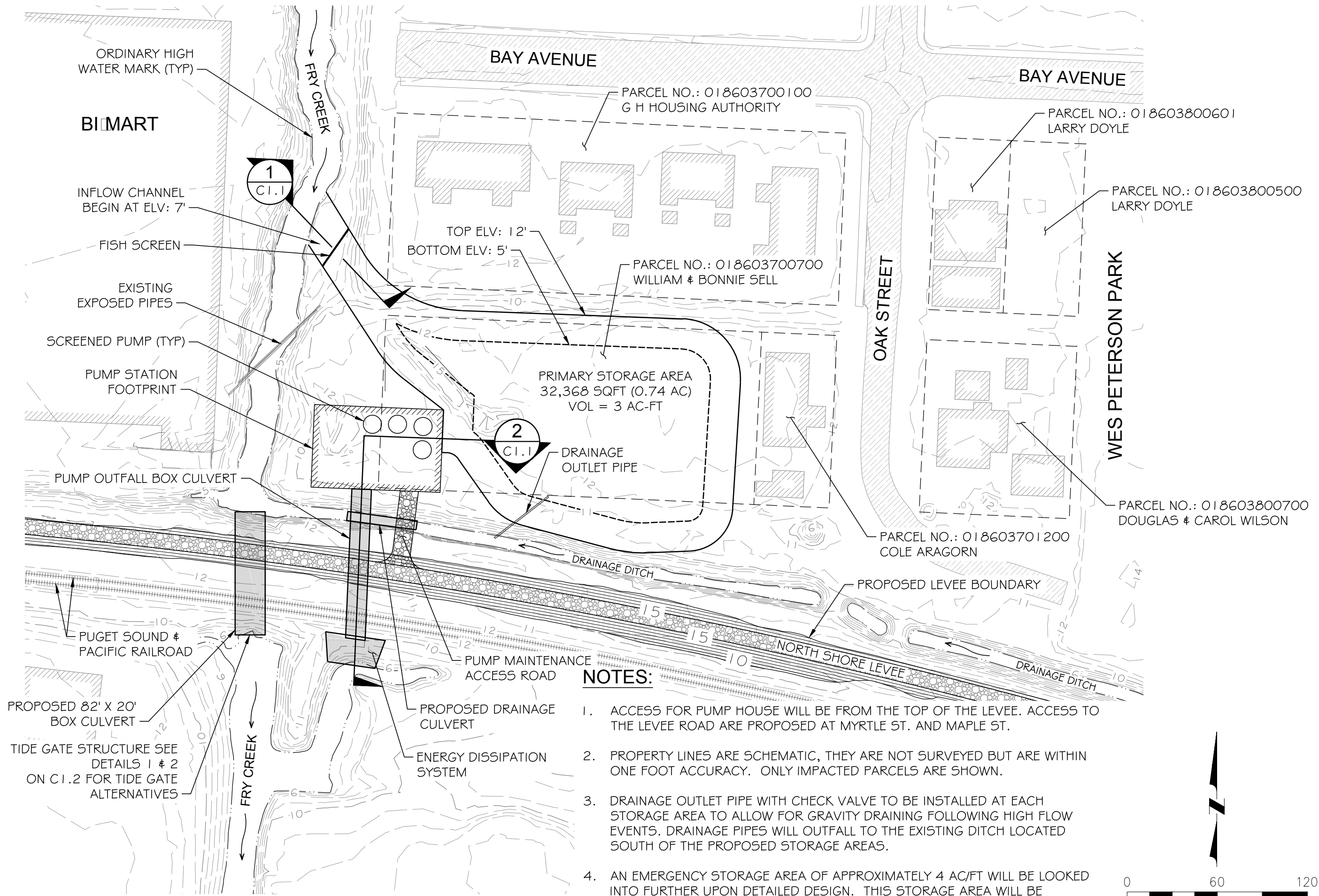
Image 10. Rip rap may also be used to line the outlet channel as a somewhat more natural way to dissipate energy.



APPENDIX A

Plan Set

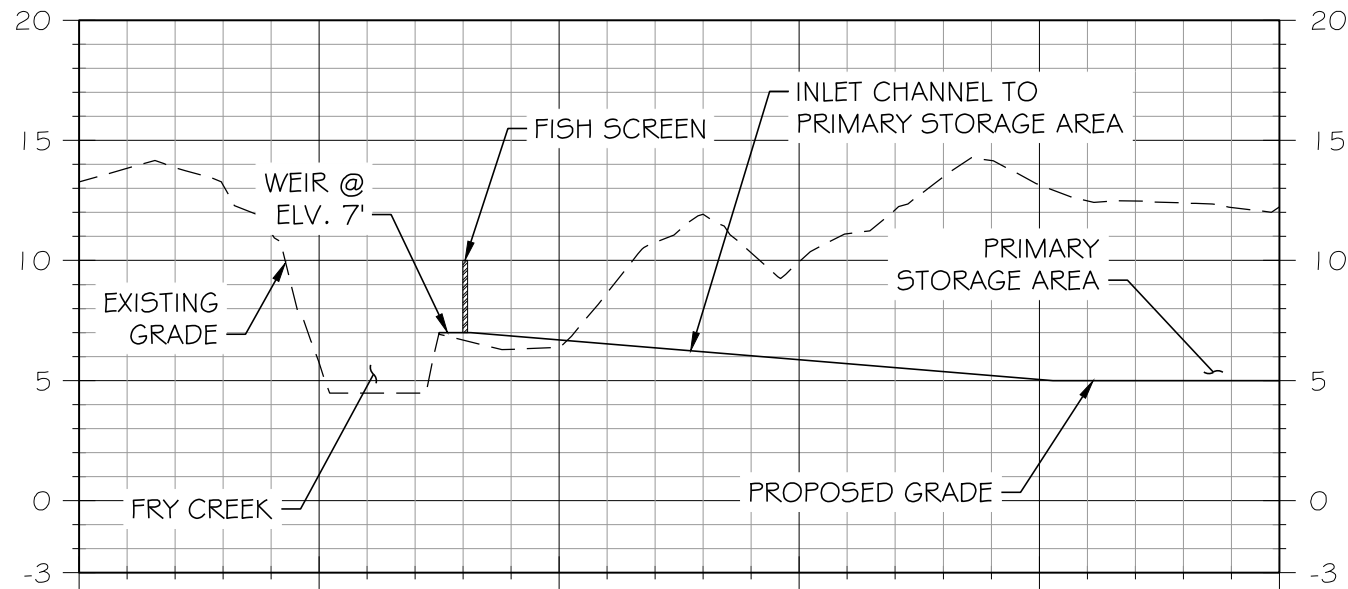
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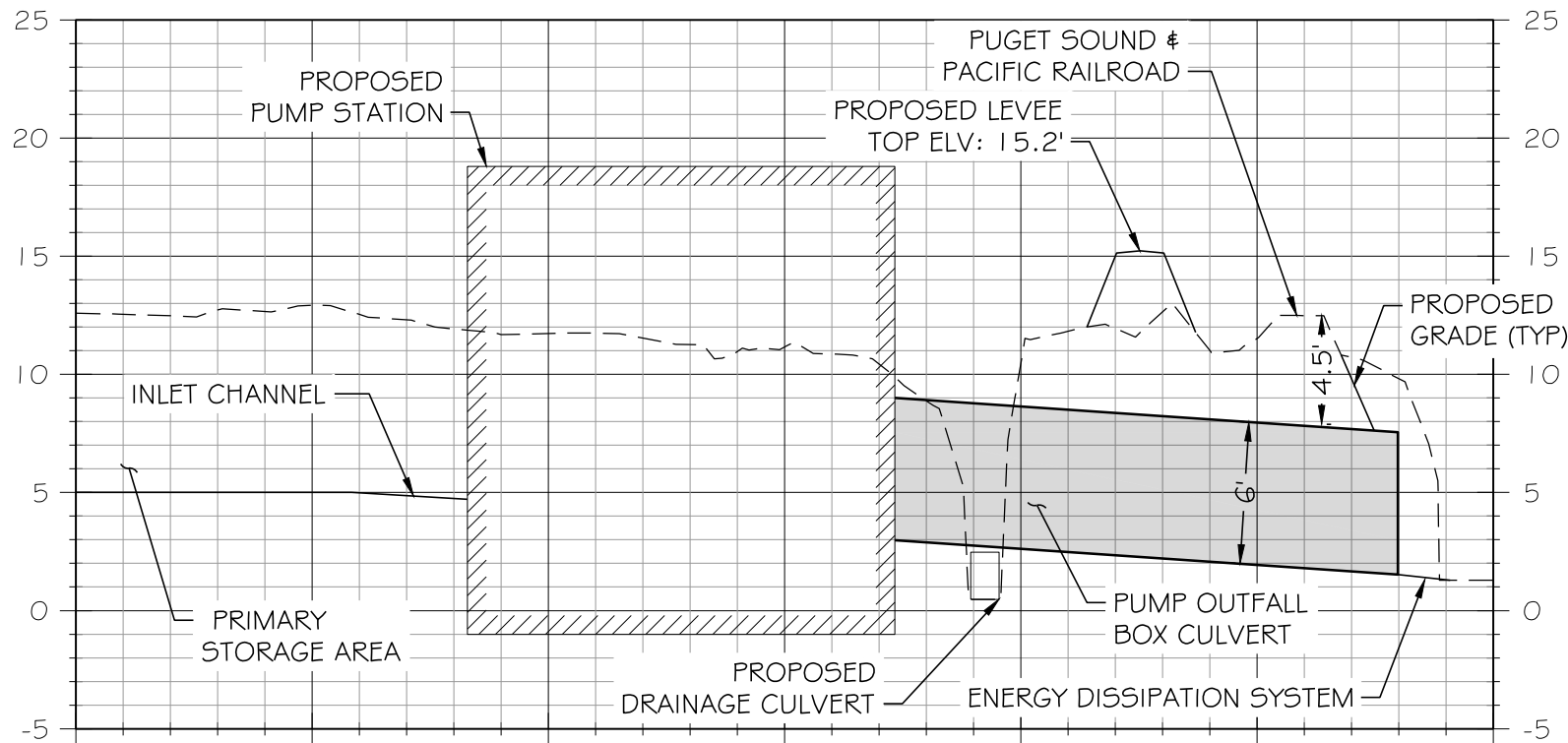
NOTES:

1. ACCESS FOR PUMP HOUSE WILL BE FROM THE TOP OF THE LEVEE. ACCESS TO THE LEVEE ROAD ARE PROPOSED AT MYRTLE ST. AND MAPLE ST.
2. PROPERTY LINES ARE SCHEMATIC, THEY ARE NOT SURVEYED BUT ARE WITHIN ONE FOOT ACCURACY. ONLY IMPACTED PARCELS ARE SHOWN.
3. DRAINAGE OUTLET PIPE WITH CHECK VALVE TO BE INSTALLED AT EACH STORAGE AREA TO ALLOW FOR GRAVITY DRAINING FOLLOWING HIGH FLOW EVENTS. DRAINAGE PIPES WILL OUTFALL TO THE EXISTING DITCH LOCATED SOUTH OF THE PROPOSED STORAGE AREAS.
4. AN EMERGENCY STORAGE AREA OF APPROXIMATELY 4 AC/FT WILL BE LOOKED INTO FURTHER UPON DETAILED DESIGN. THIS STORAGE AREA WILL BE DESIGNED FOR EXTREME EVENTS TO ALLOW RELIEF TO THE PUMPS & PRIMARY STORAGE AREA.

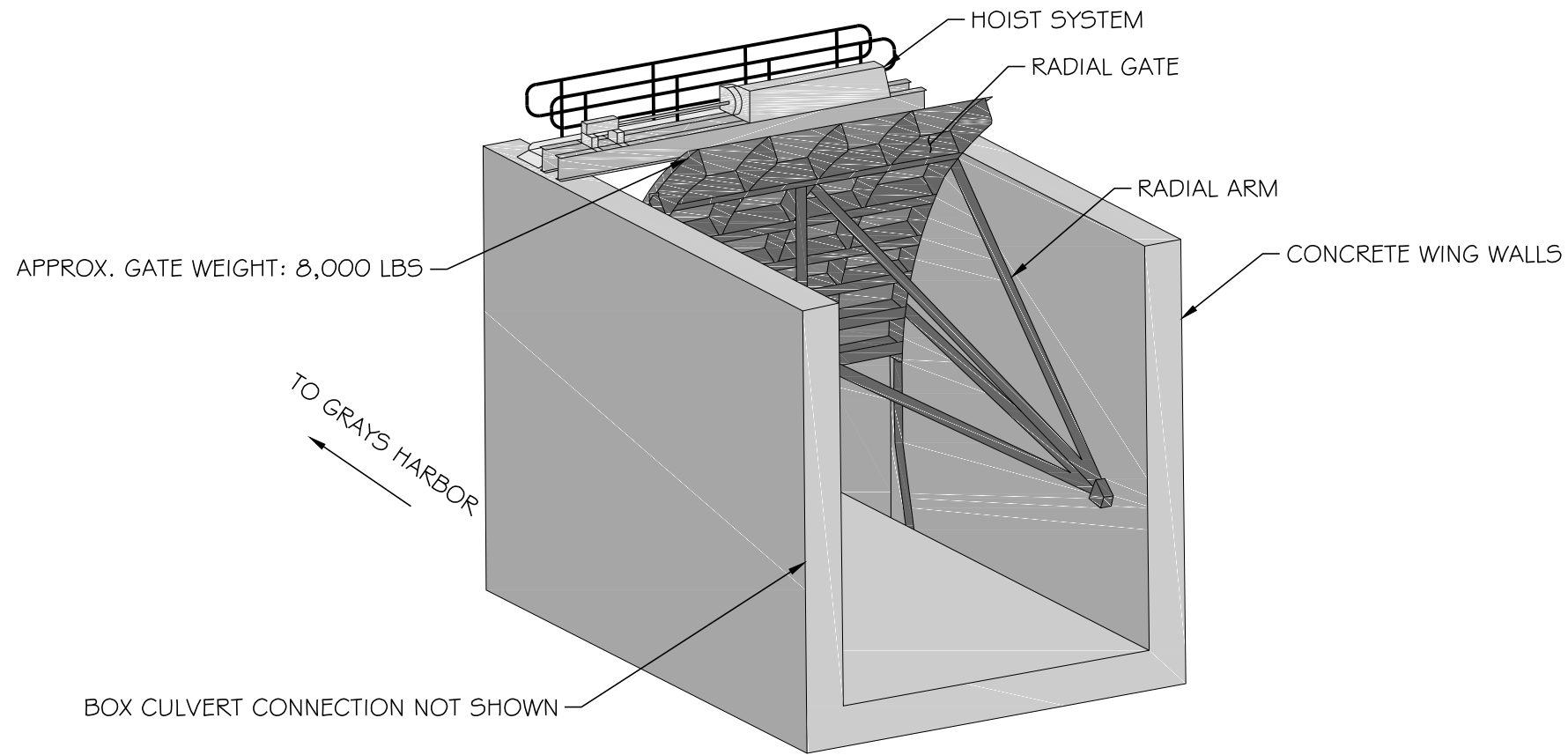
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CHECKED BY:	DATE: 8-3-2017		
SCALE: 1" = 60'			
FRY CREEK RESTORATION & FLOOD REDUCTION		SITE PLAN	
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SHEET		1 OF 11	



