Springbank Off-Stream Storage Project Preliminary Design Report

Appendix F - Civil

September 25, 2020

Prepared for:

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Sign-off Sheet

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2020-09-25

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Stantec Consulting Ltd.
APEGA Permit Number P258

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Eric Monteith P.Eng., Senior Vice President

APPENDIX F.1 – DIVERSION STRUCTURE

APPENDIX F.1-1 – DIVERSION STRUCTURE UPSTREAM RIPRAP APRON

Riprap Apron for Diversion Structures Calculations

Springbank Off-Stream Reservior Project
Alberta, Canada
Alberta Transportation Department

1. OBJECTIVE/PURPOSE

The objectives of this calculation package is to size the appropriate rip rap for upstream protection of the diversion structures.

2. CRITERIA

USACE EM 1110-2-1601 (1991) Method and Mark Slack Associates (2004)

3. REFERENCES

1. USACE. (1991). Hydraulic Design of Flood Control Channels. U.S. Army Corps of Engineers.

2. Mark Slack Associates (2004). Water Control Structures Selected Design Guidelines. Submitted to: Alberta Transportation Department. Calgary, Alberta.

4. Riprap Size Calculations

4.1 Channel Velocity and Depth

The channel velocity was determined by reviewing the output of the RIVER FLOW 2D Model velocity distribution profiles for the 765 cms, 1240 cms no diversion and 1240 events. The highest velocities at five different locations were identified based on overall velocity distribtion (Figure 1: next page) and channel depth (Figure 2).

Point E shown below would require significant armoring, therefore the concrete apron has been extended out to armor this location. The rip rap apron in front of the diversion inlet and service spillway has been design by utilizin the flow velocities and depth at Point D. This location resulted required in the highest required protection.

Point A and B represent the higher velocities and depth experienced near the debris barrier. The rip rap apron has been extended between the shoreline and the debris barrier for additional armoring.

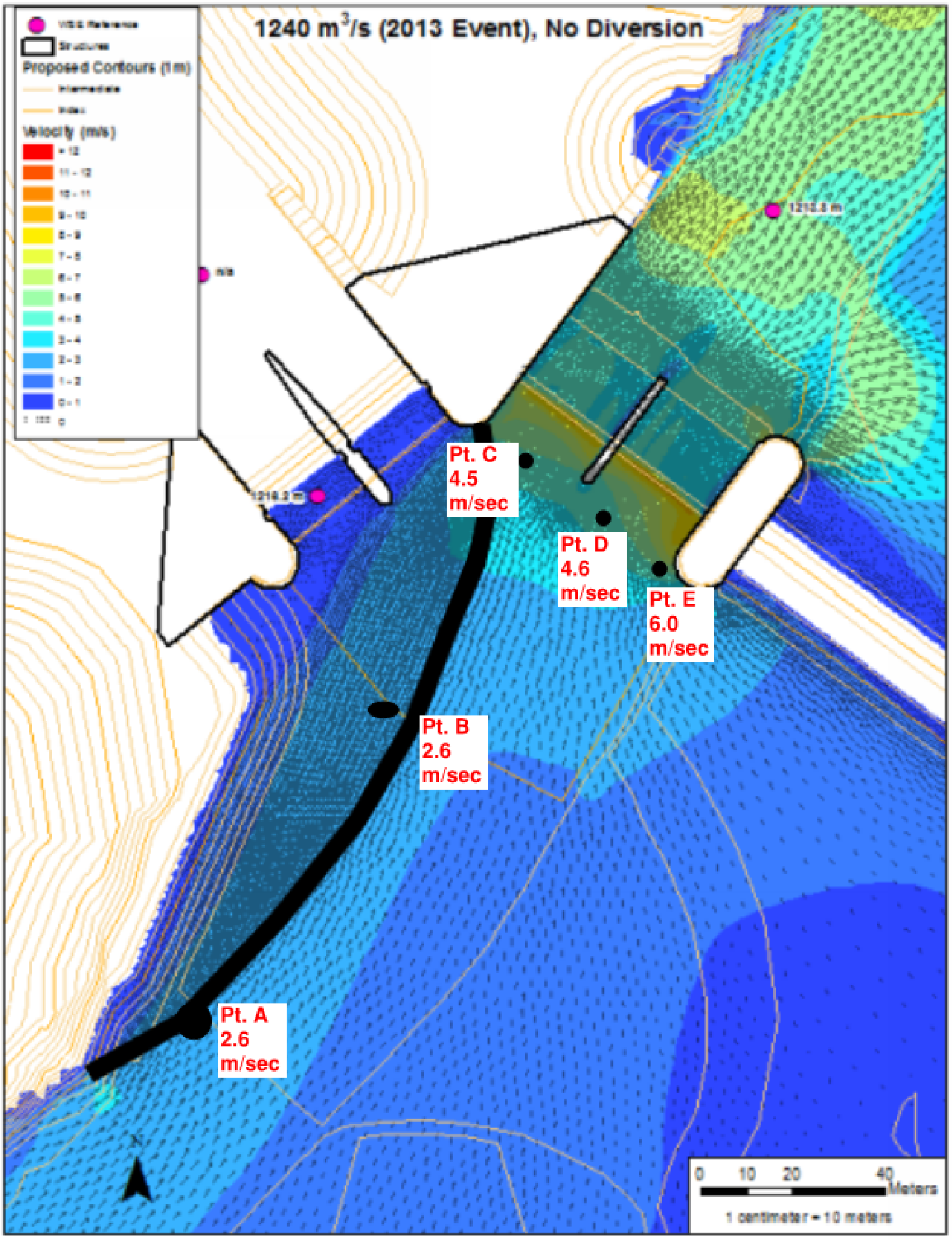


Figure 1. Velocity profile- 1240 cms No Diversion Event

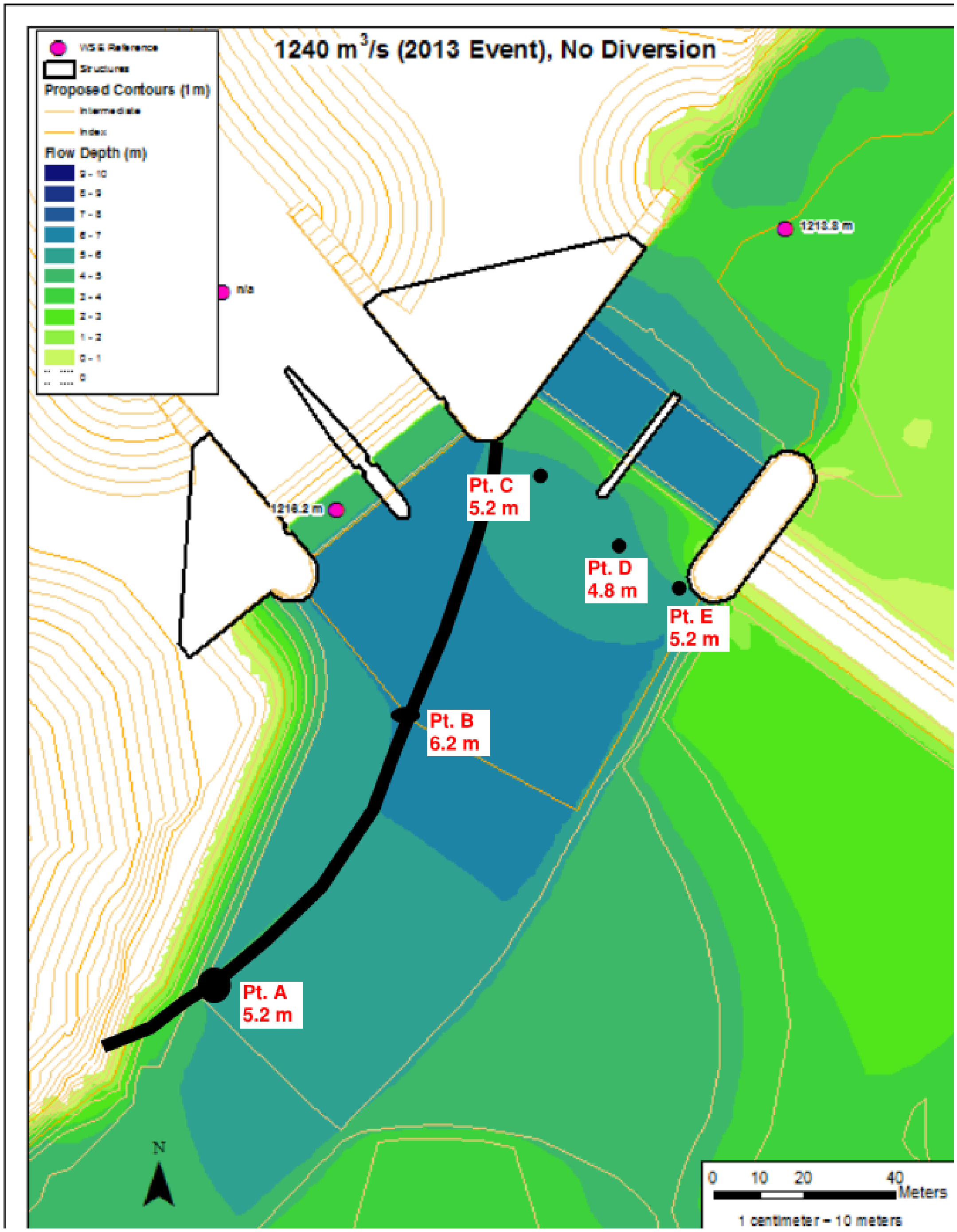


Figure 2. Depth profile-1240 cms No Diversion Event

4.2 Calculations

Using equation 3-3 of USACE (1994):

$$D_{30} = S_f C_S C_V C_T d \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{1/2} \frac{V}{\sqrt{K_1 g d}} \right]^{2.5}$$

Where

Saftey Factor: $S_f := 1.3$

Stability coefficient for incipient failure: $C_s := 0.3$ (Angular rock)

Vertical velocity distribution coefficient: $C_v := 1$ (For straight channels)

Thickness coefficient $C_T := 1$ [For thickness 1D100(max) or 1.5D50(max)]

Velocity: $v := 4.6 \frac{m}{s}$ (From Figure 1)

Local depth of flow: $d := 4.8m$ (From Figure 2)

Unit weight of water $\gamma_w := 1000 \frac{kg}{m^3}$

Unit weight of stone: $\gamma_s := 2643 \frac{kg}{m^3}$

Side slope correction factor:

Currently the riprap apron is not anticipated to have a significant side slope. However final grading of the area may include partial side slopes. Therefore, a 5 percent angle of the side slope has been included as a conservative estimate to account for any potential side slope which may result from final grading of the channel.

Angle of side slope with horizontal: $\theta := 5°$

Angle of repose of riprap material: $\varphi := 35°$

Side slope correction factor: $K_1 := \sqrt{1 - \frac{(\sin(\theta))^2}{(\sin(\varphi))^2}} = 0.99$

Gravitational Constant: $g = 9.81 \frac{m}{s^2}$

4.2.1 Riprap sizing (D30)

$$D_{30} := S_f \cdot C_s \cdot C_v \cdot C_T \cdot d \cdot \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{0.5} \frac{v}{\sqrt{K_1 \cdot g \cdot d}} \right]^{2.5} = 376 \cdot mm$$

5.0 Riprap sizing (D50)

$$D_{50} := 1.25 \cdot D_{30} = 470 \cdot mm$$

6.0 Select Appropriate Alberta Transportation Riprap Class

$D_{30} = 376 \cdot mm$

$D_{50} = 470 \cdot mm$

From Figure 3, the Alberta Transportation Class 2 Riprap has a D50 of 500 mm and D100 of 800 mm which exceeds the required D50 of 470 mm and therefore appropriate for this application.

Assume riprap layer thickness of larger of 2X D50 or D100, which in this case 1600 mm (2 x D50)

		CLASS			
		1M	**1**	**2**	**3**
Nominal Mass (kg) **Nominal Diameter (mm)**		**7** **175**	**40** **300**	**200** **500**	**700** **800**
None greater than:	kg or mm	40 300	130 450	700 800	1800 1100
20% to 50%	kg or mm	10 200	70 350	300 600	1100 900
50% to 80%	kg or mm	7 175	40 300	200 500	700 800
100% greater than:	kg or mm	3 125	10 200	40 300	200 500

Figure 3. Alberta Transportation-Typical Rip Rap Gradations

APPENDIX F.1-2 – DIVERSION STRUCTURE DOWNSTREAM SCOUR CALCULATIONS

Scour Analysis

Springbank Off-Stream Reservior Project
Alberta, Canada
Alberta Transportation Department

1. OBJECTIVE/PURPOSE

The objectives of this calculation package is to determine the elevation where scour of the bedrock is unlikely to occur at the downstream side of the service spillway during the 1240 m^3/s event with no diversion by utilizing Annadale Method.

2. CRITERIA

Stream power-erodibility index method (USBR and USACE, 2015)

3. REFERENCES

1. USBR & USACE. (2015). Best Practices in Dam and Levee Saftey Risk Analysis. U.S. Department of the Interior, Bureau of Reclamation, and U.S. Army Corps of Engineers.

2.Annadale, G.W. (1995). Erodibilit. Journal Hydraulic Research, IAHR, Vol 33(4):471-494.

3. Wibowo, J.L., D.E. Yule and Villanueva (2005). Earth and Rock Surface Spillway Erosion Risk Assesment, Proceedings, 40th U.S. Symposium on Rock Mechanics, Anchorage Alaska.

4. Erodability Index Calculation

Bedrock Erodibility Index

Bedrock Consist of ~40% Mudstone, 30% Shale, 20% Claystone and 10% Sandstone

Mass Strength: $M_{s1} := 1.86$ MPa Based on lab testing results

Rock Quality Designation: $RQD_1 := 20$ Based on the general RQD of the top 5m of bedrock

Modified Joint Set Number: $J_{n1} := 5$ More than 5 joints sets

Particle of Fragment Size of the Rock that form the Mass: $K_{b1} := \frac{RQD_1}{J_{n1}} = 4$

Joint Roughness: $J_{r1} := 1$ Assume worse case

Joint Alteration Numbers: $J_{a1} := 13$ Worst case for joint alteration

Interparticle Bond Shear Strength: $K_{d1} := \frac{J_{r1}}{J_{a1}} = 0.08$

Coefficient to Account for Relative Shape and Orientation: $J_{s1} := 0.57$ Worst case 85% dip against the direction of flow

Erodibility Index: $K_{h1} := M_{s1} \cdot K_{b1} \cdot K_{d1} \cdot J_{s1} = 0.326$

5. Stream Power Potential

5.1 Hydraulic Analysis

Hydraulic analysis performed using the results of the 2D hydraulic model. The 2D model simulation assumed formation of a scour hole would form in the bedrock down to a minimum elevation of 1207.0 m . Refer to Hydraulic Appendix for hydraulic analysis results.

The Table Below Summarizes the Results of the 2-D Model for a Ground Elevation of 1207m

Station from DS of wall (m)	Avg Vel (m/s)	Avg WSE (m)	Avg Dep (m)	EGL Slope (m/m)	Stream Power (kN/m-s)
0+00	3.49	1214.05	7.04	0.0004	0.11
0+20	3.12	1214.17	6.98	0.0010	0.21
0+40	3.33	1214.07	6.05	0.0020	0.39
0+60	3.22	1214.06	5.99	0.0025	0.47
0+80	3.15	1214.02	5.92	0.0028	0.51
1+00	3.33	1213.91	5.35	0.0029	0.51

5.1 Stream Power for Surface Flow (Example Calculation - Sta: 0+00)

Unit weight of water: $\gamma_w := 9.82 \ \frac{kN}{m^3}$

Average Velocity: $v_1 := 3.49 \ \frac{m}{s}$

Depth of Flow: $d_1 := 7.04 \ m$

Slope of Energy Grade Line: $sl := .000442 \frac{m}{m}$

Stream Power Potential: $p_1 := \gamma_w \cdot v_1 \cdot d_1 \cdot sl = 0.107 \ \frac{kW}{m^2}$

6. Likelihood of Erosion

The figure shown below can be used to estimate the erosion potential based upon the Erodibility Index and Stream Power Estimate. The dashed line in the figure is the initial erosion threshold proposed by Annadale (1995) based on a review of 150 field observations from spillway channels and plunge pools.

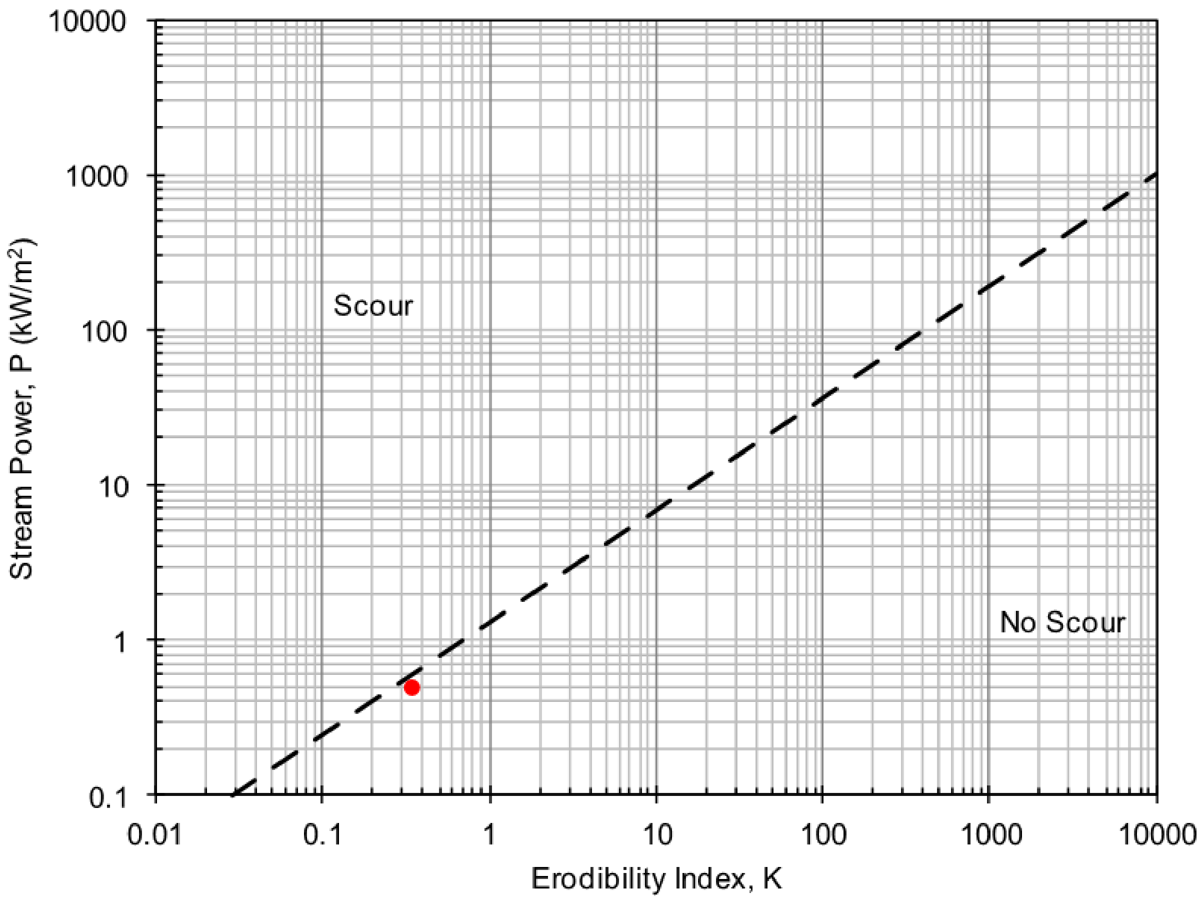


Figure IV-1-6 – Erodibility Threshold Graph (Annandale, 1995)

The red dot on the figure represents the highest calculated Stream Power value as shown in the table above (Stream Power = 0.51 kN/m^2). This point is slightly below the dashed line indicated it is unlikely it will scour. Given the short duration of the peak flows of the 1240- No diversion event, it is unlikley their will be significant scour during this time.

Therefore once the ground Elevation has reached 1207.0 m, scour is considered to be unlikely and thus scour protection is needed to a minimum elevation of 1207.0 m

APPENDIX F.1-3 – DIVERSION STRUCTURE AREA DRAINAGE

Drainage Ditch Runoff

Springbank Off-Stream Reservoir Project

Alberta, Canada

Alberta Transportation Department

Objective/Purpose

The objective of this calculation is to calculate runoff to the drainage ditch leading to the in-stream gate structure and size the drainage ditch.

Criteria

Rational Method (AT, 2011)

References

1. AT (2011). Erosion and Sediment Control Manual. Government of Alberta Transportation (AT).
2. USACE (2011). AED Design Requirements: Hydrology Studies, Various Locations, Afghanistan. US Army Corps of Engineers, Afghanistan Engineer District.
3. AEP (1999). Stormwater Management Guidelines for the Province of Alberta. Alberta Environmental Projection. Edmonton, Alberta.
4. Rainfall Intensity_Calgary International Airport, AB 3031093 Rainfall Duration Curves.
5. Chow, Maidment, and Mays. Applied Hydrology. McGraw-Hill. 1988.

Calculations

Rational Method: $Q = 0.278\ C \times I \times A$

Where,

Q = Peak flow (cms)

C = Dimensionless runoff coefficient

I = Rainfall Intensity (mm/hr)

A = Drainage Area (square km)

Runoff Coefficient

Earth embankments at 10-year storm frequency, USACE (2011), reported runoff coefficients as 0.6. For 25-year frequency, runoff coefficient is generally multiplied by a factor of 1.10 (AEP 1999). Embankment C = 0.66.

From Chow, Maidment, and Mays: C for forest woodlands, flat (0 – 2% slope), 25-year storm frequency, C = 0.31. C for pasture/range, flat (0 – 2% slope), 25-year storm frequency, C = 0.34.

From AEP (1999) Stormwater Management Guidelines, for paved parking, mean C = 0.83 for 10-year storm frequency. Adjusting for 25-year storm frequency (multiply by 1.1), C = 0.91.

