TETRA TECH

MEMORANDUM

TNC – Fisher Slough Final Design and Permitting
Subject: Inverted Siphon – Pipe Design

To: Internal Memo for Record
Yen Hsu Chen
Marty McCabe (URS)
John Plump (Tetra Tech INCA)

From: David Cline (Tetra Tech)

Date: Nov. 3, 2009

Introduction

This technical memorandum addresses and documents the pipe design and construction elements of the inverted siphon at Fisher Slough. The pipe design is broken down into the following design elements:

- Pipe diameter and conveyance requirements
- Clearance or burial depth requirements
- Pipe material type and thickness
- Pipe deflection
- Pipe buckling
- Bending stress
- Bending strain
- Pipe bouyancy
- Pipe connections, sealing and waterproofing
- Foundation and bedding requirements
- Filter diaphragm design

Design plans of the pipe design are included in Attachment A.

Pipe diameter and conveyance requirements

The diameter of the pipe and conveyance of the proposed pipe was evaluated using multiple engineering methods. A HEC-RAS model was developed to assess conveyance properties of the existing crossing sag culverts, which was estimated at 235cfs for the Skagit River 100-year flood water surface elevations. A separate runoff analysis was performed for the Big Ditch watershed, using scaling parameters developed for the adjacent Carpenter Creek watershed hydrologic analysis. The 100-year runoff for the Big Ditch watershed was estimated at 400cfs. However, the channel capacity is much lower and there is significant attenuation and losses along the downstream segments of Big Ditch. Therefore, the 235cfs flow analysis was used as this is the worst case flood condition resulting from major Skagit River floods and upstream levee breaches that would affect the proposed pipe system.

The pipes can readily convey 235cfs, with 3.5 feet lower water surface elevation (driving head) on the upstream side compared to the existing condition. **Table 1-3** summarize the flow rates for the existing culvert, the proposed inverted siphon, and comparison of the two conditions. Overall, the proposed inverted siphon significantly outperforms the existing structure.

The resulting pipe velocities are low, which is a function of the fish passage design criteria. The low velocities can result in sedimentation within the pipe system. The basin has a volume of 67CY. The WinSAM annual yield analysis estimated an annual rate of 7.8CY/YR. It is estimated that the basin will fill in a 5-10YR period. The designers recommend cleaning the sedimentation basin every year.

In the event that pipe sedimentation does occur, the pipes will need to be cleaned. A number of cleaning methods are available including the following:

- Closing 1 pipe gate and flushing the second pipe
- Jet vacuum cleaning
- Mechanical pipe cleaning pig

Table 1. Big Ditch Existing Culvert Hydrology and Hydraulics

Design Discharge	Flow Rate (cfs)	No. Culverts	Culvert Flow Depth	WSE U/S Culverts	Culvert Velocity (fps)
$Q_{\text{Low Flow}}$	8.7	6	0.9	3.6	0.4
$Q_{\text{Fish Passage}}$	63.1	6	2.4	5.5	1.0
$Q_{\text{Channel Capacity}}$	80.0	6	2.7	5.9	1.1
$Q_{\text{100 WSE = 16.7ft}}$	235.0	6	4.5	13.3	1.9

Table 2. Big Ditch Proposed Inverted Siphon Hydrology and Hydraulics

Design Discharge	Channel Flow Rate (cfs)	Siphon Losses (ft)	No. of Pipes	Pipe Dia. (ft)	WSE U/S Inverted Siphon Pipes	Pipe Velocity (fps)
$Q_{\text{Low Flow}}$	8.7	0.0028	2	4.5	3.1	0.3
$Q_{\text{Fish Passage}}$	63.1	0.1741	2	4.5	4.2	2.0
$Q_{\text{Channel Capacity}}$	80.0	0.2841	2	4.5	4.7	2.5
$Q_{\text{100 Exist Flow}}$	235.0	2.5267	2	4.5	9.6	7.4
$Q_{\text{100 WSE = 16.7ft}}$	455.0	9.5469	2	4.5	16.7	14.3

Table 3. Big Ditch Proposed Inverted Siphon Hydrology and Hydraulics

WSE U/S CULVERT/SIPHON (FT)			
Flow Rate (cfs)	**Existing Culvert**	**Proposed Inverted Siphon**	**Difference Proposed-Existing**
8.7	3.7	2.9	-0.3
63.1	5.6	5.0	-0.6
80.0	5.9	5.5	-0.4
235.0	13.6	10.1	-3.5
CULVERT/SIPHON VEL. (FPS)			
Flow Rate (cfs)	**Existing Culvert**	**Proposed Inverted Siphon**	**Difference Proposed-Existing**
8.7	0.4	0.3	-0.1
63.1	1.0	2.0	1.0
80.0	1.1	2.5	1.4
235.0	1.9	7.4	5.5
CULVERT DEPTH (FT)			
Flow Rate (cfs)	**Existing Culvert**	**Proposed Inverted Siphon**	**Difference Proposed-Existing**
8.7	0.9	4.5	3.6
63.1	2.4	4.5	2.1
80.0	2.7	4.5	1.8
235.0	4.5	4.5	0.0

Pipe Clearance and Scour Protection

The pipe is designed with a minimum cover of 3ft, per the USBR Design of Small Canal Structures (USBR, 1978). For Fisher Slough, the bed upstream from the floodgate and bridge runs along an elevation of 3ft. The primary floodgate sill elevation is at 4.3ft, which generally controls the upstream bed elevation. Beneath the main floodgates are two submerged flapgates with an invert elevation 0.0ft. Local scour occurs near these structures and is measured at a -4.8ft downstream and -1.4ft upstream.

Local plunge scour at the floodgate occurs 240ft downstream of the pipes and was predicted at a depth of 4.6ft deep, which is nearly identical to the existing scour conditions at the floodgate. This type of scour is expected to remain localized in nature and will not extend upstream a distance of 240ft to the pipes.

The second type of scour evaluates the potential for lowering or changing of the bed elevation where the channel contracts near the bridge. Contraction scour was evaluated using FHWA HEC-18, Live Bed contraction scour analysis methods (**Attachment A**).

A few key concepts were evaluated in developing an understanding of the potential for scouring of the bed. First, it is fairly likely that the upstream main tidal channel will expand in the future as a result of keeping the floodgates open for longer periods in conjunction with setting back the

South Levee. The Deepwater Slough Monitoring Report (Corps, 2006) was reviewed to document the changes in channel depth and widths in a 5-year monitoring period resulting from levee breach and removal on the nearby slough. Observations in the form of cross section surveys showed that many channels deepened on the order o 1M (3.3ft) and expanded in width up to 4M (13ft).

The current channel bottom width at the inverted siphon crossing location is approximately 50ft in width with upstream channel bottom widths approximately 60ft wide. Adding 13ft indicates a possible channel expansion width of 73ft. Using the live bed scour analysis method predicts a scour depth of 3.1ft (to a -3.1ft), nearly identical to those observed at Deepwater Slough (SRSC, 2003). Using this scour estimate, the invert of the pipe would need to be established at a -10.6 to provide 3ft of cover over the pipe.

However, at the Deepwater Slough bridge cross section for which the bridge width remained constant, the observed scour depth was 6.0ft (to a -6.0ft), indicating the variability along these observed sections. A six foot deep scour estimate correlates well with a 50ft (doubling) expansion of channel width, which is not currently anticipated. The invert of the pipe would need to be established at a -13.5ft to accommodate 3ft of cover for this condition.

Each of these scour conditions were considered for final establishment of the pipe invert elevations. The average channel expansion and -3.1ft of scour was determined to best represent conditions likely to occur at the project site. Additional scour protective measures are recommended including placement of pipe bedding material to a depth 1.0ft above the crown of the pipe to provide armoring protection if excessive scour does occur. A few of the reasons for selecting this scour design depth include the following:

- The floodgate sill and submerged flapgate invert elevations act as hydraulic and sediment controls on the upstream channel and marsh system. It is not likely that the channel will significantly scour below these controlling elevations.
- The addition of pipe bedding material 1.0ft above the top of the pipe would resist transport and erosion and likely develop an armoring surface if exposed to flows.
- If the -6.0ft scour condition did occur, the scour depth would remove the 3.0ft of pipe cover material and be nearly equal in depth to the top of the pipe. The pipe would not be fully exposed. The limitation of this condition is that the pipes should not be fully drained as buoyancy will become an issue without the three feet of cover.

For simplicity purposes, and to ensure the central portions of the pipe meet the specified cover requirements of 3.0ft, the lowest invert of the pipe will be established at -11.0ft.

Pipe Material Type and Specification

The recommended pipe material type for the project is to use high density polyethylene (HDPE) for its flexibility during construction, low hydraulic roughness, and demonstrated effectiveness on other pipeline projects. The ability to fuse weld the pipe pieces in the field is a positive for installing a watertight system in poor soil foundation conditions. Pipe jacking or trenchless construction is an option for the contractor using HDPE.

Soil external pressures were evaluated assessing the saturated soil conditions for the entire levee assuming a drained pipe condition. The drained pipe condition could occur during routine maintenance conditions if the pipe were to be pumped out for inspections or cleaning.

Fully Saturated Soil Unit Weight:
Suppose $\gamma_s = 165.4$ lb/ft^3, and $\gamma_w = 62.4$ lb/ ft^3 and a void ratio e = 0.3:

$$\gamma_{sat} = \frac{(G_s + e)\gamma_w}{1+e} = \frac{(2.65+0.3)62.4}{1+0.3} = 141.6 lb / ft^3$$

Maximum pipe burial depth (Ymax soil – top of pipe crown) = (18.0ft – (-5.65ft)) = 23.65ft

Soil Pressure Force Ps = $\frac{\gamma_{sat} Y_{\max}}{144 in^2 / ft^2} = 23.25 psi$

Live loads will occur on the tops of the levees from vehicle access. An H-20 live load rating of 80psi was used for evaluating active loads on the pipe. The additional stress on the pipe can be evaluated using the Boussinesque line load equation for an infinite strip.

Assuming B = Tire width of 20in (1.67ft) the stress factor is 0.125P.