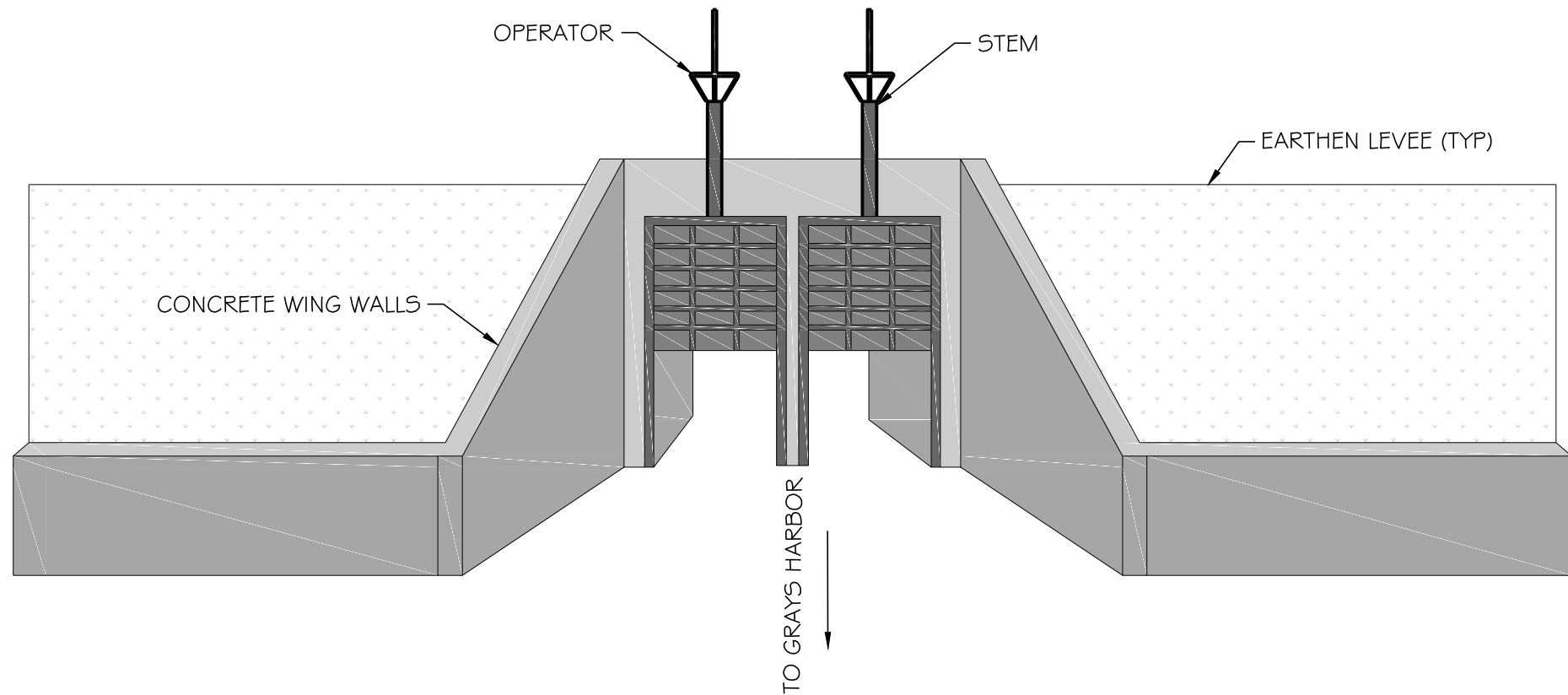
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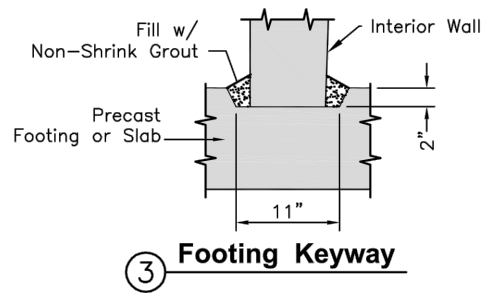
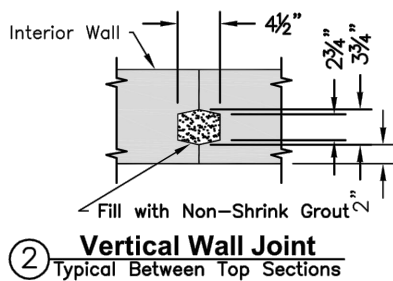
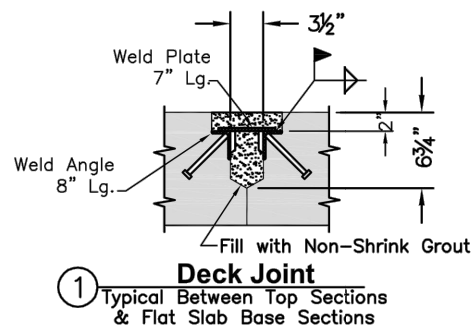
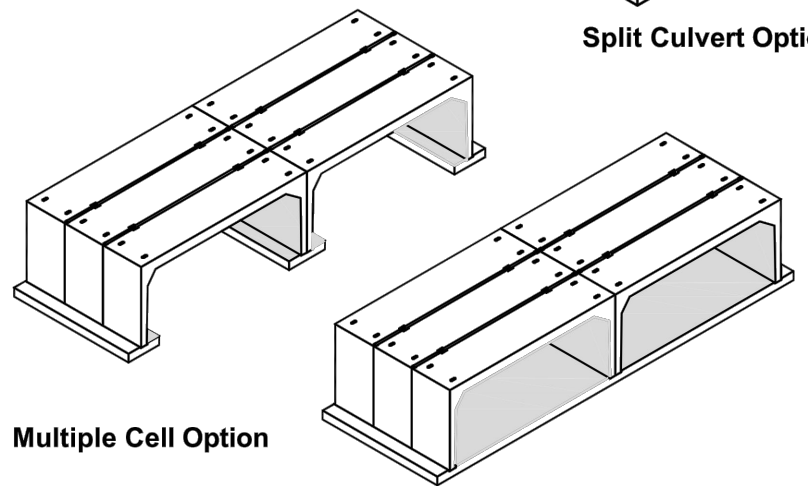
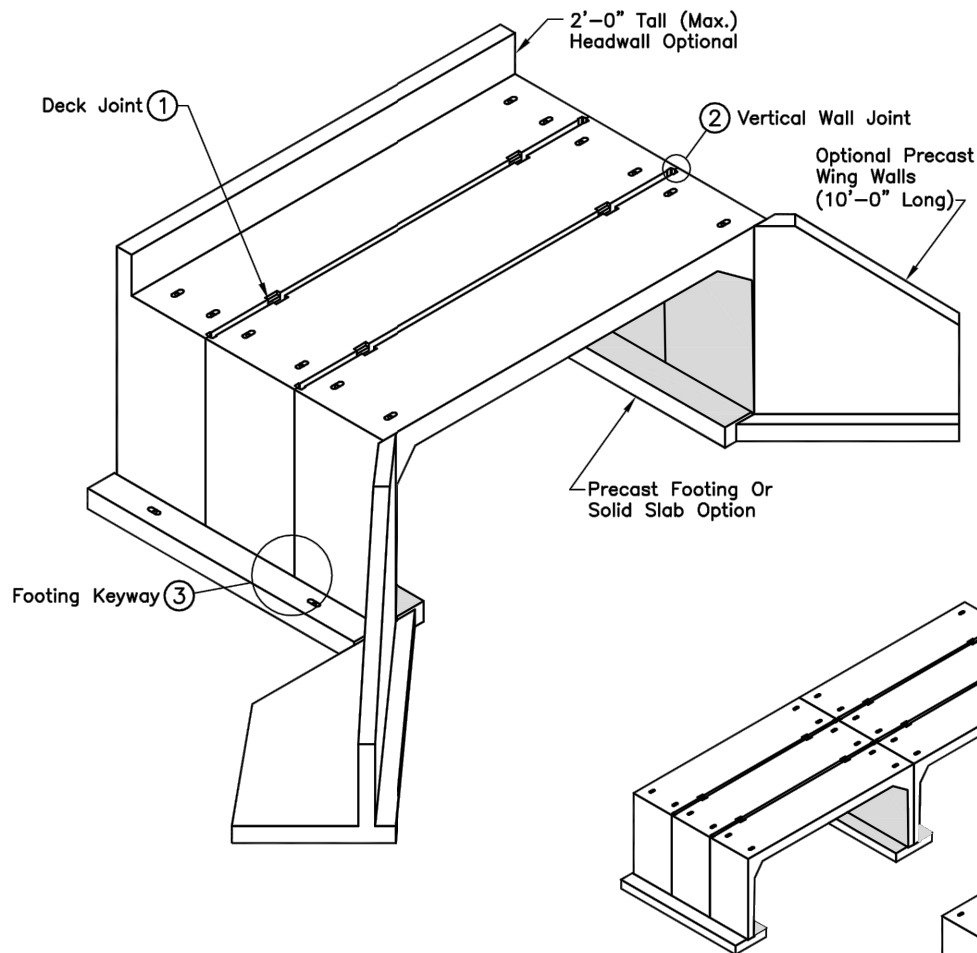
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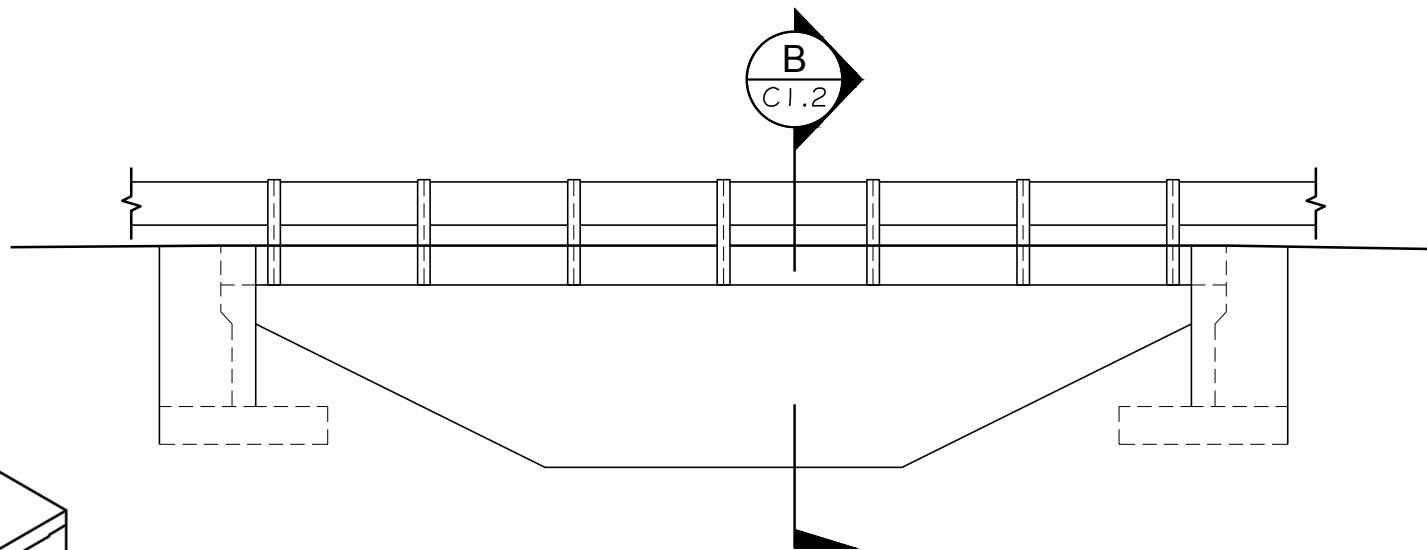
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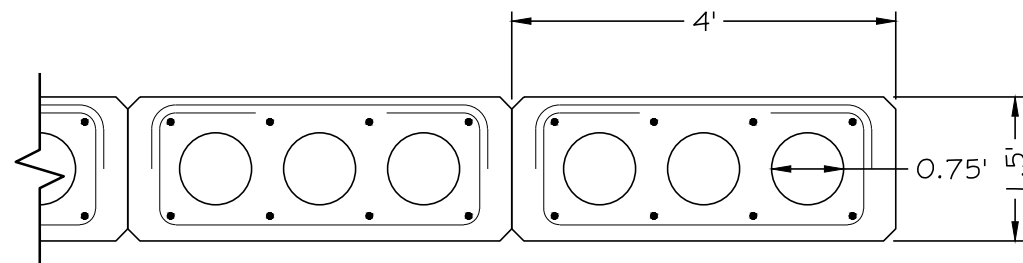
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SCALE: N.T.S.



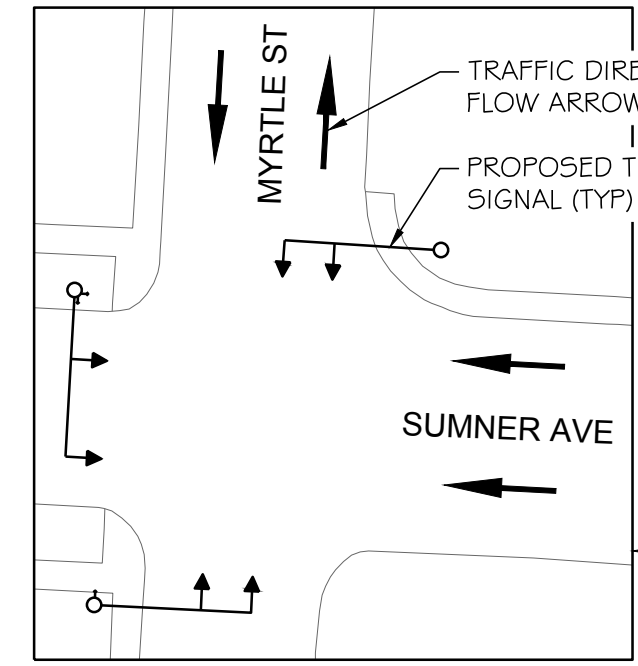
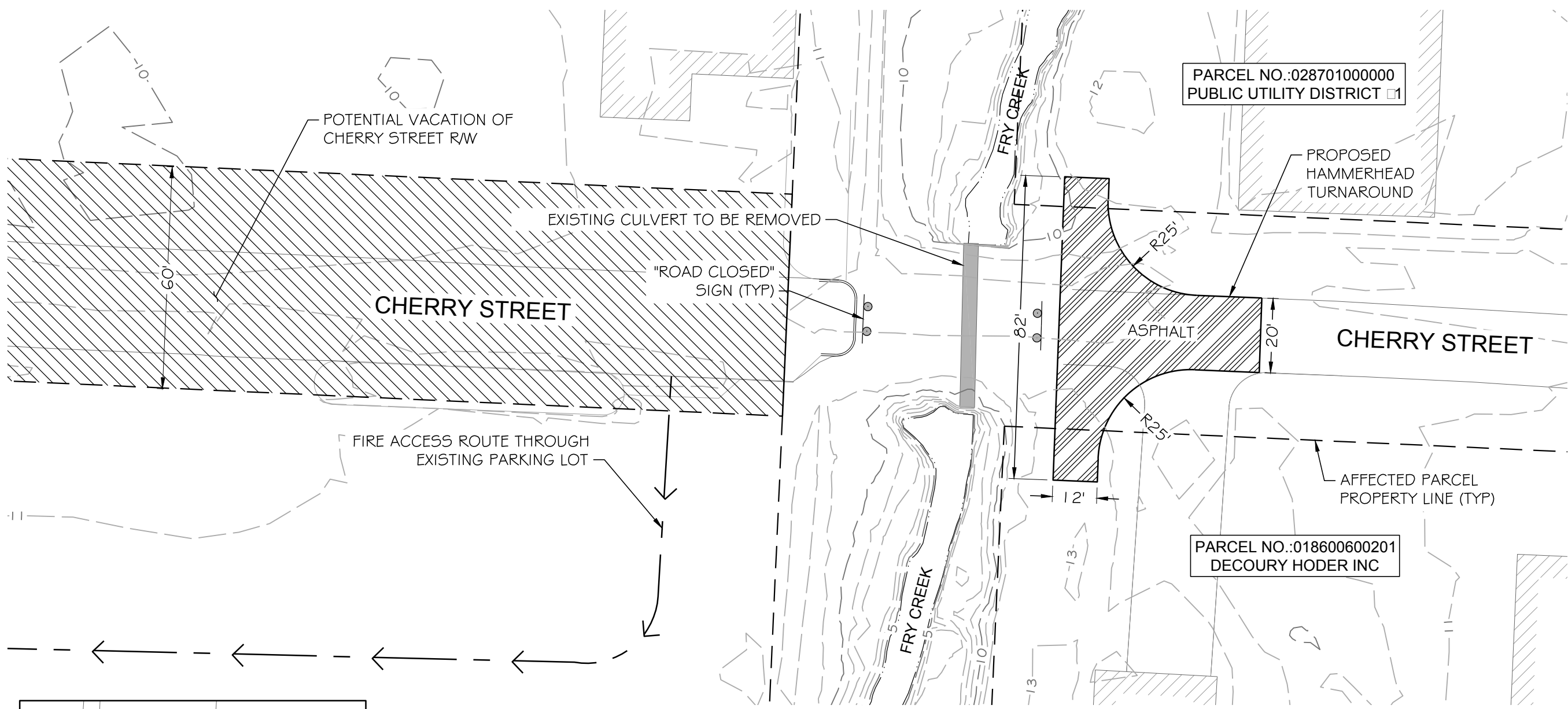
ALTERNATE ①
3-SIDED CULVERT ELEVATION
SCALE: N.T.S.