Rainfall Intensity: Calgary Airport, AB 3031093

25-year Rainfall Intensity: 33 mm/hr

Discharge Areas:

From attached drainage area map, total drainage area = 87,970 sq m

Range ≈ 25% ≈ 21,993 sq m ≈ 0.02199 sq km

Forest ≈ 10% ≈ 8797 sq m ≈ 0.008797 sq km

Embankment ≈ 65% ≈ 57180 sq m ≈ 0.05718 sq km

Peak Discharge Calculation: Q = 0.278 C x I x A

Range: Q = 0.278*0.34*33mm/hr*0.02199 sq km = 0.0686 cms

Forest: Q = 0.278*0.31*33mm/hr*0.008797 sq km = 0.025 cms

Embankment: Q = 0.278*0.66*33mm/hr*0.05718 sq km = 0.346 cms

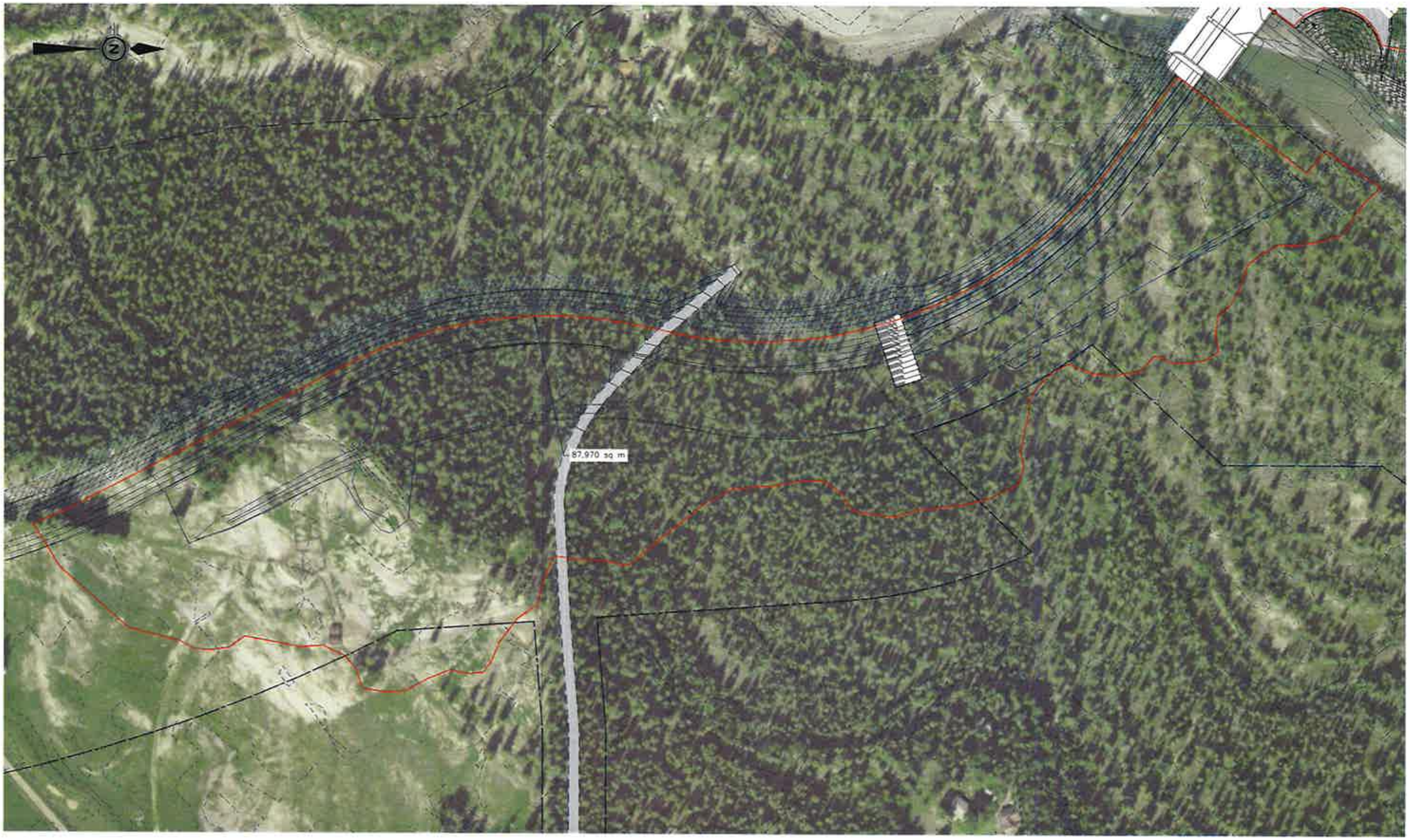
Total Q = 0.4396, using SF = 2.5 for ditch sizing, Q = 1.1 cms

Ditch Sizing

Assume 1 m bottom width, 3H:1V side slopes. See attached spreadsheet for ditch sizing calculations.

Water depth in ditch = 0.5 m

Velocity = 0.87 m/s



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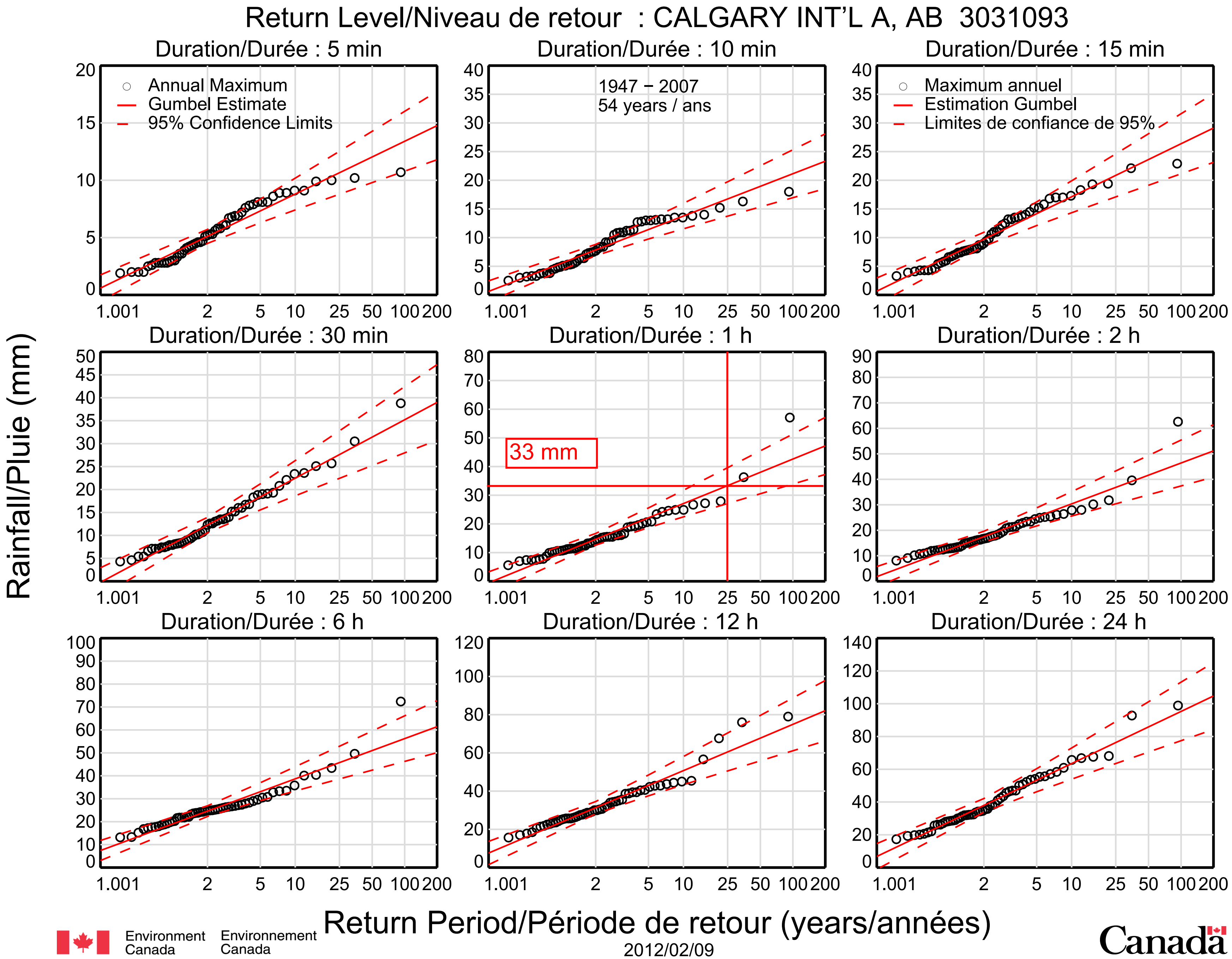


Environment Canada Environnement Canada

Canada

Drainage Ditch

Side slope of channel (z)	3	
Roughness	0.04	$s/(m^{1/3})$
Bottom width of channel (wb)	1	m
Slope	0.006	m/m
Q	1.1	m^3/s
h	0.50	m guess
Area (A)	1.262314	
Wetted Perimeter (P)	4.181704	
f(h)	1.1	
f(h)-Q	5.63E-08	

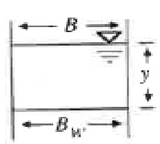
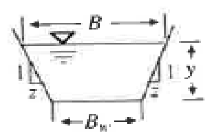
Check Velocity

v = 0.87 m/s

Manning's Equation x Area to solve for Q, for Trapezoidal Channel

$$f(h) = \frac{1}{n}\left[\frac{(wb + z * h)h}{wb + 2h\sqrt{1+z^2}}\right]^{\frac{2}{3}} * \sqrt{S} * [(wb + zh)h]$$

TABLE 5.6.1
Geometric functions for channel elements

Section:	Rectangle	Trapezoid
		
Area A	$B_w y$	$(B_w + zy)y$
Wetted perimeter P	$B_w + 2y$	$B_w + 2y\sqrt{1+z^2}$
Hydraulic radius R	$\frac{B_w y}{B_w + 2y}$	$\frac{(B_w + zy)y}{B_w + 2y\sqrt{1+z^2}}$
Top width B	B_w	$B_w + 2zy$
$\frac{2}{3R}\frac{dR}{dy} + \frac{1}{A}\frac{dA}{dy}$	$\frac{5B_w + 6y}{3y(B_w + 2y)}$	$\frac{(B_w + 2zy)(5B_w + 6y\sqrt{1+z^2}) + 4zy^2\sqrt{1+z^2}}{3y(B_w + zy)(B_w + 2y\sqrt{1+z^2})}$

Source: Chow, V. T., *Open-Channel Hydraulics*, McGraw-Hill, New York, 1959, Table 2.1, p. 21 (with additions).

from Chow, Maidment, and Mays. Applied Hydrology. McGraw Hill 1988. p 162

from Chow, Maidment, and Mays. Applied Hydrology. McGraw Hill 1988. p 498

TABLE 15.1.1
Runoff coefficients for use in the rational method

Character of surface	2	5	10	25	50	100	500
	Return Period (years)						
Developed							
Asphaltic	0.73	0.77	0.81	0.86	0.90	0.95	1.00
Concrete/roof	0.75	0.80	0.83	0.88	0.92	0.97	1.00
Grass areas (lawns, parks, etc.)							
Poor condition (grass cover less than 50% of the area)							
Flat, 0–2%	0.32	0.34	0.37	0.40	0.44	0.47	0.58
Average, 2–7%	0.37	0.40	0.43	0.46	0.49	0.53	0.61
Steep, over 7%	0.40	0.43	0.45	0.49	0.52	0.55	0.62
Fair condition (grass cover on 50% to 75% of the area)							
Flat, 0–2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2–7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Good condition (grass cover larger than 75% of the area)							
Flat, 0–2%	0.21	0.23	0.25	0.29	0.32	0.36	0.49
Average, 2–7%	0.29	0.32	0.35	0.39	0.42	0.46	0.56
Steep, over 7%	0.34	0.37	0.40	0.44	0.47	0.51	0.58
Undeveloped							
Cultivated Land							
Flat, 0–2%	0.31	0.34	0.36	0.40	0.43	0.47	0.57
Average, 2–7%	0.35	0.38	0.41	0.44	0.48	0.51	0.60
Steep, over 7%	0.39	0.42	0.44	0.48	0.51	0.54	0.61
Pasture/Range							
Flat, 0–2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2–7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Forest/Woodlands							
Flat, 0–2%	0.22	0.25	0.28	0.31	0.35	0.39	0.48
Average, 2–7%	0.31	0.34	0.36	0.40	0.43	0.47	0.56
Steep, over 7%	0.35	0.39	0.41	0.45	0.48	0.52	0.58

Note: The values in the table are the standards used by the City of Austin, Texas. Used with permission.

Table 4-3
Typical Urban Runoff Coefficients for 5- to 10-year Storms

Description		Runoff Coefficient		
		Minimum	Mean	Maximum
Pavement	asphalt or concrete	0.70	0.83	0.95
Roofs		0.70	0.83	0.95
Business	downtown	0.70	0.83	0.95
	neighbourhood	0.50	0.60	0.70
Industrial	light	0.50	0.65	0.80
	heavy	0.60	0.75	0.90
Residential	single family urban	0.30	0.40	0.50
	multiple, detached	0.40	0.50	0.60
	multiple, attached	0.60	0.68	0.75
	suburban	0.25	0.33	0.40
Apartments		0.50	0.60	0.70
Parks, Cemeteries		0.10	0.18	0.25
Playgrounds		0.20	0.28	0.35
Railroad yards		0.20	0.28	0.35
Unimproved		0.10	0.20	0.30

Notes:

1. Values within the range given depend on the soil type if the watershed is significantly unpaved (sand is minimum, clay is maximum), and on the nature of the development.

2. For storms having return periods of more than 10 years, increase the listed values as follows, up to a maximum coefficient of 0.95:

   25 year - add 10 percent
   50 year - add 20 percent
   100 year - add 25 percent

3. The coefficients listed are for unfrozen ground. Taken from RTAC (1982).

Parking Lot and Discharge Channel Runoff

Springbank Off-Stream Reservoir Project

Alberta, Canada

Alberta Transportation Department

Objective/Purpose

The objective of this calculation is to calculate runoff from the parking lots and other drainage areas to the discharge channel and to size runoff channels for the parking lots and drainage areas.

Criteria

Rational Method (AT, 2011)

References

1. AT (2011). Erosion and Sediment Control Manual. Government of Alberta Transportation (AT).
2. USACE (2011). AED Design Requirements: Hydrology Studies, Various Locations, Afghanistan. US Army Corps of Engineers, Afghanistan Engineer District.
3. AEP (1999). Stormwater Management Guidelines for the Province of Alberta. Alberta Environmental Projection. Edmonton, Alberta.
4. Rainfall Intensity_Calgary International Airport, AB 3031093 Rainfall Duration Curves.
5. Chow, Maidment, and Mays. Applied Hydrology. McGraw-Hill. 1988.

Calculations

Rational Method: $Q = 0.278\ C \times I \times A$

Where,

Q = Peak flow (cms)

C = Dimensionless runoff coefficient

I = Rainfall Intensity (mm/hr)

A = Drainage Area (square km)

Runoff Coefficient

Earth embankments at 10-year storm frequency, USACE (2011), reported runoff coefficients as 0.6. For 25-year frequency, runoff coefficient is generally multiplied by a factor of 1.10 (AEP 1999). Embankment C = 0.66.

From AEP (1999) Stormwater Management Guidelines, for paved parking, mean C = 0.83 for 10-year storm frequency. Adjusting for 25-year storm frequency (multiply by 1.1), C = 0.91.

Rainfall Intensity: Calgary Airport, AB 3031093

25-year Rainfall Intensity: 33 mm/hr

Discharge Areas:

From attached drainage area map

East Parking Area = 6,250 sq m = 0.00625 sq km

West Parking Area = 3,910 sq m = 0.00391 sq km

East Area 1 = 7,720 sq m = 0.00772 sq km

West Area 2 = 22,690 sq m = 0.02269 sq km

West Area 3 = 131,950 sq m = 0.13195 sq km

Peak Discharge Calculation: Q = 0.278 C x I x A

East Parking Area: Q = 0.278*0.91*33mm/hr*0.00625 sq km = 0.0522 cms

West Parking Area: Q = 0.278*0.91*33mm/hr*0.00391 sq km = 0.0326 cms

East Area 1: Q = 0.278*0.66*33mm/hr*0.00772 sq km = 0.0467 cms

West Area 2: Q = 0.278*0.66*33mm/hr*0.02269 sq km = 0.1374 cms

West Area 3: Q = 0.278*0.66*33mm/hr*0.13195 sq km = 0.7989 cms

Ditch/Gutter Sizing

For East and West Parking Areas:

Assume drainage from each half of each parking area is directed to gutter and combined to run down slope into drainage channel, so for each gutter:

East Parking Area:

Q = 0.5*0.0522 cms * 2.5 (safety factor for gutter sizing) = 0.06525 cms

Two gutter geometries were considered:

1. Trapezoidal channel, riprap lining, bottom width = 0.5m, side slopes 3H:1V, no cover. Water depth = 0.15 m, velocity = 0.45 m/s
2. Rectangular channel that would be covered by grating to allow vehicles to drive over it, concrete lining, bottom width = 0.5 m. Water depth = 0.25 m, velocity = 0.53 m/s

West Parking Area:

Q = 0.5*0.0326 cms * 2.5 (safety factor for gutter sizing) = 0.04075 cms

Two gutter geometries were considered:

3. Trapezoidal channel, riprap lining, bottom width = 0.5m, side slopes 3H:1V, no cover. Water depth = 0.19 m, velocity = 0.19 m/s
4. Rectangular channel that would be covered by grating to allow vehicles to drive over it, concrete lining, bottom width = 0.5 m. Water depth = 0.18 m, velocity = 0.462 m/s

See attached spreadsheet for calculations.

East Area 1 – Assume all flow in one gutter that will then be routed down into the discharge channel. See attached spreadsheet for calculations. Using SF = 2.5 for gutter sizing, Q = 0.1168 cms. Bottom width = 0.5m, side slopes = 3H:1V, water depth = 0.13 m, velocity = 1 m/s.

West Areas 2 and 3 – West Area 3 will drain downhill to West Area 2, which has an access road on the downstream side. A couple different configurations could be used.

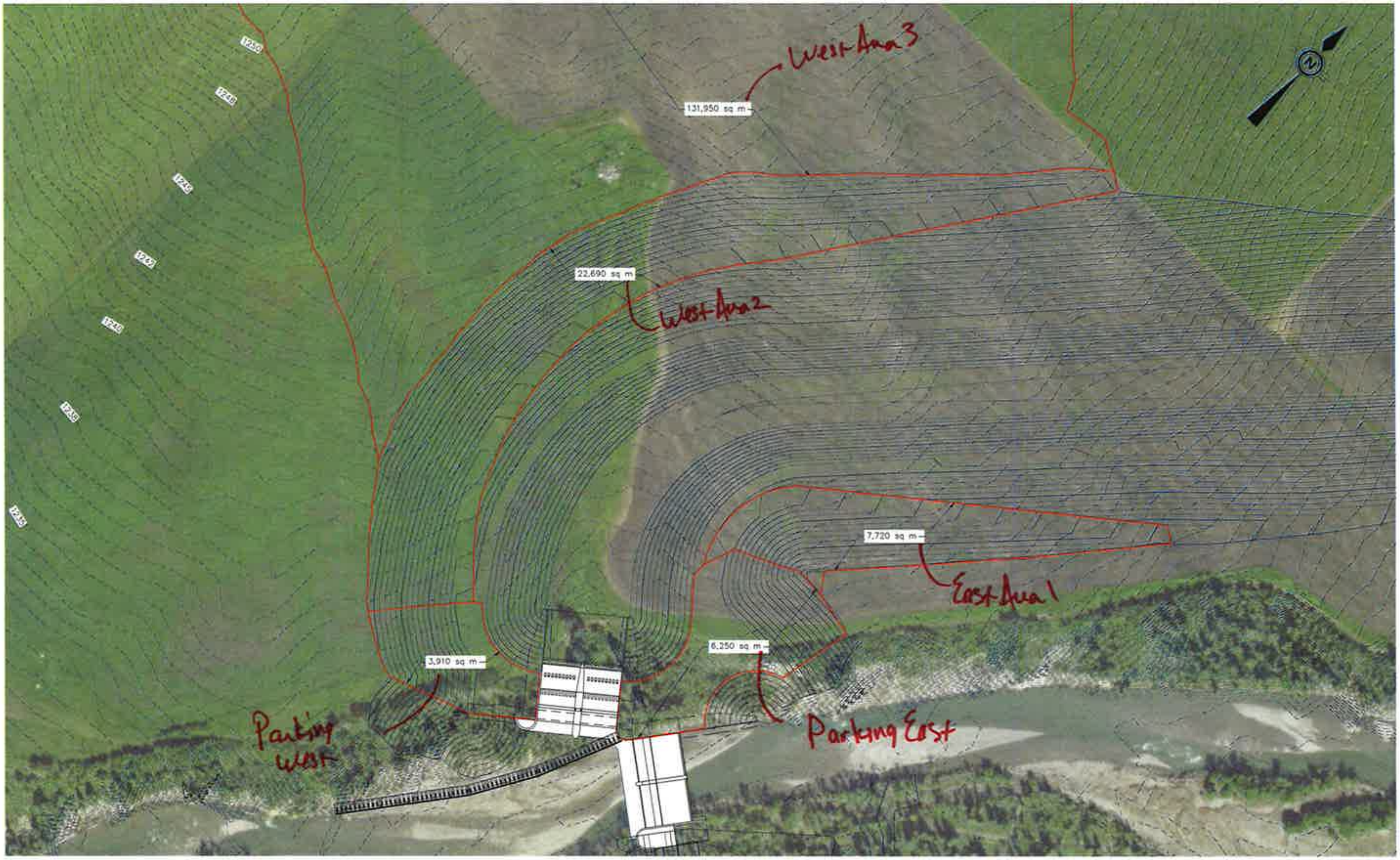
1. Single ditch on the downstream side of the access road to route water to the north end of the drainage area and then down into the drainage ditch.

   Combined flow with SF = 2.5 = 2.34 cms. Assuming a 1 m bottom width with 3H:1V side slopes, water depth = 0.46 m, velocity = 2.1 m/s.

2. Ditch on the downstream side of West Area 3, route flows from West Area 3 down to the drainage ditch at the downstream end of West Area 2, separate ditch on the downstream side of West Area 2.

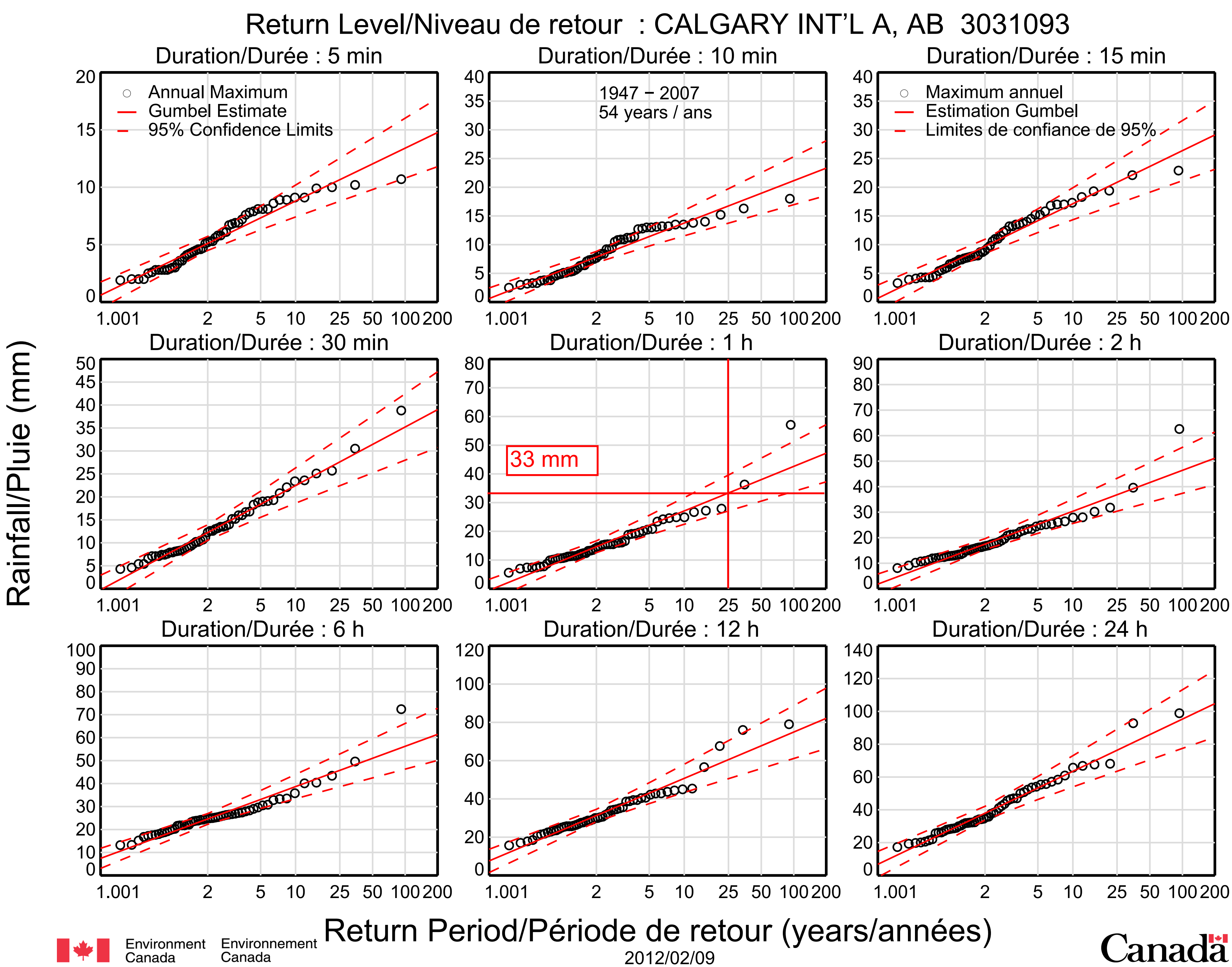
   Area 3 flow (with SF = 2.5) = 1.997 cms. Assuming a 1 m bottom width with 3H:1V side slopes, water depth = 0.43 m, velocity = 2.1 m/s.