P_L - Boussinesq Stress at Pipe Depth (at shallowest soil point = 8ft) = 0.125(80.0psi) = 10.0psi

P_T = Ps + P_L = 23.0lbs/ in^2 + 10.0lbs/ in^2 = 33.0 lbs/ in^2

Internal water pressure within the pipe walls is (Ymax water – lowest pipe invert) = (16.7ft – (-9.15ft)) = 25.85ft

Internal water pressure force Pw = $\frac{\gamma w Y_{\max}}{144 in^2 / ft^2} = 11 psi$

The maximum stress is therefore 33.0lbs/in^2.

Specifications sheets for HDPE pipe were reviewed to determine the necessary wall thickness. A schedule DR41, 4710 pipe with a 54inch outer diameter and 1.317 inch wall thickness can withstand up to 50psi pressure, and was selected as the material specification for this project (Attachment B).

Pipe Deflections

Pipe deflections were evaluated using methods prescribed in an HDPE design manual (Hancor, 1998). The following equation can be used to estimate the vertical pipe deflection.

$$\Delta y = \frac{K\left(D_L W_C + W_L\right)}{0.149PS + 0.061E'}$$

Where,

Δy = Deflection (1.7in)
K = Bedding constant (0.11)
D_L = Deflection lag factor (1.0 when soil column load is used)
W_C = Soil column load on pipe (lb/linear in of pipe)
W_L = Live load (negligible per guidance) (lb/linear inch of pipe)
PS = Pipe stiffness (16 psi)
E' = Backfill modulus (1,000 psi)

And,

$$W_C = \frac{H\gamma_S OD}{144}$$

Where,

W_C = Soil column load on pipe (1,317lb/linear in of pipe)
H = Burial depth (24.5ft)
γ_s = Soil density (141.6 pcf)
OD = Outside diameter of pipe (54.0 in)

% Deflection = 3.0% of total deflection (checks with 7.5% guidance)

Pipe Buckling

Pipe wall buckline is determined by the burial conditions (E') and the Pipe Stiffness (PS). The critical buckling pressure must be greater than the calculated actual pressure.

$$P_{CR} = \frac{0.772}{SF}\left[\frac{E'PS}{1-v^2}\right]^{\frac{1}{2}}$$

Where,

P_{CR} = Critical buckling pressure (53.3 psi)

E’ = Backfill modulus (1,000 psi)
PS = Pipe stiffness (16 psi)
V = Poisson ratio (0.4 for polyethylene)
SF = Safety factor (2.0)

$$P_V = \frac{R_W H \gamma_s}{144} + \frac{\gamma_w H_W}{144} + \frac{W_L}{OD}$$

Where,

P_V = Actual buckling pressure (26.5psi)
Rw = Water buoyancy factor = 1-0.33(Hw/H)
Hw = Height of groundwater above top of pipe (22.4ft)
H = Burial depth (24.5ft)
γ_s = Saturated soil density (141.6 pcf)
γ_W = Water density (62.4 pcf)
W_L = Live load (lb/linear inch of pipe)
OD = Outside diameter of pipe (54.0 in)

The criteria check with $P_{CR} > P_V$.

Pipe Bending Stress and Bending Strain

Pipe bending stress is check so that it does not exceed 3,000psi and bending strain should not exceed 5% for polyethylene. The following equations were evaluated.

$$\sigma_B = \frac{2DfE\Delta yy_o SF}{Dm^2}$$

Where,

σ_B = Bending stress (856.8 psi)
Df = Shape factor (6.8 for highly compacted SM backfill)
E = Modulus of elasticity (110,000psi for polyethylene)
Δy = Deflection (1.7in)
y_o = Distance from centroid of pipe wall to the furthest surface of the pipe (0.6585in)
OD = Outside diameter of pipe (54.0 in)
ID = Inside diameter of pipe (51.366in)
SF = Safety factor, 1.5
Dm = Mean pipe diameter = ID +2c = (53.866in)
c = Distance from inside surface to the neutral axis = (1.25in)

The criteria for bending stress check where 856.8psi<3,000psi.

$$\varepsilon_B = \frac{2Df\Delta yy_o SF}{Dm^2}$$

The criteria for bending strain check where 0.787% < 5.0%.

Pipe Buoyancy

In evaluating pipeline buoyancy, the standard methods are typically to evaluate a dewatered condition. This condition could only occur if the pipe was drained using a pump system, as the pipe is below the local groundwater table. Considering the fully drained condition, pipe buoyancy is determined by evaluating the downward saturated soil and pipe weight against the upward buoyancy force equivalent to the weight of the water displaced by the pipe. The following equations are used to determine if the critical section of pipe is buoyant.

$$W_C + W_p \geq F_{BP}$$

$$F_{BP} = A_p L_P \gamma_w$$

Where,

$$W_C = \frac{H\gamma_S OD}{144}$$

Where,

W_C = Soil column load on pipe (159.3lb/linear in or 1,911.6lb/linear ft of pipe)
H = Burial depth (3.0ft)
γ_s = Soil density (141.6 pcf)
OD = Outside diameter of pipe (54.0 in)

Wp = 95.92lb/ft

Wc + Wp = 2007.5lb/lf

F_{BP} = (15.89sf/lf)(1ft)(62.4pcf) = 991.93lb/lf

For the minimum cover condition, the soil load on the 100ft section of pipe provides adequate protection, with a factor of safety of 2.0. This analysis does not account for additional resistance factors such as the pipe behaving as a singular structure connected to the headwalls with significantly more cover underneath the levees. Accordingly, the pipe is not expected to float when empty of water.

Pipe Connections

The pipes will be connected via HDPE fusion welding which provides a completely watertight seal in the field. Pipe connections and waterproofing will be tested and inspected upon completion prior to initiating backfilling the excavated areas.

Sealing & Waterproofing (Waterstops)

Waterproofing seals are required for the pipe penetrations through the concrete headwalls, and will be included in the specifications. A number of products are available for waterproof seals or connections at the headwall. The following types were reviewed for this project:

- Hydraulic concrete grouts
- Rubberized grouting rings and gaskets
- Elastometric sealants
- Structural flanges/boots with grout and sealants

Standard hydraulic concrete grouts are typically filled around the pipe penetration through the headwall connection. Issues related to using waterproof concrete grout only are related to water seepage resulting from shrinkage of the concrete and grout, and shifting or settlement of the pipe, both can cause cracks in the grout.

Rubberized grouting rings are typically a gasket ring that slides around the pipe and is placed in the concrete form. These gasket rings are manually tightened around the pipe, and then concrete poured around the gasket, and filled with waterproof grout sealant. On of the problems with rubberized gaskets is that they can dry out and deteriorate if exposed to air or sunlight. The pipe will be submerged nearly full time, so air should not be an issue.

Another category of waterstops are structural flanges that are either connected to the headwall and then filled with grout and sealant, or welded to the outside of the pipe and placed in the headwall with concrete poured around the flange, and backfilled with grout and sealants. The structural flanges can provide excellent water sealant, but have limitations for flexibility due to pipe shifting and settlement.

Elastometric sealants are typically a rolls of adhesive materials (Prostik and Synko-flex or Hydro-flex) that are wrapped sealants on the pipes. These gaskets are flexible and can accommodate some shifting and pipe settlement. However, some products can deteriorate over time if exposed to sunlight and air.

Due to the potential for settlement and shifting of the pipe, we are recommending an elastometric sealant and waterstop for the structure such as Hydro-flex, HF-302 product made by Henry.

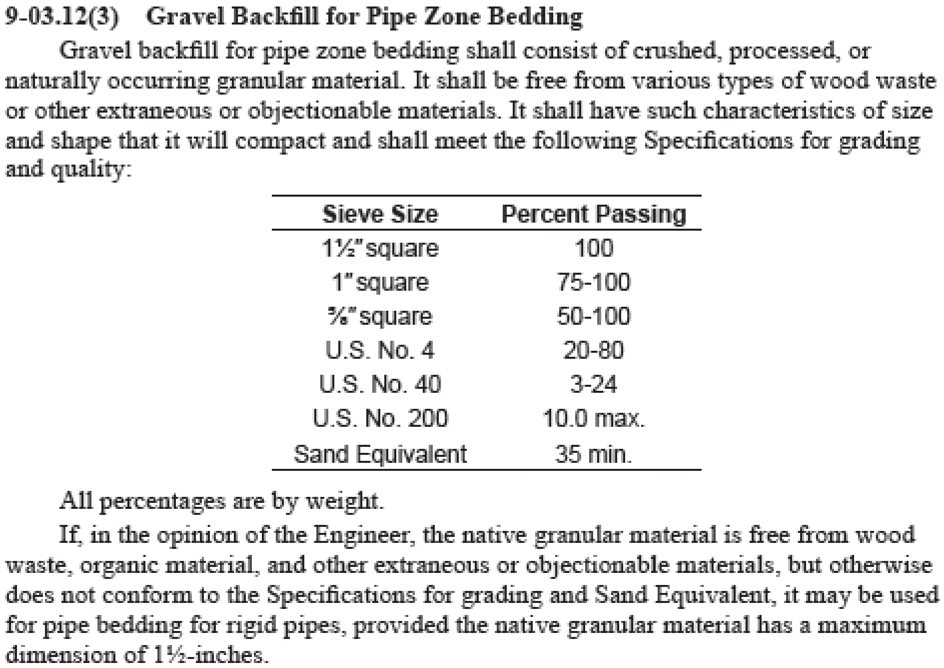
Foundation, Bedding and Backfill Requirements

The foundation of the pipe will use a composite of geotextiles fabric laying on in-situ soils, and then a layer of pipe backfill material placed up to the mid-point or spring line of the pipe. Levee suitable fill material will be placed on top of the pipe and in the excavated levee areas. Towards both ends of the pipe, a filter diaphragm will be installed to prevent seepage along the pipe system, and limit the potential for soil erosion through the embankment.