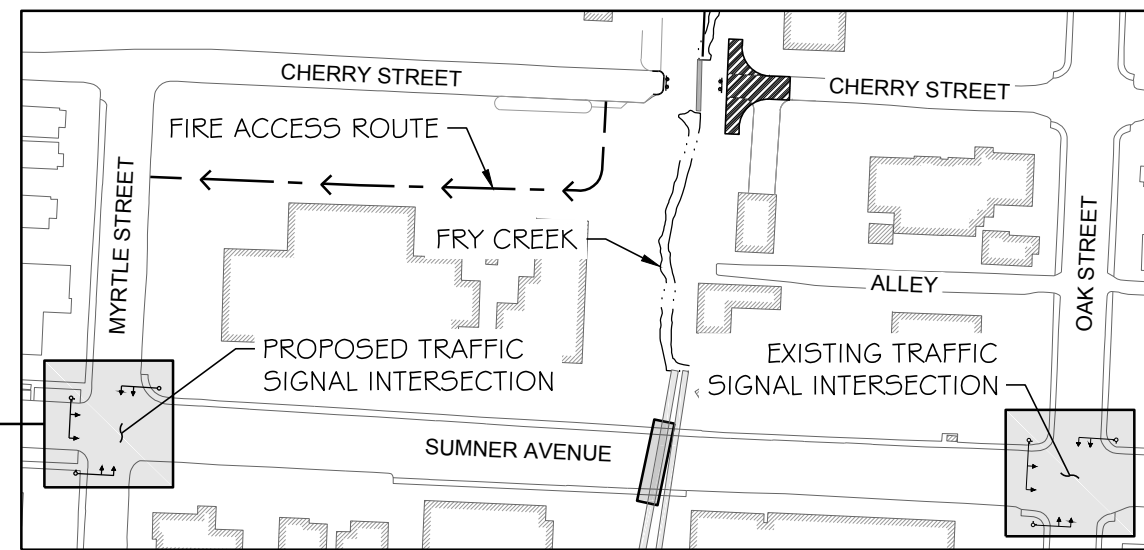
ALTERNATE ②
VOIDED SLAB BRIDGE ELEVATION
SCALE: N.T.S.



ALTERNATE ③
VOIDED SLAB BRIDGE SECTION
SCALE: N.T.S.



PROPOSED TRAFFIC SIGNALS
SCALE: 1" = 40'



TRAFFIC SIGNAL MAP
NOT TO SCALE

NOTE:

PROPERTY LINES ARE APPROXIMATE, THEY ARE NOT SURVEYED BUT ARE WITHIN ONE FOOT ACCURACY. PROPERTY LINES OBTAINED FROM CITY OF ABERDEEN.



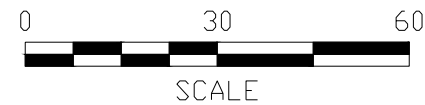
kpff		612 Woodland Square Loop, Suite 100 Lacey, WA 98503 360.292.7230 www.kpff.com	
CALL 48 HOURS BEFORE YOU DIG 811		PROJ NO: 41600607 DRAWN BY: BNT, NLA CHECKED BY: DATE: 7-18-2017 SCALE: 1" = 30'	
FRY CREEK RESTORATION & FLOOD REDUCTION			
CHERRY STREET OPTION 1			
DRAWING			
C1.4 SHEET 5 OF 11			

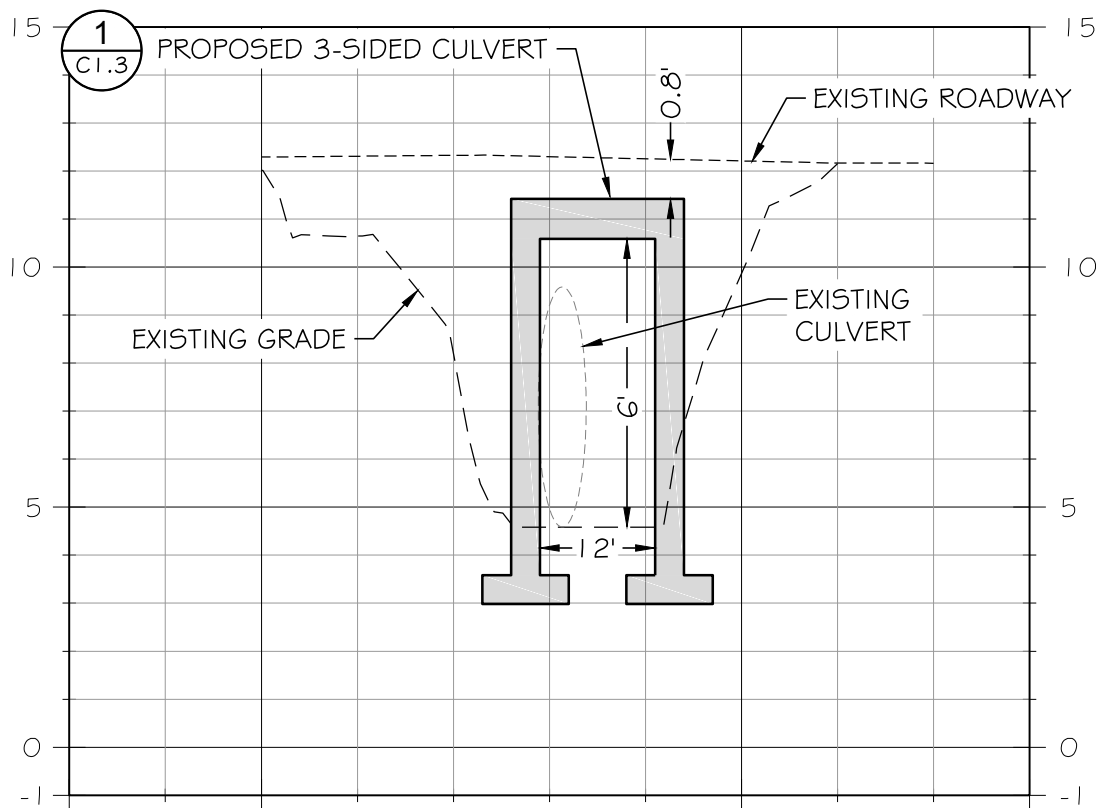
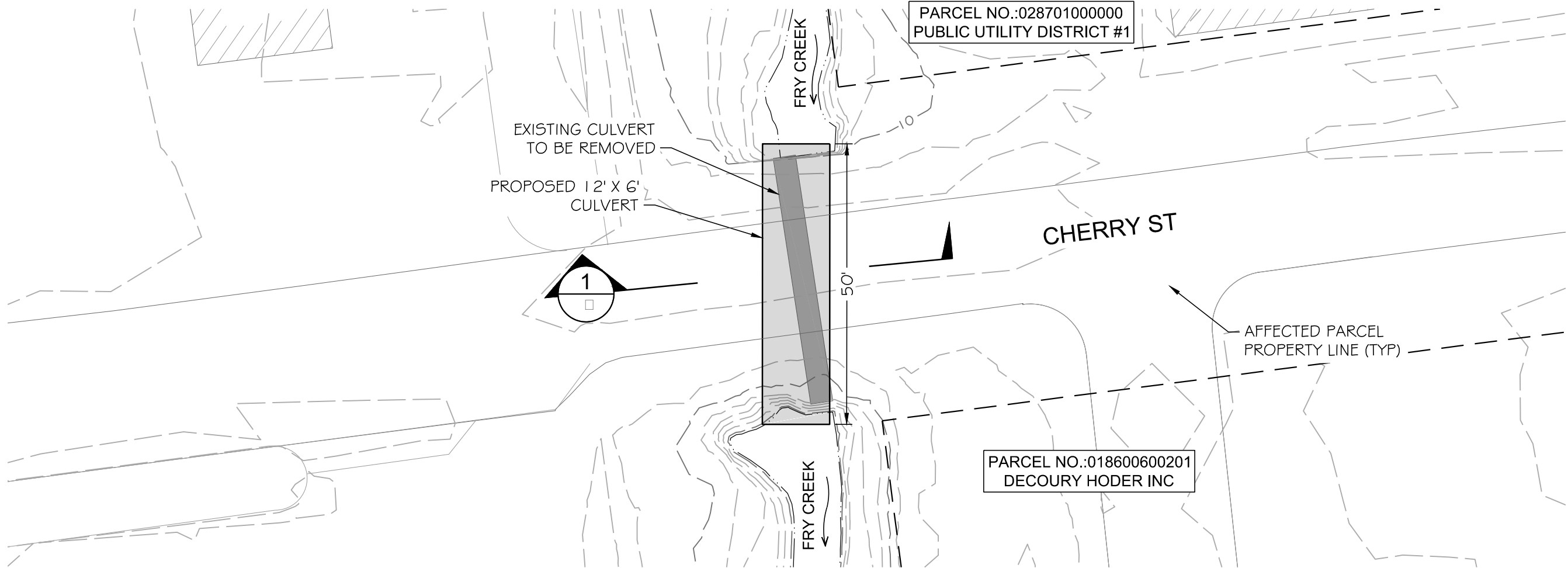


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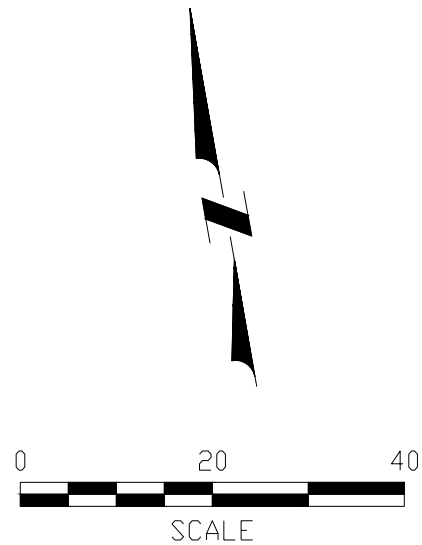


NOT TO SCALE





CHERRY STREET CROSS SECTION
SCALE: HORZ: 1" = 20', VERT: 1" = 4'



FRY CREEK RESTORATION & FLOOD REDUCTION

CHERRY STREET OPTION 3
PLAN SECTION

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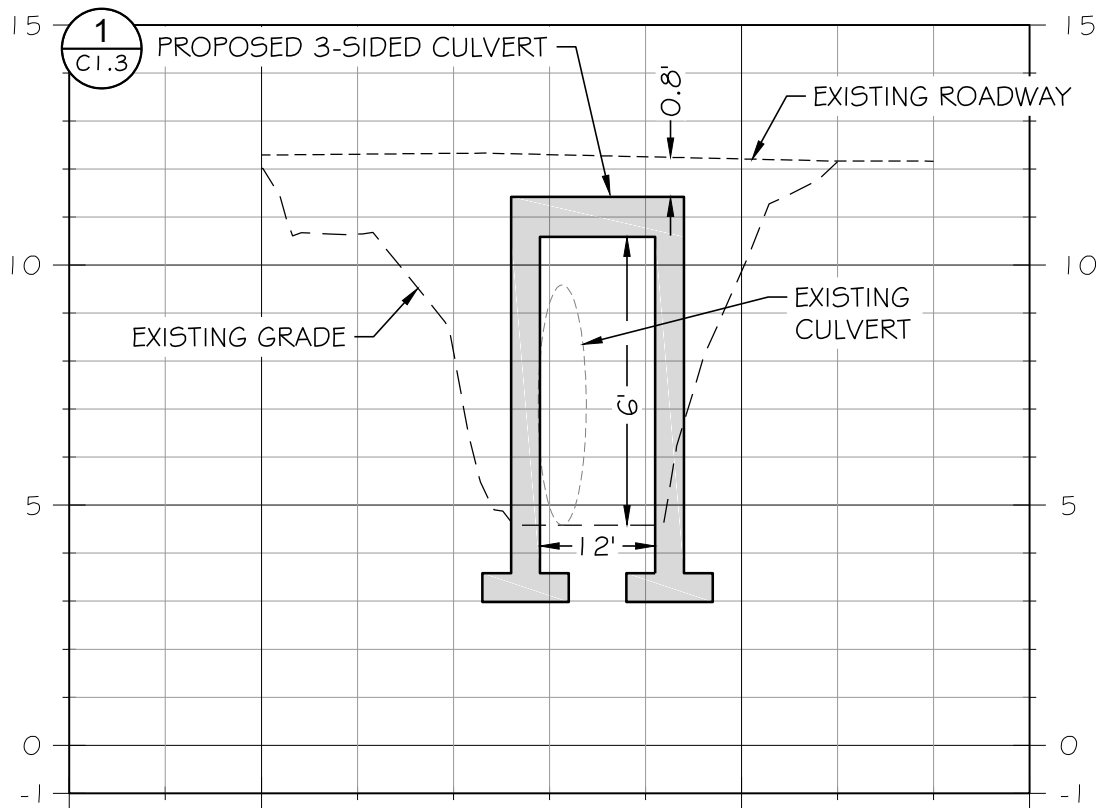
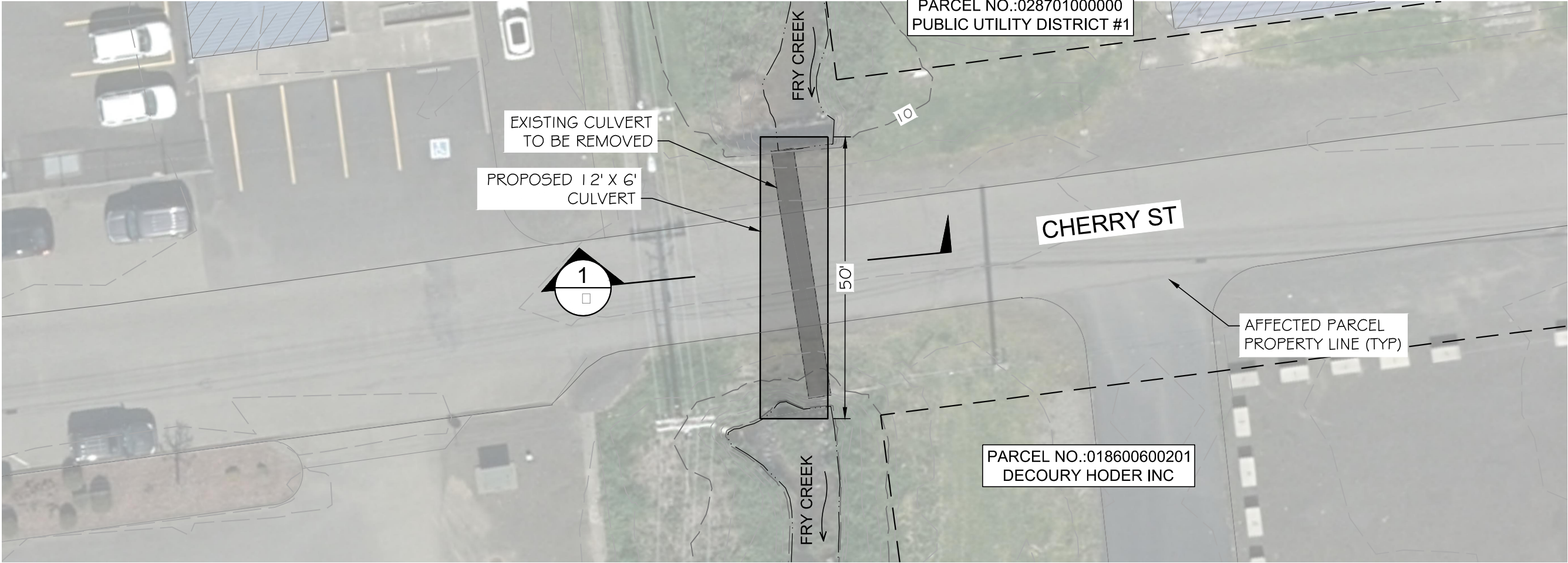
SCALE: 1" = 20'