   Area 2 flow (with SF = 2.5) = 0.3435 cms. Assuming a 0.5 m bottom width with 3H:1V side slopes, water depth = 0.22 m, velocity = 1.3 m/s.


West Area 3
131,950 sq m
22,690 sq m
West Area 2
7,720 sq m
East Area 1
3,910 sq m
6,250 sq m
Parking West
Parking East

PLAN
1:1000


0
40
80
Meters



Return Level/Niveau de retour : CALGARY INT'L A, AB 3031093
Duration/Durée : 5 min
Duration/Durée : 10 min
Duration/Durée : 15 min
Duration/Durée : 30 min
Duration/Durée : 1 h
Duration/Durée : 2 h
Duration/Durée : 6 h
Duration/Durée : 12 h
Duration/Durée : 24 h
Annual Maximum
Gumbel Estimate
95% Confidence Limits
1947 – 2007
54 years / ans
Maximum annuel
Estimation Gumbel
Limites de confiance de 95%
33 mm
Rainfall/Pluie (mm)
1.001 2 5 10 25 50 100 200
Return Period/Période de retour (years/années)
2012/02/09
Environment Canada
Environnement Canada
Canada

East Parking Area
Trapezoidal Channel

Side slope of channel (z)	3	
Roughness	0.015	$s/(m^{1/3})$
Bottom width of channel (wb)	0.5	m
Slope	0.001	m/m
Q	0.06525	m^3/s
h	0.151425	m guess
Area (A)	0.1445	
Wetted Perimeter (P)	1.457693	
f(h)	0.06525	
f(h)-Q	-5E-08	

Check Velocity
v = 0.451556 m/s

Manning's Equation x Area to solve for Q, for Trapezoidal Channel

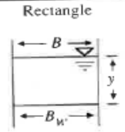
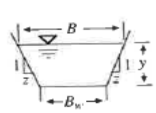
$$f(h) = \frac{1}{n}\left[\frac{(wb + z*h)h}{wb + 2h\sqrt{1+z^2}}\right]^{\frac{2}{3}} * \sqrt{S} * [(wb + zh)h]$$

Table 3-1
Permissible Depths for Submerged Objects

Water Velocity (m/s)	Permissible Depth (m)
0.5	0.80
1.0	0.32
2.0	0.21
3.0	0.09

Note: Based on a 20-kg child and concrete-lined channels.
Larger persons may be able to withstand deeper flows.

TABLE 5.6.1
Geometric functions for channel elements

Section:	Rectangle	Trapezoid
		
Area A	$B_w y$	$(B_w + zy)y$
Wetted perimeter P	$B_w + 2y$	$B_w + 2y\sqrt{1+z^2}$
Hydraulic radius R	$\frac{B_w y}{B_w + 2y}$	$\frac{(B_w + zy)y}{B_w + 2y\sqrt{1+z^2}}$
Top width B	B_w	$B_w + 2zy$
$\frac{2}{3R}\frac{dR}{dy} + \frac{1}{A}\frac{dA}{dy}$	$\frac{5B_w + 6y}{3y(B_w + 2y)}$	$\frac{(B_w + 2zy)(5B_w + 6y\sqrt{1+z^2}) + 4zy^2\sqrt{1+z^2}}{3y(B_w + zy)(B_w + 2y\sqrt{1+z^2})}$

Source: Chow, V. T., *Open-Channel Hydraulics*, McGraw-Hill, New York, 1959, Table 2.1, p. 21 (with additions).

from Chow, Maidment, and Mays. Applied Hydrology. McGraw Hill 1988. p 162

East Parking Area
Rectangular Channel

Side slope of channel (z)	0	
Roughness	0.015	$s/(m^{1/3})$
Bottom width of channel (wb)	0.5	m
Slope	0.001	m/m
Q	0.06525	m^3/s
h	0.248203	m guess
Area (A)	0.124102	
Wetted Perimeter (P)	0.996407	
f(h)	0.06525	
f(h)-Q	6.11E-09	

Check Velocity
v = 0.525778 m/s

Assume grate over channel. Losses for grate not accounted for.

West Parking Area
Trapezoidal Channel

Side slope of channel (z)	3	
Roughness	0.04	$s/(m^{1/3})$
Bottom width of channel (wb)	0.5	m
Slope	0.001	m/m
Q	0.04075	m^3/s
h	0.19407	m — guess
Area (A)	0.210025	
Wetted Perimeter (P)	1.727407	
f(h)	0.04075	
f(h)-Q	-2.4E-08	

Check Velocity
v = 0.194025 m/s

Manning's Equation x Area to solve for Q, for Trapezoidal Channel

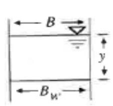
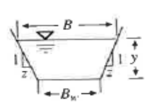
$$f(h) = \frac{1}{n}\left[\frac{(wb + z*h)h}{wb + 2h\sqrt{1+z^2}}\right]^{\frac{2}{3}} * \sqrt{S} * [(wb + zh)h]$$

Table 3-1
Permissible Depths for Submerged Objects

Water Velocity (m/s)	Permissible Depth (m)
0.5	0.80
1.0	0.32
2.0	0.21
3.0	0.09

Note: Based on a 20-kg child and concrete-lined channels.
Larger persons may be able to withstand deeper flows.

TABLE 5.6.1
Geometric functions for channel elements

Section:	Rectangle	Trapezoid
		
Area A	$B_w y$	$(B_w + zy)y$
Wetted perimeter P	$B_w + 2y$	$B_w + 2y\sqrt{1+z^2}$
Hydraulic radius R	$\frac{B_w y}{B_w + 2y}$	$\frac{(B_w + zy)y}{B_w + 2y\sqrt{1+z^2}}$
Top width B	B_w	$B_w + 2zy$
$\frac{2}{3R}\frac{dR}{dy} + \frac{1}{A}\frac{dA}{dy}$	$\frac{5B_w + 6y}{3y(B_w + 2y)}$	$\frac{(B_w + 2zy)(5B_w + 6y\sqrt{1+z^2}) + 4zy^2\sqrt{1+z^2}}{3y(B_w + zy)(B_w + 2y\sqrt{1+z^2})}$

Source: Chow, V. T., *Open-Channel Hydraulics*, McGraw-Hill, New York, 1959, Table 2.1, p. 21 (with additions).

from Chow, Maidment, and Mays. Applied Hydrology. McGraw Hill 1988. p 162

West Parking Area

Rectangular Channel

Side slope of channel (z)	0	
Roughness	0.015	s/($m^{1/3}$)
Bottom width of channel (wb)	0.5	m
Slope	0.001	m/m
Q	0.04075	m^3/s
h	0.175721	m guess
Area (A)	0.08786	
Wetted Perimeter (P)	0.851442	
f(h)	0.04075	
f(h)-Q	-1.3E-08	

Check Velocity

v = 0.463804 m/s

Assume grate over channel. Losses for grate not accounted for.

East Area 1

Side slope of channel (z)	3				
Roughness	0.04	$s/(m^{1/3})$			
Bottom width of channel (wb)	0.5	m			
Slope	0.04	m/m			
Q	0.1168	m^3/s			
h	0.131586	m	guess		
Area (A)	0.117737		Check Velocity		
Wetted Perimeter (P)	1.332222		v =	0.992039	m/s
f(h)	0.1168				
f(h)-Q	-3.4E-08				

$$f(h) = \frac{1}{n}\left[\frac{(wb + z * h)h}{wb + 2h\sqrt{1+z^2}}\right]^{\frac{2}{3}} * \sqrt{S} * [(wb + zh)h]$$

West Areas 2 and 3

Single Ditch on downstream side of Area 2.

Side slope of channel (z)	3	
Roughness	0.04	s/(m$^{1/3}$)
Bottom width of channel (wb)	1	m
Slope	0.04	m/m
Q	2.34	m^3/s
h	0.459713	m	guess
Area (A)	1.09372	
Wetted Perimeter (P)	3.907478	
f(h)	2.34	
f(h)-Q	-1.7E-07	

Check Velocity

v = 2.139487 m/s

$$f(h) = \frac{1}{n}\left[\frac{(wb + z * h)h}{wb + 2h\sqrt{1+z^2}}\right]^{\frac{2}{3}} * \sqrt{S} * [(wb + zh)h]$$

West Areas 2 and 3

Ditch on downstream side of Area 3.

Side slope of channel (z)	3	
Roughness	0.04	$s/(m^{1/3})$
Bottom width of channel (wb)	1	m
Slope	0.04	m/m
Q	1.9973	m^3/s
h	0.426721	m guess
Area (A)	0.972992	
Wetted Perimeter (P)	3.698818	
f(h)	1.9973	
f(h)-Q	5.91E-09	

Check Velocity

v = 2.052741 m/s

$$f(h) = \frac{1}{n}\left[\frac{(wb + z * h)h}{wb + 2h\sqrt{1+z^2}}\right]^{\frac{2}{3}} * \sqrt{S} * [(wb + zh)h]$$

West Areas 2 and 3

Ditch on downstream side of Area 2, only for Area 2 flows.

Side slope of channel (z)	3	
Roughness	0.04	$s/(m^{1/3})$
Bottom width of channel (wb)	0.5	m
Slope	0.04	m/m
Q	0.3435	m^3/s
h	0.222398	m guess
Area (A)	0.259582	
Wetted Perimeter (P)	1.906571	
f(h)	0.3435	
f(h)-Q	9.15E-08	

Check Velocity

v = 1.323279 m/s

$$f(h) = \frac{1}{n}\left[\frac{(wb + z * h)h}{wb + 2h\sqrt{1+z^2}}\right]^{\frac{2}{3}} * \sqrt{S} * [(wb + zh)h]$$

APPENDIX F.2 – FLOODPLAIN BERM ARMOURING

APPENDIX F.2.1 – FLOODPLAIN BERM ARMOURING MEMO

Stantec

Memo

To: Mark Willis. P.E.
Stantec - Lexington, Kentucky

From: Matt Wood, P.Eng., CPESC
Stantec, 25 Street Calgary, Alberta

File: 10773396 SR1

Date: October 20, 2016

Reference: Reference

This memo provides the recommendations for armouring of the floodplain berm on the SR1 diversion structure to resist structural damage from floods up to the 1000 – year flood event on the Elbow River.

1.0 Basis

The recommendations herein are based upon:

- Site visits conducted by Stantec within the vicinity of the diversion structure.
- The results of various sediment analysis and related literature specific to the Elbow River including:
    - Stantec's environmental and engineering studies of this reach including assessment of bedload characteristics.
- Past assessments of the composition of bed and floodplain alluvium as provided in:
    - "Hydrology and Sediment Transport in the Elbow River Basin SW Alberta" Figure 4.43 Bulk Particle Size Distribution Elbow River Reach Near Bragg Creek which suggests a D_{50} in the bank alluvium composite of 64 mm (Hudson, 1986).
    - "Hydraulic and Geomorphic Characteristics of Rivers in Alberta" (Neill, ET. AL. 1972 which suggests a D_{50} of 41mm for the Elbow River at Fullarton Loop
- Preliminary geotechnical investigation results indicating bedrock under the berm is at a depth of approximately 4 m, but is undulating and of varying quality.
- Observation in existing cuts that alluvium under the berm is not heterogeneous and layers of fines including sand and silt, are present.
- The 2D hydraulic model results provided by Daniel Hoffman for flows up to 1240 m^3/s in the Elbow River and which are based on the Conceptual Geometry of the Berm as provided in Stantec April 2015 memo and later validated for the current arrangement.
- The general arrangement of the floodplain berm, current to this memo's date of issue. Its cross-section, materials, RCC spillway geometry and drainage appurtenances as shown in Figure 1.

Figure 1: Berm Concept Cross-Section and Basis for Revetment Arrangement

Reference: Reference

2.0 Berm Setting

The SR1 diversion structure's floodplain berm is located on the right floodplain of the Elbow River. Its planform geometry considers approach hydraulics for the diversion structure and its lateral extent runs from the diversion structure's service spillway in 2-10-024-04 W5M to a high floodplain terrace located in 10-03-024-04-W5M. The upstream endpoint of the berm was determined through hydraulic analysis of the PMF event (2770 m^3/s) and is intended to contain the backwater from that event without circumvention. As shown in Figure 2, there are four (4) prominent floodplain terraces in the backwater, and which the diversion berm crosses each getting progressively higher the further they are form the river. The fourth terrace is the highest, and the tie in point for the upstream end of the berm.

3.0 Flood Driven Changes at the Site

3.1 Progressive Lateral Erosion

In typical years the main channel of the Elbow River meanders through its terraced floodplain and that pattern is affected by various states of confinement. This progressive lateral erosion is important to consider; but, overall lateral migration is dominated by episodic channel switches and rapid single planform changes that dominate the design basis.

3.2 Scour

Net scour potential on a representative section of the main channel is approximately 3.5 m using both Lacey and Blench methods and through observation of existing, post-flood scour holes in similar configurations along the Elbow River. This net-potential scour is largely muted by the presence of the shallow bedrock in the area, which daylights in several locations on the main channel and was captured in boreholes under the proposed floodplain berm. Though heavily weathered, this bedrock limits the potential for scour to its top elevation.

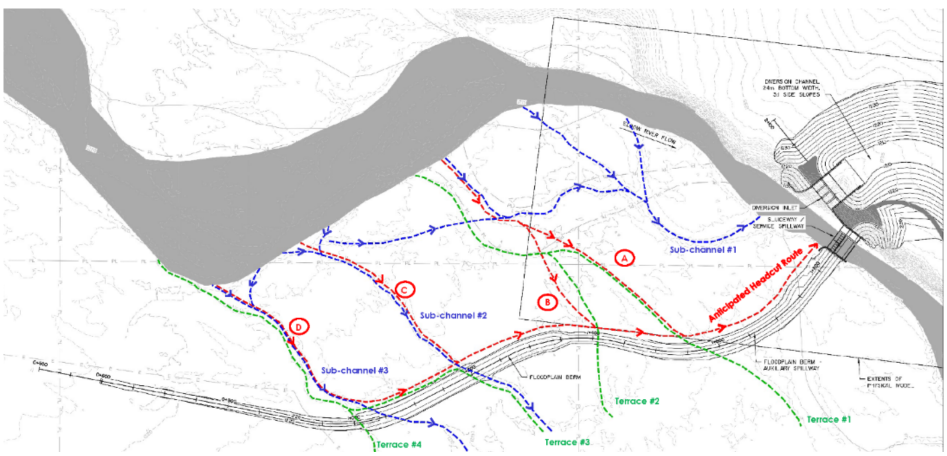
3.3 Channel Switch

During flood, the Elbow River's channel processes are dominated by woody debris and sediment deposition; and, the subsequent erosion that can induce rapid channel planform changes and switches that can span between floodplain terraces. Such switches can occur multiple times during a single flood event. Post-flood evidence on site suggests such channel changes occurred in this floodplain location during the 2013 event.

A channel switch is induced when flows to overtop the banks in the upstream, from either clear-water hydraulics, or heighted water levels from debris jamming in the main channel. When that overland flow finds an easier and sometimes shorter path through the low lying sub-channels and channel remnants within that floodplain, it can circumvent the main channel at a different hydraulic profile than that being experienced by the main channel. When that overland flow returns to the main channel, it does so at a higher elevation than the main channel and its return can induce head-cutting that progresses through the floodplain from downstream to upstream. The extent of which is dependent on the duration that the overland flow occurs. As shear stresses from the overland flow increases, avulsions along the overland flow route can increase the flow through the sub-channel and can rapidly accelerate the channel switch process in a sort of positive feedback loop that further speeds up the process.

Figure 2 shows the terraces and sub-channels identified in the diversion berm's backwater as they could affect channel switch potential. These sub-channels are the most likely path for a channel switch to take. A third probable route exist up against the toe of the diversion berm as it guides the overland flow to the diversion structure. If the process occurs over a long enough duration to head-cut under the toe of the berm, there is the potential for it to undermine its foundation. The anticipated routes for channel switches within the SR1 diversion structure backwater is provided in red in Figure 2.

Figure 2 – Floodplain Terraces in the Backwater and Potential Channel Switch Routes



4.0 **Damage Potential and Design Basis Scenarios**

The above listed mechanisms of change were reviewed in consideration of the 2D modelling results of the conceptual berm arrangement for a flow of 1240 m^3/s and validated for events up to the 1000-year event with no measurable impact on the proposed armour arrangement. Three scenarios, each as likely to occur, and their potential impact to the berm were identified for the basis of the armour design and are as follows:

Scenario 1: Channel and floodplain remain fixed as per existing arrangement and they experience velocities as simulated in the model.

- Velocities against the berm are less than 1.5 m/s and suggest vegetation is sufficient to resist erosion, except for a small, localized area near the service spillway and on any maintenance approach roads (protrusions) along the berm face.
- A Turf Reinforcement Mat (TRM) could provide some additional factor of safety to erosion but is not necessary based on the modeled velocities and depths.

Scenario 2: Progressive lateral erosion of main channel into the toe of the berm.

Reference: Reference

- Can assume similar velocities to main channel throughout its lateral migration.
- River training or localized armour can limit the lateral erosion.
- Lateral erosion against the berm could also create a minor maintenance issue and may further support the implementation of localized armour or river training in the main channel.

Scenario 3: Main channel switch up against the berm.

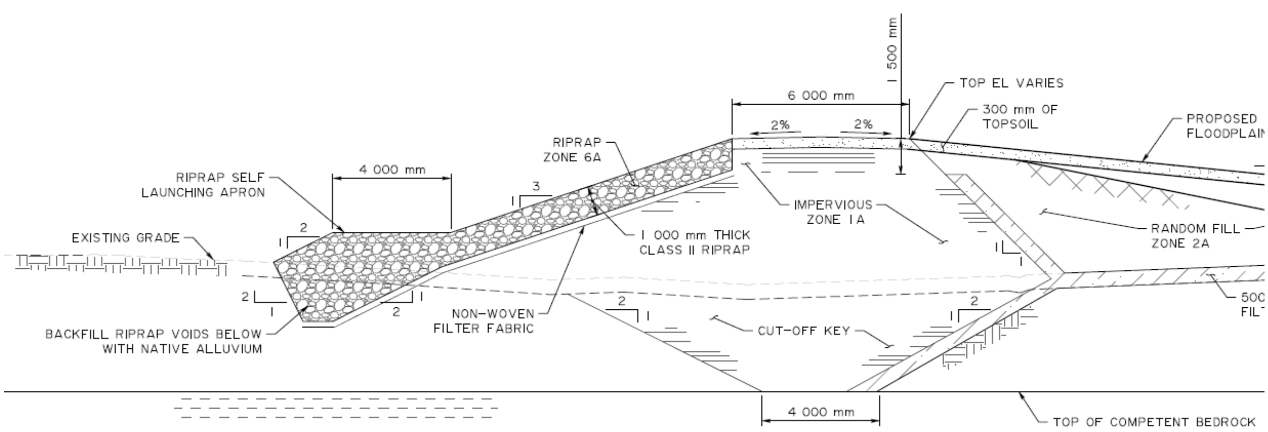
- Can assume existing main channel geometry, plus net scour potential is transposed to the toe of the berm.
- Switched main channel has the potential to scour to bedrock and could undermine the berm toe to the depth of bedrock.
- Velocities can assume to match those of the existing main channel and can average near 3.5 m/s.

All three identified scenarios have an equal likelihood of occurring during a large flood event; however, Scenario 2 and Scenario 3 dictate the required protection measures and form the design basis for the armour.

5.0 Armouring Recommendations

Figure 3: Provides the general arrangement and cross-section details for the proposed armoring protection to resist damage to the floodplain berm under Scenario 2 and Scenario 3 up to a 1000-year design flood event.

Figure 3: Typical Corss-Section of Armour for Floodplain Berm (Eathern Section)



Reference: Reference

5.1 Berm Armor

The berm is armored with a typical riprap revetment featuring a self-launching apron to prevent undermining, should the channel switch up against berm's toe (Scenario 3). The self-launching apron was selected to minimize the excavation required to reach the required protection depth for scour. The design assumes mid-channel velocities of up to 3.5 m per second in the switched channel; as the 2D models suggests would be experienced in the existing main channel, thought they are likely less than this during a single event as head-cutting for the full switch requires considerable time to develop. A Class II riprap (D_{100} = 800 mm) is proposed for the revetment, and its self- launching apron.

5.2 Head-cut Prevention Spillway

The effects of Scenario 3 may be mitigated by resisting the potential for head-cut, where floodplain flows against the berm, return to the main channel. A Class III riprap spillway is proposed in the right bank of the existing main channel, in the areas where the berm and auxiliary spillway meet the service gate bays. This is the location where the head-cut will begin.

Class III riprap (D_{100} = 1100 mm) was selected for this high energy environment as it is the largest, common riprap size that can be procured in the region. Calculations suggest it is sufficient for the spillway but consideration should be made to the possibility of these stones rolling off the spillway and into the service gate bays. For this reason, it may be prudent to replace this spillway with a grouted riprap spillway, a concrete spillway; or, a concrete or sheetpile cutoff wall. Those options were not investigated as part of this memo.

5.3 Main Channel Migration Prevention

The potential for lateral migration is most prevalent on the outside right-bank bend of the main channel in the upper portions of the diversion backwater. No armour or bank stabilization is proposed at this location to resist the progressive lateral migration of the main channel, into the berm (Scenario 2). Stabilization of this bank is not warranted because of the presence of the floodplain berm armour.

5.4 Riprap and Filter Specification

All riprap arrangements proposed in this memo consider the use of competent angular blast rock as typically sourced from the local quarries near Exshaw, Alberta. Riprap gradations and material specifications must follow the Alberta Transportation standards for heavy rock riprap F515 and F525, and shall be as provided in Table 1 and Table 2. All riprap in the floodplain berm revetment shall be placed on non-woven filter fabric; though this can be switched with a granular bedding material meeting the performance specification in Table 1. A filter layer is not warranted for the Class III riprap in the head-cut prevention as the alluvial gravels in the floodplain loosely meet standard requriements for granular filters, and with the voids of the riprap backfilled in that arrangement, will be sufficient for the head-cut prevention's serviceable intent. Should the head-cut prevention ever become exposed to the river, it would not be desirable to have the black fabric present.

Table 1: Gradation for Class 2 Riprap		
% Passing	Dia. (mm)	Mass (kg)
100	800	700
50-80	600	300
20-50	500	200
0	300	40
D50	**500**	**200**

Table 2: Gradation for Class 3 Riprap		
% Passing	Dia. (mm)	Mass (kg)
100	1100	1800
50-80	900	1100
20-50	800	700
0	500	200
D50	**800**	**700**

Table 3: Non-Woven Geotextile Filter Fabric for Class II Riprap	
Grab Strength	650 N
Elongation (Failure)	50%
Puncture Strength	275 N
Burst Strength	2.1 MPa
Trapezoidal Tear	250 N
Minimum Fabric Lap to be 300 mm.	

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References:

Hudson, R. Henry, “Hydrology and Sediment Transport in the Elbow River Basin SW Alberta”, University of Alberta 1983.

Neill, C.R., Kellerhalls, R. and D.I. Bray, 1972. “Hydraulic and Geomorphic Characteristics of Rivers in Alberta.” River Engineering and Surface Hydrology Report 72-1, Research Council of Alberta.

Stantec Consulting Ltd. “Conceptual Design Update Memo”, April 3, 2015

APPENDIX F.3 – AUXILIARY SPILLWAY DESIGN

APPENDIX F.3-1 – FUSE PLUG DESIGN

Fuse Plug Calculations

Springbank Off-Stream Reservior Project
Alberta, Canada
Alberta Transportation Department

1. OBJECTIVE/PURPOSE

The objectives of this calculation package is to determine if the auxiliary spillway fuse plug will fully erode before the arriva of the peak of the IDF, preventing the water surface elevation from increasing to an elevation above the IDF water surface elevation, and to determine dimensions of the fuse plug.