The underlying geotextiles fabric will be used as a filter to prevent seepage and erosion of underlying soils into the bedding and backfill layers, which could create adverse seepage and settlement in and around the pipe. The geotextiles fabric will also provide an initial working base for the construction contractor to begin to lay down the bedding material and create a working platform for pipe installation. The material specification for the underlying fabric is a Mirafi Non-Woven 180N equivalent or better (Attachment B).

The next layer of material is pipe bedding material to be laid along the foundation and bedding zone of the pipe. A typical specification is recommended using WSDOT pipe bedding material. WSDOT, for plastic and thermo-plastic pipes, specifies backfill of the pipe bedding and pipe backfill zones using the pipe bedding material specification 9-03.12(3) (WSDOT, Standard Specifications 2008). The material will be compacted to 90% maximum dry density, per Standard Proctor.

The upper layers of materials will be suitable levee materials (as shown in other sections of the design plans and specifications) compacted to 95% maximum dry density per standard proctor ASTM D-698.



9-03.12(3) Gravel Backfill for Pipe Zone Bedding

Gravel backfill for pipe zone bedding shall consist of crushed, processed, or naturally occurring granular material. It shall be free from various types of wood waste or other extraneous or objectionable materials. It shall have such characteristics of size and shape that it will compact and shall meet the following Specifications for grading and quality:

Sieve Size	Percent Passing
1½" square	100
1" square	75-100
⅝" square	50-100
U.S. No. 4	20-80
U.S. No. 40	3-24
U.S. No. 200	10.0 max.
Sand Equivalent	35 min.

All percentages are by weight.

If, in the opinion of the Engineer, the native granular material is free from wood waste, organic material, and other extraneous or objectionable materials, but otherwise does not conform to the Specifications for grading and Sand Equivalent, it may be used for pipe bedding for rigid pipes, provided the native granular material has a maximum dimension of 1½-inches.

Filter Diaphragm Design

A comment was provided by the TNC engineering design review if a seepage collar may be necessary along the pipes. Upon review, Tetra Tech and URS concluded that a filter diaphragm along the pipes in the levee embankment was warranted to reduce seepage velocities and protect from material piping and erosion. The filter diaphragm design method uses the NRCS, NEH Part 628 Chapter 45 Filter Diaphragm Design and 633 Chapter 26 Determining Filter Gradation Limits. The filter diaphragm design is configured with the filter diaphragm dimensions equal to 2D on the sides and top of the pipe, and 1D below the pipe. The materials for the filter diaphragm are specified as ASTM C-33 concrete sands, compacted to 90% maximum dry density, per ASTM D-698.

References

Hancor, 1998. Hancor Inc. Drainage Handbook.

Skagit River System Cooperative (SRSC), 2003. Deepwater Slough Monitoring Report

Federal Highways Administration (FWHA), 2001. HEC-18 Evaluating Scour at Bridges

Natural Resource Conservation Service (NRCS), 2007. National Engineering Handbook (NEH) Part 628 Dams Part 45 Filter Diaphragms.

Attachment A – Inverted Siphon Scour Analysis

TETRA TECH

MEMORANDUM

Live - Bed Contraction Scour Estimate

Guidance Document: FHWA, Evaluating Scour at Bridges 4th Ed. Hydraulic Engineering Circular No. 18. US Dept. of Transporation. May 2001, 380 p.

Date: **11/3/2009**
Project: **Fisher Slough Floodgate**
Design By: **D Cline**
Checked By:

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{6/7} \left(\frac{W_1}{W_2}\right)^{k_1}$$

$y_s = y_2 - y_o =$ (average contraction scour depth)

Average Depth in the Upstream Main Channel, Y_1 =	**FT**	**9.32**	**9.32**	**9.32**	**9.32**	**9.32**	**9.32**	**9.32**	**9.32**
Existing Depth in the Contracted Section before Scour, Yo =	**FT**	**9.02**	**9.02**	**9.02**	**9.02**	**9.02**	**9.02**	**9.02**	**9.02**
Flow in the Upstream Channel Transporting Sediment, Q_1 =	**CFS**	**614**	**614**	**614**	**614**	**614**	**614**	**614**	**614**
Flow in the Contracted Channel, Q_2 =	**CFS**	**614**	**614**	**614**	**614**	**614**	**614**	**614**	**614**
Bottom (or Top) width of the Upstream Main Channel that is Transporting Sediment, W_1 =	**FT**	**50**	**60**	**70**	**73**	**80**	**90**	**100**	**120**
Bottom (or Top) width of the Main Channel in the Contracted Section less Pier Widths, W_2 =	**FT**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**
Water Surface Elevation in the Upstream Main Channel, EL_1 =	**FT**	**9.32**	**9.32**	**9.32**	**9.32**	**9.32**	**9.32**	**9.32**	**9.32**
Water Surface Elevation in the Upstream Main Channel, EL_2 =	**FT**	**9.02**	**9.02**	**9.02**	**9.02**	**9.02**	**9.02**	**9.02**	**9.02**
Length of Water Surface Drop	**FT**	**200.0**	**200.0**	**200.0**	**200.0**	**200.0**	**200.0**	**200.0**	**200.0**
Slope of Water Surface	**FT**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**
$V_* = (GY_1S_1)^{0.5}$ =	**FT/S**	**0.67**	**0.67**	**0.67**	**0.67**	**0.67**	**0.67**	**0.67**	**0.67**
ω (Fig 5.8) =	**FT/S**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**	**0.15**
V_*/ω =		**4.47**	**4.47**	**4.47**	**4.47**	**4.47**	**4.47**	**4.47**	**4.47**
K_1 =		**0.69**	**0.69**	**0.69**	**0.69**	**0.69**	**0.69**	**0.69**	**0.69**
Average Depth in the Contracted Section, Y_2 =	**FT**	**9.32**	**10.57**	**11.76**	**12.10**	**12.89**	**13.98**	**15.04**	**17.05**
Average Contraction Scour Depth (Live-Bed), Ys =	**FT**	**-0.30**	**-1.55**	**-2.74**	**-3.08**	**-3.87**	**-4.96**	**-6.02**	**-8.03**
Pipe Cover w/ Current Crown at -4.65ft		**4.35**	**3.10**	**1.91**	**1.57**	**0.78**	**-0.31**	**-1.37**	**-3.38**
Necessary crown elevation for expected scour		**-3.30**	**-4.55**	**-5.74**	**-6.08**	**-6.87**	**-7.96**	**-9.02**	**-11.03**
Pipe invert elevation for expected scour		**-7.80**	**-9.05**	**-10.24**	**-10.58**	**-11.37**	**-12.46**	**-13.52**	**-15.53**

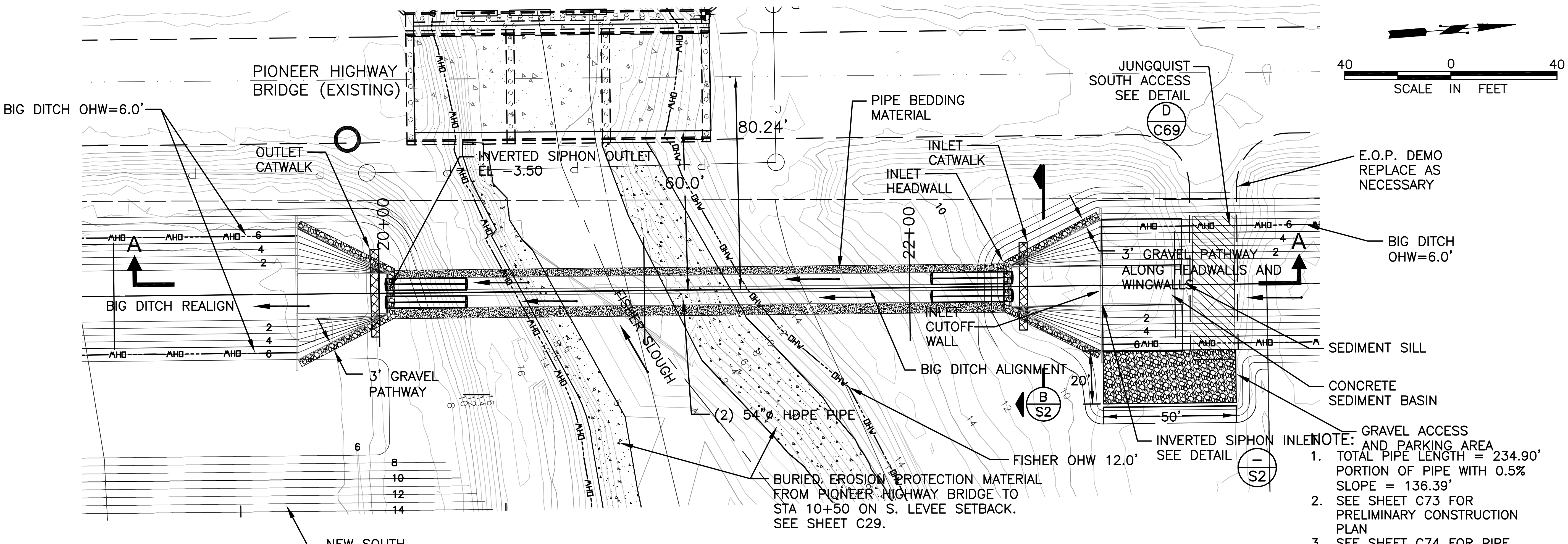
K_1 Exponent

V_*/ω	**K_1**	**Mode of Bed Material Transport**
<0.50	0.59	Mostly contact bed material discharge
0.50 to 2.0	0.64	Some suspended bed material discharge
>2.0	0.69	Mostly suspended bed material discharge

▨	Current upstream channel width
🟦	Likely channel width expansion based on deepwater slough monitoring report (Corps, 2006)
🟨	Possible scour depth using wide expansion and deeper scour per Deepwater Slough bridge