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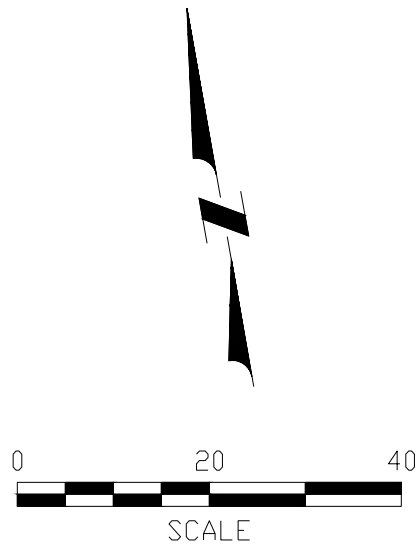
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DRAWING
C1.6
SHEET 7 OF 11



1 CHERRY STREET CROSS SECTION
SCALE: HORZ: 1" = 20', VERT: 1" = 4'



FRY CREEK RESTORATION & FLOOD REDUCTION

CHERRY STREET OPTION 3
PLAN □ SECTION

PROJ NO:41600607

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CHECKED BY:

DATE: 7-18-2017

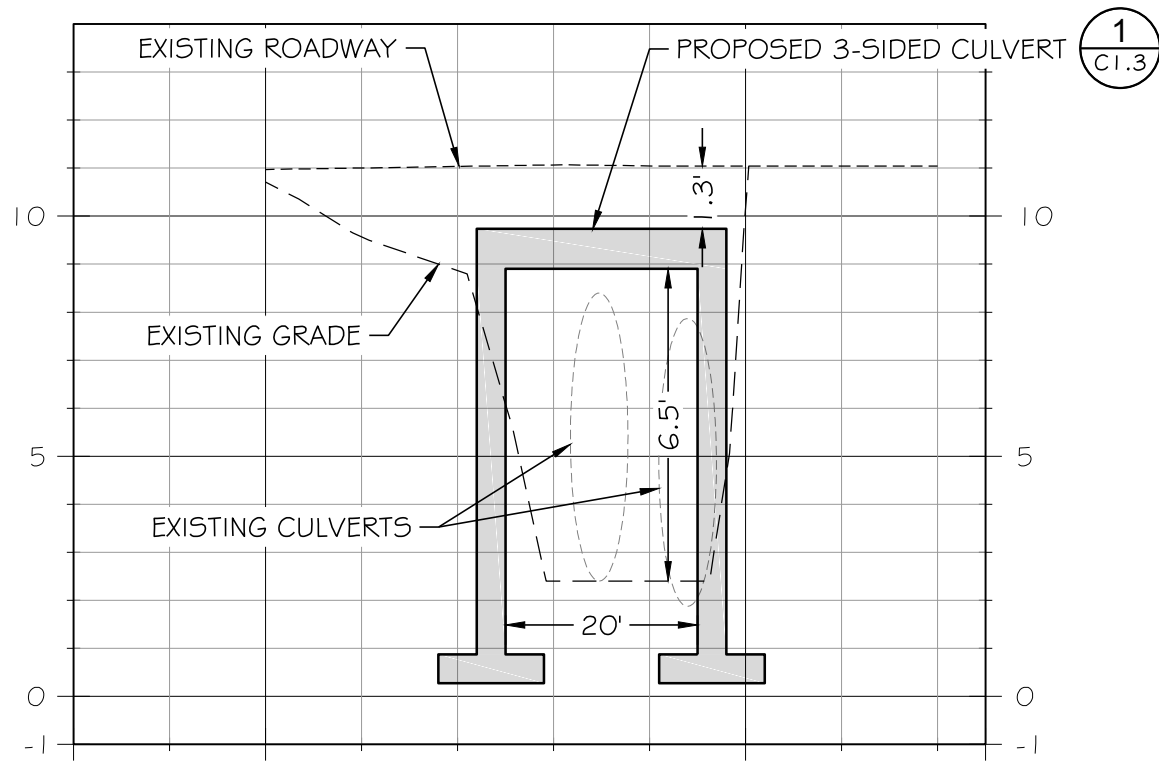
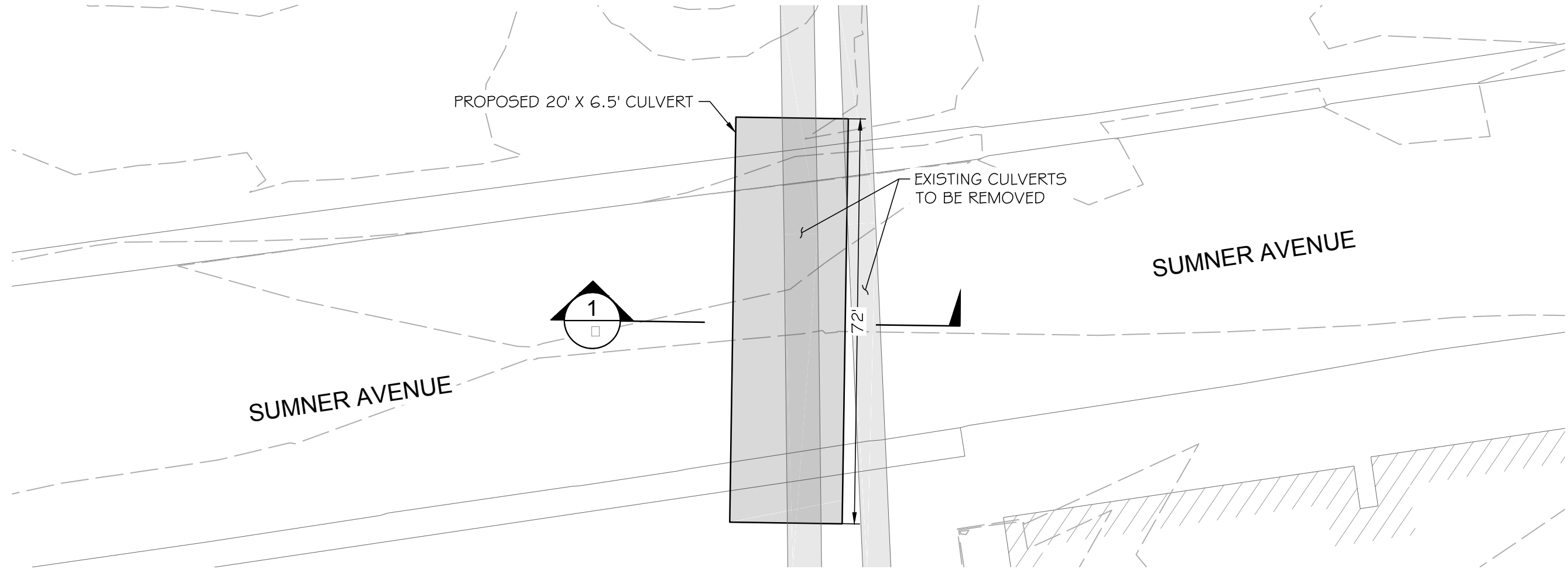
SCALE: 1" = 20'

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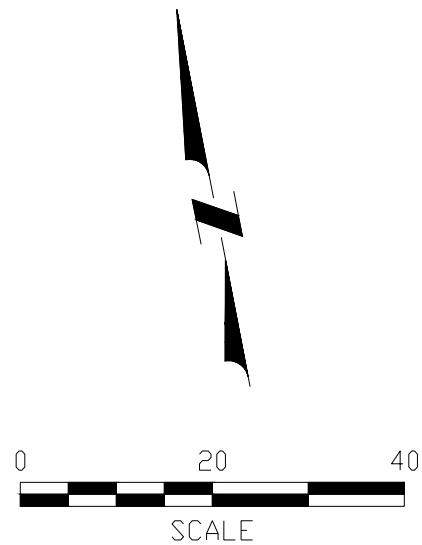


1 SUMNER STREET CROSS SECTION

SCALE: HORZ: 1" = 20', VERT: 1" = 4'

NOTE:

SEE MFA PLANS FOR CHANNEL RESTORATION



FRY CREEK RESTORATION & FLOOD REDUCTION

SUMNER AVENUE
PLAN □ SECTION

PROJ NO: 41600607

DRAWN BY: BNT, NLA

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DATE: 8-3-2017

SCALE: 1" = 20'

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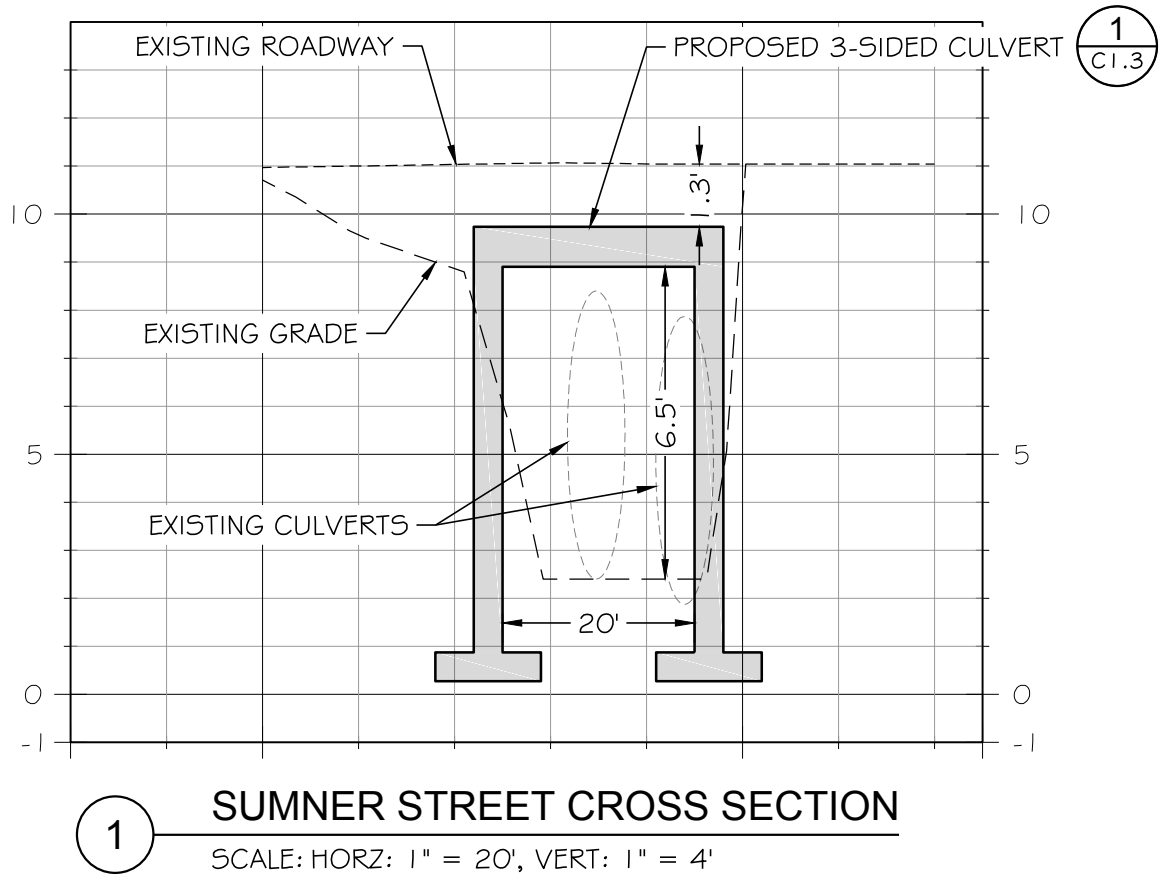
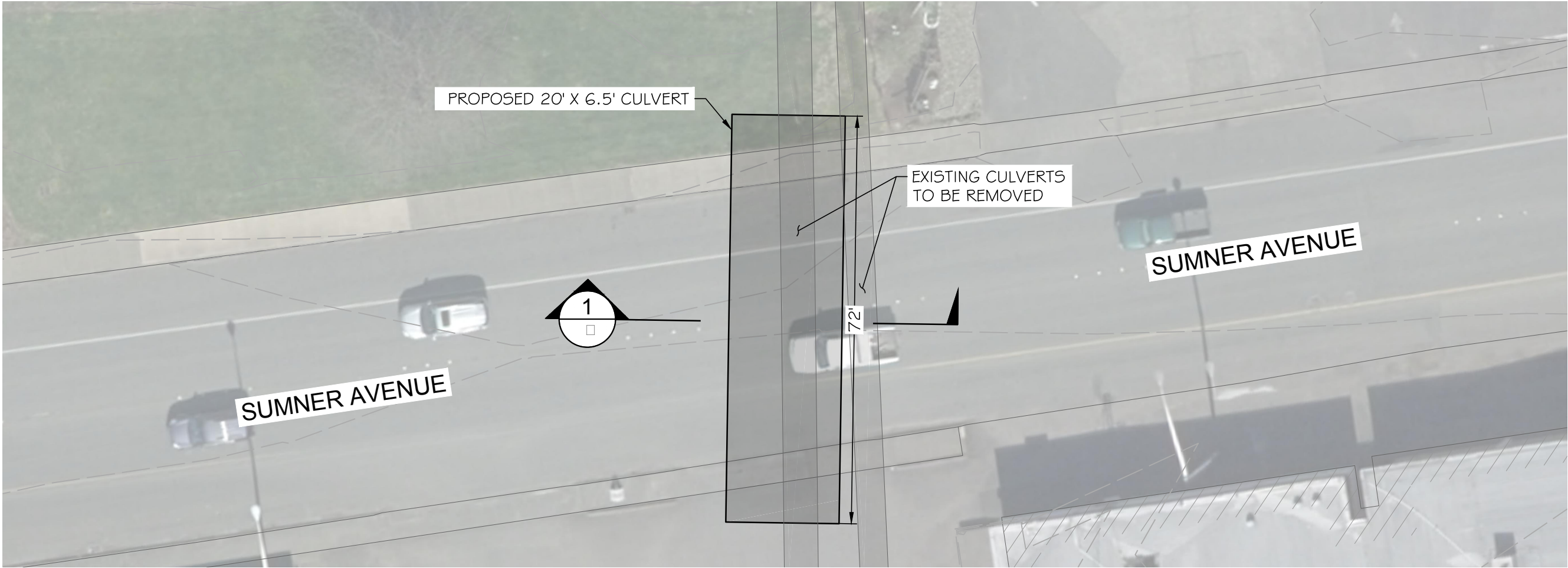
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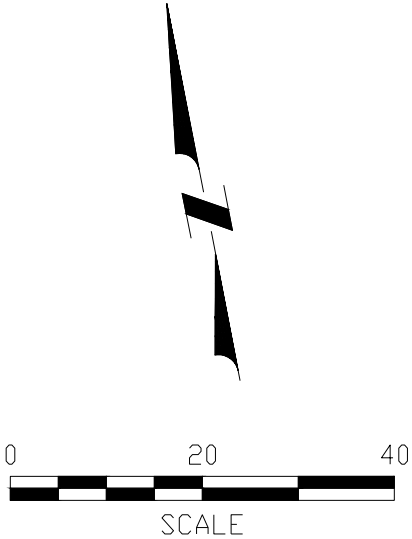
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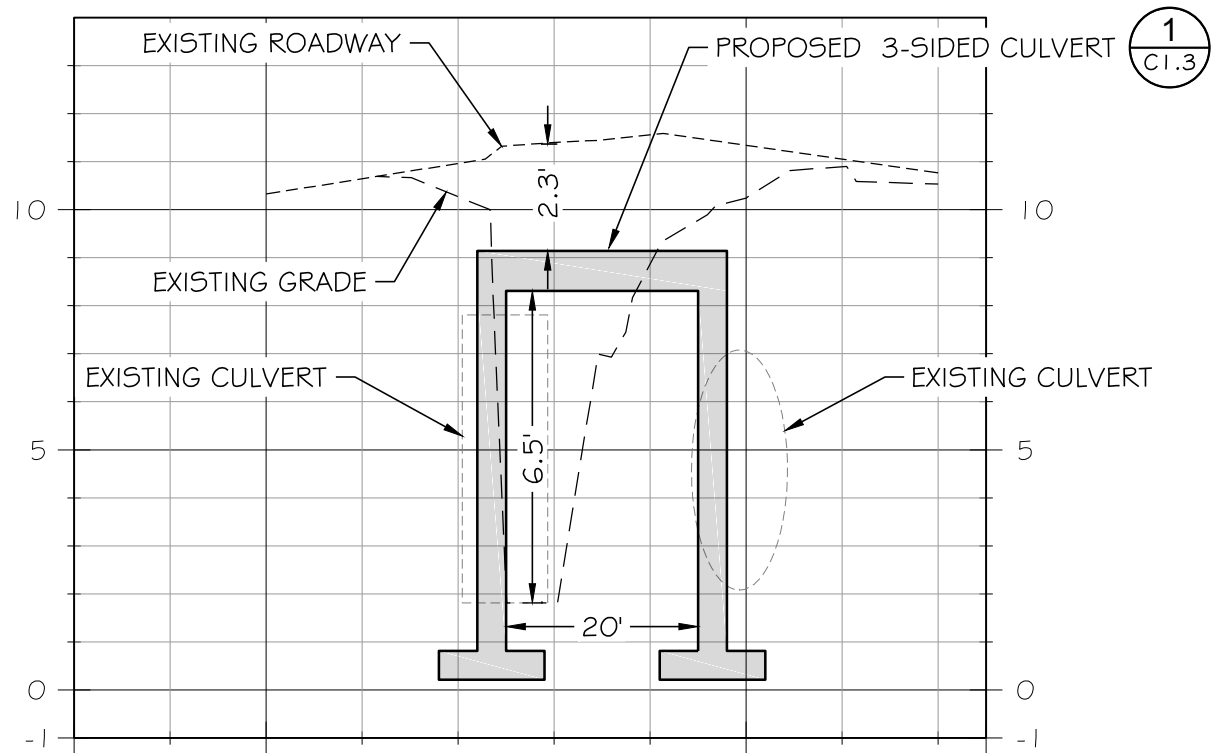
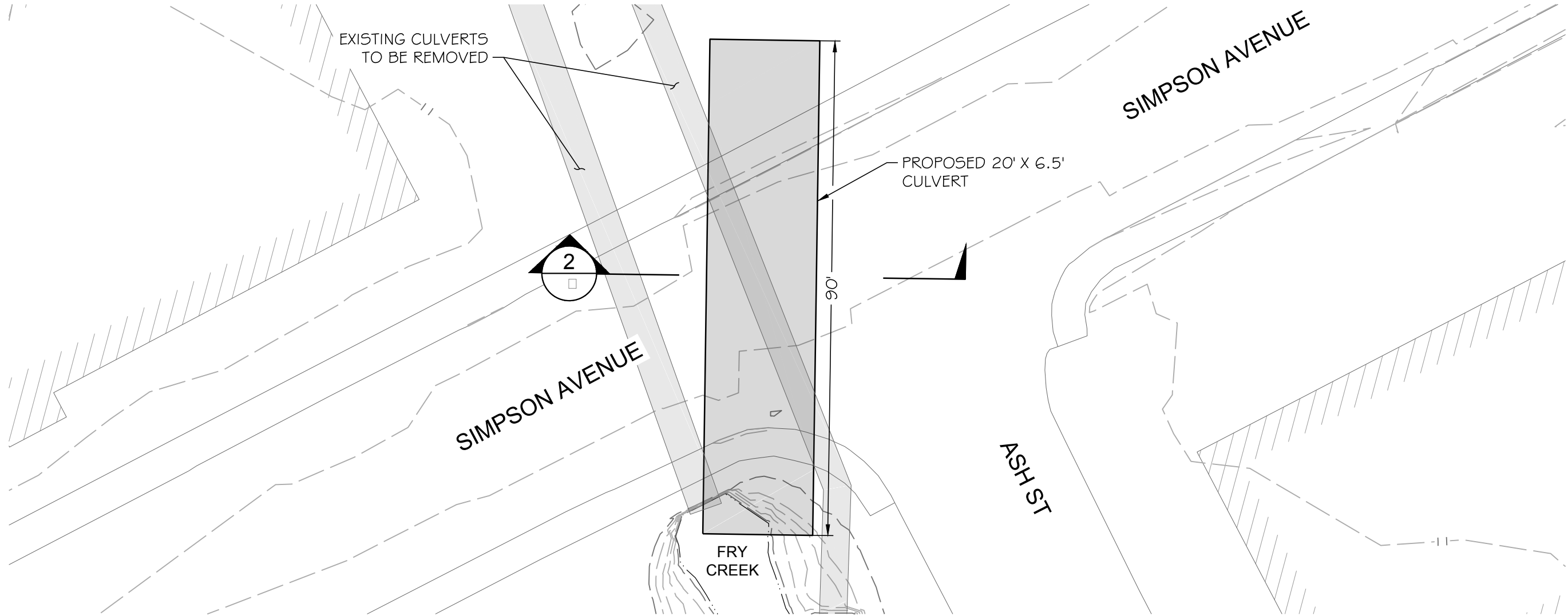
SHEET 8 OF 11