2. CRITERIA

Emperical Methods: USBR & USACE 2015, Pugh 1985, Schmocker et al 2013

Required to have entire fuse plug erode prior to the arrival of the IDF peak.

3. REFERENCES

1. USBR & USACE. (2015). Best Practices in Dam and Levee Safety Risk Analysis. U.S. Department of the Interior, Bureau of Reclamation, and U.S. Army Corps of Engineers.

2. USBR (1985). Hydraulic Model Studies of Fuse Plug Embankments. Clifford A. Pugh.

3. Stantec, Springbank Off-Storage Project Preliminary Geotechnical Assessment Report, March 29, 2017.

4. Stantec, Material Property Derivations, SR1 Floodplain Berm.

5. Annandale, George and Steve Smith (2001). Calculation of Bridge Pier Scour Using the Erodibility Index Method. Colorado Department of Transportation Report No. CDOT-DTD-R-2000-9.

6. Hanson, G. J. Temple, D.M, Hunt, S.L. & Tejral, R.D. (2011). Development and Characterization of Soil Material Parameters for Embankment Breach. Applied Engineering in Agriculture, Vol 24 (4): 587-595.

7. Schmocker, Lukas, Esther Hock, Pierre Andre Mayor, and Volker Weitbrecht. Hydraulic Model Study of the Fuse Plug Spillway at Hagneck Canal, Switzerland. ASCE Journal of Hydraulic Engineering, August 2013: 894-904.

Calculation Files on Cincinnati Server:
U:\110773396\component_work\dams_diversion\civil\design\design_calculations\RCC_Auxillary_Spillway\Fuse Plug Design

4. Calculation Approach Erosion Rate Calculations

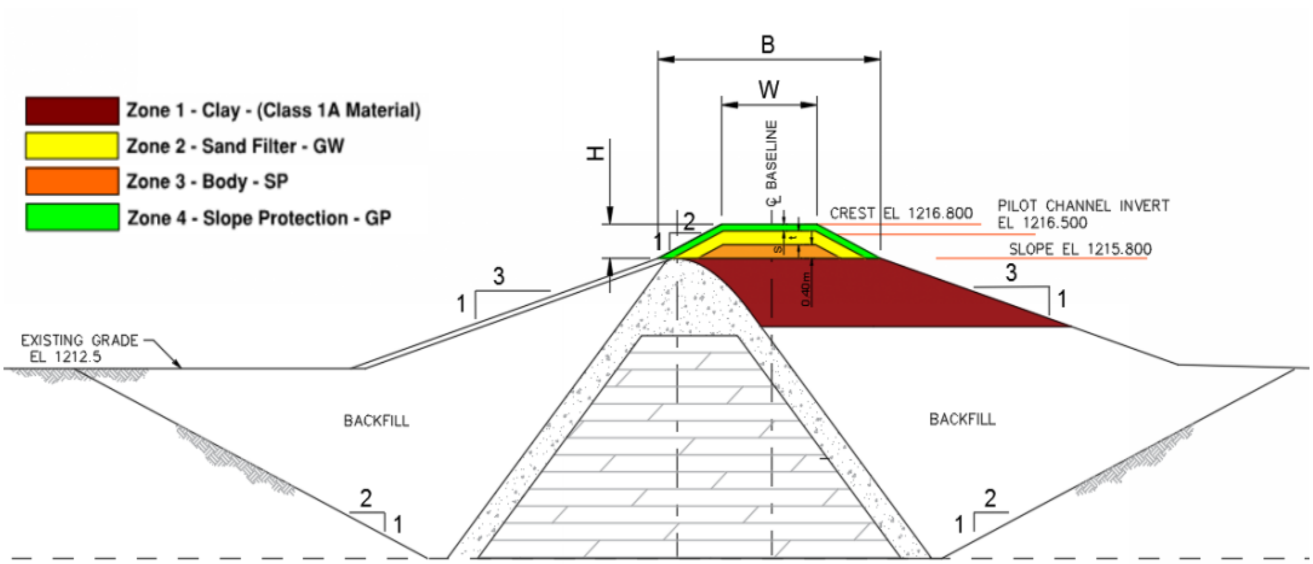
Calculation Steps:
A. Size Fuse Plug Dimensions/Material
B. Check Erosion Initiation on Downstream Slope
C. Check Erosion Rate using Pugh and Schmocker et al Lateral Erosion relationships

4.1 Determine Fuse Plug Dimensions

Fuse plug dimensions based on USBR 1985 Pugh and Schmocker et al 2013. The Fuse plug dimensions were similiar to those constructed as part of Schmockers Study on Fuse Plug erosion for a Fuse plug up to 1.2 m tall. Geotechnical Calculations showed no seepage protection or clay core was required for the current fuse plug design so these layers were removed. A 2 meter deep section of Clay material was placed on the downstream end to prevent piping.

The slope protection layer (Zone 4) was assigned a width of 0.2 m to allow for constructability.
The sand filter layer (Zone 3) was assigned a width of 0.4 m to allow for constructability of the layer.
The fuse plug height was assigned a height of 1.0 meter. A top width of 3 meters was selected to allow for the crest elevation to be maintained in the event of settlement or erosion of the top layer.

Core and sand filters may need to be overbuilt and trimmed to desired width. Sand filter is essential as Pugh tests show slower erosion and breach development times with no sand filter present. Core is expected to break away as undermined by erosion of sand and gravel layer downstream. This sand and gravel slope protection should be cohesionless and sized as discussed later in this calculation to be effective.



FUSE PLUG
TYPICAL SECTION

Height of Fuse Plug, H

$H := 1.0\text{m}$

Total Bottom width, B

$B := 7\text{m}$

Top Width of Fuse Plug, W

$W := 3\text{m}$

Base Width, J

$J := B = 7\text{m}$

Auxilliary Spillway Width

$AuxW := 214\text{m}$

Two Pilot Channels are anticipated to be located at 1/4 of the length of the Auxilliary Spillway and 3/4 of the length of the Auxiliary Spillway. This results in the required length for lateral erosion (L) of the Fuse Plug which needs to be eroded to be 1/4 of the length of the Auxilliary Spillway. Pugh indicated the location of the pilot channel did not have a noticeable effect on the lateral erosion rate.

$$L := \frac{AuxW}{4} = 53.5\,m$$

Pilot Channel Dimensions

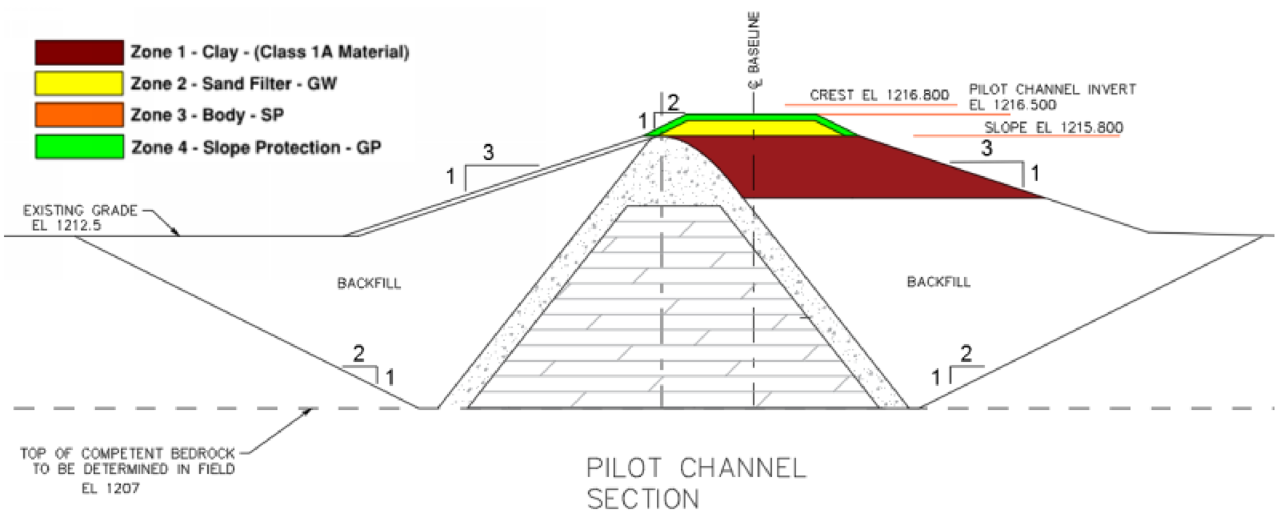
Pugh observed from a Qualitative observation of the model tests indicate that the pilot channel width (p) should be about 1/2 the fuse plug Height to ensure adequate breaching flow passes through the pilot channel. However Pugh model tests were performed for p/H ranging from 0.24 to 0.88.

Pilot Channel Width p $p := H \cdot .88 = 0.88\,m$

Pugh observed model runs had a ratio of Pilot channel height to Height of Fuse plug ranging from 0.12 to 0.24. A ratio of 0.3 was chosen to represent the ratio of the pilot channel height to the height of the fuse plug.

Height of the Pilot Channel $h := .3 \cdot H = 0.3\,m$

The side slopes of the pilot channel are anticipated to be set at 1:1 as was the side slopes utilized in the Oxbow Study and in Schmocker Study



PILOT CHANNEL SECTION

Verification of the proposed material for the Fuse Plug Design will be performed as a separate calculations. The Fus plug will be analyzed for Slope stability, pore water pressure and seepage.

Proposed Fuse Plug Material is as Follows:

Zone 1 - Clay - Class 1A Material
Zone 2 - Sand Filter - GW
Zone 3 - Body - SP
Zone 4 - Slope Protection GP
Zone 5 - Compacted Rock Fill

4.2. Check Erosion Initiation on Downstream Slope

Erodibility Threshold (Annandale) Method was applied to ensure that erosion occured along the Fuse Plug/Pilot Channel

Mass Strength: $M_s := 0.04$ MPa From Table 1. Mass Strength number for granular soil

Consistency	Identification in Profile	SPT Blow Count	Mass Strength Number (M_s)
Very loose	Crumbles very easily when scraped with geological pick	0-4	0.02
Loose	Small resistance to penetration by sharp end of geological pick	4-10	0.04
Medium dense	Considerable resistance to penetration by sharp end of geological pick	10-30	0.09
Dense	Very high resistance to penetration of sharp end of geological pick – requires many blows of pick for excavation	30-50	0.19
Very dense	High resistance to repeated blows of geological pick – requires power tools for excavation	50-80	0.41
Note: Granular materials in which the SPT blow count exceeds 80 to be taken as rock – see table 3.			

Source - Table 1 from Reference 5 (Annandale and Smith)

Particle of Fragment Size of the Rock that form the Mass, use equation for cohesionless, granular soils:

Slope Protection Layer will have the highest D50 and highest erodibility Index.
For Slope Protection Assume D50 = 0.25 m. To be conservative, assume $D50 := 0.25$

$$Kb := 1000 \cdot D50^3$$

$$Kb = 15.63$$

Interparticle Bond Shear Strength, Kd, use equation for cohesionless, granular soils, Kd = tangent ϕ:

From Material Property Derivations: $\phi := 40deg$

$$Kd := \tan(\phi)$$
$$\tan(\phi) = 0.84$$

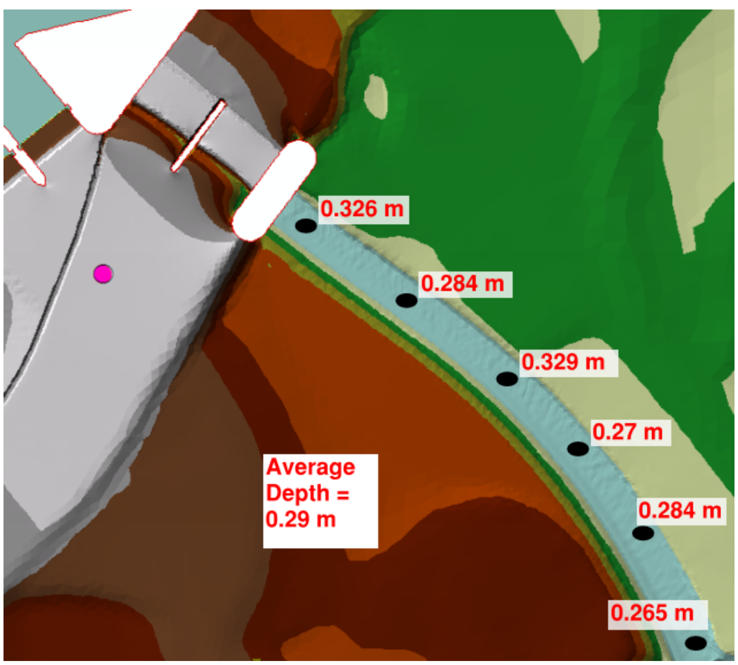
Coefficient to Account for Relative Shape and Orientation: $J_{s1} := 1.0$

Erodibility Index: $K_{h1} := M_s \cdot Kb \cdot Kd \cdot J_{s1} = 0.524$

Stream Power for Surface Flow (Downstream Slope = 0.33)

Average velocity and Depth of Flow from "Preliminary_Design_Results, 1930cms_Aux_Cover_Not_Eroded vel_tin and dep_tin".

Velocity Tins Figure



Depth Tins Figure

Unit weight of water: $\gamma_w := 9.82 \frac{kN}{m^3}$

Average Velocity: $v_1 := 4.45 \frac{m}{s}$

Depth of Flow: $d_1 := 0.29$ m

Slope of Energy Grade Line: $sl := 0.5 \frac{m}{m}$

Hydraulic Radius: $H_{R1} := 0.29$ m

Shear Stress of Open Channel: $\tau_{b1} := \gamma_w \cdot sl \cdot H_{R1} = 1.42$

Stream Power Potential: $p_1 := \gamma_w \cdot v_1 \cdot d_1 \cdot sl = 6.336 \frac{kW}{m^2}$

From Figure IV-1-6, **Material is likely to Scour**

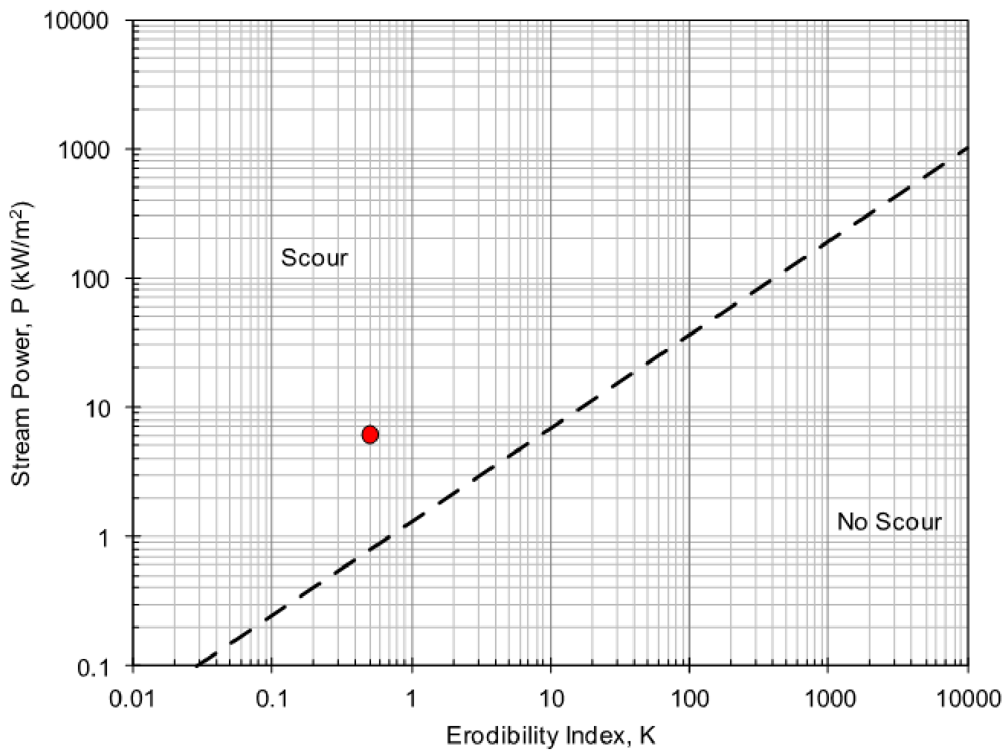


Figure IV-1-6 – Erodibility Threshold Graph (Annandale, 1995)

Source - Reference 1 (USBR & USACE)

4.3. Erosion Head Cutting Rates

For 1000-year Flood Event on downstream slope of fuse plug:

Unit weight of water: $\gamma_w := 9.82 \frac{kN}{m^3}$

Average Velocity: $v := 4.45 \frac{m}{s}$

Slope of Energy Grade Line: $sl := 0.5 \frac{m}{m}$

Flow Depth: $d := 0.29m$

Width of Spillway: $w := 214m$

Flow Area: $A := d \cdot w$

$A = 62.06\,m^2$

Flow Wetted Perimeter: $P := 2d + w$

$P = 214.58\,m$

Hydraulic Radius: $R := \frac{A}{P}$

$R = 0.29\,m$

Applied Boundary Shear Stress: $\tau := \gamma_w \cdot sl \cdot R = 1.42 \times 10^3\,Pa$

Erodibility coefficient: $k_d := 0.35 \frac{cm^3}{N \cdot s}$ [From Figure IV-1-11 (USBR & USACE., 2015)]

Critical Shear Stress: $\tau_c := 8 \frac{N}{m^2}$

Erosion Rate: $\varepsilon_r := k_d \cdot (\tau - \tau_c)$ (From Hansen et al., 2011)

$\varepsilon_r = 1779.2 \cdot \frac{mm}{hr}$

Figure IV-1-10 (USBR & USACE, 2015, pp IV-1-19)

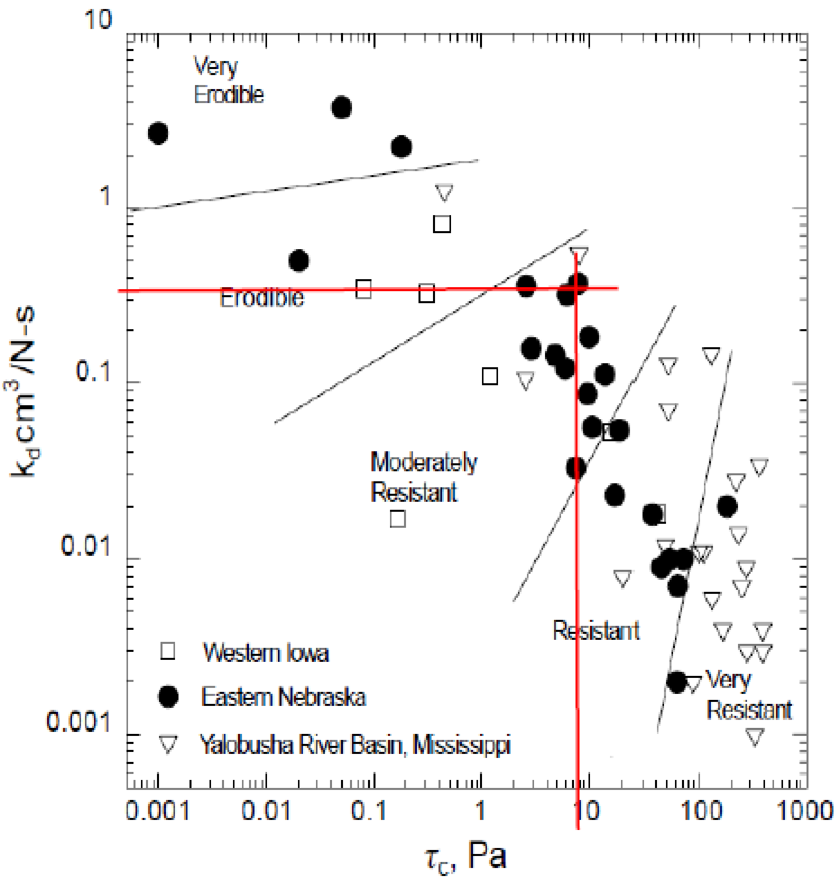


Figure IV-1-10 - τ_c versus k_d from cohesive streambed submerged JET tests (Hanson and Simon 2001)

4.4. DESIGN EROSION TIME FRAME

Assume during the IDF Flood event, erosion begins on the Auxilliary Spillway Fuse Plug at a flowrate equivalent to the peak inflow of the 1000-year flood of 1930 m^3/s.

Previous hydraulic calculations for the 1000-year flood (attached) show a water surface elevation of 1216.9 m at the auxiliary spillway when there is no diversion and there is no erosion of the fuse plug, which is 0.4 meters above the fuse plug elevation pilot channel elevation invert of 1216.5 m. Erosion of the fuse plug may begin at lower water surface elevations, however, 0.4 meter of overtopping is a conservative assumption for erosion initiation. T**he entire fuseplug needs to erode during the IDF event prior to the the WSE reaching the peak WSE of the IDF event.** A hydrograph of the IDF event was developed by proportionally adjusting the PMF hydrograph. Based on hydrologic calculations (attached) the inflow hyrdrograph for the PMF reaches a flow rate of 1930 m^3/s at approximately 13:00 and reaches the peak of 2210 m^3/s at 17:00. Assuming breach initiation at 13:00, there is an erosion duration of 4 hours before the arrival of the peak IDF flowrate.

4.5. Check Lateral Erosion Rate

From USBR 1985, Pugh: The lateral erosion rate in Pugh assumes erosion initiation by flow at a specific pilot channel location, on fuse plug sections ranging from 3m to 9 meter in height. The relative dimensions in the model tests also differ from the SR1 fuse plug as they assume a fuse plug height greater than top width but an overtopping depth lower than the fuse plug height, which are the opposite from the SR1 fuseplug. Pugh study also assumes the lateral erosion rate is only representative of fuse plugs built in the configuration shown in Figure 8 of the Pugh paper. Schmocker et. al. (2013) tested fuse plug erodibility based on the inclined core fuse plug developed by Pugh but for different fuse plug heights. This paper concluded that Pughs fuse plug concept may be adopted for any dimension and developed an emperical formula for estimating the lateral erosion rate.

Pugh Observed lateral erosion rates are graphed in the Figure Below. Pugh Lateral Erosion Rates curve has been extrapolated resulting in an erosion rate of 195 ft/hour. Additionally the curve has been slanted down to capture the lowest data point. Extrapolated the curve this way would result in an erosion rate of 140 ft/hour.

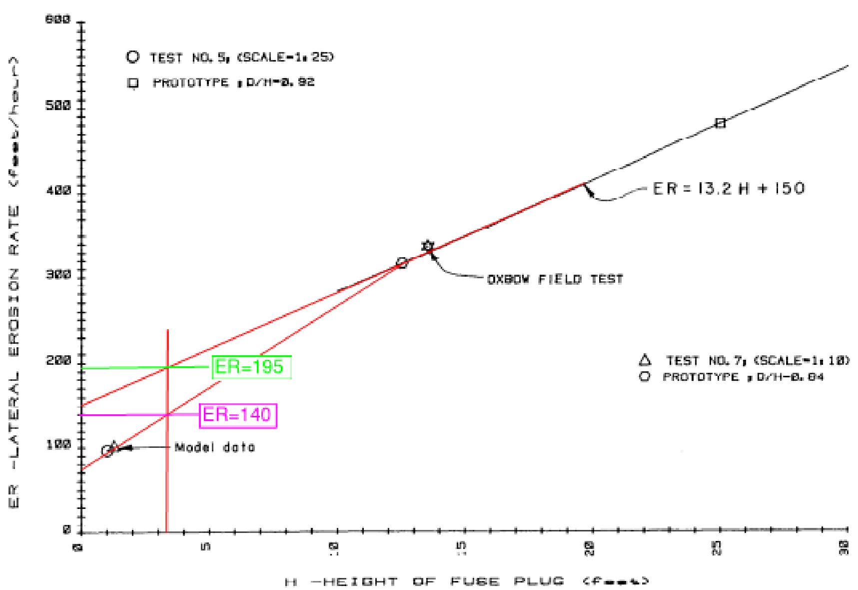


Figure 31. – Lateral erosion rates (after initial breach) for a fuse plug embankment with the geometric features of tests No. 5 and 7 (see table 1).