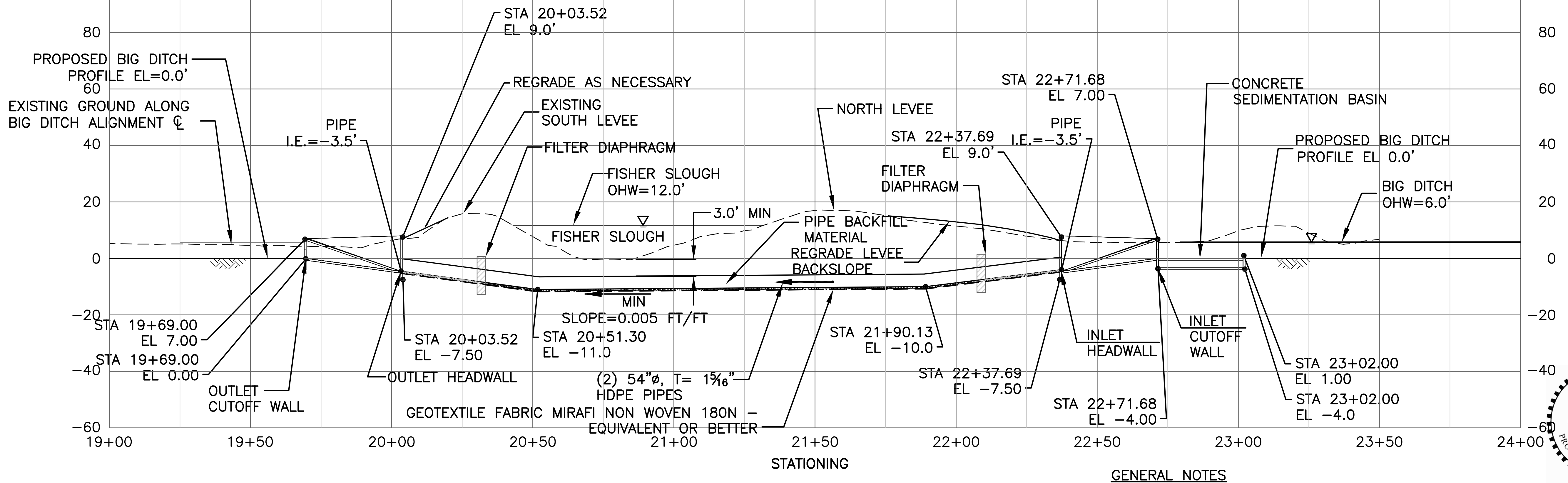
Notes:
Channel velocity at maximum discharge is = 0.1fps. Max velocity is 2.0fps (flood tide at gate with minimum depth over sill)
Channel shear stress = 0.013N/m2 = .000272PSF
Dcr = .0007in = .0178mm (fine sands - found at site)
Deepwater Slough Monitoring report 2000-2006 shows channel adjustments of +1M (3.28ft) scour depth and avg. +4M (13ft) channel width increases. Max scour 2M (6.56ft)
Fisher Slough has controlling sill at 4.3ft, and submerged flapgates at 0.0ft.
Current pipe crown located at -4.65. If scour elevation (in this case equals scour depth) = -1.55ft then 3.1ft cover. If scour elevation -6.02ft then 1.37ft exposed pipe.

Attachment B – Inverted Siphon Pipe Design Plan Sheets



INVERTED SIPHON CROSSING DETAILED PLAN

NOTE:
1. TOTAL PIPE LENGTH = 234.90' PORTION OF PIPE WITH 0.5% SLOPE = 136.39'
2. SEE SHEET C73 FOR PRELIMINARY CONSTRUCTION PLAN
3. SEE SHEET C74 FOR PIPE BACKFILL, GEOTEXTILE DETAILS



SECTION A-A C7

GENERAL NOTES
SEE SHEET S1-S6 FOR DETAILED INVERTED SIPHON LAYOUT.

DAVID R. CLINE
39326

EXPIRES

NOT FOR CONSTRUCTION

		Date
Designed	D. CLINE	DEC 18 2009
Drawn	J. OLMSTED	DEC 18 2009
Checked	Y CHEN	DEC 18 2009
Approved		
Title		

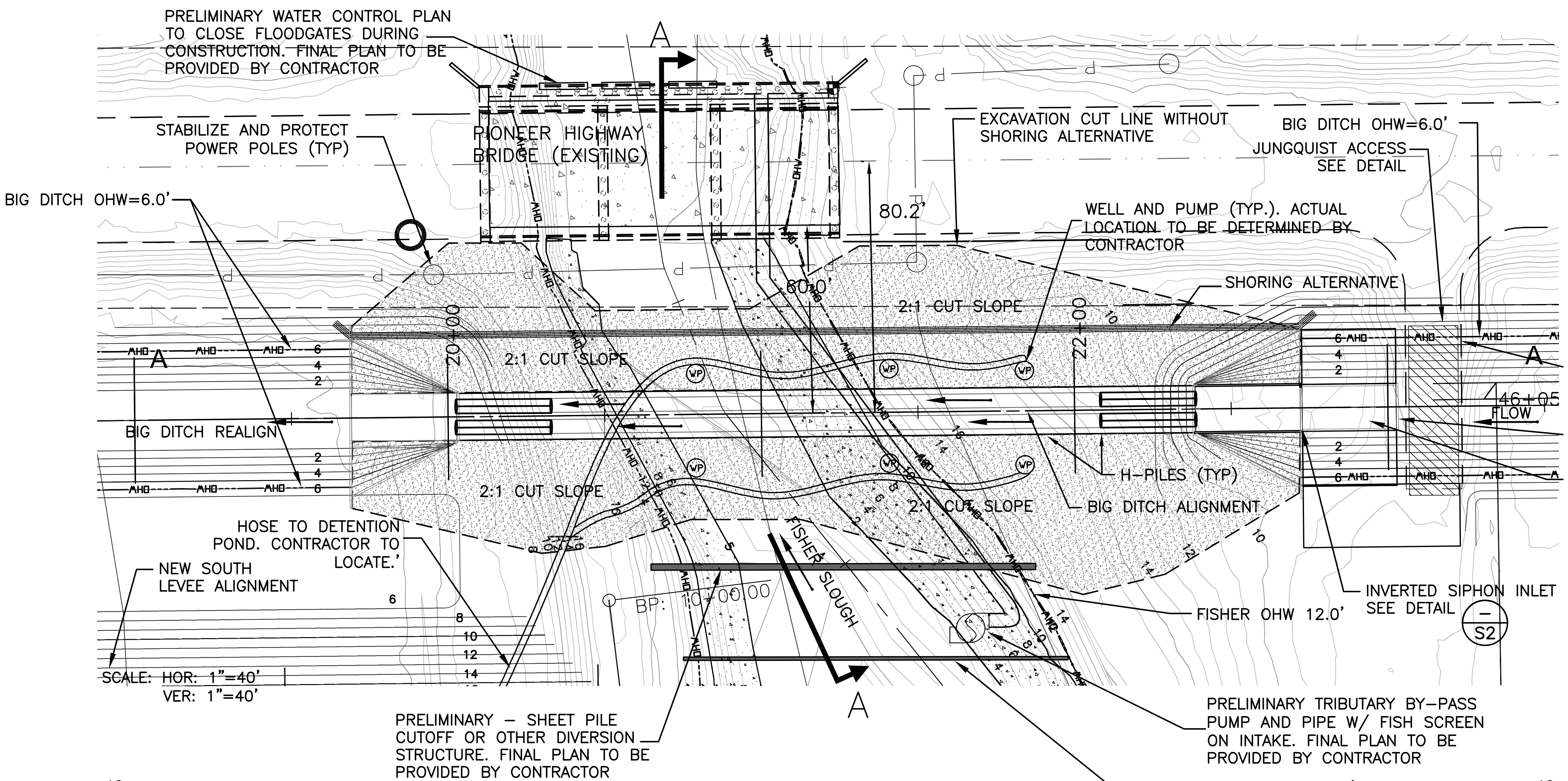
THE NATURE CONSERVANCY
FISHER SLOUGH RESTORATION PROJECT
INVERTED SIPHON PLAN AND PROFILE
SKAGIT COUNTY, WASHINGTON

TETRA TECH
1420 Fifth Avenue, Suite 550
Seattle, Washington 98101
206-728-9655 Fax: 206-728-9670

File Name

Drawing No.
C7

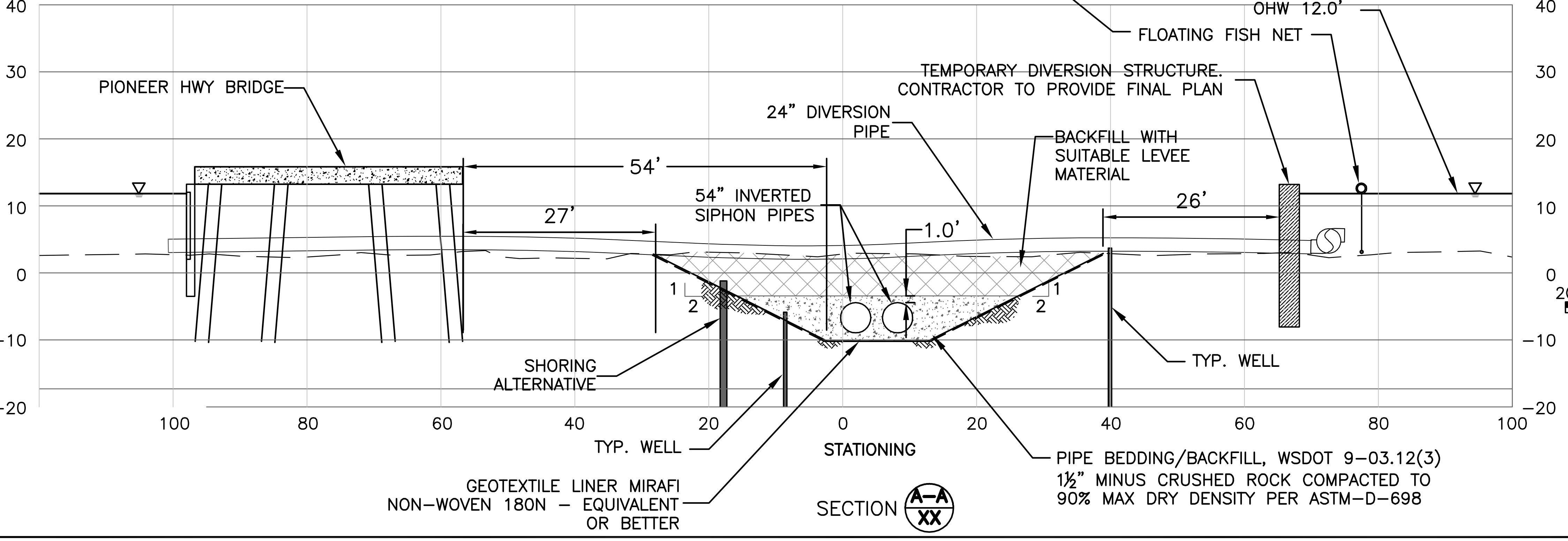
Sheet 18 of 96



40 0 40
SCALE IN FEET

LEGEND

– – –	EXISTING GROUND
——	PROPOSED CHANNEL INVERT
——	SIPHON STRUCTURE AND PIPE
←——	FLOW DIRECTION ARROW



SECTION A–A / XX

20 0 20
SCALE IN FEET

CONSTRUCTION NOTES:

1. THIS IS A PRELIMINARY PLAN ONLY. NOT FOR CONSTRUCTION.
2. CONTRACTOR REQUIRED TO SUBMIT FINAL PLAN FOR APPROVAL.
3. TRENCH CONSTRUCTION WITH WATER DIVERSION IS THE PROPOSED CONSTRUCTION METHOD FOR PROJECT PERMITS. OTHER CONSTRUCTION METHODS, SUCH AS TRENCHLESS PIPE JACKING, ALLOWED. CONTRACTOR TO PROVIDE PROPOSAL FOR CHANGES IN CONSTRUCTION METHODS.
4. CONSTRUCTION PLAN SHALL INCLUDE INFORMATION REGARDING DIVERSION PLANS, SCHEDULES, DETENTION AND SEDIMENTATION FACILILITIES, AND PROTECTIVE MEASURES FOR FISH.

		Date
Designed	D. CLINE	DEC 18 2009
Drawn	J. OLMSTED	DEC 18 2009
Checked	Y CHEN	DEC 18 2009
Approved		
Title		

THE NATURE CONSERVANCY

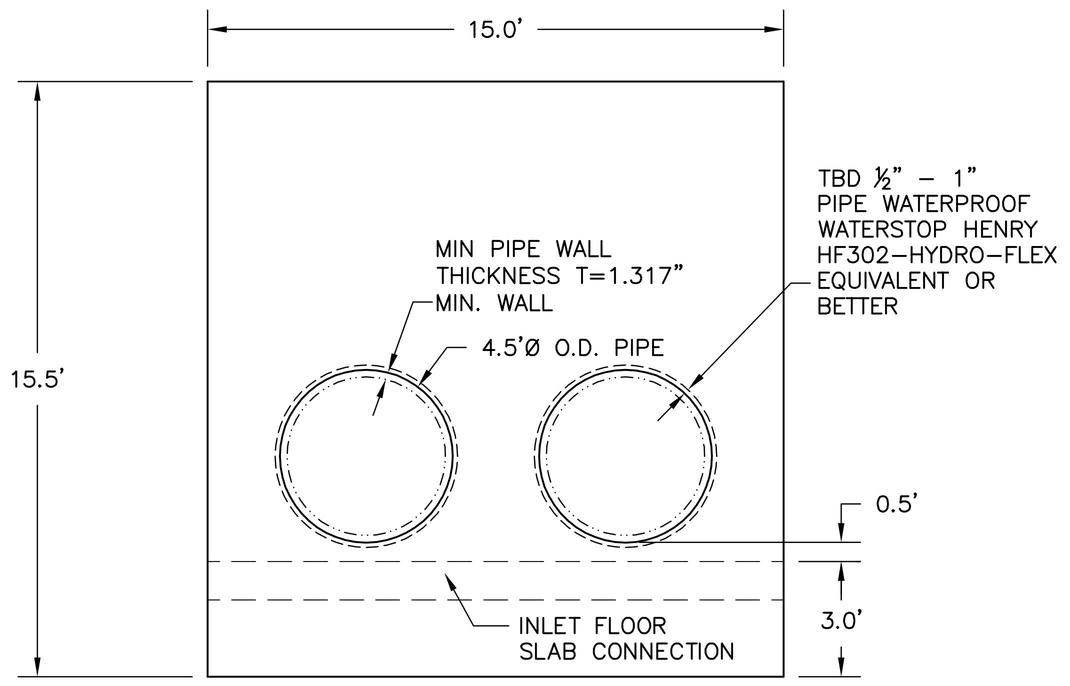
FISHER SLOUGH RESTORATION PROJECT

PRELIMINARY INVERTED SIPHON CONSTRUCTION PLAN
SKAGIT COUNTY, WASHINGTON

TETRA TECH
1420 Fifth Avenue, Suite 550
Seattle, Washington 98101
206-728-9655 Fax: 206-728-9670