NOTE:
SEE MFA PLANS FOR CHANNEL RESTORATION



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FRY CREEK RESTORATION & FLOOD REDUCTION			
SUMNER AVENUE PLAN □ SECTION			
DRAWING		C1.7	
SHEET 8		OF 11	



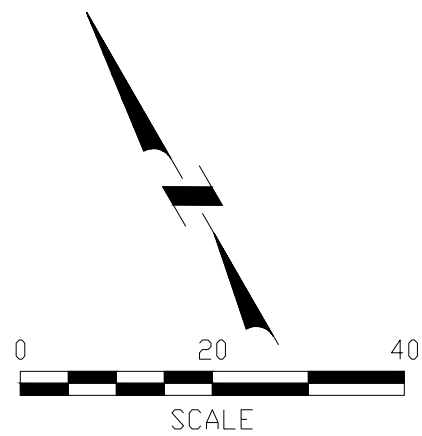
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SIMPSON AVE CROSS SECTION

SCALE: HORZ: 1" = 20', VERT: 1" = 4'

NOTE:

SEE MFA PLANS FOR CHANNEL RESTORATION



FRY CREEK RESTORATION & FLOOD REDUCTION

SIMPSON AVENUE
PLAN □ SECTION

PROJ NO: 41600607

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SCALE: 1" = 20'

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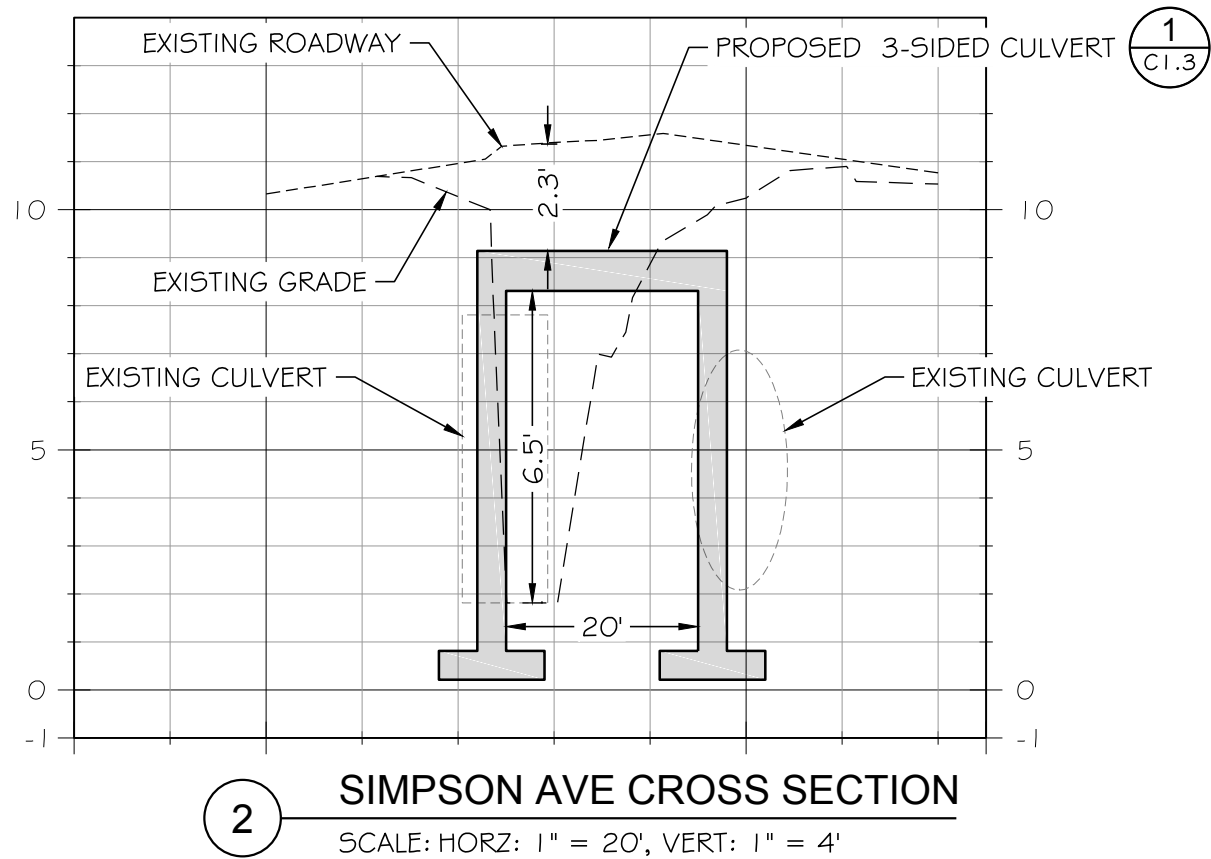
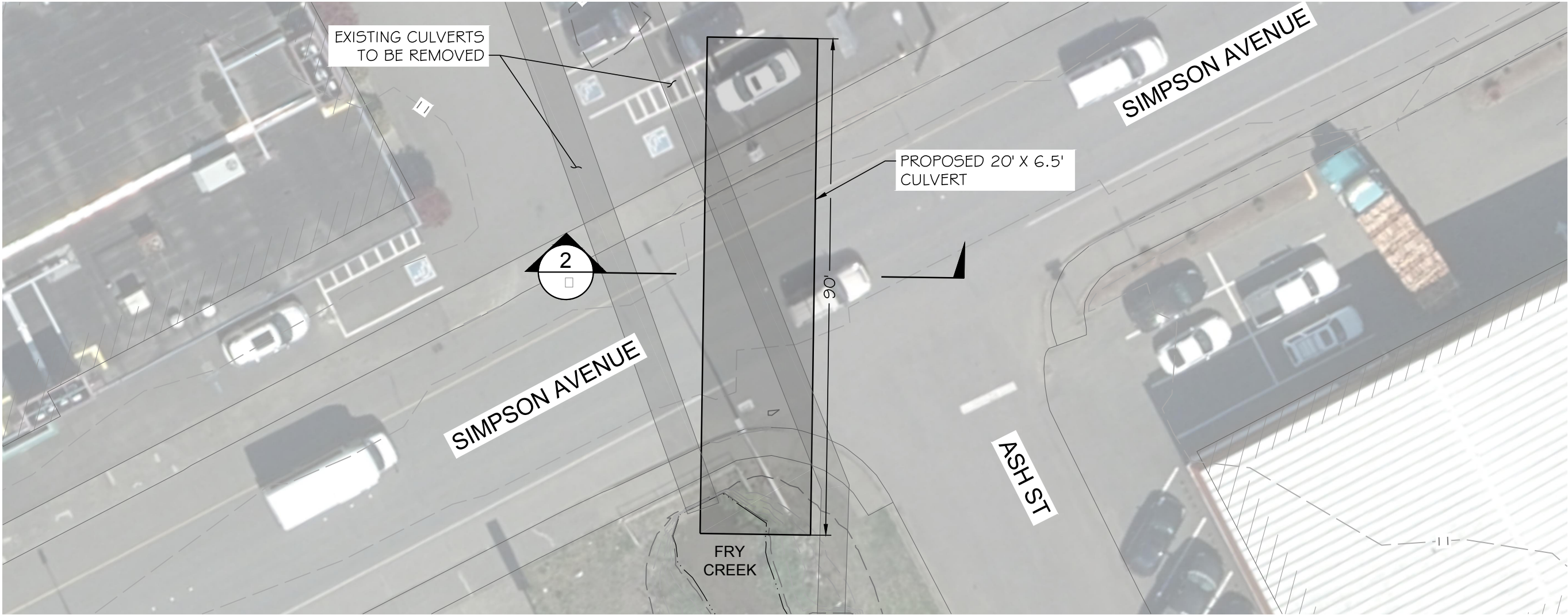
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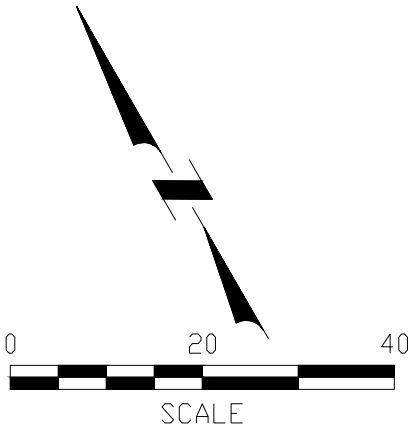
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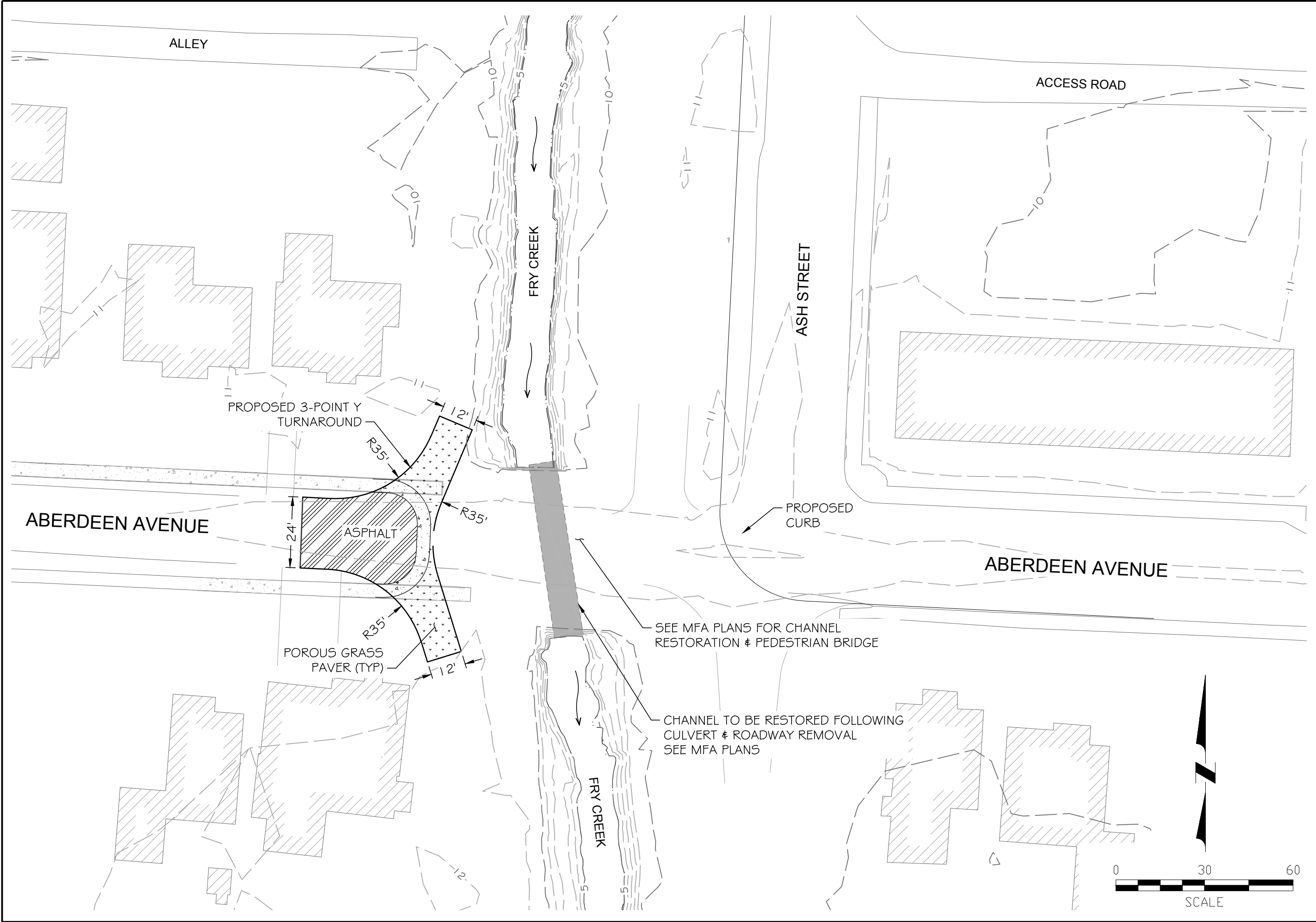
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NOTE:
SEE MFA PLANS FOR CHANNEL RESTORATION