Pugh's empirical formula of ER = 13.2*H + 150 which applies to fuse plugs with an incline core between 3m and 9m was shown to predict lateral erosion for observed from Schmockers Hydraulic Model Study for a Fuse Plug which wa much smaller in height.

$$ER1 := 140\frac{ft}{hr}$$

$$ER2 := 195\frac{ft}{hr}$$

Lateral Erosion Rate from Pugh

Pilot Channels are placed at 1/4 and 3/4 of the length of the Spillway. Thus at each Pilot channel location, the Latera erosion must travel the distance of 1/4 of the full length of the dam.

Required Lateral Erosion Distance:

$L = 53.5\,m \qquad ER1 = 140\cdot\frac{ft}{hr} \qquad ER2 = 195\cdot\frac{ft}{hr}$

Pugh calculations were created using the fuse plug geometries in his study. As Pugh points out increasing the embankment materials dimensions can cause the embankment to erode either faster or slower. The proposed embankment is larger than the referenced embankment in Pugh study. Therefore as pugh points out an increase in areas will decrease the overall lateral erosion rate by a percentage equal to the increased areas.

Pugh's Embankment Parameters
W/H = 0.8 B/H = 4.8

Current Design Embankment

$\frac{W}{H} = 3 \qquad \frac{B}{H} = 7$

The cross section area downstream from the Embankment Core is about ~1.5 times or 50% larger than than Pugh's referenced Embankment. Therefore the lateral erosion should be decreased by 50% from the computed value to determine the anticipated erosion value.

$$ER1_{adj} := \frac{ER1}{2} = 70\cdot\frac{ft}{hr}$$

$$ER2_{adj} := \frac{ER2}{2} = 97.5\cdot\frac{ft}{hr}$$

Adjustments are not necessary for the long approach channel. According to Figure 31 from Pughs Paper. If (D/J) < 0.12 (Where D is the water surface against the fuse plug), then an adjustment would be needed to reduce the erosion rate. The relative erosion rate for D/J < 0.12 is divided by the relative erosion rate for D/J > 0.12. However the design D/J ratio is greater than 0.12 and therefore no correction is necessary.

$$D := 1216.9m - 1215.8m = 1.1\cdot m$$

$$\frac{D}{J} = 0.16$$

Based on Pugh and Schmocker Study- The Pilot Channel in both of the studies was able to erode in less than 5 minutes. Therefore an assigned time of 15 minutes will be estimated to account for Pilot Channel Erosion.

$$PE := 15min$$

Time required for Lateral Erosion to occur over the length of the Dam

$$Time1 := \left(\frac{L}{ER1_{adj}}\right) + PE = 2.76\cdot hr$$

$$Time2 := \left(\frac{L}{ER2_{adj}}\right) + PE = 2.05\cdot hr$$

The time required using either value of the Lateral Erosion rate takes less than 4 hours to achieve full erosion. Therefore the Fuse Plug is anticipated to completely erode in the alloted 4 hours time frame prior to reaching the IDF Maximum Water Surface Elevation Flood Level.

Theoretical IDF Hydrograph at SR1 Diversion

Max Diversion Rate (m^3/s) : 480

re EM spillway activates) **Total Diversion Volume (dam^3) :** 73407 (78000 dam^3 r

Date / Time	Time (hr)	PMF US Discharge (m^3/s)	Diversion Rate (m^3/s) Potential	Diversion Rate (m^3/s)	Incremental Diversion Volume (dam^3)	Cumulative Diversion Volume (dam^3)	PMF DS Discharge (m^3/s)
6/5/00 0:00	0	84	0	0	0	0	84
6/5/00 1:00	1	90	0	0	0	0	90
6/5/00 2:00	2	52	0	0	0	0	52
6/5/00 3:00	3	89	0	0	0	0	89
6/5/00 4:00	4	117	0	0	0	0	117
6/5/00 5:00	5	131	0	0	0	0	131
6/5/00 6:00	6	138	0	0	0	0	138
6/5/00 7:00	7	140	0	0	0	0	140
6/5/00 8:00	8	141	0	0	0	0	141
6/5/00 9:00	9	141	0	0	0	0	141
6/5/00 10:00	10	141	0	0	0	0	141
6/5/00 11:00	11	141	0	0	0	0	141
6/5/00 12:00	12	142	0	0	0	0	142
6/5/00 13:00	13	146	0	0	0	0	146
6/5/00 14:00	14	152	0	0	0	0	152
6/5/00 15:00	15	162	2	2	7	7	160
6/5/00 16:00	16	175	15	15	53	59	160
6/5/00 17:00	17	190	30	30	108	167	160
6/5/00 18:00	18	208	48	48	172	339	160
6/5/00 19:00	19	228	68	68	245	584	160
6/5/00 20:00	20	250	90	90	326	909	160
6/5/00 21:00	21	276	116	116	419	1328	160
6/5/00 22:00	22	308	148	148	534	1862	160
6/5/00 23:00	23	348	188	188	675	2537	160
6/6/00 0:00	24	399	239	239	861	3398	160
6/6/00 1:00	25	475	315	315	1135	4533	160
6/6/00 2:00	26	572	412	412	1483	6015	160
6/6/00 3:00	27	672	512	480	1728	7743	192
6/6/00 4:00	28	753	593	480	1728	9471	273
6/6/00 5:00	29	839	679	480	1728	11199	359
6/6/00 6:00	30	942	782	480	1728	12927	462
6/6/00 7:00	31	1063	903	480	1728	14655	583
6/6/00 8:00	32	1195	1035	480	1728	16383	715
6/6/00 9:00	33	1340	1180	480	1728	18111	860
6/6/00 10:00	34	1492	1332	480	1728	19839	1012
6/6/00 11:00	35	1654	1494	480	1728	21567	1174
6/6/00 12:00	36	1816	1656	480	1728	23295	1336
6/6/00 13:00	37	1964	1804	480	1728	25023	1484
6/6/00 14:00	38	2082	1922	480	1728	26751	1602
6/6/00 15:00	39	2162	2002	480	1728	28479	1682
6/6/00 16:00	40	2204	2044	480	1728	30207	1724
6/6/00 17:00	41	2213	2053	480	1728	31935	1733
6/6/00 18:00	42	2195	2035	480	1728	33663	1715
6/6/00 19:00	43	2159	1999	480	1728	35391	1679
6/6/00 20:00	44	2108	1948	480	1728	37119	1628
6/6/00 21:00	45	2045	1885	480	1728	38847	1565
6/6/00 22:00	46	1973	1813	480	1728	40575	1493
6/6/00 23:00	47	1892	1732	480	1728	42303	1412
6/7/00 0:00	48	1807	1647	480	1728	44031	1327

Tabular Summary of Diversion Structure 2D Hydraulic Model Results

Scenario	Total Inflow (m^3/s)	Service Spillway Discharge (m^3/s)			Diversion Inlet Discharge (m^3/s)			Auxiliary Spillway Discharge (m^3/s)	Head water (m)	Service Spillway Tailwater (m)	Diversion Inlet Tailwater (m)*	Notes
		Left Gate	Right Gate	Total	Left Gate	Right Gate	Total					
2013 Event, No Diversion, Scour hole assumed downstream of Service Spillway down to elevation 1207.0 m	1240	641	601	1242	n/a	n/a	0	n/a	1216.2	1214.1	n/a	Diversion Inlet gates closed and Service Spillway gates fully open. Scour hole down to minimum of 1207 m assumed to have formed downstream of Service Spillway
2013 Event, Service Spillway Stuck	1240	519	46	565	344	337	681	n/a	1216.0	1212.0	1213.5	Diversion Inlet gates open, left 24 m crest gate at elevation 1210.0 m and right 24 m crest gate at 1215.0 m
1000-yr Event, No Diversion, Auxiliary Spillway cover eroded	1930	749	730	1480	n/a	n/a	0	444	1216.9	1214.1	n/a	Diversion Inlet gates closed and Service Spillway gates fully open. Auxilliary Spillway fuse plug cover eroded.
1/3 Between 1000-yr and PMF, No Diversion, Auxiliary Spillway cover eroded	2210	804	779	1584	n/a	n/a	0	618	1217.2	1214.2	n/a	Diversion Inlet gates closed and Service Spillway gates fully open. Auxilliary Spillway fuse plug cover eroded.
PMF Event, No Diversion, Auxiliary Spillway cover eroded	2770	906	874	1780	n/a	n/a	0	976	1217.8	1214.4	n/a	Diversion Inlet gates closed and Service Spillway gates fully open. Auxilliary Spillway fuse plug cover eroded.
160 m^3/s, Gate Failure	160	77	65	142	8	10	18	n/a	1211.9	1211.4	1207.5	Diversion Inlet gates open and Service Spillway gates fully open. Fish passage grading in place.
10-yr Event, Gate Failure	200	91	81	171	13	15	29	n/a	1212.0	1211.6	1207.8	Diversion Inlet gates open and Service Spillway gates fully open.
20-yr Event, Gate Failure	330	143	113	256	35	39	73	n/a	1212.4	1212.0	1208.7	Diversion Inlet gates open and Service Spillway gates fully open.
50-yr Event, Gate Failure	530	211	180	391	67	71	138	n/a	1212.9	1212.5	1209.7	Diversion Inlet gates open and Service Spillway gates fully open.
100-yr Event, Gate Failure	765	289	257	545	108	112	219	n/a	1213.4	1212.9	1210.6	Diversion Inlet gates open and Service Spillway gates fully open.
1000 m^3/s Event, Gate Failure	1000	364	325	689	156	155	310	n/a	1213.9	1213.2	1211.3	Diversion Inlet gates open and Service Spillway gates fully open.
2013 Event, Gate Failure	1240	440	391	831	207	201	408	n/a	1214.4	1213.4	1212.0	Diversion Inlet gates open and Service Spillway gates fully open.
1500 m^3/s Event, Gate Failure	1500	523	454	977	266	256	522	n/a	1215.0	1213.5	1212.7	Diversion Inlet gates open and Service Spillway gates fully open.

* Diversion Inlet Tailwater column values were updated based on results of the diversion channel steady flow HEC-RAS model documented in Appendix B of the Preliminary Design Report

** Tailwater used for stilling basin design.

APPENDIX F.3-2 – FUSE PLUG STABILITY CALCULATIONS

FUSE PLUG
GEOTECHNICAL EVALUATION

Springbank Off-Stream Reservoir Project
Alberta, Canada
Alberta Transportation Department

1. SCOPE

The scope of this analysis is to evaluate the filter compatibility of the materials that comprise the fuse plug and the pilot channel, and their stability considering a water level at the crest of the pilot channel. Erodibility of the materials are presented in a separated calculation report.

2. FUSE PLUG CONFIGURATION

The geometry and configuration of the fuse plug and the pilot channel were selected based on the case studies performed by Schmocker et al (2013) and Pugh (1985), material erodibility, and stability of the structure.

The fuse plug is comprised of 4 zones as shown in the figure below. Zone 4 with a width of 0.2m provides slope protection while Zone 2 with a width of 0.4m serves as a sand filter to protect the core (Zone 3) of the fuse plug. Zone 1 protects the integrity of the fuse plug from possible piping at its foundation. Soil nomenclature was assumed based on soil description presented in the Schmocker et al (2013) reference.

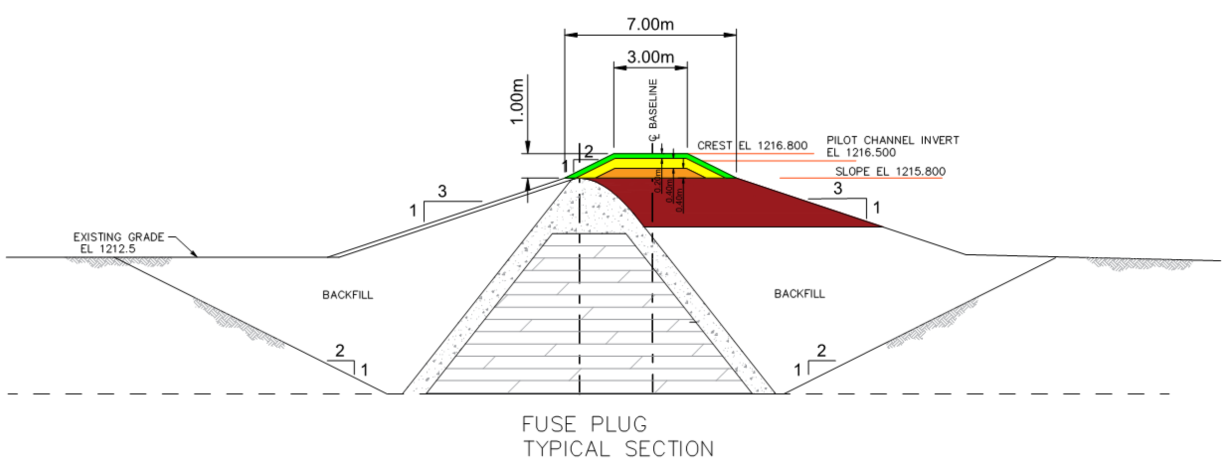


Figure 1. Fuse Plug Configuration

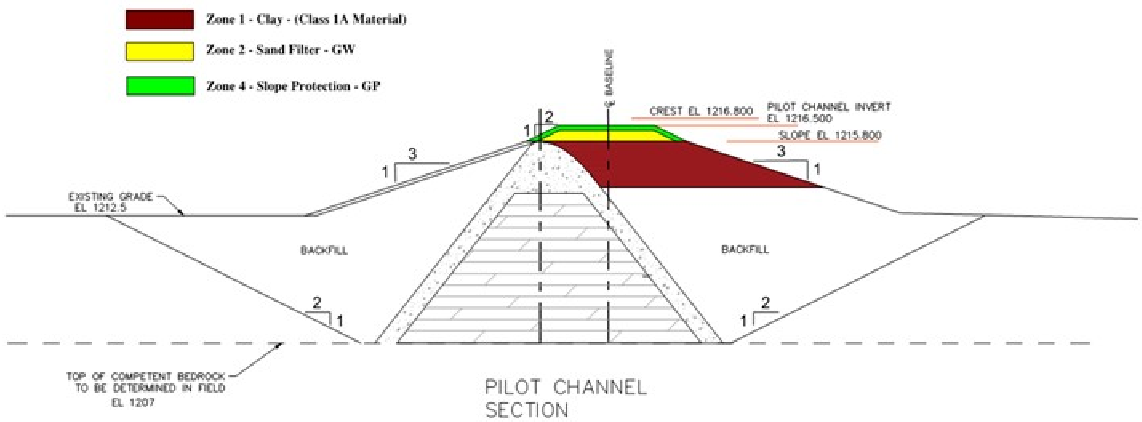


Figure 2. Pilot Channel Section

3. MATERIAL CHARACTERISTICS

The grain size distribution for each material was selected based on the grain size distribution reported on the case studies by Schmocker et al (2013) as shown in Figure 3. The upper and lower bound of the grain size distribution curves for each material were adjusted based on the filer compatibility calculations presented in Section 4.

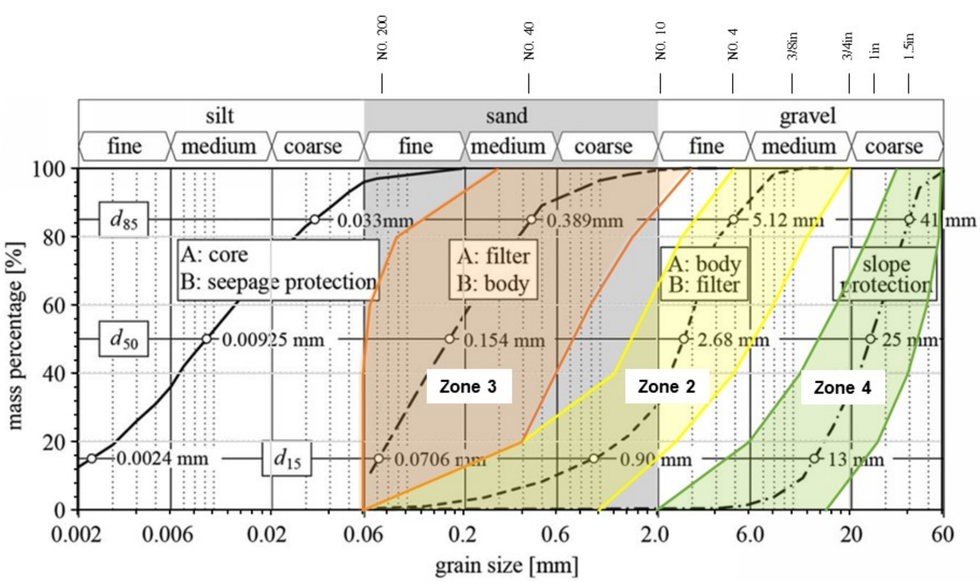


Figure 3. Grain size distribution of fuse plug materials.

4. FILTER COMPATIBILITY CHECK

Filer compatibility between materials was evaluated using the design criteria described in the U.S. Army Corps of Engineers (2004). Table 1 summarizes the filter compatibility checks performed for the fuse plug. Calculations are presented in Attachment A.

Table 1. Filter Compatibility Checks

Base Soil	Filter Soil	Results
Zone 3 – Body - SP	Zone 2 – Sand Filter -GW	Pass
Zone 2 – Sand Filter -GW	Zone 4 – Slope Protection - GP	Pass

5. EVALUATION OF PIPING FAILURE

Considering a water level at the crest of the pilot channel, evaluation of a piping failure was performed considering the exit gradient at the toe of the fuse plug. The factor of safety against piping at the exit is defined as follows per Duncan et al (2011) :

$$FS_{exit-SF} = \frac{i_{crit}}{i}$$

where:

i_{crit} = critical hydraulic gradient
i = hydraulic gradient
$FS_{exit-SF}$ = factor of safety at the seepage exit

The critical hydraulic gradient and the exit hydraulic gradient can be estimated using the relationship proposed by Iverson and Major (1986), and Kovács (1981) as presented in Attachment B.

Seepage analysis of the fuse plug was performed using the computer program Geostudio (2018). The following material properties were considered in the model:

Table 2. Soil Characteristic for seepage analysis

Material	Hydraulic conductivity ***k* (m/s)**	Void ratio e
Zone 3 – Body - SP	7.5×10^{-5}	0.50
Zone 2 – Sand Filter -GW	1.45×10^{-3}	0.33
Zone 4 – Slope Protection - GP	5×10^{-2}	0.33

Figure 4 and Figure 5 show the water pressure head contour diagram resulted from the seepage analysis.

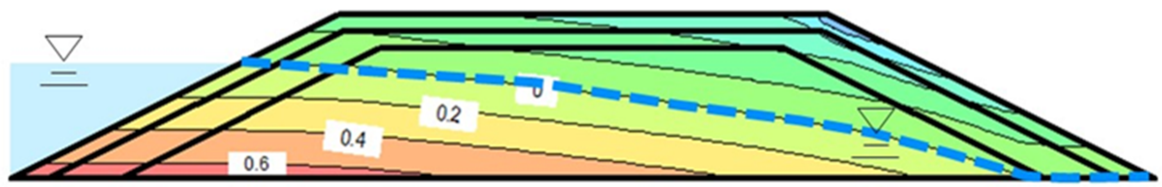


Figure 4. Fuse Plug - Water Pressure Head (m)

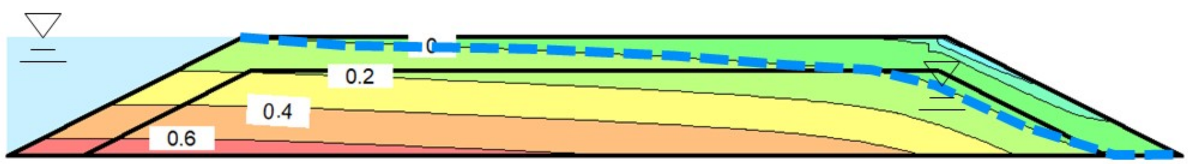


Figure 5. Pilot Channel - Water Pressure Head (m)

The resultant factor of safety at the seepage exit ($FS_{exit-SF}$) is equal to 1.1 for both cases. Nevertheless, the exit is considered stable because the method used to calculate the factor of safety for this analysis is limited since other considerations are in play such as the water level at the exit compared with the grain size distribution of the materials. Also, Schmocker et al (2013) did not report any piping failure after keeping the elevation of the reservoir upstream, 0.20 m below the crest, constant for approximately four weeks on a similar fuse plug structure tested in the laboratory.

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6. SLOPE STABILITY

The stability of the slopes was evaluated using the computer program Geostudio (2018). The following material properties were assumed for the stability analysis, considering a Mohr-Coulomb model.

Table 3. Material Strength Parameters and Unit Weights

Material	Unit weight (kN/m3)	Friction angle (deg)	Cohesion (kPa)
Zone 3 – Body - SP	21	35	0
Zone 2 – Sand Filter -GW	22	38	0
Zone 4 – Slope Protection - GP	22	38	0

The seepage analysis was considered as parent analysis for the slope stability evaluation, therefore phreatic surface from the seepage analysis was used in the slope stability analysis. Spencer methodology was used to determine the factor of safety against sliding. Figure 4 and 5 show the result of the slope stability analysis. A factor of safety (FoS) equal to 1.6 was calculated for the downstream slope for both structures.

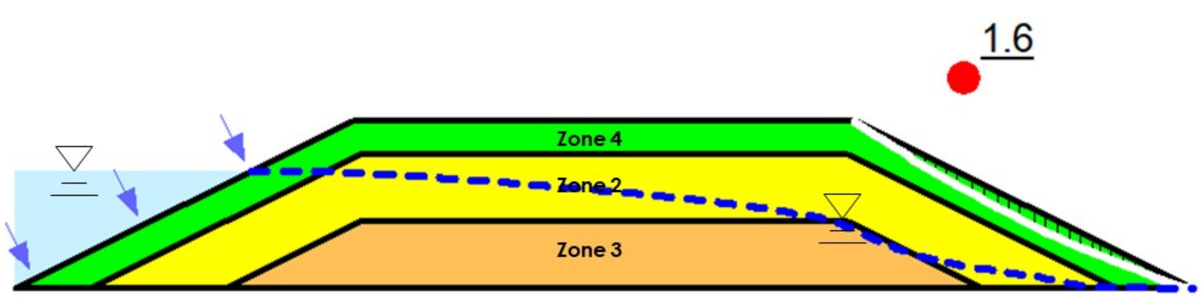

Figure 6. Fuse Plug - Slope Stability Analysis

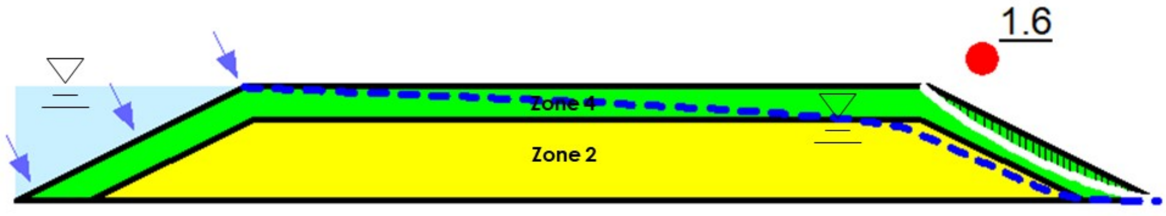

Figure 7. Pilot Channel Slope Stability Analysis

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Pugh, C. (1985). *Hydraulic Model Studies of Fuse Plug Embankments.* REC-ERC-85-7. U.S. Department of the Interior Bureau of Reclamation. Engineering and Research Center. Denver, December.