File Name

Drawing No.
C74

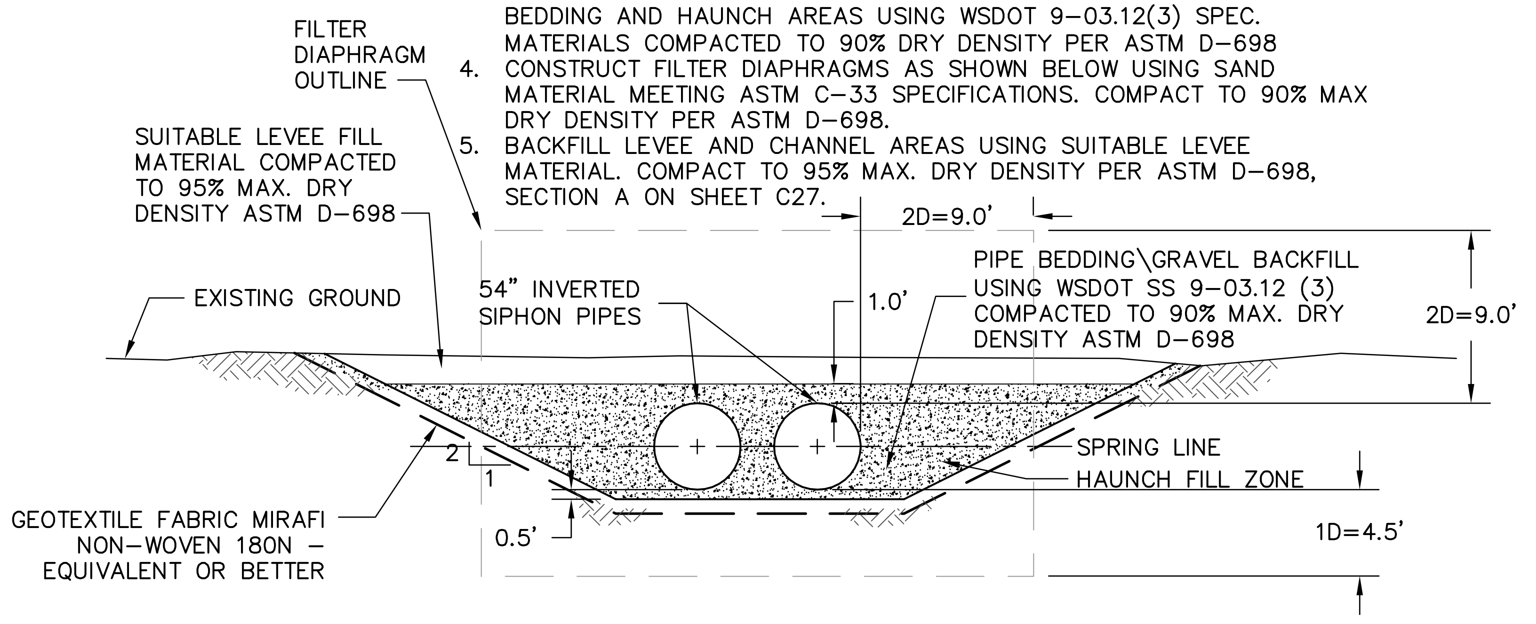


PIPE HEADWALL LAYOUT

NTS

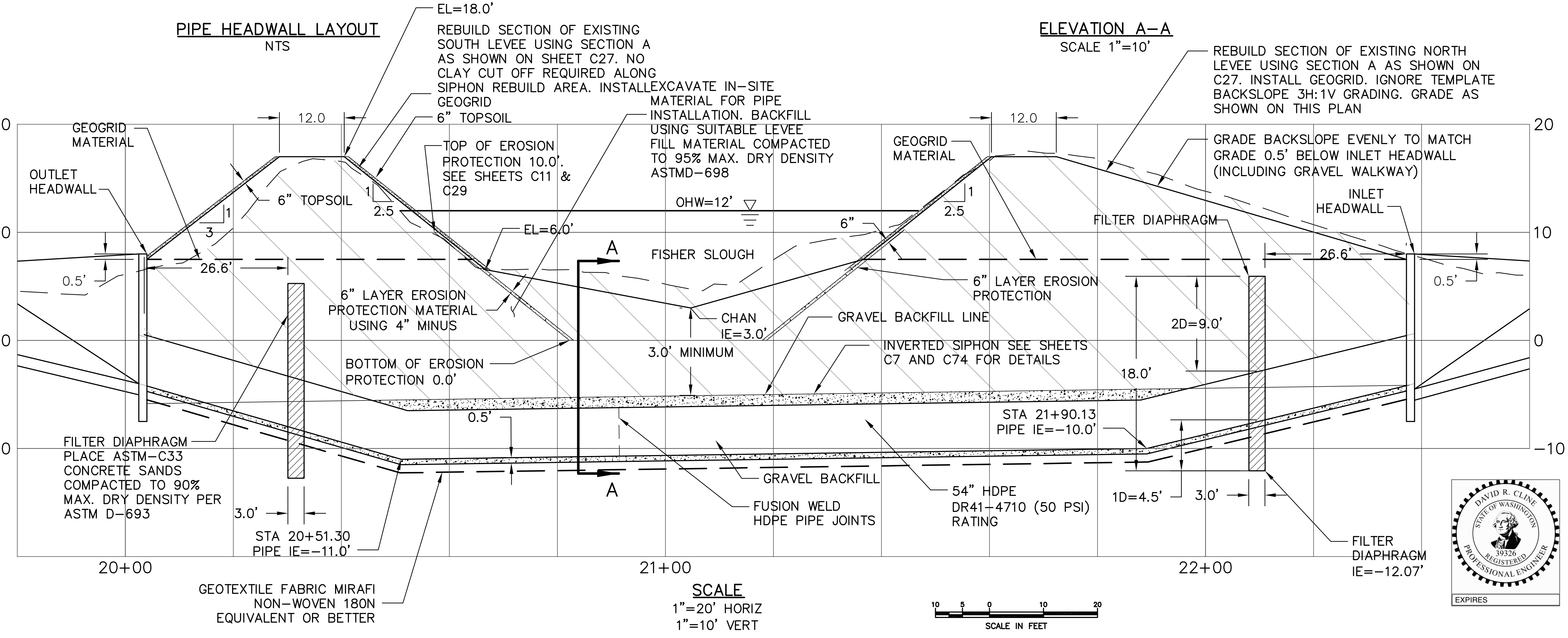
NOTES

1. INSTALL INVERTED SIPHON INLET/OUTLET, PIPES AND FOUNDATION MATERIALS PER THE PLANS BELOW.
2. CONSTRUCTION METHODS AND REQUIREMENTS SHALL BE FOLLOWED PER CONTRACTOR REVISED PLAN AS SHOWN ON C74.
3. UPON INSTALLATION OF PIPE, PRIOR TO BACKFILLING, CONTRACTOR SHALL DEMONSTRATE LEAK TEST FOR INSPECTION OF PIPE. BACKFILL BEDDING AND HAUNCH AREAS USING WSDOT 9-03.12(3) SPEC. MATERIALS COMPACTED TO 90% DRY DENSITY PER ASTM D-698
4. CONSTRUCT FILTER DIAPHRAGMS AS SHOWN BELOW USING SAND MATERIAL MEETING ASTM C-33 SPECIFICATIONS. COMPACT TO 90% MAX DRY DENSITY PER ASTM D-698.
5. BACKFILL LEVEE AND CHANNEL AREAS USING SUITABLE LEVEE MATERIAL. COMPACT TO 95% MAX. DRY DENSITY PER ASTM D-698, SECTION A ON SHEET C27.



ELEVATION A–A

SCALE 1"=10'



SCALE

1"=20' HORIZ
1"=10' VERT

DAVID R. CLINE
39326
EXPIRES

	Date
Designed D CLINE	DEC 18 2009
Drawn J BLAIR	DEC 18 2009
Checked Y CHEN	DEC 18 2009
Approved	
Title	

THE NATURE CONSERVANCY

FISHER SLOUGH RESTORATION PROJECT

FILTER DIAPHRAGM INSTALLATION
SKAGIT COUNTY, WASHINGTON

TETRA TECH
1420 Fifth Avenue, Suite 550
Seattle, Washington 98101
206-728-9655 Fax: 206-728-9670

File Name

Drawing No.
C75

Sheet 86 of 96

Attachment C – Manufacturer Example Specifications

HDPE_SCHEDULE_4710
HF302
MIRAFI_Non-Woven 180N

Building essentials
for a better tomorrow™

POLYETHYLENE WATER & SEWER

SUBMITTAL AND DATA SHEET

HDPE IRON PIPE SIZE (I.P.S.) PRESSURE PIPE

ANSI/NSF-61, 14 LISTED

PE 4710		DR 7 (335 psi)			DR 9 (250 psi)			DR 11 (200 psi)		
PE 3408/3608		DR 7 (265 psi)			DR 9 (200 psi)			DR 11 (160 psi)		
PIPE SIZE	AVG. O.D.	MIN. T.	AVG. I.D.	WEIGHT LB/FT	MIN. T.	AVG. I.D.	WEIGHT LB/FT	MIN. T.	AVG. I.D.	WEIGHT LB/FT
1/2	0.840	0.120	0.586	0.12	0.093	0.643	0.10	0.076	0.679	0.08
3/4	1.050	0.150	0.732	0.18	0.117	0.802	0.15	0.095	0.849	0.12
1	1.315	0.188	0.916	0.29	0.146	1.005	0.23	0.120	1.061	0.20
1-1/4	1.660	0.237	1.158	0.46	0.184	1.270	0.37	0.151	1.340	0.31
1-1/2	1.900	0.271	1.325	0.60	0.211	1.453	0.49	0.173	1.533	0.41
2	2.375	0.339	1.656	0.94	0.264	1.815	0.76	0.216	1.917	0.64
3	3.500	0.500	2.440	2.05	0.389	2.675	1.66	0.318	2.826	1.39
4	4.500	0.643	3.137	3.39	0.500	3.440	2.74	0.409	3.633	2.29
5-3/8	5.375	0.768	3.747	3.75	0.597	4.109	4.11	0.489	4.338	4.34
5	5.563	0.795	3.878	5.17	0.618	4.253	4.18	0.506	4.490	3.51
6	6.625	0.946	4.619	7.33	0.736	5.065	5.93	0.602	5.349	4.97
7	7.125	0.976	5.056	8.20	0.792	5.446	6.86	0.648	5.751	5.75
8	8.625	1.232	6.013	12.43	0.958	6.594	10.05	0.784	6.963	8.43
10	10.750	1.536	7.494	19.32	1.194	8.219	15.61	0.977	8.679	13.09
12	12.750	1.821	8.889	27.16	1.417	9.746	21.97	1.159	10.293	18.41
14	14.000	2.000	9.760	32.76	1.556	10.107	26.50	1.273	11.301	22.20
16	16.000	2.286	11.154	42.79	1.778	12.231	34.60	1.455	12.915	29.00
18	18.000	2.571	12.549	54.14	2.000	13.760	43.79	1.636	14.532	36.69
20	20.000	2.857	13.943	66.85	2.222	15.289	54.05	1.818	16.146	45.30
22	22.000	3.143	15.337	80.89	2.444	16.819	65.40	2.000	17.76	54.82
24	24.000	3.429	16.732	96.27	2.667	18.346	77.85	2.182	19.374	65.24
26	26.000	—	—	—	2.889	19.875	91.36	2.364	20.988	76.57
28	28.000	—	—	—	3.111	21.405	105.95	2.545	22.605	88.78
30	30.000	—	—	—	3.333	22.934	121.62	2.727	24.219	101.92
32	32.000	—	—	—	—	—	—	2.909	25.833	115.97
34	34.000	—	—	—	—	—	—	3.091	27.447	130.93
36	36.000	—	—	—	—	—	—	3.273	29.061	146.80

I.D. : Inside Diameter
O.D. : Outside Diameter
T. : Wall Thickness

* For data, sizes, or classes not reflected in these charts, please contact JM Eagle™ for assistance.

HDPE IRON PIPE SIZE (I.P.S.) PRESSURE PIPE (continued)

ANSI/NSF-61, 14 LISTED

PE 4710		DR 13.5 (160 psi)			DR 17 (125 psi)			DR 19 (112 psi)		
PE 3408/3608		DR 13.5 (128 psi)			DR 17 (100 psi)			DR 19 (90 psi)		
PIPE SIZE	AVG. O.D.	MIN. T.	AVG. I.D.	WEIGHT LB/FT	MIN. T.	AVG. I.D.	WEIGHT LB/FT	MIN. T.	AVG. I.D.	WEIGHT LB/FT
1/2	0.840	—	—	—	—	—	—	—	—	—
3/4	1.050	0.078	0.885	0.10	—	—	—	—	—	—
1	1.315	0.097	1.109	0.16	—	—	—	—	—	—
1-1/4	1.660	0.123	1.399	0.26	—	—	—	—	—	—
1-1/2	1.900	0.141	1.601	0.34	—	—	—	—	—	—
2	2.375	0.176	2.002	0.53	0.140	2.078	0.43	—	—	—
3	3.500	0.259	2.951	1.15	0.206	3.063	0.93	0.184	3.110	0.84
4	4.500	0.333	3.794	1.90	0.265	3.938	1.54	0.237	3.998	1.39
5-3/8	5.375	0.398	4.531	4.53	0.316	4.705	2.20	0.283	4.775	1.98
5	5.563	0.412	4.690	2.91	0.327	4.870	2.35	0.293	4.942	2.12
6	6.625	0.491	5.584	4.13	0.390	5.798	3.34	0.349	5.885	3.01
7	7.125	0.528	6.006	4.78	0.419	6.237	3.86	0.375	6.330	3.48
8	8.625	0.639	7.270	7.00	0.507	7.550	5.65	0.454	7.663	5.10
10	10.750	0.796	9.062	10.87	0.632	9.410	8.87	0.566	9.550	7.92
12	12.750	0.944	10.749	15.29	0.750	11.160	12.36	0.671	11.327	11.14
14	14.000	1.037	11.802	18.45	0.824	12.253	14.91	0.737	12.438	13.43
16	16.000	1.185	13.488	24.09	0.941	14.005	19.46	0.842	14.215	17.54
18	18.000	1.333	15.174	30.48	1.059	15.755	24.64	0.947	15.992	22.20
20	20.000	1.481	16.860	37.63	1.176	17.507	30.41	1.053	17.768	27.41
22	22.000	1.630	18.544	45.56	1.294	19.257	36.80	1.158	19.545	33.16
24	24.000	1.778	20.231	54.21	1.412	21.007	43.81	1.263	21.322	39.47
26	26.000	1.926	21.917	63.62	1.529	22.759	51.39	1.368	23.100	46.32
28	28.000	2.074	23.603	73.78	1.647	24.508	59.62	1.474	24.875	53.72
30	30.000	2.222	25.289	84.69	1.765	26.258	68.45	1.579	26.653	61.66
32	32.000	2.370	26.976	96.35	1.882	28.010	77.86	1.684	28.430	70.16
34	34.000	2.519	28.660	108.81	2.000	29.760	87.91	1.790	30.205	79.20
36	36.000	2.667	30.346	121.98	2.118	31.510	98.57	1.895	31.983	88.80
42	42.000	—	—	—	2.471	36.761	134.16	2.211	37.314	120.86
48	48.000	—	—	—	2.824	42.013	175.23	2.526	42.644	157.86
54	54.000	—	—	—	3.177	47.265	221.71	2.842	47.975	199.79
63	63.000	—	—	—	—	—	—	—	—	—

* For data, sizes, or classes not reflected in these charts, please contact JM Eagle™ for assistance.