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Fry Creek Restoration & Flood Reduction		
SIMPSON AVENUE PLAN □ SECTION		
DRAWING		
C1.8		
SHEET 9 OF 11		



FRY CREEK RESTORATION & FLOOD REDUCTION

PROJ NO: 41600607

DRAWN BY: BNT, NLA

CHECKED BY:

DATE: 7-18-2017

SCALE: 1" = 30'

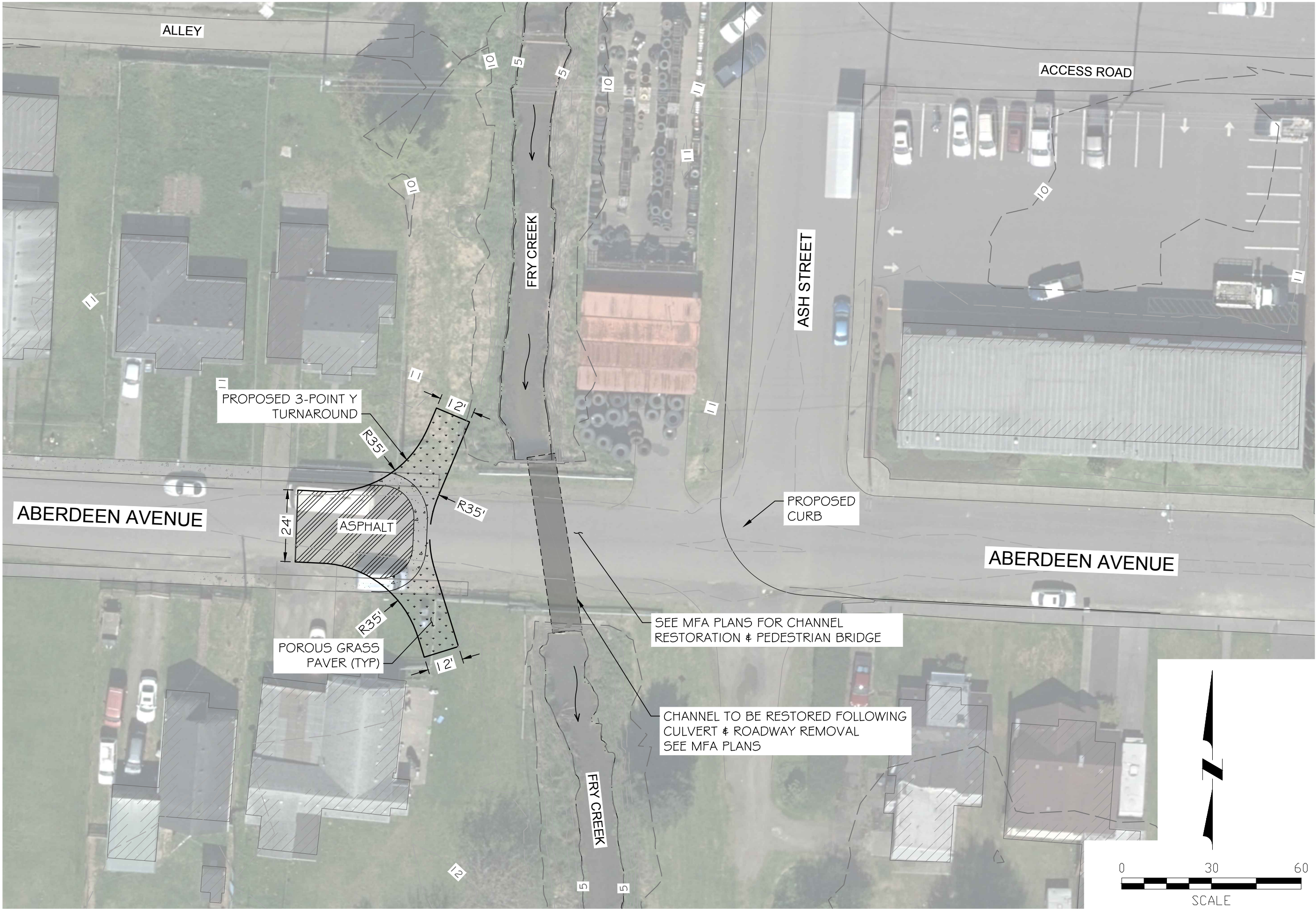
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DRAWING
C1.9
SHEET 10 OF 11

ABERDEEN AVENUE



FRY CREEK RESTORATION & FLOOD REDUCTION

ABERDEEN AVENUE

PROJ NO: 41600607

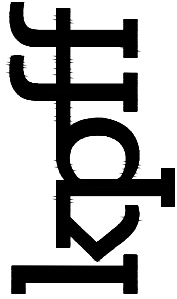
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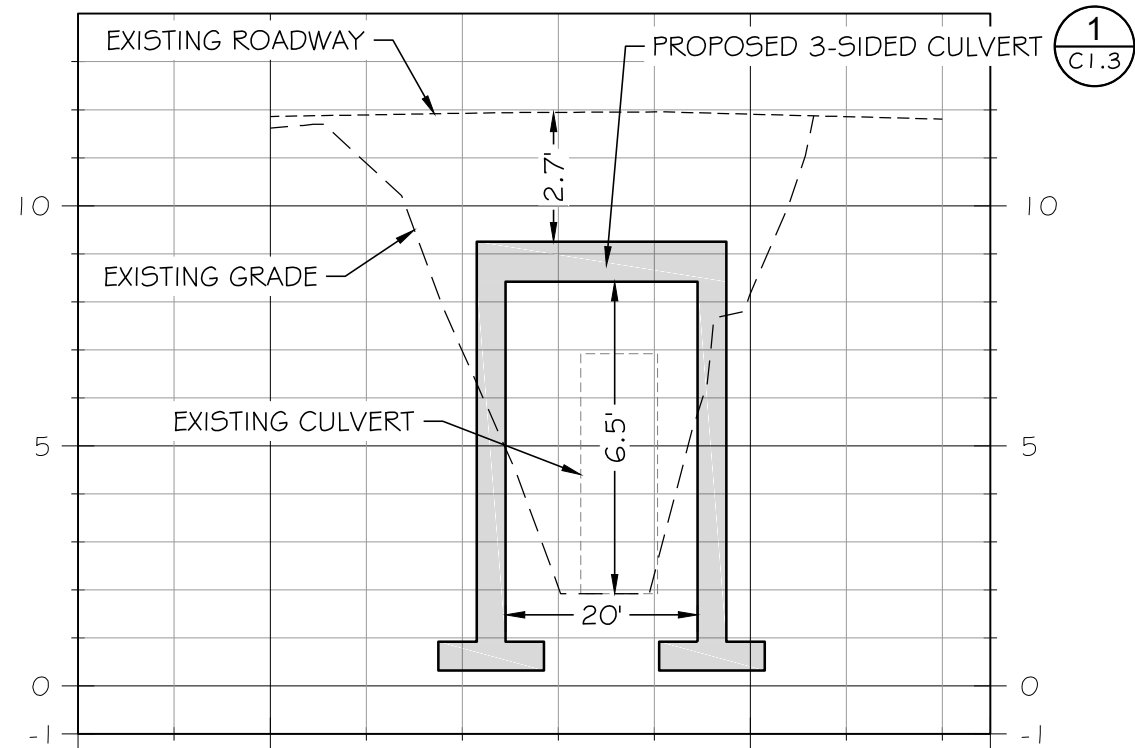
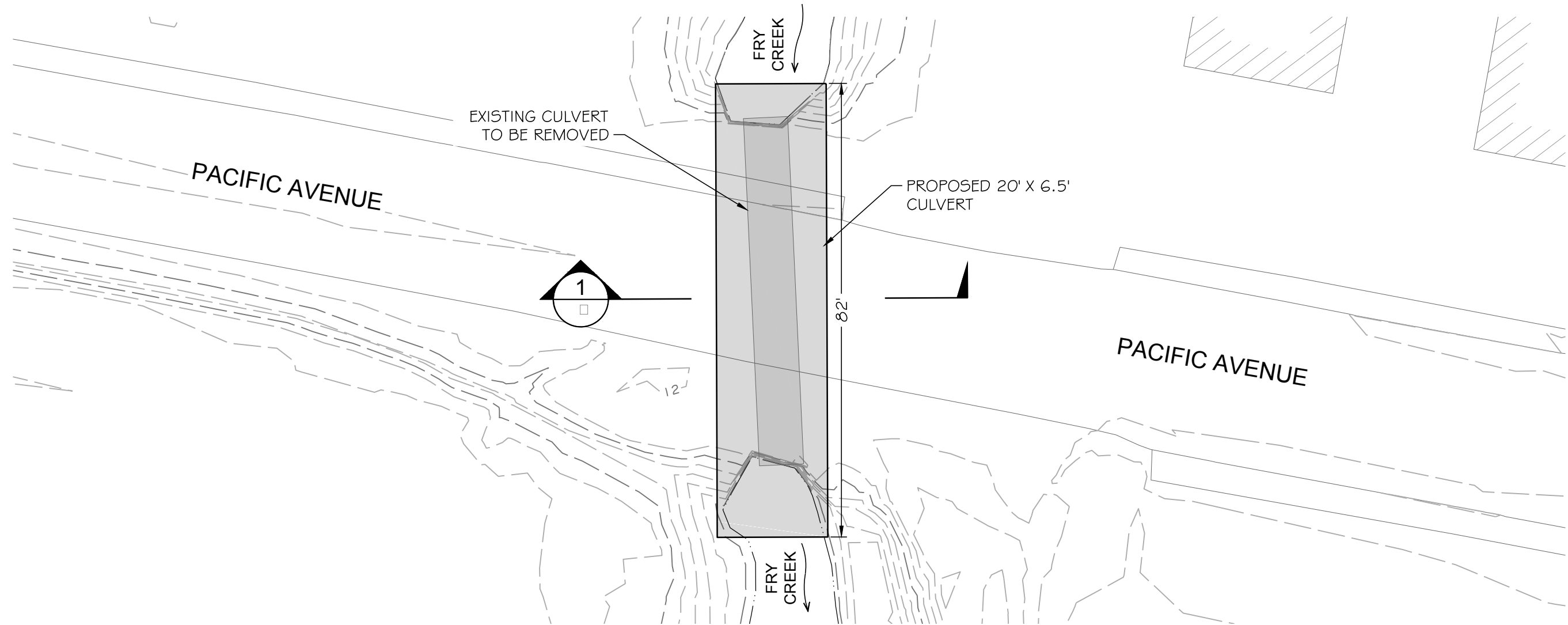
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SCALE: 1" = 30'

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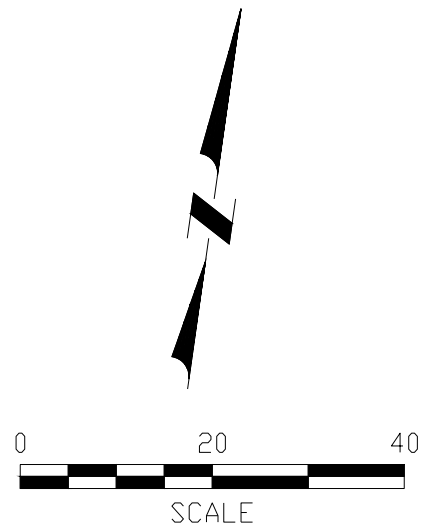


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PACIFIC AVE CROSS SECTION

SCALE: HORZ: 1" = 20', VERT: 1" = 4'



FRY CREEK RESTORATION & FLOOD REDUCTION

**PACIFIC AVENUE
PLAN □ SECTION**

DRAWING

C1.10

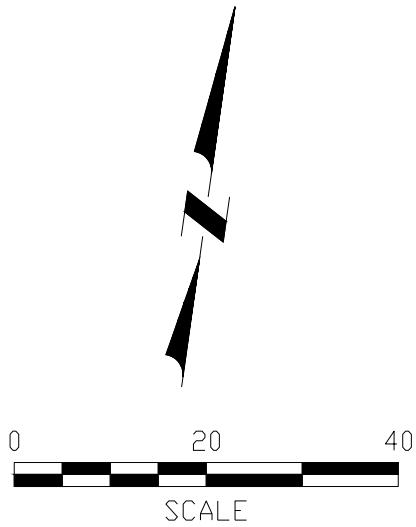
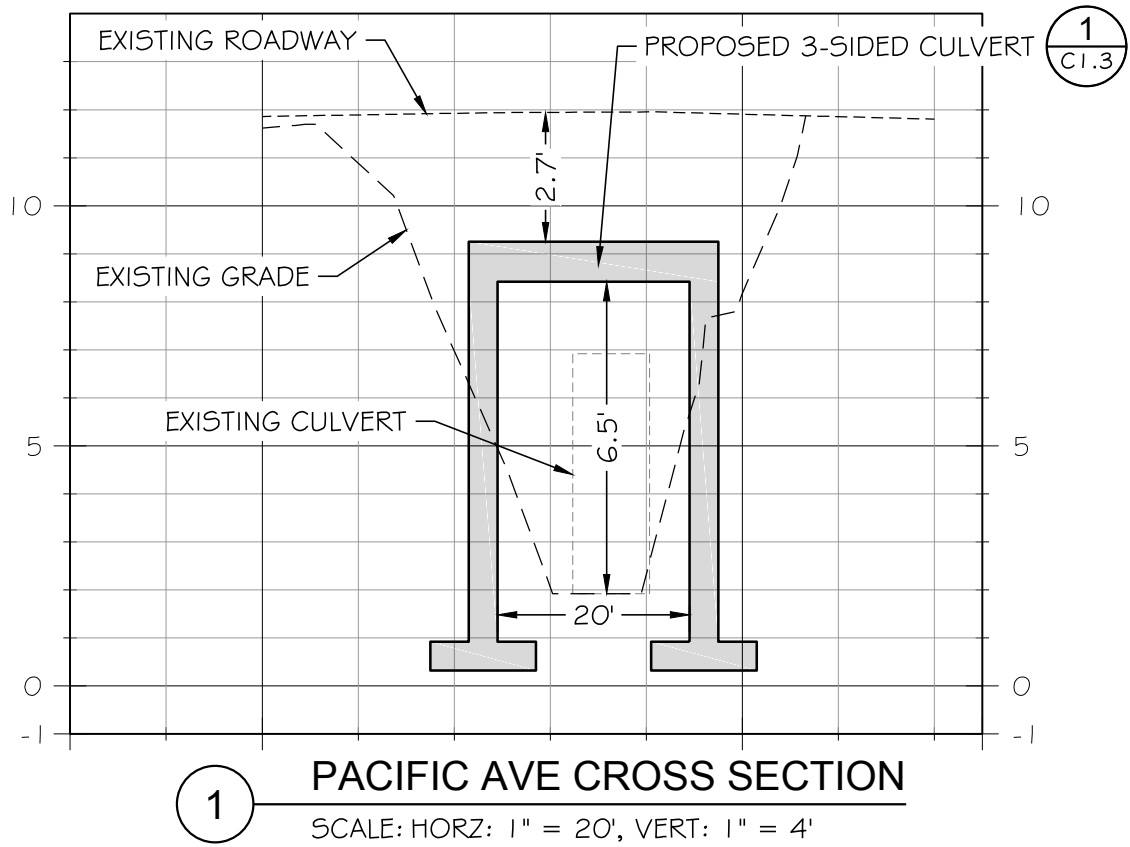
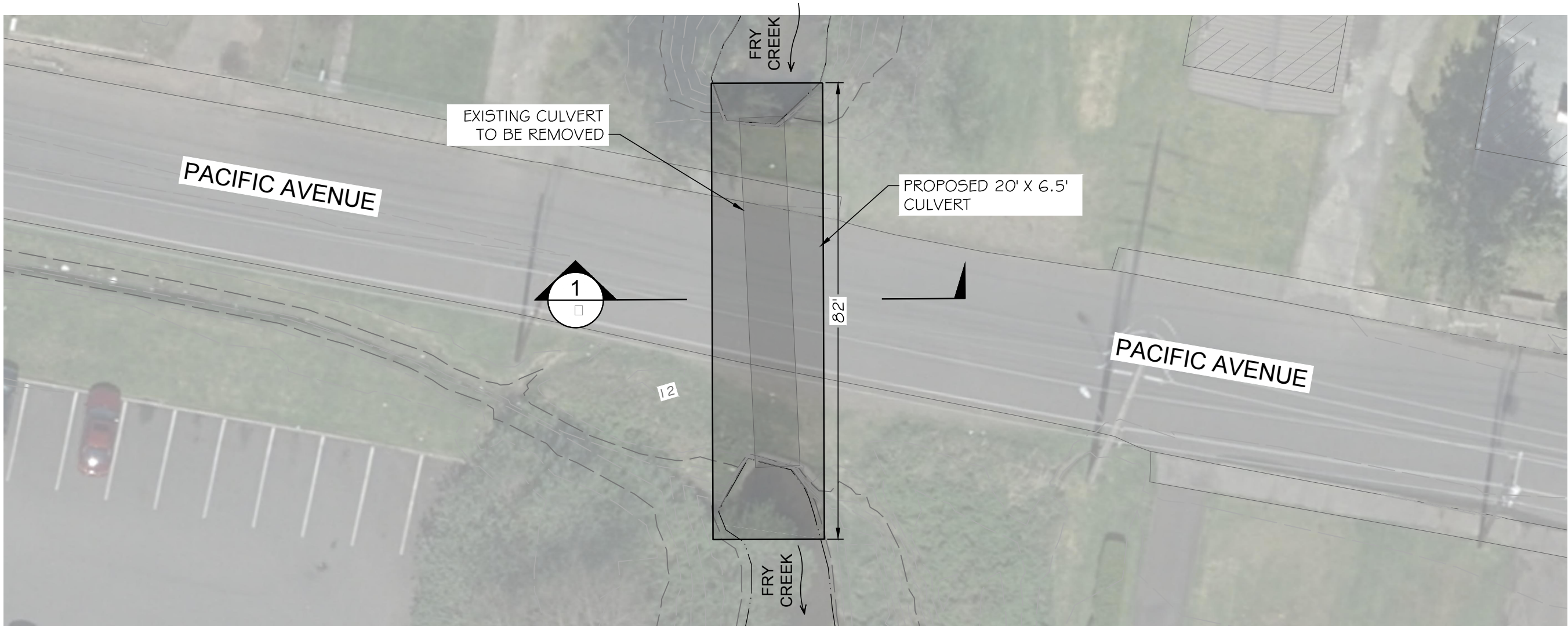
SHEET 11 OF 11