ATTACHMENT A

	Amounts Finer than Each Laboratory Sieve (Square Openings), Percent by Weight														
	4 in.	3.5 in.	3 in.	1.5 in.	1 in.	3/4 in.	3/8 in.	No. 4	No. 10	No. 40	No. 200	0.02 mm	0.005 mm	0.002 mm	0.001 mm
Name (Must be unique)	**101.6 mm**	**88.9 mm**	**76.2 mm**	**38.1 mm**	**25.4 mm**	**19.05 mm**	**9.525 mm**	**4.75 mm**	**2 mm**	**0.425mm**	**0.075 mm**				
Zone 3 - Body - SP	--	--	--	--	--	--	--	100	100-91	100-22	100-68	0	--	--	--
Zone 2 - Slope Protection -GW	--	--	--	--	100	100-99	100-68	100-38	65-14	21-0	1-0	0	--	--	--
Zone 4 - Sand Filter -GP			100	100-37	81-16	66-6	35-0	14-0	0	--	--	--	--	--	--

Design Criteria

After U.S. Army Corps of Engineers (2004). "General Design and Construction Considerations for Earth and Rock-Fill Dams." EM-1110-2-2300, July 30.

Base Soil Designation

Base Soil Category	Percent Passing No. 200	Soil Description
1	>85%	Fine silts and clays
2	40%-85%	Sands, silts, and silty and clayey sands
3	15%-39%	Silty and clayey sands and gravels
4	<15%	Sands and gravels

Stability (Particle Migration) Criteria

Base Soil Category	Criteria for Maximum D_{15} Size of the Filter Material
1	$D_{15} \leq 9 \times d_{85}$ If 9 x d85 < 0.2mm, then $D_{15} \leq 0.2$
2	$D_{15} \leq 0.7$ mm
3	$D_{15} \leq (4\text{-}A)/25 \times [((4 \times d_{85})\text{-}0.\text{ mm})+0.7\text{mm}]$, where A = percent passing No. 200 sieve If $4 \times d_{85} < 0.7$ mm, then $D_{15} \leq 0.7$mm
4	For filters subject to wave action: $D_{15} \leq 4 \times d_{85}$ For other filters: $D_{15} \leq 5 \times d_{85}$

Permeability Criteria

Base Soil Category	Criteria for Minimum D_{15} Size of the Filter Material
All Categories	Use the maximum d_{15} of base soil, coarse envelope unadjusted
	$D_{15} \geq [(3 \text{ to } 5) \times d_{15}]$
	If $[(3 \text{ to } 5) x d_{15}] \leq 0.1$mm, then $D_{15} \geq 0.1$ mm

Limits to Prevent Segregation During Filter Construction

If Minimum D_{10} (mm)	Then Maximum D_{90} (mm)
< 0.5	20
0.5 - 1	25
1-2	30
2-5	40
5-10	50
10-50	60

Additional Criteria for Filter Material

Maximum particle size of 3 inches
Maximum of 5% passing the No. 200 sieve
Material passing the No. 40 sieve must have PI = 0
Gap-graded filter materials are not acceptable

Project:

Material Inputs

Base Soil: Project Gradations, Zone 3 - Body - SP

Diameter Percent Finer	Sieve Size, mm			
	Coarse Envelope		Fine Envelope	
	Unadjusted	Adjusted	Unadjusted	Adjusted
d_{85}	0.19	0.19	1.75	1.75
d_{15}	0.03	0.03	0.24	0.24

Base Soil (Fine Env., Adj.) % Passing No. 200: 1.00

Filter Soil: Project Gradations, Zone 2 - Sand Filter -GW

Is the interface a designed filter zone?	Yes
Is Filter Material subject to wave action?	No
Is material gap-graded?	No

Diameter Percent Finer	Filter Soil Inputs (Sieve Size, mm)	
	Coarse Envelope	Fine Envelope
D_{90}	3.71	15.58
D_{15}	0.25	2.07
D_{10}	0.16	1.28

Maximum Particle Size (Coarse Env.) (mm):	4.75
Filter Soil (Fine Env.) % Passing No. 200 Sieve:	0.00
Filter Soil Plasticity Index:	

Results Summary

Criteria	Result
Base Soil Category	4
Particle Stability	Pass
Permeability	Pass
Segregation During Construction	Pass
Max. Particle Size	Pass
Fines Content	Pass
Plasticity Index	Pass
Gap Graded	Pass

Filter Compatibility Calculations

Base Soil:	Project Gradations, Zone 3 - Body - SP
Filter Soil:	Project Gradations, Zone 2 - Sand Filter -GW

Base Soil Designation

Base Soil Category:	4

Stability (Particle Migration) Assessment

Criteria, $D_{15} \leq$ (mm):	**8.74**
Filter (Coarse Envelope) D_{15} (mm):	0.25
Result	Pass

Permeability Assessment

Borderline Criteria, $D_{15} \geq$ (mm):	**0.08**
Preferred Criteria, $D_{15} \geq$ (mm):	**0.13**
Filter (Fine Envelope) D_{15} (mm):	2.07
Result	Pass

Segregation During Construction Assessment

Filter (Fine Envelope) D_{10} (mm)	1.28
Criteria, $D_{90} \leq$ (mm):	**30.00**
Filter (Coarse Envelope), D_{90} (mm):	3.71
Result	Pass

Additional Criteria for Designed Filter Materials

Criteria, Max. Particle Size $\leq$ (mm)	**75**
Filter, Max. Particle Size (mm)	5
Result	Pass

Criteria, Fines Content $\leq$ (%)	**5**
Filter, Fines Content (%)	0.0
Result	Pass

Criteria, Plasticity Index	**0**
Filter, Plasticity Index	0
Result	Pass

Filter Is Not Gap-Graded	Pass

Project:

Material Inputs

Base Soil: Project Gradations, Zone 2 - Sand Filter -GW

Diameter Percent Finer	Sieve Size, mm			
	Coarse Envelope		Fine Envelope	
	Unadjusted	Adjusted	Unadjusted	Adjusted
d_{85}	3.28	3.28	13.93	3.87
d_{15}	0.25	0.25	2.07	0.80

Base Soil (Fine Env., Adj.) % Passing No. 200: 0.00

Filter Soil: Project Gradations, Zone 4 - Slope Protection -GP

Is the interface a designed filter zone?	Yes
Is Filter Material subject to wave action?	No
Is material gap-graded?	No

Diameter Percent Finer	Filter Soil Inputs (Sieve Size, mm)	
	Coarse Envelope	Fine Envelope
D_{90}	30.78	68.26
D_{15}	4.91	24.68
D_{10}	3.71	21.37

Maximum Particle Size (Coarse Env.) (mm):	38.10
Filter Soil (Fine Env.) % Passing No. 200 Sieve:	0.00
Filter Soil Plasticity Index:	

Results Summary

Criteria	Result
Base Soil Category	4
Particle Stability	Pass
Permeability	Pass
Segregation During Construction	Pass
Max. Particle Size	Pass
Fines Content	Pass
Plasticity Index	Pass
Gap Graded	Pass

Filter Compatibility Calculations

Base Soil:	Project Gradations, Zone 2 - Sand Filter -GW
Filter Soil:	Project Gradations, Zone 4 - Slope Protection -GP

Base Soil Designation

Base Soil Category:	4

Stability (Particle Migration) Assessment

Criteria, $D_{15} \leq$ (mm):	**69.65**
Filter (Coarse Envelope) D_{15} (mm):	4.91
Result	Pass

Permeability Assessment

Borderline Criteria, $D_{15} \geq$ (mm):	**0.76**
Preferred Criteria, $D_{15} \geq$ (mm):	**1.26**
Filter (Fine Envelope) D_{15} (mm):	24.68
Result	Pass

Segregation During Construction Assessment

Filter (Fine Envelope) D_{10} (mm)	21.37
Criteria, $D_{90} \leq$ (mm):	**60.00**
Filter (Coarse Envelope), D_{90} (mm):	30.78
Result	Pass

Additional Criteria for Designed Filter Materials

Criteria, Max. Particle Size $\leq$ (mm)	**75**
Filter, Max. Particle Size (mm)	38
Result	Pass

Criteria, Fines Content $\leq$ (%)	**5**
Filter, Fines Content (%)	0.0
Result	Pass

Criteria, Plasticity Index	**0**
Filter, Plasticity Index	0
Result	Pass

Filter Is Not Gap-Graded	Pass

ATTACHMENT B

Scope:

Evaluate the factor of safety for piping at the seepage exit using the seepage force method.

Assumptions:

- Bulk unit weight is considered for the calculation of the critical gradient sisnce seepage exit water level is lower than the GP particle size material.
- Afriction angle equal to 40 degrees is considered for the friction angle ar the exit of the seepage.

Calculations:

$$\gamma_w = 9.8\frac{kN}{m^3}$$ unit weight of water

$$\gamma = 22\frac{kN}{m^3}$$ bulk unit weight of soil (embankment shell)

$$\gamma_{sub} = \gamma - \gamma_w$$ sumerged unit weight of soil

$$\phi = 40deg$$

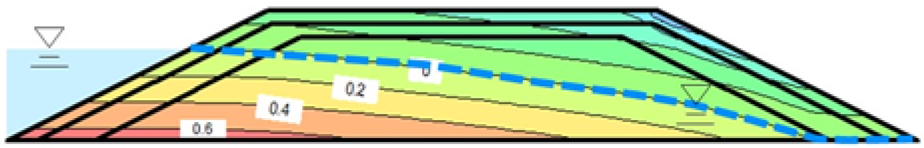
$$\beta = 26.6deg$$ (1V:2H slope)

$$\alpha = 0deg$$ (Exit angle of seepage flow line)

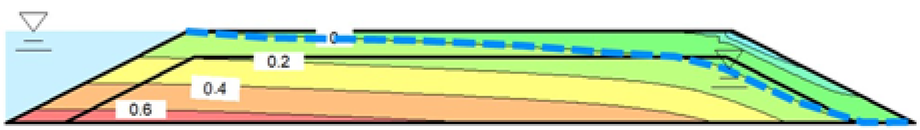
$$i_{crit} = \left(\frac{\gamma}{\gamma_w}\right)\cdot\left(\frac{\tan(\phi)\cdot\cos(\beta) - \sin(\beta)}{\cos(\beta-\alpha) + \tan(\phi)\cdot\sin(\beta-\alpha)}\right) = 0.535$$

$$i = \frac{\sin(\beta)}{\cos(\beta-\alpha)} = 0.501$$

$$FS_{exit\_SL} = \frac{i_{crit}}{i} = 1.1$$

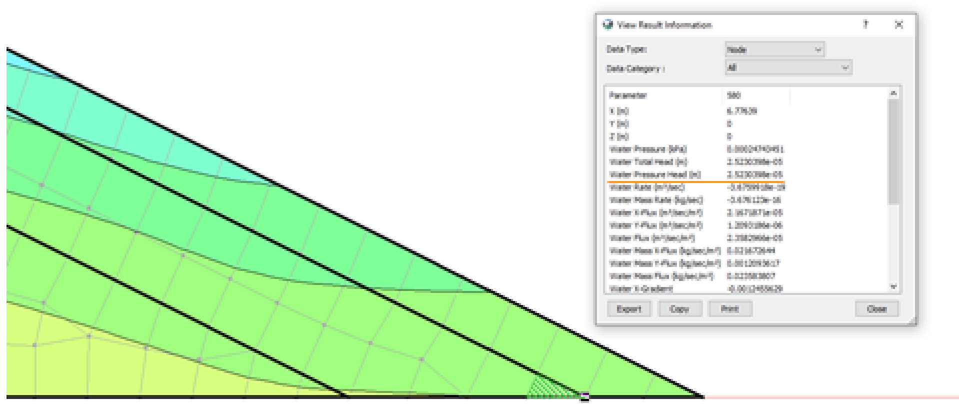


Fuse Plug - Water Pressure Head (m) and Seepage Flow Lines

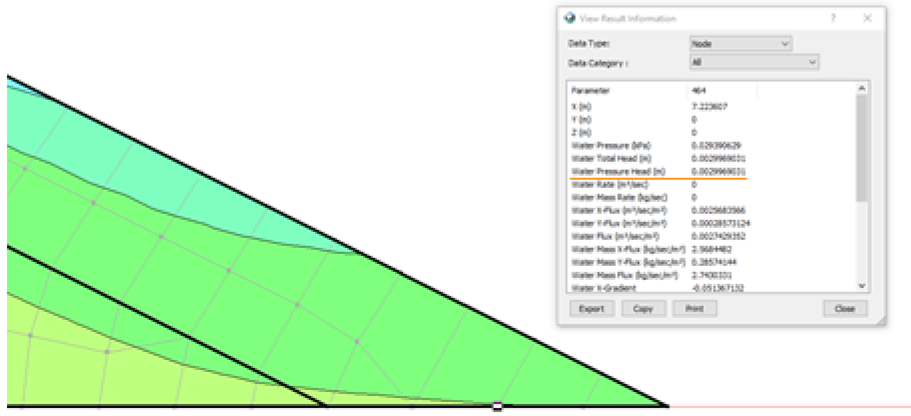


Pilot Channel - Total Head (m) and Seepage Flow Lines

According to the seepage analysis, the water depth at the exit of the seepage flow is approximatelly $H_{wfp} = 0.025mm$ at the fuse plug, and $H_{wpc} = 3mm$ at the pilot channel.



Fuse Plug - Exit Water Level



Pilot Channel - Exit Water Level

The specification of the grain size distribution for the slope protection (GP) material is substantially bigger than the calculated seepage flow depth:

$0.002996m = 2.996 \cdot mm$

Zone 4 - Slope Protection - GP

d_{50} varies 15 mm to 45

min size 2 mm > $H_{wfp} = 0.025 \cdot mm$ and $H_{wpc} = 3mm$

max size 60 mm

Therefore, the application of the seepage analysis methodology used herein is limited for this case, and greater factor of safety could exist against piping at the toe at the fuse plug. Schmocker et al (2013) did not report any piping failure after keeping the elevation of the reservoir upstream, 0.20 m below crest, constant for approximately four weeks on a similar fuse plug structure tested in the laboratory.

References:

Duncan, J. M., O'Neil, B., Brandon, T., and VandenBerge, D. R. (2011). "Evaluation of Potential Erosion in Levees and Levee Foundations." Report CGPR #64, Center for Geotechnical Practice and Research, Virginia Tech, Blacksburg, Virginia, February.

Iverson, R. M., and Major, J. J. (1986). "Groundwater Seepage Vectors and the Potential for Hillslope Failure and Debris Flow Mobilization." Water Resources Research, Vol. 22, No. 11, pp. 1543-1548, October.
Kovács, G. (1981). Seepage Hydraulics. Elsevier Scientific, Amsterdam, pp. 349-379.

Kovács, G. (1981). Seepage Hydraulics. Elsevier Scientific, Amsterdam, pp. 349-379.

APPENDIX F.3-3 – AUXILIARY SPILLWAY DOWNSTREAM SCOUR ANALYSIS

Auxiliary Spillway - Scour Potential
Downstream of Auxiliary Spillway

Springbank Off-Stream Storage Project (SR1)
Rocky View, Alberta
Alberta Transportation Department

1. OBJECTIVE/PURPOSE

Determine the possibility of scour into bedrock downstream of the auxiliary spillway fixed crest during the IDF.

2. REFERENCES

1. USBR and USACE (2015). Best Practices in Dam and Levee Safety Risk Analysis. U.S. Department of the Interior, Bureau of Reclamation, and U.S. Army Corps of Engineers.

2. Stantec, Auxiliary Spillway Hydraulic Load Cases Memorandum, Revision B, September 25, 2019.

3. DATA PROVIDED

IDF Flows over Auxiliary Spillway after Fuse Plug Erosion

$Q := 618\,\frac{m^3}{s}$ Flow over auxiliary spillway during IDF with spillway fuse plug eroded.

$Length := 208m$ Auxiliary Spillway Length

$q := \frac{Q}{Length}$

$q = 2.97\,\frac{m^2}{s}$ $\frac{\frac{m^3}{s}}{m}$ Unit Discharge

Headwater and Tailwater During IDF

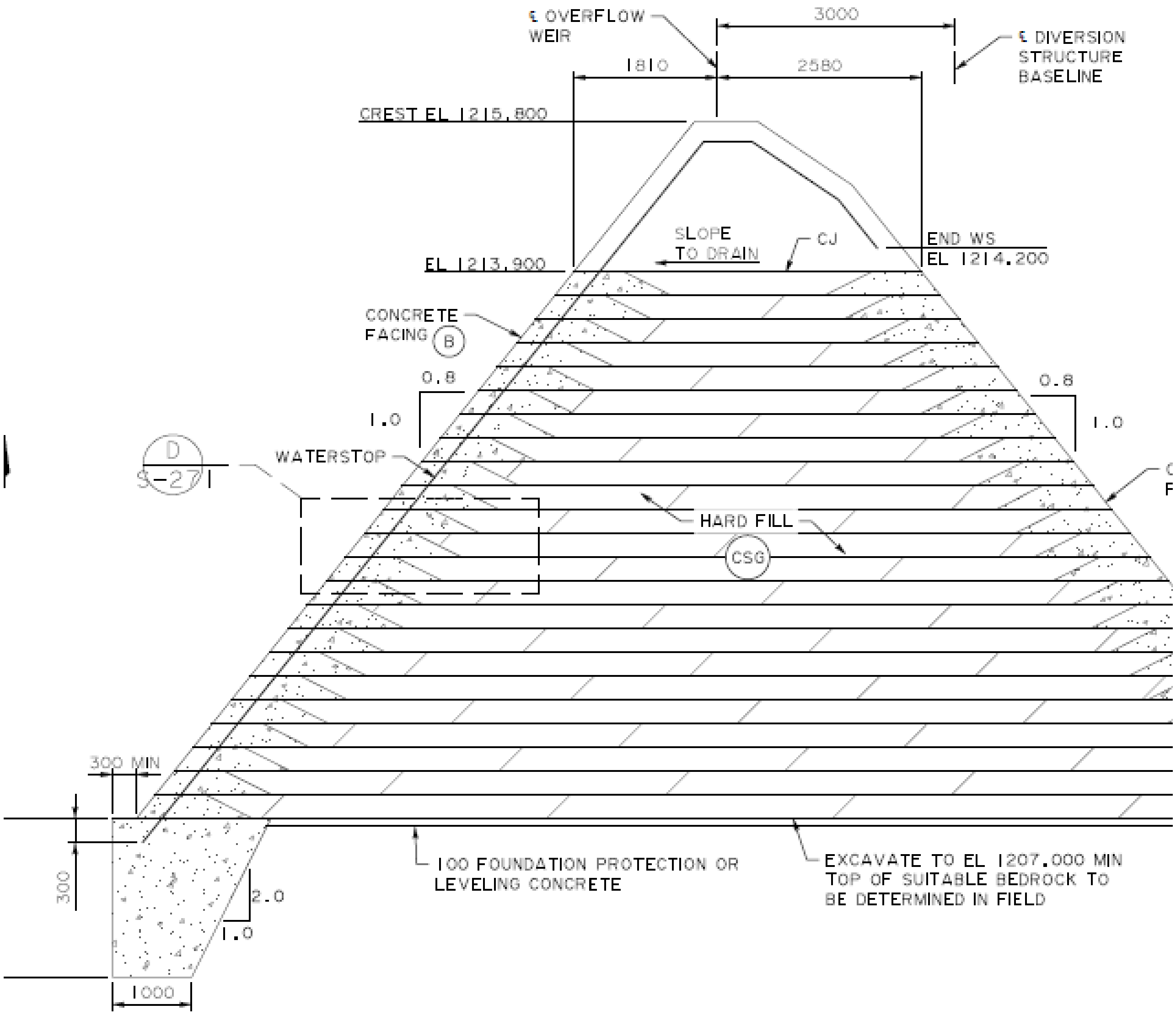
Load Case	2D Model Scenario	Notes
Usual Condition (U1)	160 m^3/s, no diversion	Diversion inlet gates closed and service spillway gates fully open
Unusual Condition 1 (UN1a)	1850 m^3/s event, gate failure	Diversion inlet gates open and service spillway fully open
Unusual Condition 1 (UN1b)	1240 m^3/s event, no diversion	Diversion inlet gates closed and service spillway fully open
Unusual Condition 2 (UN2)	1930 m^3/s event, auxiliary spillway fuse plug eroded	Diversion inlet gates closed and service spillway fully open. Auxiliary spillway fuse plug eroded
Extreme Condition 1 (E1-F)	1/3 Between 1000-yr and PMF, no diversion, auxiliary spillway fuse plug eroded	Diversion inlet gates closed and service spillway gates fully open. Auxiliary spillway fuse plug eroded
Extreme Condition 2 (E2-Q)	160 m^3/s, no diversion	Diversion inlet gates closed and service spillway gates fully open

Load Case	Extreme Condition 1 (E1-F)	
Station	**Headwater Elevation (m)**	**Tailwater Elevation (m)**
1+630	1217.3	1213.8
1+650	1217.3	1213.9
1+700	1217.3	1214.2
1+750	1217.3	1214.4
1+800	1217.3	1214.6
1+840	1217.3	1214.9

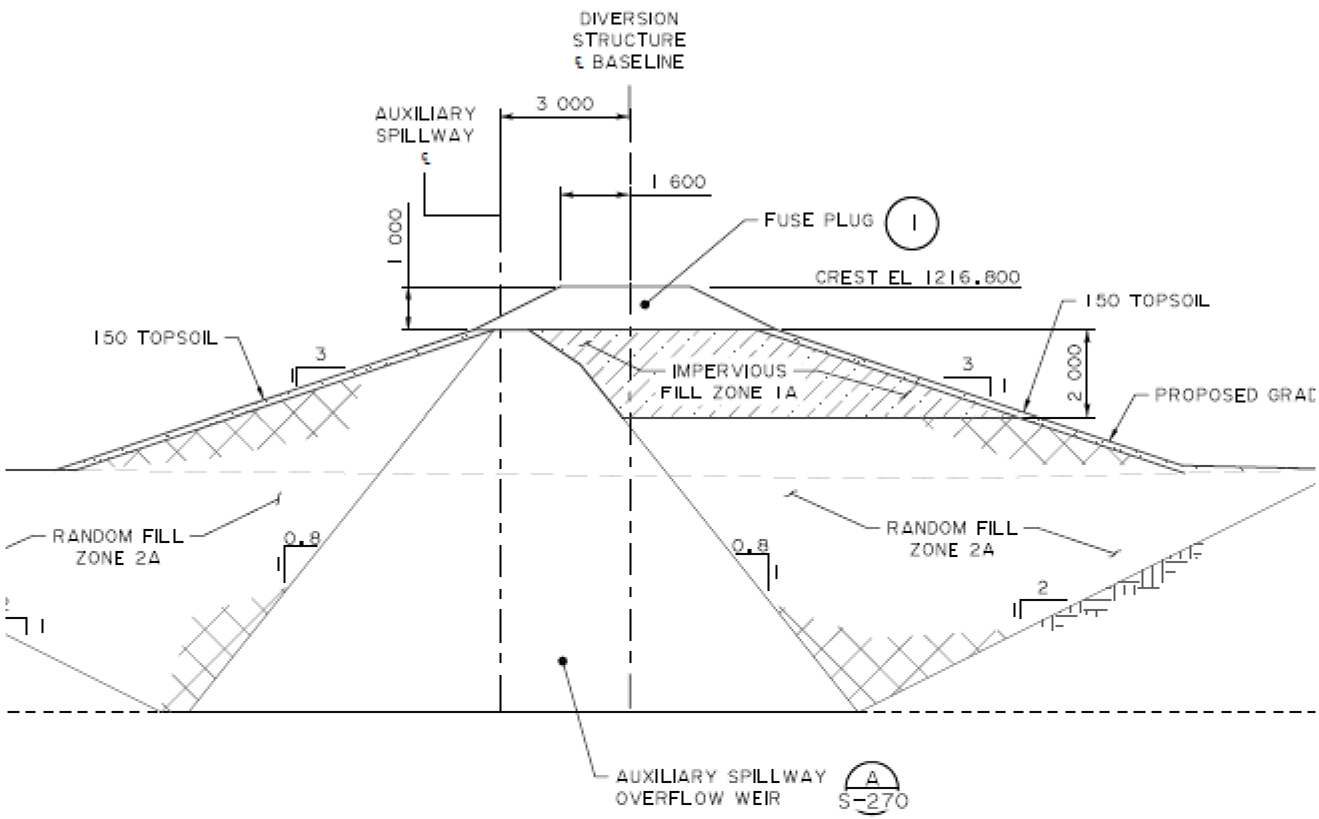
Stations are along auxiliary spillway crest. Use headwater elevation and lowest tailwater elevation.