HDPE IRON PIPE SIZE (I.P.S.) PRESSURE PIPE (continued)

ANSI/NSF-61, 14 LISTED

PE 4710		**DR 21 (100 psi)**			**DR 26 (80 psi)**			**DR 32.5 (63 psi)**		
PE 3408/3608		**DR 21 (80 psi)**			**DR 26 (64 psi)**			**DR 32.5 (50 psi)**		
PIPE SIZE	**AVG. O.D.**	**MIN. T.**	**AVG. I.D.**	**WEIGHT LB/FT**	**MIN. T.**	**AVG. I.D.**	**WEIGHT LB/FT**	**MIN. T.**	**AVG. I.D.**	**WEIGHT LB/FT**
3	3.500	0.167	3.146	0.77	0.135	3.214	0.63	0.108	3.271	0.50
4	4.500	0.214	4.046	1.26	0.173	4.133	1.03	0.138	4.207	0.83
5-3/8	5.375	0.256	4.832	1.80	0.207	4.936	1.47	0.165	5.025	1.18
5	5.563	0.265	5.001	1.93	0.214	5.109	1.57	0.171	5.200	1.27
6	6.625	0.315	5.957	2.73	0.255	6.084	2.23	0.204	6.193	1.80
7	7.125	0.339	6.406	3.16	0.274	6.544	2.58	0.219	6.661	2.08
8	8.625	0.411	7.754	4.64	0.332	7.921	3.79	0.265	8.063	3.05
10	10.750	0.512	9.665	7.21	0.413	9.874	5.87	0.331	10.048	4.75
12	12.750	0.607	11.463	10.13	0.490	11.711	8.26	0.392	11.919	6.67
14	14.000	0.667	12.586	12.22	0.538	12.859	9.96	0.431	13.086	8.05
16	16.000	0.762	14.385	15.96	0.615	14.696	13.01	0.492	14.957	10.50
18	18.000	0.857	16.183	20.20	0.692	16.533	16.47	0.554	16.826	13.30
20	20.000	0.952	17.982	24.93	0.769	18.370	20.34	0.615	18.696	16.41
22	22.000	1.048	19.778	30.18	0.846	20.206	24.61	0.677	20.565	19.86
24	24.000	1.143	21.577	35.19	0.923	22.043	29.30	0.738	22.435	23.62
26	26.000	1.238	23.375	42.14	1.000	23.880	34.39	0.800	24.304	27.74
28	28.000	1.333	25.174	48.86	1.077	25.717	39.88	0.862	26.173	32.19
30	30.000	1.429	26.971	56.12	1.154	27.554	45.79	0.923	28.043	36.93
32	32.000	1.542	28.730	63.84	1.231	29.390	52.10	0.985	29.912	42.04
34	34.000	1.619	30.568	72.06	1.308	31.227	58.81	1.046	31.782	47.43
36	36.000	1.714	32.366	80.78	1.385	33.064	65.94	1.108	33.651	53.20
42	42.000	2.000	37.760	109.97	1.615	38.576	89.71	1.292	39.261	72.37
48	48.000	2.286	43.154	143.65	1.846	44.086	117.18	1.477	44.869	94.56
54	54.000	2.571	48.549	181.75	2.077	49.597	148.33	1.662	50.477	119.70
63	63.000	3.000	56.640	247.42	2.423	57.863	201.88	1.938	58.891	162.84

* For custom DR, perforated pipe, please contact JM Eagle™ PE sales at (800) 621-4404 for availability.
* All dimensions are in inches unless noted otherwise.

I.D. : Inside Diameter
O.D. : Outside Diameter
T. : Wall Thickness

POLYETHYLENE WATER & SEWER

JM Eagle

Building essentials for a better tomorrow™

SUBMITTAL AND DATA SHEET

JM EAGLE™ HDPE DUCTILE IRON PIPE SIZE (D.I.P.S.) PRESSURE PIPE

ANSI/NSF-61, 14 LISTED

PE 4710		DR 7 (335 psi)			DR 9 (250 psi)			DR 11 (200 psi)		
PE 3408/3608		DR 7 (265 psi)			DR 9 (200 psi)			DR 11 (160 psi)		
PIPE SIZE	AVG. O.D.	MIN. T.	AVG. I.D.	WEIGHT LB/FT	MIN. T.	AVG. I.D.	WEIGHT LB/FT	MIN. T.	AVG. I.D.	WEIGHT LB/FT
4	4.800	0.686	3.346	3.85	0.533	3.670	3.11	0.436	3.876	2.61
6	6.900	0.946	4.894	7.96	0.767	5.274	6.43	0.627	5.571	5.39
8	9.050	1.293	6.309	13.69	1.006	6.917	11.07	0.823	7.305	9.28
10	11.100	1.586	7.738	20.59	1.233	8.486	16.65	1.009	8.961	13.95
12	13.200	1.886	9.202	29.12	1.467	10.090	23.55	1.200	10.656	19.73
14	15.300	2.186	10.666	39.12	1.700	11.696	31.64	1.391	12.351	26.51
16	17.400	2.486	12.130	50.60	1.933	13.302	40.92	1.582	14.046	34.29
18	19.500	2.786	13.594	63.55	2.167	14.906	51.39	1.773	15.741	43.07
20	21.600	3.086	15.058	77.98	2.400	16.512	63.05	1.964	17.436	52.85
24	25.800	—	—	—	2.867	19.722	89.96	2.345	20.829	75.38
30	32.000	—	—	—	—	—	—	2.909	25.833	115.97
36	—	—	—	—	—	—	—	—	—	—
42	—	—	—	—	—	—	—	—	—	—
48	—	—	—	—	—	—	—	—	—	—
54	—	—	—	—	—	—	—	—	—	—

* For data, sizes, or classes not reflected in these charts, please contact JM Eagle™ for assistance.

PE 4710		DR 13.5 (160 psi)			DR 17 (125 psi)			DR 19 (112 psi)		
PE 3408/3608		DR 13.5 (128 psi)			DR 17 (100 psi)			DR 19 (90 psi)		
PIPE SIZE	AVG. O.D.	MIN. T.	AVG. I.D.	WEIGHT LB/FT	MIN. T.	AVG. I.D.	WEIGHT LB/FT	MIN. T.	AVG. I.D.	WEIGHT LB/FT
4	4.800	0.356	4.045	2.17	0.282	4.202	1.75	0.253	4.264	1.58
6	6.900	0.511	5.817	4.48	0.406	6.039	3.62	0.363	6.130	3.26
8	9.050	0.670	7.630	7.70	0.532	7.922	6.22	0.476	8.041	5.61
10	11.100	0.822	9.357	11.59	0.653	9.761	9.37	0.584	9.862	8.44
12	13.200	0.978	11.127	16.40	0.776	11.555	13.24	0.695	11.727	11.94
14	15.300	1.133	12.898	22.02	0.900	13.392	17.80	0.805	13.593	16.04
16	17.400	1.289	14.667	28.49	1.024	15.229	23.03	0.916	15.458	20.74
18	19.500	1.444	16.439	35.77	1.147	17.068	28.91	1.026	17.325	26.05
20	21.600	1.600	18.208	43.91	1.271	18.905	35.49	1.137	19.190	31.97
24	25.800	1.911	21.749	62.64	1.518	22.582	50.63	1.358	22.921	45.61
30	32.000	2.370	26.976	96.35	1.880	28.014	77.86	1.684	28.430	70.16
36	38.300	2.837	32.286	138.04	2.253	33.524	111.55	2.016	34.026	100.50
42	44.500	—	—	—	2.618	38.950	150.60	2.342	39.535	135.68
48	50.800	—	—	—	2.988	44.465	196.23	2.674	45.131	176.81
54	57.100	—	—	—	—	—	—	—	—	—

JM EAGLE™ HDPE DUCTILE IRON PIPE SIZE (D.I.P.S.) PRESSURE PIPE (continued)

ANSI/NSF-61, 14 LISTED

PE 4710		DR 21 (100 psi)			DR 26 (80 psi)			DR 32.5 (63 psi)		
PE 3408/3608		**DR 21 (80 psi)**			**DR 26 (64 psi)**			**DR 32.5 (50 psi)**		
PIPE SIZE	**AVG. O.D.**	**MIN. T.**	**AVG. I.D.**	**WEIGHT LB/FT**	**MIN. T.**	**AVG. I.D.**	**WEIGHT LB/FT**	**MIN. T.**	**AVG. I.D.**	**WEIGHT LB/FT**
4	4.800	0.229	4.315	1.44	0.185	4.408	1.17	0.148	4.486	0.95
6	6.900	0.329	6.203	2.97	0.265	6.338	2.42	0.212	6.451	1.95
8	9.050	0.431	8.136	5.11	0.348	8.312	4.17	0.278	8.461	3.36
10	11.100	0.529	9.979	7.69	0.427	10.195	6.27	0.342	10.375	5.06
12	13.200	0.629	11.867	10.87	0.508	12.123	8.87	0.406	12.339	7.15
14	15.300	0.729	13.755	14.60	0.588	14.053	11.90	0.471	14.301	9.61
16	17.400	0.829	15.643	18.88	0.669	15.982	15.39	0.536	16.264	12.44
18	19.500	0.929	17.531	23.71	0.750	17.910	19.34	0.600	18.228	15.60
20	21.600	1.029	19.419	29.10	0.831	19.838	23.74	0.665	20.190	19.16
24	25.800	1.229	23.195	41.51	0.992	23.697	33.85	0.794	24.117	27.32
30	32.000	1.524	28.769	63.84	1.231	29.390	52.10	0.985	29.912	42.04
36	38.300	1.824	34.433	91.45	1.473	35.177	74.61	1.179	35.801	60.18
42	44.500	2.119	40.008	123.44	1.712	40.871	100.75	1.370	41.596	81.25
48	50.800	2.419	45.672	160.87	1.954	46.658	131.28	1.563	47.486	105.90
54	57.100	2.719	51.336	203.25	2.196	52.444	165.83	1.757	53.375	133.81

* For custom DR, perforated pipe, please contact JM Eagle™ PE sales at (800) 621-4404 for availability.