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SCALE: 1" = 20'

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FRY CREEK RESTORATION & FLOOD REDUCTION

PACIFIC AVENUE
PLAN □ SECTION

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SHEET 11 OF 11

PROJ NO: 41600607

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CHECKED BY:

DATE: 8-3-2017

SCALE: 1" = 20'

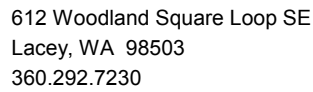
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APPENDIX B

Cost Estimate



Project	Fry Creek Restoration and Flood Reduction
Location	Aberdeen, WA
Date	3-Aug-17
KPFF Job #:	41600607
By	KPFF Design Team



612 Woodland Square Loop SE
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Schematic Design Cost Estimate

Project	Fry Creek Restoration and Flood Reduction
Location	Aberdeen, WA
Client	City of Aberdeen
KPFF Job #:	41600607
By	KPFF Design Team

Pump Station and Fish Screens

	QTY	UNIT	UNIT COST	TOTAL COST
Temporary Erosion and Sediment Control	1	LS	\$10,000	\$10,000
Pump(s)	4	EST	\$205,000	\$820,000
Pump Building Mechanical, Electrical, and Piping	1	EST	\$3,300,000	\$3,300,000
Excavation (for primary storage area)	1	LS	\$82,000	\$82,000
Pump Outfall Box Culvert and Energy Dissipation System	1	LS	\$250,000	\$250,000
Flat Fish Screen (for primary storage area)	1	LS	\$155,000	\$155,000
Cylindrical Tee Screen (for pumps)	1	LS	\$390,000	\$390,000
Property Acquisition	1	LS	\$45,000	\$45,000

TOTAL

\$5,052,000

Assumptions

Complete pump station including pumps, piping, electrical, auxiliary equipment and engineering is assumed to be 5x the total costs of pumps
Cost estimation and multiplier for pumps and pump station were provided by Morrison Pump
Total cost includes the cost of construction



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Schematic Design Cost Estimate

Project	Fry Creek Restoration and Flood Reduction
Location	Aberdeen, WA
Client	City of Aberdeen
KPFF Job #:	41600607
By	KPFF Design Team

Tide Gate

Alternative 1: Radial Gate	QTY	UNIT	UNIT COST	TOTAL COST
Radial Gate(s)	1	EA	\$250,000	\$250,000
Drive & Actuator	1	EA	\$40,000	\$40,000
SCADA System	1	EA	\$30,000	\$30,000
Construction & Installation	1	EST	\$300,000	\$300,000

TOTAL	\$620,000
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Alternative 2: Sluice Gate	QTY	UNIT	UNIT COST	TOTAL COST
Sluice Gate(s)	4	EA	\$50,000	\$200,000
Drive & Actuator	1	EA	\$20,000	\$20,000
SCADA System	1	EA	\$30,000	\$30,000
Construction & Installation	1	EST	\$150,000	\$150,000

TOTAL	\$400,000
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Assumptions

Cost of gate includes all mounting hardware
Construction & Installation costs are estimates based on similar projects and manufacturers estimates
Construction & Installation cost of Radial Gate includes estimate for concrete wing walls and extensive structural supports
Sluice Gate alternative assumes that two sluice gates will be needed.
Radial Gate alternative assumes that one radial gate will be adequate.
Proposed SCADA system is assumed to control preferred gate and pumps



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Schematic Design Cost Estimate

Project	Fry Creek Restoration and Flood Reduction
Location	Aberdeen, WA
Client	City of Aberdeen
KPFF Job #:	41600607
By	KPFF Design Team

Box Culvert at Levee

Alternative 1: One Span	QTY	UNIT	UNIT COST	TOTAL COST
Demolition	1	LS	\$5,000	\$5,000
Temporary Erosion and Sediment Control	1	LS	\$10,000	\$10,000
Temporary Stream Bypass	1	LS	\$25,000	\$25,000
20' x 6.5' x 84' Box Culvert	1	LS	\$260,000	\$260,000

TOTAL	\$300,000
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Alternative 2: Two Spans	QTY	UNIT	UNIT COST	TOTAL COST
Demolition	1	LS	\$5,000	\$5,000
Temporary Erosion and Sediment Control	1	LS	\$10,000	\$10,000
Temporary Stream Bypass	1	LS	\$25,000	\$25,000
10' x 6.5' x 84' Box Culvert	1	LS	\$305,000	\$305,000

TOTAL	\$345,000
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Assumptions

Costs for box culverts includes linear foot price, delivery, installment, and foundation costs

Linear foot cost for box culverts were provided by Old Castle. One span is \$2,500/LF, two spans is \$3,000/LF



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Schematic Design Cost Estimate

Project	Fry Creek Restoration and Flood Reduction
Location	Aberdeen, WA
Client	City of Aberdeen
KPFF Job #:	41600607
By	KPFF Design Team

Cherry Street

Alternative 1: Hammerhead Turnaround	QTY	UNIT	UNIT COST	TOTAL COST
Road Demolition	1	LS	\$12,000	\$12,000
Temporary Erosion and Sediment Control	1	LS	\$10,000	\$10,000
Temporary Stream Bypass	1	LS	\$25,000	\$25,000
Utility Relocations	1	LS	\$12,000	\$12,000
Traffic Signals at Sumner Ave and Myrtle St	1	LS	\$250,000	\$250,000
Turnaround Construction	1	LS	\$45,000	\$45,000
Guardrail / Barrier	140	LF	\$200	\$28,000
TOTAL				\$382,000

Alternative 2: End Road Design	QTY	UNIT	UNIT COST	TOTAL COST
Road Demolition	1	LS	\$12,000	\$12,000
Temporary Erosion and Sediment Control	1	LS	\$10,000	\$10,000
Temporary Stream Bypass	1	LS	\$25,000	\$25,000
Utility Relocations	1	LS	\$12,000	\$12,000
Traffic Signals at Sumner Ave and Myrtle St	1	LS	\$250,000	\$250,000
Turnaround Construction	1	LS	\$20,000	\$20,000
Guardrail / Barrier	140	LF	\$200	\$28,000
TOTAL				\$345,000

Alternative 3: Culvert Replacement and Upgrade	QTY	UNIT	UNIT COST	TOTAL COST
Demolition	1	LS	\$5,000	\$5,000
Temporary Erosion and Sediment Control	1	LS	\$10,000	\$10,000
Temporary Stream Bypass	1	LS	\$25,000	\$25,000
Utility Relocations	1	LS	\$9,000	\$9,000
Roadway Reconstruction	1	LS	\$45,000	\$45,000
12' x 6' x 50' Box Culvert	1	LS	\$75,000	\$75,000
Construction & Installation	1	LS	\$60,000	\$60,000
TOTAL				\$229,000

Assumptions

Culvert replacement costs do not assume any change to the existing roadway profile

A voided slab bridge may cause less impacts to utilities, roadway profile, and the creek cross section. This design will be looked into upon further design.

A voided slab bridge is estimated \$250/LF, this includes all demolition and construction related items

Costs for box culverts includes linear foot price, delivery, installment, and foundation costs. Linear foot estimation was provided by Old Castle to be \$1,600/LF

Utility relocations include any impacted sewer, storm, water, gas, or telephone lines that may need to be removed and relocated

Stream bed restoration costs are not included in this cost estimate.



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Schematic Design Cost Estimate

Project	Fry Creek Restoration and Flood Reduction
Location	Aberdeen, WA
Client	City of Aberdeen
KPFF Job #:	41600607
By	KPFF Design Team

Sumner Avenue Culvert Replacement & Upgrade

	QTY	UNIT	UNIT COST	TOTAL COST
Demolition	1	LS	\$5,000	\$5,000
Temporary Erosion and Sediment Control	1	LS	\$10,000	\$10,000
Temporary Stream Bypass	1	LS	\$25,000	\$25,000
Utility Relocations	1	LS	\$25,000	\$25,000
Roadway Reconstruction	1	LS	\$45,000	\$45,000
20' x 6.5' x 72' Box Culvert	1	LS	\$200,000	\$200,000
Construction & Installation	1	LS	\$60,000	\$60,000
TOTAL				\$370,000

Assumptions

Culvert replacement costs do not assume any change to the existing roadway profile

A voided slab bridge may cause less impacts to utilities, roadway profile, and the creek cross section. This design will be looked into upon further design.

A voided slab bridge is estimated \$250/LF, this includes all demolition and construction related items

Costs for box culverts includes linear foot price, delivery, installment, and foundation costs. Linear foot estimation was provided by Old Castle to be \$2,300/LF

Utility relocations include any impacted sewer, storm, water, gas, or telephone lines that may need to be removed and relocated

Stream bed restoration costs are not included in this cost estimate.



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Schematic Design Cost Estimate

Project	Fry Creek Restoration and Flood Reduction
Location	Aberdeen, WA
Client	City of Aberdeen
KPFF Job #:	41600607
By	KPFF Design Team

Simpson Avenue Culvert Replacement & Upgrade

	QTY	UNIT	UNIT COST	TOTAL COST
Demolition	1	LS	\$5,000	\$5,000
Temporary Erosion and Sediment Control	1	LS	\$10,000	\$10,000
Temporary Stream Bypass	1	LS	\$25,000	\$25,000
Utility Relocations	1	LS	\$15,000	\$15,000
Roadway Reconstruction	1	LS	\$45,000	\$45,000
20' x 6.5' x 90' Box Culvert	1	LS	\$250,000	\$250,000
Construction & Installation	1	LS	\$60,000	\$60,000
TOTAL				\$410,000

Assumptions

Culvert replacement costs do not assume any change to the existing roadway profile

A voided slab bridge may cause less impacts to utilities, roadway profile, and the creek cross section. This design will be looked into upon further design.

A voided slab bridge is estimated \$250/LF, this includes all demolition and construction related items

Costs for box culverts includes linear foot price, delivery, installment, and foundation costs. Linear foot estimation was provided by Old Castle to be \$2,300/LF

Utility relocations include any impacted sewer, storm, water, gas, or telephone lines that may need to be removed and relocated

Stream bed restoration costs are not included in this cost estimate.



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Schematic Design Cost Estimate

Project	Fry Creek Restoration and Flood Reduction
Location	Aberdeen, WA
Client	City of Aberdeen
KPFF Job #:	41600607
By	KPFF Design Team

Aberdeen Avenue 3-Point Y Turnaround

	QTY	UNIT	UNIT COST	TOTAL COST
Road Demolition	1	LS	\$12,000	\$12,000
Temporary Erosion and Sediment Control	1	LS	\$10,000	\$10,000
Temporary Stream Bypass	1	LS	\$25,000	\$25,000
Utility relocations	1	LS	\$15,000	\$15,000
Turnaround Construction	1	LS	\$45,000	\$45,000
Guardrail/Barrier	140	LF	\$200	\$28,000

TOTAL

\$135,000

Assumptions

Utility relocations include any impacted sewer, storm, water, gas, or telephone lines that may need to be removed and relocated

Stream bed restoration costs are not included in this cost estimate.



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Schematic Design Cost Estimate

Project	Fry Creek Restoration and Flood Reduction
Location	Aberdeen, WA
Client	City of Aberdeen
KPFF Job #:	41600607
By	KPFF Design Team

Pacific Avenue Culvert Replacement & Upgrade

	QTY	UNIT	UNIT COST	TOTAL COST
Demolition	1	LS	\$5,000	\$5,000
Temporary Erosion and Sediment Control	1	LS	\$10,000	\$10,000
Temporary Stream Bypass	1	LS	\$25,000	\$25,000
Utility Relocations	1	LS	\$15,000	\$15,000
Roadway Reconstruction	1	LS	\$45,000	\$45,000
20' x 6.5' x 82' Box Culvert	1	LS	\$250,000	\$250,000
Construction & Installation	1	LS	\$60,000	\$60,000
TOTAL				\$410,000

Assumptions

Culvert replacement costs do not assume any change to the existing roadway profile

A voided slab bridge may cause less impacts to utilities, roadway profile, and the creek cross section. This design will be looked into upon further design.

A voided slab bridge is estimated \$250/LF, this includes all demolition and construction related items

Costs for box culverts includes linear foot price, delivery, installment, and foundation costs. Linear foot estimation was provided by Old Castle to be \$2,300/LF

Utility relocations include any impacted sewer, storm, water, gas, or telephone lines that may need to be removed and relocated

Stream bed restoration costs are not included in this cost estimate.



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Schematic Design Cost Estimate

Project	Fry Creek Restoration and Flood Reduction
Location	Aberdeen, WA
Client	City of Aberdeen
KPFF Job #:	41600607
By	KPFF Design Team

Fish Screens

	QTY	UNIT	UNIT COST	TOTAL COST
Screen Framework/Foundation Construction	1	LS	\$35,000	\$35,000
Flat Fish Screen	144	SF	\$350	\$50,400
Flat Fish Screen Install	1	LS	\$85,000	\$85,000
Cylindrical Tee Screen and Install	4	EA	\$96,000	\$384,000
Erosion Control	1	LS	\$5,000	\$5,000
TOTAL				\$559,400

Assumptions


Point of diversion requires erosion control pad or roughened channel for flood water entry into pump area

APPENDIX C

MFA COST ESTIMATES



ENGINEER'S PRELIMINARY OPINION OF PROBABLE COST

Title:	Fry Creek—Sumner to Simpson		 MAUL FOSTER ALONG 2001 NW 19th Avenue, Suite 200 Portland, OR 97209 971.544.2139 (p) 971.544.2140 (f) www.maulfoster.com
Project:	Fry Creek Restoration		
Client:	City of Aberdeen		
Project #/Task:	0922.04.01-02A	Initial	
Prepared By:	J. Faust		
Checked By:	A. Kaparos		
Date:	8/4/2017		
Revision #.:	0		

Cost Estimate Summary—Feasibility Level

Schedule A—General	\$	314,076
Schedule B—Demolition	\$	251,178
Schedule C—Creek Channel Construction	\$	174,447
Schedule D—Site Improvements	\$	596,616
Schedule E—Landscaping	\$	113,267
Schedule F—Soft Cost	\$	724,792
Total:		\$ 2,174,376

Assumptions:

1. Does not include costs for road crossing culverts.
2. Project involves daylighting of creek channel (currently piped) from Sumner to Simpson, demolition of existing conveyance piping, and site improvements to the commercial center to mitigate lost parking facilities.
3. Project is assumed phased from other Fry Creek projects, with independent design and mobilization efforts.