$HW := 1217.3m$

$TW := 1213.8m$



℄ OVERFLOW WEIR
3000
℄ DIVERSION STRUCTURE BASELINE
1810
2580
CREST EL 1215.800
SLOPE TO DRAIN
CJ
END WS EL 1214.200
EL 1213.900
CONCRETE FACING (B)
0.8
1.0
0.8
1.0
D S-271
WATERSTOP
HARD FILL
CSG
300 MIN
300
2.0
1.0
1000
100 FOUNDATION PROTECTION OR LEVELING CONCRETE
EXCAVATE TO EL 1207.000 MIN TOP OF SUITABLE BEDROCK TO BE DETERMINED IN FIELD



DIVERSION
STRUCTURE
℄ BASELINE
AUXILIARY
SPILLWAY
℄
3 000
1 600
1 000
FUSE PLUG
1
CREST EL 1216.800
150 TOPSOIL
150 TOPSOIL
3
1
IMPERVIOUS
FILL ZONE 1A
3
1
2 000
PROPOSED GRAD
RANDOM FILL
ZONE 2A
0.8
1
0.8
1
RANDOM FILL
ZONE 2A
2
1
AUXILIARY SPILLWAY
OVERFLOW WEIR
A
S-270

4. Plunge Pool Calculation

Use equation to determine depth of scour below tailwater in a plunge pool, from USBR USACE 2015.

Plunge Pools

When flow is concentrated into a plunge pool or at the base of a headcut, the energy dissipation rate is a function of the flow rate, the height of the drop, and the size of the jet at the impingement point. An illustration of flow overtopping a dam into a plunge pool is shown in Figure IV-1-5.

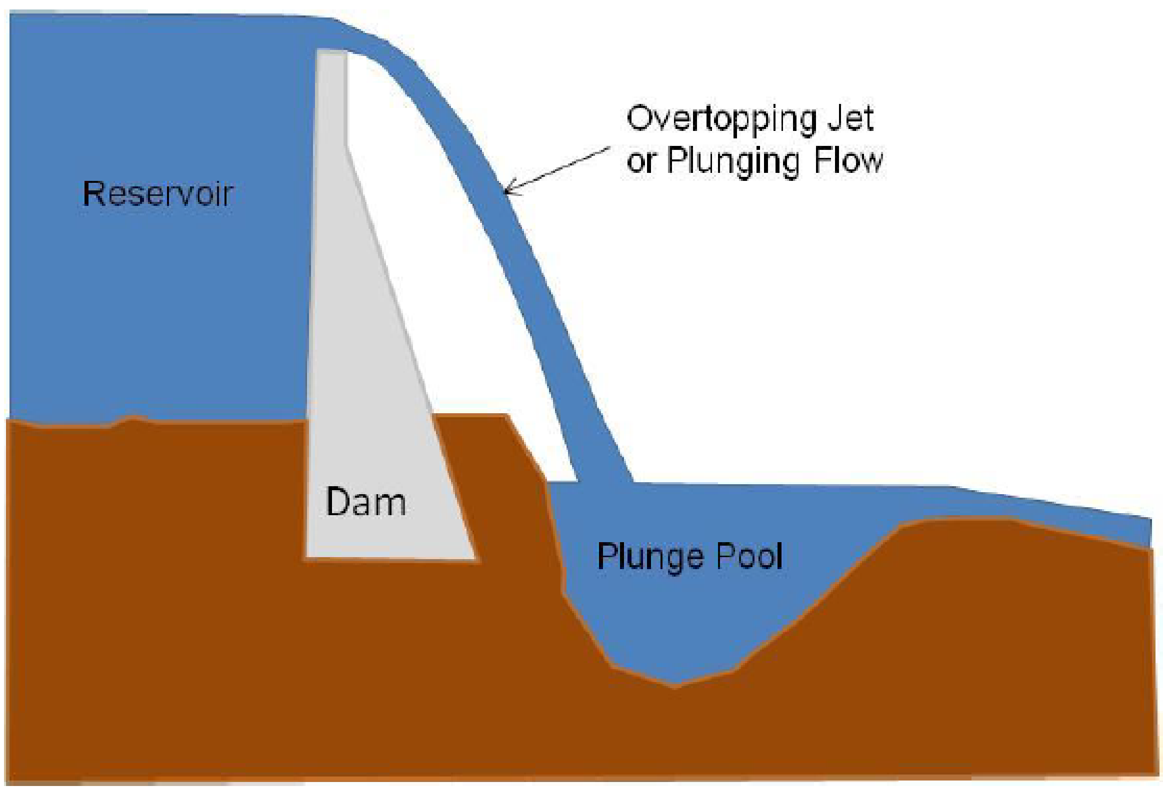


Figure IV-1-5 –Example of Plunging Flow

Equations have been proposed to predict ultimate plunge pool scour depth based on hydraulic model studies using a "moveable bed" or cohesionless sands or small gravel sizes to represent the potentially erodible material.

Equations used in the past to calculate plunge pool scour are the Veronese, Mason and Arumugam, and Yildiz and Uzucek equations. Of these equations only the Mason and Arumugam equation acknowledges that material resistance plays a role in scour. The Veronese (1937) equation is as follows.

$$Y_S = 1.90H^{0.225}q^{0.54}$$

Ys = depth of erosion below tailwater (meters)
H = elevation difference between reservoir and tailwater (meters)
q = unit discharge ($m^3/s/m$)

$Hdiff := HW - TW$

$Ys := 1.9 \cdot Hdiff^{0.225} \cdot q^{0.54}$

$Ys = 4.53$ Units are meters

5. Depth from Tailwater to Bedrock

$Bedrock := 1207m$ Approximate elevation of competent bedrock at auxiliary spillway. Actual elevation to be determined during construction.

$Depth := HW - Bedrock$

$Depth = 10.3\ m$

Depth to bedrock is greater than depth of scour forces below tailwater. Rock below auxiliary spillway will not scour.

APPENDIX F.4 – DIVERSION CHANNEL

APPENDIX F.4-1 – FREEBOARD CALCULATIONS

Diversion Channel Freeboard Criteria

Springbank Off-Stream Reservoir Project
Alberta, Canada
Alberta Transportation Department

1. OBJECTIVE/PURPOSE

The objective of this calculation package is to establish diversion channel freeboard criteria for the Springbank Off-Stream Diversion project and to confirm that Freeboard Criteria is achieved.

2. CRITERIA

Water Control Structures - Selected Design Guidelines (Alberta Transportation and Alberta Environment 2004).

Freeboard Requirement (USBR 1967).

3. REFERENCES

1. Alberta Transportation and Alberta Environment (2004). Water Control Structures - Selected Design Guidelines. Prepared by Mack Slack & Associates, Inc.

2. USBR (1967). Design Standards No. 3 - Canals and Related Structures, Release No. DS-3-5. United States Department of the Interior, Bureau of Reclamation.

3.1 Hydraulic Results

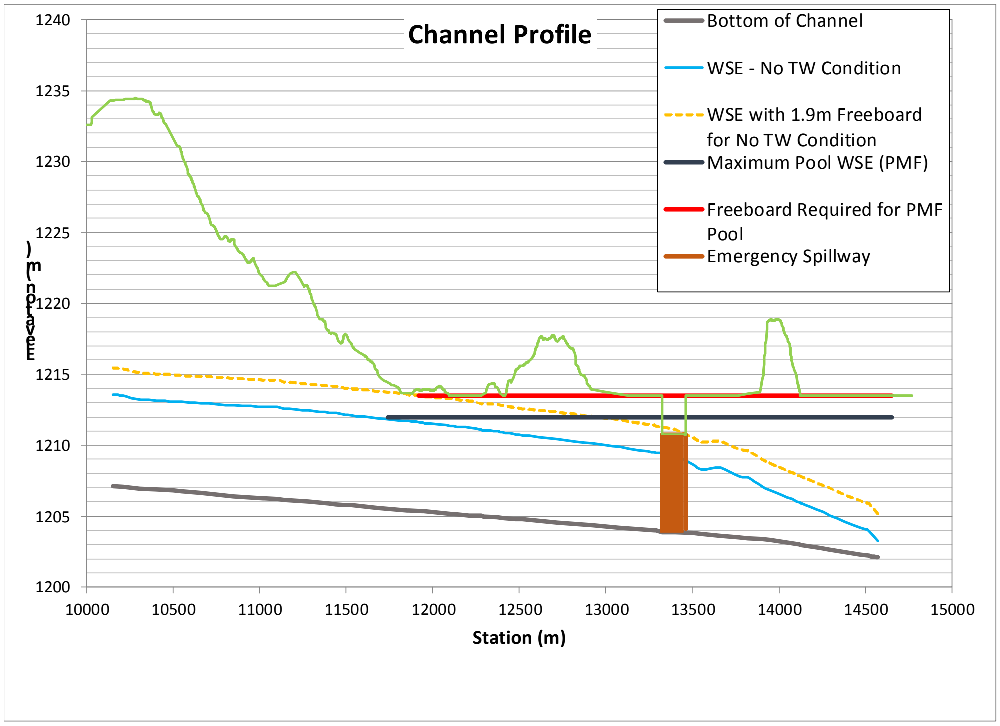
The Hydraulics of the Channel for Sta. 10+150 to Sta. 12+470 were developed using the HEC-RAS Model. Freeboard criteria was determined using the High Mannings "n" value discussed in the Hydraulic Appendix.

4. FIGURES AND CHARTS

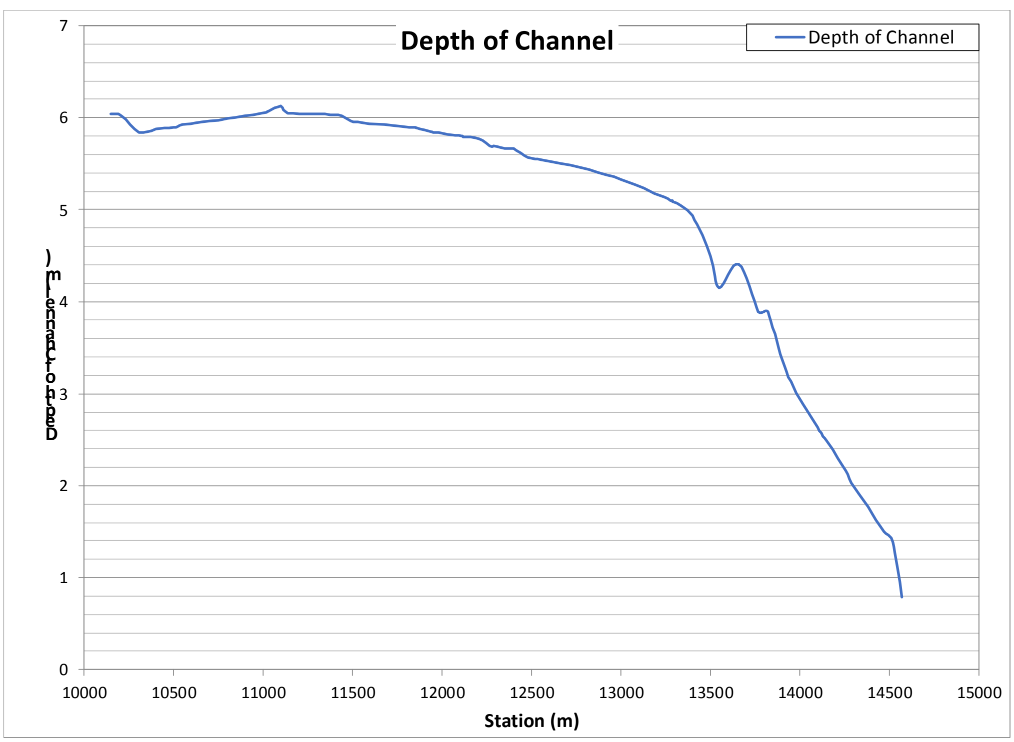
6.2 feet (1.9 meters) of freeboard is required. See Figure below (USBR).

BANK HEIGHT FOR CANALS
AND
FREEBOARD FOR HARD SURFACE, BURIED MEMBRANE, AND EARTH LININGS

Channel Profile



Channel Depth



5. TABLES

Station	Ground Elev.	W.S. Elev	Channel Depth
	(m)	(m)	(m)
10+150	1207.5	1213.6	6.0
10+210	1207.5	1213.5	6.0
10+310	1207.4	1213.2	5.8
10+400	1207.3	1213.1	5.9
10+500	1207.2	1213.1	5.9
10+550	1207.1	1213.0	5.9
10+660	1207.0	1213.0	5.9
10+850	1206.8	1212.8	6.0
11+020	1206.7	1212.7	6.1
11+030	1206.6	1212.7	6.1
11+100	1206.6	1212.7	6.1
11+140	1206.5	1212.6	6.0
11+280	1206.4	1212.4	6.0
11+400	1206.3	1212.3	6.0
11+440	1206.2	1212.3	6.0
11+490	1206.2	1212.1	6.0
11+530	1206.1	1212.1	5.9
11+680	1206.0	1211.9	5.9
11+850	1205.8	1211.7	5.9
11+860	1205.8	1211.7	5.9
11+940	1205.7	1211.6	5.9
11+950	1205.7	1211.6	5.8
12+110	1205.6	1211.4	5.8
12+120	1205.6	1211.3	5.8
12+210	1205.5	1211.2	5.8
12+280	1205.4	1211.1	5.7
12+290	1205.4	1211.1	5.7
12+370	1205.3	1211.0	5.7
12+400	1205.3	1210.9	5.7
12+480	1205.2	1210.8	5.6
12+520	1205.2	1210.7	5.6
12+720	1205.0	1210.4	5.5
12+920	1204.8	1210.1	5.4
13+080	1204.6	1209.9	5.3
13+280	1204.4	1209.5	5.1
13+290	1204.4	1209.5	5.1
13+400	1204.3	1209.2	4.9
13+500	1204.2	1208.7	4.5
13+550	1204.1	1208.3	4.1
13+660	1204.0	1208.4	4.4
13+770	1203.9	1207.8	3.9
13+820	1203.8	1207.7	3.9
13+900	1203.8	1207.1	3.4
13+950	1203.7	1206.8	3.1
14+020	1203.6	1206.5	2.9
14+120	1203.4	1206.0	2.6
14+130	1203.4	1205.9	2.5
14+240	1203.2	1205.4	2.2
14+290	1203.1	1205.1	2.0
14+380	1202.9	1204.6	1.8
14+470	1202.7	1204.2	1.5
14+520	1202.6	1204.0	1.4
14+570	1202.5	1203.3	0.8

Stationin	Crest	Stationin	Crest	Stationin	Crest	Stationin	Crest	Stationing	Crest	Stationing	Crest
10000	1232.6	10784	1224.5	11439	1217.8	12128	1213.5	12805	1216.8	14093	1215.2
10023	1232.6	10788	1224.6	11442	1217.8	12133	1213.5	12807	1216.8	14096	1215.1
10028	1232.7	10792	1224.6	11447	1217.6	12135	1213.5	12809	1216.8	14099	1215.0
10029	1232.8	10794	1224.6	11454	1217.4	12138	1213.5	12812	1216.8	14099	1215.0
10031	1233.0	10796	1224.7	11463	1217.3	12143	1213.5	12813	1216.7	14102	1214.9
10032	1233.1	10798	1224.8	11467	1217.2	12145	1213.5	12814	1216.7	14103	1214.9
10135	1234.3	10801	1224.8	11478	1217.3	12148	1213.5	12817	1216.6	14104	1214.9
10144	1234.3	10803	1224.7	11481	1217.4	12152	1213.5	12820	1216.5	14107	1214.4
10157	1234.3	10805	1224.7	11484	1217.5	12155	1213.5	12825	1216.2	14109	1214.3
10166	1234.3	10807	1224.7	11486	1217.6	12158	1213.5	12825	1215.9	14111	1214.2
10176	1234.3	10809	1224.7	11486	1217.7	12163	1213.5	12828	1215.7	14114	1214.0
10185	1234.4	10811	1224.6	11488	1217.8	12165	1213.5	12834	1215.6	14117	1213.9
10194	1234.4	10813	1224.6	11491	1217.8	12168	1213.5	12839	1215.5	14120	1213.8
10204	1234.4	10815	1224.6	11494	1217.8	12173	1213.5	12842	1215.4	14122	1213.7
10213	1234.4	10817	1224.5	11496	1217.8	12175	1213.5	12843	1215.4	14123	1213.6
10222	1234.4	10819	1224.4	11499	1217.8	12178	1213.5	12846	1215.3	14124	1213.5
10232	1234.4	10825	1224.4	11501	1217.8	12182	1213.5	12849	1215.2	14126	1213.5
10241	1234.4	10832	1224.4	11503	1217.7	12185	1213.5	12850	1215.1	14128	1213.5
10251	1234.4	10834	1224.5	11503	1217.7	12188	1213.5	12853	1215.0	14133	1213.5
10260	1234.4	10835	1224.5	11503	1217.7	12192	1213.5	12858	1215.0	14134	1213.5
10268	1234.4	10838	1224.5	11505	1217.7	12195	1213.5	12862	1215.0	14136	1213.5
10276	1234.4	10840	1224.5	11507	1217.6	12198	1213.5	12867	1214.9	14138	1213.5
10277	1234.5	10842	1224.5	11509	1217.6	12202	1213.5	12870	1214.9	14139	1213.5
10284	1234.5	10844	1224.5	11510	1217.6	12205	1213.5	12875	1214.9	14141	1213.5
10292	1234.4	10846	1224.5	11510	1217.5	12208	1213.5	12875	1214.9	14142	1213.5
10299	1234.4	10848	1224.5	11511	1217.5	12212	1213.5	12878	1214.8	14144	1213.5
10306	1234.4	10851	1224.5	11513	1217.4	12215	1213.5	12882	1214.8	14148	1213.5
10318	1234.4	10853	1224.4	11514	1217.4	12218	1213.5	12885	1214.7	14148	1213.5
10321	1234.4	10855	1224.2	11520	1217.3	12222	1213.5	12887	1214.6	14148	1213.5
10321	1234.4	10859	1224.1	11522	1217.3	12225	1213.5	12890	1214.5	14149	1213.5
10321	1234.4	10862	1224.0	11525	1217.2	12228	1213.5	12893	1214.5	14150	1213.5
10323	1234.4	10864	1224.0	11527	1217.2	12232	1213.5	12894	1214.4	14151	1213.5
10327	1234.4	10866	1223.9	11529	1217.1	12235	1213.5	12897	1214.3	14154	1213.5
10331	1234.3	10866	1223.9	11532	1217.1	12238	1213.5	12900	1214.2	14156	1213.5
10333	1234.3	10867	1223.9	11534	1217.0	12242	1213.5	12901	1214.2	14156	1213.5
10338	1234.3	10868	1223.9	11537	1217.0	12245	1213.5	12905	1214.2	14158	1213.5
10343	1234.3	10872	1223.8	11539	1216.9	12248	1213.5	12908	1214.1	14161	1213.5
10343	1234.3	10874	1223.8	11542	1216.9	12252	1213.5	12911	1214.0	14164	1213.5
10343	1234.3	10877	1223.7	11545	1216.8	12255	1213.5	12913	1214.0	14166	1213.5
10344	1234.2	10879	1223.7	11548	1216.8	12258	1213.5	12916	1213.9	14168	1213.5
10344	1234.2	10883	1223.6	11550	1216.7	12262	1213.5	12919	1213.9	14170	1213.5
10349	1234.2	10887	1223.6	11564	1216.6	12265	1213.5	13003	1213.8	14173	1213.5
10349	1234.2	10889	1223.6	11577	1216.5	12270	1213.5	13128	1213.5	14174	1213.5
10349	1234.2	10892	1223.5	11591	1216.4	12273	1213.5	13137	1213.5	14177	1213.5
10349	1234.2	10896	1223.5	11605	1216.3	12282	1213.5	13149	1213.5	14181	1213.5
10350	1234.2	10899	1223.5	11607	1216.3	12297	1213.6	13152	1213.5	14181	1213.5
10354	1234.2	10903	1223.4	11609	1216.3	12305	1213.7	13155	1213.5	14181	1213.5
10356	1234.2	10905	1223.4	11612	1216.3	12314	1214.0	13155	1213.5	14186	1213.5
10356	1234.2	10907	1223.4	11612	1216.3	12322	1214.3	13156	1213.5	14188	1213.5
10360	1234.2	10909	1223.4	11614	1216.2	12327	1214.3	13156	1213.5	14190	1213.5
10362	1234.2	10910	1223.3	11618	1216.2	12333	1214.3	13156	1213.5	14192	1213.5
10362	1234.2	10912	1223.3	11619	1216.2	12340	1214.4	13160	1213.5	14194	1213.5
10366	1234.2	10914	1223.2	11623	1216.1	12345	1214.4	13163	1213.5	14195	1213.5
10367	1234.2	10918	1223.2	11625	1216.1	12351	1214.4	13165	1213.5	14198	1213.5
10367	1234.2	10921	1223.1	11627	1216.0	12357	1214.4	13167	1213.5	14199	1213.5
10367	1234.2	10925	1223.0	11630	1216.0	12361	1214.1	13167	1213.5	14200	1213.5
10370	1234.1	10930	1222.9	11632	1216.0	12365	1214.1	13167	1213.5	14201	1213.5
10370	1234.1	10935	1222.9	11633	1216.0	12370	1214.1	13168	1213.5	14203	1213.5
10370	1234.1	10937	1222.9	11635	1216.0	12390	1213.6	13169	1213.5	14208	1213.5
10370	1234.1	10939	1222.9	11637	1216.0	12405	1213.5	13170	1213.5	14208	1213.5
10371	1233.9	10944	1222.9	11638	1215.9	12417	1213.5	13171	1213.5	14211	1213.5
10376	1233.7	10948	1223.0	11642	1215.9	12420	1213.6	13171	1213.5	14213	1213.5
10376	1233.7	10950	1223.0	11644	1215.9	12423	1213.6	13172	1213.5	14214	1213.5

APPENDIX F.4-2 – CHANNEL LINING SIZING AND BEDROCK SCOUR

Riprap Sizing for Diversion Channel Amoring

Springbank Off-Stream Storage Project
Alberta, Canada
Alberta Transportation Department

1. OBJECTIVE/PURPOSE

The objective of this calculation package is to size the appropriate riprap for the Diversion Channel.

2. CRITERIA

USACE EM 1110-2-1601 (1991) Method and Mark Slack Associates (2004)

3. REFERENCES

1. USACE. (1991). Hydraulic Design of Flood Control Channels. U.S. Army Corps of Engineers.

2. Mark Slack Associates (2004). Water Control Structures Selected Design Guidelines. Submitted to: Alberta Transportation Department. Calgary, Alberta.

3. Alberta Transportation (2011), Erosion and Sediment Control Manual. Calgary, Alberta

4. Hydraulic Modeling Results

The Hydraulics of the Channel for Sta. 10+100 to Sta. 10+150 were determined from Still Basin Calculations for the Diversion Inlet included in Appendix C.6. The hydraulics of the channel for Sta 10+150 to Sta. 12+470 were developed using the HEC-RAS Model. For Sta. 13+470 to 14+570, 2D hydraulic modeling software was utilized for channel lining armoring. Refer to the Hydraulic Appendix regarding the hydraulic design of Diversion Channel in C.2 and C.7. All Rip Rap sizing calculations were performed utilizing a flowrate of 600 m^3/s down the channel with no tailwater, using the Low "n" mannings values.