* All dimensions are in inches unless noted otherwise.

COPPER TUBING SIZES (C.T.S.) PRESSURE PIPE ASTM D2737

ANSI/NSF-61, 14 LISTED

PE 4710		DR 7 (335 psi)			DR 9 (250 psi)			DR 11 (200 psi)		
PE 3408/3608		**DR 7 (265 psi)**			**DR 9 (200 psi)**			**DR 11 (160 psi)**		
PIPE SIZE	**AVG. O.D.**	**MIN. T.**	**AVG. I.D.**	**WEIGHT LB/FT**	**MIN. T.**	**AVG. I.D.**	**WEIGHT LB/FT**	**MIN. T.**	**AVG. I.D.**	**WEIGHT LB/FT**
1/2	0.625	0.090	0.434	0.07	0.069	0.479	0.05	0.062	0.494	0.05
3/4	0.875	0.125	0.610	0.13	0.097	0.669	0.10	0.080	0.705	0.09
1	1.125	0.160	0.786	0.21	0.125	0.860	0.17	0.102	0.909	0.14
1-1/4	1.375	0.196	0.959	0.32	0.153	1.051	0.26	0.125	1.110	0.21
1-1/2	1.625	0.232	1.133	0.44	0.181	1.241	0.36	0.148	1.311	0.30
2	2.125	0.304	1.481	0.76	0.236	1.625	0.61	0.193	1.716	0.51

Building essentials
for a better tomorrow™

POLYETHYLENE WATER & SEWER

SUBMITTAL AND DATA SHEET

S.I.D.R. PRESSURE PIPE ASTM D2239

ANSI/NSF-61, 14 LISTED

PE 4710		DR 7 (335 psi)			DR 9 (250 psi)			DR 11.5 (190 psi)		
PE 3408/3608		DR 7 (200 psi)			DR 9 (160 psi)			DR 11.5 (125 psi)		
PIPE SIZE	AVG. I.D.	MIN. T.	AVG. O.D.	WEIGHT LB/FT	MIN. T.	AVG. O.D.	WEIGHT LB/FT	MIN. T.	AVG. I.D.	WEIGHT LB/FT
½	0.622	0.089	0.800	0.09	0.069	0.760	0.07	0.060	0.742	0.06
¾	0.824	0.118	1.060	0.15	0.092	1.008	0.12	0.072	0.968	0.09
1	1.049	0.150	1.349	0.25	0.117	1.283	0.19	0.091	1.231	0.14
1¼	1.380	0.197	1.774	0.43	0.153	1.686	0.33	0.120	1.620	0.25
1½	1.610	0.230	2.070	0.59	0.179	1.968	0.44	0.140	1.890	0.34
2	2.067	0.295	2.657	0.97	0.230	2.527	0.73	0.180	2.427	0.56
2½	2.469	—	—	—	—	—	—	0.215	2.899	0.80
3	3.068	—	—	—	—	—	—	0.267	3.602	1.23
4	4.026	—	—	—	—	—	—	0.350	4.726	2.12
6	6.065	—	—	—	—	—	—	0.527	7.119	4.81

PE 4710		DR 15 (144 psi)			DR 19 (112 psi)		
PE 3408/3608		DR 15 (100 psi)			DR 19 (80 psi)		
PIPE SIZE	AVG. I.D.	MIN. T.	AVG. O.D.	WEIGHT LB/FT	MIN. T.	AVG. O.D.	WEIGHT LB/FT
½	0.622	0.060	0.742	0.06	0.060	0.742	0.06
¾	0.824	0.060	0.944	0.07	0.060	0.944	0.07
1	1.049	0.070	1.189	0.11	0.060	1.169	0.09
1¼	1.380	0.092	1.564	0.19	0.073	1.526	0.15
1½	1.610	0.107	1.824	0.25	0.085	1.780	0.20
2	2.067	0.138	2.343	0.42	0.109	2.285	0.33
2½	2.469	0.165	2.799	0.60	0.130	2.729	0.47
3	3.068	0.205	3.478	0.93	0.161	3.390	0.72
4	4.026	0.268	4.562	1.59	0.212	4.450	1.24
6	6.065	0.404	6.873	3.62	0.319	6.703	2.82

I.D. : Inside Diameter
O.D. : Outside Diameter
T. : Wall Thickness

* For data, sizes, or classes not reflected in these charts, please contact JM Eagle™ for assistance.

Building essentials
for a better tomorrow™

POLYETHYLENE WATER & SEWER

SUBMITTAL AND DATA SHEET

GEO-FLO HDPE GEOTHERMAL PIPE AND TUBING

Geo-flo HDPE Geothermal Pipe and tubing is produced to ASTM D3035 for smaller diameters and ASTM F714 for sizes 3” through 12”.

ANSI/NSF-61, 14 LISTED

NOMINAL PIPE SIZE (IN)	AVERAGE O.D. (IN)	APPROX. I.D. (IN)	MIN. WALL THICKNESS (IN)	APPROX. WEIGHT (LBS/FT)
HDPE SDR 7 - P.R. 265 psi				
¾	1.050	0.730	0.150	0.18
1	1.315	0.910	0.188	0.28
1¼	1.660	1.150	0.237	0.45
1½	1.900	1.320	0.271	0.59
2	2.375	1.650	0.339	0.92
HDPE SDR 9 - P.R. 200 psi				
¾	1.050	0.800	0.117	0.15
1	1.315	1.000	0.146	0.23
1¼	1.660	1.270	0.184	0.36
1½	1.900	1.450	0.211	0.48
2	2.375	1.810	0.264	0.75
3	3.500	2.670	0.389	1.62
4	4.500	3.450	0.500	2.67
6	6.625	5.030	0.736	5.79
8	8.625	6.593	0.958	10.05
10	10.750	8.218	1.194	15.61
12	12.750	9.747	1.417	21.97
HDPE SDR 11 - P.R. 160 psi				
¾	1.050	0.850	0.095	0.12
1	1.315	1.060	0.120	0.19
1¼	1.660	1.340	0.151	0.30
1½	1.900	1.530	0.173	0.40
2	2.375	1.910	0.216	0.62
3	3.500	2.820	0.318	1.35
4	4.500	3.640	0.409	2.24
6	6.625	5.360	0.602	4.85
8	8.625	6.960	0.784	8.42
10	10.750	8.680	0.977	13.09
12	12.750	10.290	1.159	18.41

POLYETHYLENE WATER & SEWER

SUBMITTAL AND DATA SHEET

REFERENCE STANDARDS

ASTM D638	Standard Test Method for Tensile Properties of Plastics
ASTM D746	Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact
ASTM D790	Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulation Materials
ASTM D1238	Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
ASTM D1505	Standard Test Method for Density of Plastics by the Density-Gradient Technique
ASTM D2239	Standard Specification for Polyethylene (PE) Plastic Pipe (S.I.D.R.-PR) Based on Controlled Inside Diameter
ASTM D2657	Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
ASTM D2737	Standard Specification for Polyethylene (PE) Plastic Tubing
ASTM D2774	Standard Practice for Underground Installation of Thermoplastic Pressure Piping
ASTM D2837	Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials
ASTM D3035	Standard Specifications for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter
ASTM D3350	Standard Specification for Polyethylene Plastic Pipe and Fittings Material
ASTM F412	Standard Terminology Relating to Plastic Piping Systems
ASTM F714	Standard Specification for Polyethylene (PE) Plastic Pipe (S.D.R.-PR) Based on Outside Diameter
ASTM F1473	Standard Test Method for Notch Tensile to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins
AWWA C901	Polyethylene (PE) Pressure Pipe and Tubing, 1/2 in. Through 3 in. For Water Service
AWWA C906	Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 63 in., For Water Distribution and Transmission
NSF Standard 014	Plastics Piping System Components and Related Materials
NSF Standard 061	Drinking Water System Components - Health Effects

MIRAFI® ____________________ TECHNICAL DATA SHEET

Mirafi ® 180N

Mirafi ® 180N is a nonwoven geotextile composed of polypropylene fibers, which are formed into a stable network such that the fibers retain their relative position. 180N is inert to biological degradation and resists naturally encountered chemicals, alkalis, and acids.

Mechanical Properties	Test Method	Unit	Minimum Average Roll Value	
			MD	CD
Grab Tensile Strength	ASTM D 4632	kN (lbs)	0.9 (205)	0.9 (205)
Grab Tensile Elongation	ASTM D 4632	%	50	50
Trapezoid Tear Strength	ASTM D 4533	kN (lbs)	0.36 (80)	0.36 (80)
Mullen Burst Strength	ASTM D 3786	kPa (psi)	2618 (380)	
Puncture Strength	ASTM D 4833	kN (lbs)	0.58 (130)	
Apparent Opening Size (AOS)	ASTM D 4751	mm (U.S. Sieve)	0.180 (80)	
Permittivity	ASTM D 4491	sec^{-1}	1.2	
Permeability	ASTM D 4491	cm/sec	0.21	
Flow Rate	ASTM D 4491	l/min/m^2 (gal/min/ft^2)	3866 (95)	
UV Resistance (at 500 hours)	ASTM D 4355	% strength retained	70	

Physical Properties	Test Method	Unit	Typical Value
Weight	ASTM D 5261	g/m^2 (oz/yd^2)	278 (8.2)
Thickness	ASTM D 5199	mm (mils)	2.3 (90)
Roll Dimensions (width x length)	--	m (ft)	4.5 x 91 (15 x 300)
Roll Area	--	m^2 (yd^2)	418 (500)
Estimated Roll Weight	--	kg (lb)	124 (273)