ENGINEER'S PRELIMINARY COST ESTIMATE
Maul, Foster Alongi, Inc.

Schedule 'A' - General				
<i>Description</i>	<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
A.1 Contractor Mobilization	15%	--	--	\$ 189,076
A.2 Erosion and Sediment Control	1	LS	\$ 25,000	\$ 25,000
A.3 Traffic Control	1	LS	\$ 25,000	\$ 25,000
A.4 Temporary Creek Diversion	1	LS	\$ 75,000	\$ 75,000
Subtotal Schedule 'A':				\$ 314,076

Schedule 'B' - Demolition				
<i>Description</i>	<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
B.1 Sawcut and Remove Asphalt, Dispose Offsite	5,688	SY	\$ 20	\$ 113,762
B.2 Demo Ex. Pipes and Manholes, Dispose Offsite	920	LF	\$ 72	\$ 66,240
B.3 Channel Excavation, Dispose of Soil Offsite	2,034	CY	\$ 35	\$ 71,176
Subtotal Schedule 'B':				\$ 251,178

Schedule 'C' - Creek Channel Construction				
<i>Description</i>	<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
C.1 Retaining Wall	2,700	SFF	\$ 30	\$ 81,000
C.2 Finished Grading	1,074	SY	\$ 5	\$ 5,371
C.3 Install Planting Medium	525	CY	\$ 35	\$ 18,362
C.4 Stream Channel Bedding	80	CY	\$ 80	\$ 6,424
C.5 Fence at Top of Wall	613	LF	\$ 50	\$ 30,650
C.6 Pedestrian Crossing Bridge	272	SF	\$ 120	\$ 32,640
Subtotal Schedule 'C':				\$ 174,447

Schedule 'D' - Site Improvements				
<i>Description</i>	<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
D.1 Install Vertical Curb	2,286	LF	\$ 29	\$ 66,294
D.2 New 30' Driveway Cut	3	EA	\$ 10,000	\$ 30,000
D.3 New Asphalt Pavement (3" Thickness)	5,688	SY	\$ 25	\$ 142,203
D.4 Asphalt Sealcoat (Primary Lot)	5,688	SY	\$ 1.26	\$ 7,167
D.5 New Sidewalk	256	SY	\$ 14	\$ 3,584
D.6 Stormwater Catch basin	4	EA	\$ 3,500	\$ 14,000
D.7 Stormwater Drainage Pipe (8" ADS)	200	LF	\$ 80	\$ 16,000
D.8 Parking Lot Striping	3,022	LF	\$ 1.50	\$ 4,533
D.9 Replace Signs for Commercial Center	3	EA	\$ 10,000	\$ 30,000
D.10 ADA Parking Markings and Sign	9	EA	\$ 315	\$ 2,835
D.11 Replace Parking Lot Lighting	2	EA	\$ 15,000	\$ 30,000
D.12 Pump Station, Wet Well, and Reroute Pipe (existing 8" sanitary pipe)	1	LS	\$ 250,000	\$ 250,000
Subtotal Schedule 'D':				\$ 596,616


Schedule 'E' - Landscaping				
<i>Description</i>	<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
E.1 Stormwater Bioswale Planting Medium	150	CY	\$ 40	\$ 6,000
E.2 Topsoil (General Landscaping)	451	CY	\$ 25	\$ 11,265
E.3 Landscape Planting (Upland, General Site)	8,111	SF	\$ 2	\$ 16,222
E.4 Landscape Planting (Submerged, Riparian, and Emergent Plants)	9,670	SF	\$ 6	\$ 58,020
E.5 Landscape Planting (Bioswales)	1,690	SF	\$ 4	\$ 6,760
E.6 Street Trees	10	EA	\$ 500	\$ 5,000
E.7 Irrigation System	1	LS	\$ 5,000	\$ 5,000
E.8 Site Features (benches, signage, etc.)	1	LS	\$ 5,000	\$ 5,000
Subtotal Schedule 'E':				\$ 113,267

Schedule 'F' - Soft Cost				
<i>Description</i>	<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
F.1 Contingency	30%	--	--	\$ 434,875
F.2 Design, Permitting, Contracting, Administration	20%	--	--	\$ 289,917
Subtotal Schedule 'F':				\$ 724,792

Project Total: \$ 2,174,376

ENGINEER'S PRELIMINARY OPINION OF PROBABLE COST

Title:	Fry Creek—Sumner to Simpson—Bypass	
Project:	Fry Creek Restoration	
Client:	City of Aberdeen	
Project #/Task:	0922.04.01-02A	Initial
Prepared By:	A. Kaparos	
Checked By:	J. Faust	
Date:	8/4/2017	
Revision #.:	0	



MAUL FOSTER ALONG

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Cost Estimate Summary—Feasibility Level

Schedule A—General	\$	179,127
Schedule B—Demolition	\$	19,250
Schedule C—Creek Channel Construction	\$	500,012
Schedule D—Site Improvements	\$	278,140
Schedule E—Landscaping	\$	13,444
Schedule F—Soft Cost	\$	593,984
Total:		\$ 1,583,958

Assumptions:

1. Project involves construction of an 84-inch-diameter bypass pipe to convey large storm events from Sumner Street to Simpson.
2. Does not include costs for road crossing culverts (and associated road work) or headwalls.
3. Dewatering will be required for trench excavation.
4. Permitting costs will increase as a result of installing a fish passage barrier pipe. The soft cost percentages have been increased as a result.

ENGINEER'S PRELIMINARY COST ESTIMATE
Maul, Foster Alongi, Inc.

Schedule 'A' - General					
<i>Description</i>		<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
A.1	Contractor Mobilization	15%	--	--	\$ 129,127
A.2	Erosion and Sediment Control	1	LS	\$ 25,000	\$ 25,000
A.3	Traffic Control	1	LS	\$ 25,000	\$ 25,000
Subtotal Schedule 'A':					\$ 179,127

Schedule 'B' - Demolition					
<i>Description</i>		<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
B.1	Sawcut and Remove Asphalt/Concrete, Dispose Offsite	770	SY	\$ 25	\$ 19,250
Subtotal Schedule 'B':					\$ 19,250

Schedule 'C' - Storm Pipe Construction					
<i>Description</i>		<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
C.1	Trench Excavation	2,189	CY	\$ 35	\$ 76,624
C.2	Dewatering	1	LS	\$ 30,000	\$ 30,000
C.3	Shoring	4,500	SF	\$ 6	\$ 27,000
C.4	Stormwater Pipe (RCP, 84" diameter)	448	LF	\$ 664	\$ 297,248
C.5	Stormwater Manhole (10' diameter)	2	EA	\$ 7,500	\$ 15,000
C.6	Backfill - utility bedding and compaction	124	CY	\$ 42	\$ 5,227
C.7	Backfill - structural backfill and compaction	1,112	CY	\$ 30	\$ 33,358
C.8	Backfill - crushed surfacing base course	622	CY	\$ 25	\$ 15,556
Subtotal Schedule 'C':					\$ 500,012


Schedule 'D' - Site Improvements					
<i>Description</i>		<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
D.1	Install Vertical Curb	80	LF	\$ 29	\$ 2,320
D.2	New Asphalt Pavement (3" Thickness)	770	SY	\$ 25	\$ 19,250
D.3	Asphalt Sealcoat	770	SY	\$ 1.26	\$ 970
D.4	New Sidewalk	50	SY	\$ 14	\$ 700
D.5	Finished Grading	770	SY	\$ 5	\$ 3,850
D.6	Parking Lot Striping	700	LF	\$ 1.50	\$ 1,050
D.7	Construct Sanitary Sewer Lift Station	1	LS	\$ 250,000.00	\$ 250,000
Subtotal Schedule 'D':					\$ 278,140

Schedule 'E' - Landscaping					
<i>Description</i>		<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
E.1	Landscape Area Backfill	236	CY	\$ 25	\$ 5,903
E.2	Topsoil (General Landscaping)	42	CY	\$ 25	\$ 1,042
E.3	Landscape Planting (General)	750	SF	\$ 2	\$ 1,500
E.4	Site Features (benches, railings, etc.)	1	LS	\$ 5,000	\$ 5,000
Subtotal Schedule 'E':					\$ 13,444

Schedule 'F' - Soft Cost					
<i>Description</i>		<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
F.1	Contingency	30%	--	--	\$ 296,992
F.2	Design, Permitting, Contracting, Administration	30%	--	--	\$ 296,992
Subtotal Schedule 'F':					\$ 593,984

Project Total: \$ 1,583,958

ENGINEER'S PRELIMINARY OPINION OF PROBABLE COST

Title:	Fry Creek—Simpson to Pacific		 MAUL FOSTER ALONG 2001 NW 19th Avenue, Suite 200 Portland, OR 97209 971.544.2139 (p) 971.544.2140 (f) www.maulfoster.com
Project:	Fry Creek Restoration		
Client:	City of Aberdeen		
Project #/Task:	0922.04.01-02A	Initial	
Prepared By:	A. Kaparos		
Checked By:	J. Faust		
Date:	8/4/2017		
Revision #.:	0		

Cost Estimate Summary—Feasibility Level

Schedule A—General	\$	198,741
Schedule B—Demolition	\$	140,938
Schedule C—Creek Channel Construction	\$	213,434
Schedule D—Site Improvements	\$	16,222
Schedule E—Landscaping	\$	187,678
Schedule F—Soft Cost	\$	378,507
Total:		\$ 1,135,520

Assumptions:

1. Project involves reshaping the stream channels, construction of flood storage benches, and a public access observation platform.
2. Assumed a phased project with independent mobilization and design costs.
3. Does not include costs for road crossing culverts.
4. Invasive plants will be removed as part of the excavation work.
5. Does not include costs for any potential dewatering.
6. Fill required for observation platform area will be obtained from excavated material during channel construction.

ENGINEER'S PRELIMINARY COST ESTIMATE
Maul, Foster Alongi, Inc.

Schedule 'A' - General				
<i>Description</i>	<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
A.1 Contractor Mobilization	15%	--	--	\$ 98,741
A.2 Erosion and Sediment Control	1	LS	\$ 15,000	\$ 15,000
A.3 Traffic Control	1	LS	\$ 10,000	\$ 10,000
A.4 Temporary Creek Diversion	1	LS	\$ 75,000	\$ 75,000
Subtotal Schedule 'A':				\$ 198,741

Schedule 'B' - Demolition				
<i>Description</i>	<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
B.1 Channel Excavation, Dispose of Soil Offsite	3,988	CY	\$ 35	\$ 139,576
B.2 Sawcut and Remove Asphalt, Dispose Offsite	68	SY	\$ 20	\$ 1,362
Subtotal Schedule 'B':				\$ 140,938

Schedule 'C' - Creek Channel Construction				
<i>Description</i>	<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
C.1 Retaining Wall	500	SFF	\$ 30	\$ 15,000
C.2 Finished Grading	3,783	SY	\$ 5	\$ 18,916
C.3 Install Planting Medium	480	CY	\$ 35	\$ 16,816
C.4 Stream Channel Bedding	679	CY	\$ 80	\$ 54,311
C.5 Creek Channel Planting	8,648	SF	\$ 4	\$ 34,592
C.6 Railing at Top of Wall	60	LF	\$ 50	\$ 3,000
C.7 Pedestrian Crossing Bridge	590	SF	\$ 120	\$ 70,800
Subtotal Schedule 'C':				\$ 213,434


Schedule 'D' - Site Improvements				
<i>Description</i>	<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
D.1 New Sidewalk/Pathways	744	SY	\$ 14	\$ 10,422
D.2 Cross Walk Striping	2	EA	\$ 400	\$ 800
D.3 Site Features (benches, signage, etc.)	1	LS	\$ 5,000	\$ 5,000
Subtotal Schedule 'D':				\$ 16,222

Schedule 'E' - Landscaping				
<i>Description</i>	<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
E.1 Topsoil (General Landscaping)	1,411	CY	\$ 25	\$ 35,278
E.2 Landscape Planting (Submerged, Riparian, and Emergent Plants)	25,400	SF	\$ 6	\$ 152,400
Subtotal Schedule 'E':				\$ 187,678

Schedule 'F' - Soft Cost				
<i>Description</i>	<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
F.1 Contingency	30%	--	--	\$ 227,104
F.2 Design, Permitting, Contracting, Administration (20%)	20%	--	--	\$ 151,403
Subtotal Schedule 'F':				\$ 378,507

Project Total: \$ 1,135,520

ENGINEER'S PRELIMINARY OPINION OF PROBABLE COST

Title: Fry Creek—Pacific to Railroad	 <p>MAUL FOSTER ALONG 2001 NW 19th Avenue, Suite 200 Portland, OR 97209 971.544.2139 (p) 971.544.2140 (f) www.maulfoster.com</p>
Project: Fry Creek Restoration	
Client: City of Aberdeen	
Project #/Task: 0922.04.01-02A Initial	
Prepared By: A. Kaparos	
Checked By: J. Faust	
Date: 8/4/2017	
Revision #.: 0	
Cost Estimate Summary—Feasibility Level	
Schedule A—General	\$ 157,435
Schedule B—Demolition	\$ 90,533
Schedule C—Creek Channel Construction	\$ 89,052
Schedule D—Site Improvements	\$ 5,000
Schedule E—Landscaping	\$ 121,317
Schedule F—Soft Cost	\$ 231,669
Total:	\$ 695,006
Assumptions: <ol style="list-style-type: none"> 1. Assumes phased project with independent mobilization costs. 2. Does not include costs for road crossing culverts. 3. Invasive plants will be removed as part of the excavation work. 4. Dewatering is not included. 5. Stream design will be approximately 388 feet long, 20 feet wide, and with 1.5 feet bedding and topsoil depths. 6. Designed improvements will also include riparian and emergent plantings. 	

ENGINEER'S PRELIMINARY COST ESTIMATE
Maul Foster Alongi, Inc.

Schedule A—General					
<i>Description</i>		<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
A.1	Contractor Mobilization	15%	LS	--	\$ 60,435
A.2	Erosion and Sediment Control	1	LS	\$ 12,000	\$ 12,000
A.3	Traffic Control	1	LS	\$ 10,000	\$ 10,000
A.4	Temporary Creek Diversion	1	LS	\$ 75,000	\$ 75,000
Subtotal Schedule A:					\$ 157,435

Schedule B—Demolition					
<i>Description</i>		<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
B.1	Channel Excavation, Dispose of Soil off Site	2,587	CY	\$ 35	\$ 90,533
Subtotal Schedule B:					\$ 90,533

Schedule C—Creek Channel Construction					
<i>Description</i>		<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
C.1	Finished Grading	2,601	SY	\$ 5	\$ 13,005
C.2	Install Planting Medium	388	CY	\$ 35	\$ 13,594
C.3	Stream Channel Bedding	431	CY	\$ 80	\$ 34,489
C.4	Creek Channel Planting	6,991	SF	\$ 4	\$ 27,964
Subtotal Schedule C:					\$ 89,052

Schedule D—Site Improvements					
<i>Description</i>		<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
D.1	Site Features (benches, signage, etc.)	1	LS	\$ 5,000	\$ 5,000
Subtotal Schedule D:					\$ 5,000

Schedule E—Landscaping					
<i>Description</i>		<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
E.1	Topsoil (general landscaping)	912	CY	\$ 25	\$ 22,804
E.2	Landscape Planting (riparian & emergent plants)	16,419	SF	\$ 6	\$ 98,513
Subtotal Schedule E:					\$ 121,317

Schedule F—Soft Cost					
<i>Description</i>		<i>Quantity</i>	<i>Unit</i>	<i>Unit Cost</i>	<i>Total Cost</i>
F.1	Contingency	30%	--	--	\$ 139,001
F.2	Design, Permitting, Contracting, Administration	30%	--	--	\$ 92,667
Subtotal Schedule F:					\$ 231,669

Project Total: \$ 695,006