5. Riprap Size Calculations

Using equation 3-3 of USACE (1994):

$$D_{30} = S_f C_S C_V C_T d \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{1/2} \frac{V}{\sqrt{K_1 g d}} \right]^{2.5}$$

Where

Saftey Factor: $S_f := 1.3$ Minimum Recommend Factor of Safety of 1.1

Stability coefficient for incipient failure: $C_s := 0.3$ (Angular rock)

Vertical velocity distribution coefficient: $C_V := 1$ (For straight channels)

Thickness coefficient $C_T := 1$ [For thickness 1D100(max) or 1.5D50(max)]

Flow: $Q := 600 \frac{m^3}{s}$

Velocity: $v := 2.3 \frac{m}{s}$

Local depth of flow: $d := 6.4m$

Unit weight of water $\gamma_w := 1000 \frac{kg}{m^3}$

Unit weight of stone: $\gamma_s := 2650 \frac{kg}{m^3}$

Minimum Unit Weight of Rock 2.5 tonnes/m^3

Side slope correction factor:

Based on the modeled 2D resuilts, Velocites significantly decrease near the side slopes, Thus it is conservative to assume that the max velocities in the channel woudl provide sufficient armoring to the side slopes of 3:1. Therefore no angle of side slope with the horizontal has been incorporated.

Angle of side slope with horizontal: $\theta := 0°$

Angle of repose of riprap material: $\varphi := 35°$

Side slope correction factor: $K_1 := \sqrt{1 - \frac{(\sin(\theta))^2}{(\sin(\varphi))^2}} = 1$

Gravitational Constant: $g = 9.81 \frac{m}{s^2}$

4.1 Riprap sizing (D30)

$$D_{30} := S_f \cdot C_s \cdot C_v \cdot C_T \cdot d \cdot \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{0.5} \frac{v}{\sqrt{K_1 \cdot g \cdot d}} \right]^{2.5} = 60.6 \cdot mm$$

6.0. Results

USACE EM 1110-2-1601 Equation 3-3: $D_{30} = 61 \cdot mm$ $W_{30} := \pi \cdot \frac{D_{30}^3}{6} \cdot \gamma_s = 0.3\,kg$

Equation 3-3 converted to D.50 (1.25): $D_{50} := 1.25 \cdot D_{30} = 76 \cdot mm$ $W_{50} := \pi \cdot \frac{D_{50}^3}{6} \cdot \gamma_s = 0.6\,kg$

The velocity and depth varies throughout the diversion channel. Therefore three tables summarize the above calculations for the different observed velocities and depth at different locations along the diversion channel. The minimum class shown is pulled from the Alberta Transportation Gradation Chart (Figure 2). As discussed above,Table 1 refers the the hydraulic calculations determined from the Stilling basin calculations, Table 2 refers to the hydraulic calculations determined from the HEC-RAS modeling and Table 3 refers to the hydraulics performed utilizing the 2D modeling.

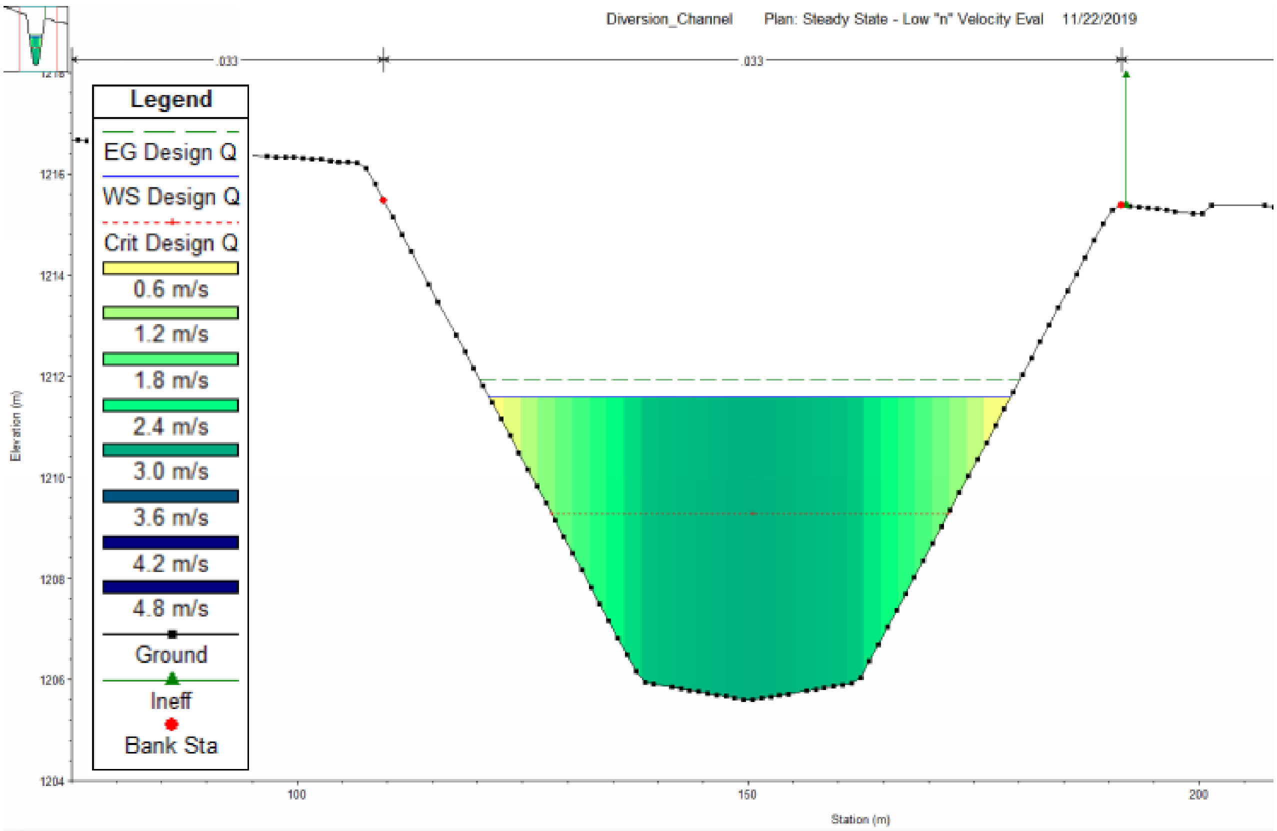


Figure 1 - Example of Velocity Distribution Profile from HEC-RAS Output

Table 1 - Sta 10+100 to 10+150 Required Armoring

	Stilling Basin Design Exit Velocity (m/s)	Centerline Depth (m)	Proposed Armoring	D50 Required (mm)
Station 10+100	2.3	6.4	Rip Rap Zone 6B	77

Table 2. Results Summary

Station	Center Line Depth (m)	Center Line Velocity (m/s)	Primary Armoring	D50 Required (mm)
10+150	6.1	1.9	Bedrock	n/a
10+210	6.0	2.3	Bedrock	n/a
10+310	5.8	3.5	Bedrock	n/a
10+400	5.8	3.4	Bedrock	n/a
10+500	5.9	3.4	Bedrock	n/a
10+550	5.9	3.4	Bedrock	n/a
10+660	6.0	3.3	Bedrock	n/a
10+850	6.0	3.6	Bedrock/ Rip Rap Zone 6B	236
11+020	6.1	3.3	Bedrock/ Rip Rap Zone 6A	151
11+030	6.1	2.8	Rip Rap Zone 6A	125
11+100	6.2	2.4	Rip Rap Zone 6A	85
11+140	6.1	2.8	Rip Rap Zone 6A	125
11+280	6.1	2.9	Rip Rap Zone 6A	137
11+400	6.1	2.9	Rip Rap Zone 6A	137
11+440	6.1	2.9	Rip Rap Zone 6A	137
11+490	6.0	2.9	Rip Rap Zone 6A	137
11+530	6.0	2.9	Rip Rap Zone 6A	137
11+680	6.0	3.0	Rip Rap Zone 6A	137
11+850	6.0	3.1	Rip Rap Zone 6A	163
11+860	6.0	3.1	Rip Rap Zone 6A	164
11+940	5.9	3.1	Rip Rap Zone 6A	164
11+950	5.9	3.1	Rip Rap Zone 6A	164
12+110	5.9	3.2	Rip Rap Zone 6B	178
12+120	5.9	3.8	Bedrock/ Rip Rap Zone 6B	274
12+210	5.9	3.7	Bedrock/ Rip Rap Zone 6B	256
12+280	5.8	3.8	Bedrock/ Rip Rap Zone 6B	275
12+290	5.8	3.8	Bedrock/ Rip Rap Zone 6B	275
12+370	5.7	3.9	Bedrock/ Rip Rap Zone 6B	295
12+400	5.7	3.9	Bedrock/ Rip Rap Zone 6C	295
12+480	5.7	4.1	Bedrock/ Rip Rap Zone 6C	335
12+520	5.6	4.0	Bedrock/ Rip Rap Zone 6C	317
12+720	5.6	3.4	Bedrock	n/a
12+920	5.5	3.4	Bedrock	n/a
13+080	5.4	3.9	Bedrock/ Rip Rap Zone 6B	295
13+280	5.3	3.5	Rip Rap Zone 6B	227
13+290	5.3	3.5	Rip Rap Zone 6B	227
13+400	5.1	3.6	Rip Rap Zone 6B	246

Table 3. Results Summary

Scenario	Sta. 13+470	Sta. 13+570	Sta. 13+625	Sta. 13+770	Sta. 13+970	Sta. 14+170	Sta. 14+270	Sta. 14+370	Sta. 14+560
Velocity (m/s)	3.6	4.2	4.68	4.0	4.2	3.8	3.6	3.3	3.0
Depth (m)	4.9	4.5	4.1	4.0	3.3	2.7	2.3	2.1	1.4
D_{30} (mm)	198	298	400	272	322	264	240	197	172
D_{50} (mm)	248	373	500	340	403	330	300	246	215
Minimum Class Required	Zone 6B	Zone 6C	Zone 6C	Zone 6C	Zone 6C	Zone 6C	Zone 6C	Zone 6B	Zone 6B
Assigned Class	Zone 6B	Zone 6C	Zone 6D	Zone 6C	Zone 6C	Zone 6C	Zone 6C	Zone 6B	Zone 6B

Note: *At Sta 14+270 m US of Stepped Spillway: Zone 6C Rip Rap is required to create the required roughness of the channel for hydraulic reasons in addition for amoring. At Sta 13+625 Zone 6D has been assigned due to the sensitivity of nearby Embankment Fill (Saddle Dam Structure) and risk associated with potential headcutting).*

		Zone 6A	Zone 6B	Zone 6C	Zone 6D
Nominal Mass (kg)		**7**	**40**	**200**	**700**
Nominal Diameter (mm)		**175**	**300**	**500**	**800**
None greater than:	kg or mm	40 300	130 450	700 800	1800 1100
20% to 50%	kg or mm	10 200	70 350	300 600	1100 900
50% to 80%	kg or mm	7 175	40 300	200 500	700 800
100% greater than:	kg or mm	3 125	10 200	40 300	200 500

Figure 2. Alberta Transportation-Typical Rip Rap Gradations

7 Required Rip Rap Armoring Height

The velocity distribution along the side slope of the Channel were evaluted using the HEC-RAS model. Based on Appendix F - Guidelines for Design of Open Channels from Water Control Structures Selected Design Guidelines, the Maximum permissible Velocities for a grass mixture on easily eroded soils is approximately 1.2 m/s. The required rip rap height was determined by selecting the elevation where the velocity against the side slope of the channel is less than 1.2m/s in the HEC-RAS Model.

Station	Primary Armoring	Elevation Where Velocity less than 1.2 m/s on Side Slopes (m)	Required Rip Rap Height* (m)	Assigned Rip Rap Height* (m)
10+150	Bedrock	1209.5	n/a	n/a
10+210	Bedrock	1209.5	n/a	n/a
10+310	Bedrock	1210.5	n/a	n/a
10+400	Bedrock	1210.5	n/a	n/a
10+500	Bedrock	1210.4	n/a	n/a
10+550	Bedrock	1210.4	n/a	n/a
10+660	Bedrock	1210.4	n/a	n/a
10+850	Bedrock/ Rip Rap Zone 6B	1208.4	1.6	4.0
11+020	Bedrock/ Rip Rap Zone 6A	1208.1	1.5	4.0
11+030	Rip Rap Zone 6A	1210.2	3.5	4.0
11+100	Rip Rap Zone 6A	1209.5	3.0	4.0
11+140	Rip Rap Zone 6A	1210.1	3.6	4.0
11+280	Rip Rap Zone 6A	1210.0	3.6	4.0
11+400	Rip Rap Zone 6A	1209.9	3.7	4.0
11+440	Rip Rap Zone 6A	1209.8	3.6	4.0
11+490	Rip Rap Zone 6A	1209.8	3.6	4.0
11+530	Rip Rap Zone 6A	1209.8	3.7	4.0
11+680	Rip Rap Zone 6A	1210.1	4.1	4.0
11+850	Rip Rap Zone 6A	1209.5	3.7	4.0
11+860	Rip Rap Zone 6A	1209.5	3.7	4.0
11+940	Rip Rap Zone 6A	1209.5	3.8	4.0
11+950	Rip Rap Zone 6A	1209.3	3.6	4.0
12+110	Rip Rap Zone 6B	1209.3	3.8	4.0
12+120	Bedrock/ Rip Rap Zone 6B	1208.2	2.7	4.0
12+210	Bedrock/ Rip Rap Zone 6B	1208.0	2.6	4.0
12+280	Bedrock/ Rip Rap Zone 6B	1208.1	2.7	4.0
12+290	Bedrock/ Rip Rap Zone 6B	1208.1	2.7	4.0
12+370	Bedrock/ Rip Rap Zone 6B	1208.0	2.7	4.0
12+400	Bedrock/ Rip Rap Zone 6C	1207.8	2.6	4.0
12+480	Bedrock/ Rip Rap Zone 6C	1207.5	2.3	4.0
12+520	Bedrock/ Rip Rap Zone 6C	1207.5	2.4	4.0
12+720	Bedrock	1208.5	n/a	n/a
12+920	Bedrock	1208.5	n/a	n/a
13+080	Bedrock/ Rip Rap Zone 6B	1208.0	3.4	4.0
13+280	Rip Rap Zone 6B	1208.0	3.6	4.0
13+290	Rip Rap Zone 6B	1207.9	3.6	4.0
13+400	Rip Rap Zone 6B	1207.7	3.4	4.0
*Rip Rap Height Recorded from Elevation when Channel begins to Slope at 3:1, not the Centerline Height				

8.0 Potential Channel Lining Calculations for Diversion Gate Failure PMF Event

8.1 SCOPE

During the PMF Event, if the Diversion Gates were left open, a peak flow of 872 m^3/s is expected to occur based on HEC-ResSim Simulations documented in Appendix B.6. The downstream portion of the DIversion Channel contains embankment fill also refered to as saddle dams. Under this extreme scenario erosion requirements were evaluated for the PMF scenario with Diversion Inlet Gates open to determine if erosion would causing a potential head cut which could further lead to erosion of the portions of the embankment fill or Saddle Dam portions of the channel.

8.2 Hydraulic Model Results

The 2D numerical model of the Diversion Channel Outlet discussed in Appendix C.2 was used to route the PMF hydrograph for the scenario when the Diversion Inlet gates are left open. Results for hours 32 through 36 of the simulation occur near the peak of the hydrograph and when the reservoir water surface elevations does not produce a signficiant tailwater. Velocity and Depth results from the model are presented below in Section 8.3.

8.3 Calculations

Calculations were performed utilizing the EM 1110-2-1601 criteria to determine rip rap size. During the peak flows of the PMF event, the factor of safety was back calculated using the assigned rip rap size to verify erosion did not occur. During the PMF event routing peak flows occured during hours 32-36 of the PMF routing. The calculated factor of safety is shown during these events.

PMF Routing at simulation time 1 day, 8 hours											
Simulation time (hr)	32										
Reservoir level near outlet (m)	1203										
Discharge (m3/s)	790.4										
Scenario		**Sta. 13+470**	**Sta. 13+570**	**Sta. 13+625**	**Sta. 13+770**	**Sta. 13+970**	**Sta. 14+170**	**Sta. 14+270**	**Sta. 14+300**	**Sta. 14+370**	**Sta. 14+560**
Velocity (m/s) (from 2D model)		3.9	4.7	5.2	4.4	4.8	4.3	4.1	4.1	3.7	3.4
Depth (m) (from 2D model		5.7	5.1	4.6	4.6	3.7	3.1	2.7	2.5	2.3	1.7
S_f , Safety Factor (determine using solver)		**1.34**	**1.36**	**1.65**	**1.56**	**1.19**	**1.50**	**1.63**	**1.60**	**1.22**	**1.39**
C_s , Stability Coefficient		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
C_v , Vertical Velocity Distribution Coefficient		1	1	1	1	1	1	1	1	1	1
C_t , Thickness Coeffcient		1	1	1	1	1	1	1	1	1	1
d , Local depth of flow (ft)		18.70	16.73	15.09	15.09	12.14	10.17	8.86	8.20	7.55	5.58
g_w , Unit weight of water (lb/ft3)		62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4
g_s , Unit weight of stone (lb/ft3)		165.36	165.36	165.36	165.36	165.36	165.36	165.36	165.36	165.36	165.36
K_1		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Θ , Angle of side slope with horizontal		0	0	0	0	0	0	0	0	0	0
, Angle of repose of riprap material (normally 40 deg)		35	35	35	35	35	35	35	35	35	35
g , Gravitational constant (ft/s2)		32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2
V , Local velocity of flow (ft/s)		12.80	15.42	17.06	14.44	15.75	14.11	13.45	13.45	12.14	11.15
D_{30} (ft)		0.79	1.31	2.10	1.31	1.31	1.31	1.31	1.31	0.79	0.79
D_{50} (ft)		0.98	1.64	2.62	1.64	1.64	1.64	1.64	1.64	0.98	0.98
D_{50} (mm) of Proposed Rip Rap Zone		300	500	800	500	500	500	500	500	300	300

PMF Routing at simulation time 1 day, 9 hours											
Simulation time (hr)	33										
Reservoir level near outlet (m)	1204										
Discharge (m3/s)	826.9										
Scenario		**Sta. 13+470**	**Sta. 13+570**	**Sta. 13+625**	**Sta. 13+770**	**Sta. 13+970**	**Sta. 14+170**	**Sta. 14+270**	**Sta. 14+300**	**Sta. 14+370**	**Sta. 14+560**
Velocity (m/s) (from 2D model)		3.9	4.7	5.2	4.5	4.9	4.4	4.2	4.2	3.8	3.4
Depth (m) (from 2D model		5.8	5.2	4.7	4.7	3.8	3.2	2.7	2.6	2.4	1.7
S_f , Safety Factor (determine using solver)		**1.34**	**1.37**	**1.65**	**1.48**	**1.14**	**1.43**	**1.54**	**1.52**	**1.15**	**1.39**
C_s , Stability Coefficient		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
C_v , Vertical Velocity Distribution Coefficient		1	1	1	1	1	1	1	1	1	1
C_t , Thickness Coeffcient		1	1	1	1	1	1	1	1	1	1
d , Local depth of flow (ft)		19.03	17.06	15.42	15.42	12.47	10.50	8.86	8.53	7.87	5.58
g_w , Unit weight of water (lb/ft3)		62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4
g_s , Unit weight of stone (lb/ft3)		165.36	165.36	165.36	165.36	165.36	165.36	165.36	165.36	165.36	165.36
K_1		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Θ , Angle of side slope with horizontal		0	0	0	0	0	0	0	0	0	0
, Angle of repose of riprap material (normally 40 deg)		35	35	35	35	35	35	35	35	35	35
g , Gravitational constant (ft/s2)		32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2
V , Local velocity of flow (ft/s)		12.80	15.42	17.06	14.76	16.08	14.44	13.78	13.78	12.47	11.15
D_{30} (ft)		0.79	1.31	2.10	1.31	1.31	1.31	1.31	1.31	0.79	0.79
D_{50} (ft)		0.98	1.64	2.62	1.64	1.64	1.64	1.64	1.64	0.98	0.98
D_{50} (mm) of Proposed Rip Rap Zone		300	500	800	500	500	500	500	500	300	300

PMF Routing at simulation time 1 day, 10 hours											
Simulation time (hr)	34										
Reservoir level near outlet (m)	1204										
Discharge (m3/s)	852.8										
Scenario		**Sta. 13+470**	**Sta. 13+570**	**Sta. 13+625**	**Sta. 13+770**	**Sta. 13+970**	**Sta. 14+170**	**Sta. 14+270**	**Sta. 14+300**	**Sta. 14+370**	**Sta. 14+560**
Velocity (m/s) (from 2D model)		4	4.8	5.3	4.5	5.0	4.5	4.3	4.2	3.9	3.4
Depth (m) (from 2D model		5.9	5.3	4.8	4.8	3.9	3.3	2.7	2.6	2.4	1.9
S_f , Safety Factor (determine using solver)		**1.27**	**1.30**	**1.59**	**1.49**	**1.09**	**1.36**	**1.45**	**1.52**	**1.08**	**1.43**
C_s , Stability Coefficient		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
C_v , Vertical Velocity Distribution Coefficient		1	1	1	1	1	1	1	1	1	1
C_t , Thickness Coeffcient		1	1	1	1	1	1	1	1	1	1
d , Local depth of flow (ft)		19.36	17.39	15.75	15.75	12.80	10.83	8.86	8.53	7.87	6.23
g_w , Unit weight of water (lb/ft3)		62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4
g_s , Unit weight of stone (lb/ft3)		165.36	165.36	165.36	165.36	165.36	165.36	165.36	165.36	165.36	165.36
K_1		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Θ , Angle of side slope with horizontal		0	0	0	0	0	0	0	0	0	0
, Angle of repose of riprap material (normally 40 deg)		35	35	35	35	35	35	35	35	35	35
g , Gravitational constant (ft/s2)		32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2
V , Local velocity of flow (ft/s)		13.12	15.75	17.39	14.76	16.40	14.76	14.11	13.78	12.80	11.15
D_{30} (ft)		0.79	1.31	2.10	1.31	1.31	1.31	1.31	1.31	0.79	0.79
D_{50} (ft)		0.98	1.64	2.62	1.64	1.64	1.64	1.64	1.64	0.98	0.98
D_{50} (mm) of Proposed Rip Rap Zone		300	500	800	500	500	500	500	500	300	300

PMF Routing at simulation time 1 day, 11 hours											
Simulation time (hr)	35										
Reservoir level near outlet (m)	1205										
Discharge (m3/s)	867.7										
Scenario		Sta. 13+470	Sta. 13+570	Sta. 13+625	Sta. 13+770	Sta. 13+970	Sta. 14+170	Sta. 14+270	Sta. 14+300	Sta. 14+370	Sta. 14+560
Velocity (m/s) (from 2D model)		4	4.8	5.3	4.5	5.0	4.5	4.3	4.2	3.8	2.9
Depth (m) (from 2D model		5.9	5.3	4.8	4.8	3.9	3.3	2.8	2.6	2.5	2.5
S_f , Safety Factor (determine using solver)		**1.27**	**1.30**	**1.59**	**1.49**	**1.09**	**1.36**	**1.46**	**1.52**	**1.16**	**2.28**
C_s , Stability Coefficient		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
C_v , Vertical Velocity Distribution Coefficient		1	1	1	1	1	1	1	1	1	1
C_t , Thickness Coeffcient		1	1	1	1	1	1	1	1	1	1
d , Local depth of flow (ft)		19.36	17.39	15.75	15.75	12.80	10.83	9.19	8.53	8.20	8.20
g_w , Unit weight of water (lb/ft3)		62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4
g_s , Unit weight of stone (lb/ft3)		165.36	165.36	165.36	165.36	165.36	165.36	165.36	165.36	165.36	165.36
K_1		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Θ , Angle of side slope with horizontal		0	0	0	0	0	0	0	0	0	0
, Angle of repose of riprap material (normally 40 deg)		35	35	35	35	35	35	35	35	35	35
g , Gravitational constant (ft/s2)		32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2
V , Local velocity of flow (ft/s)		13.12	15.75	17.39	14.76	16.40	14.76	14.11	13.78	12.47	9.51
D_{30} (ft)		0.79	1.31	2.10	1.31	1.31	1.31	1.31	1.31	0.79	0.79
D_{50} (ft)		0.98	1.64	2.62	1.64	1.64	1.64	1.64	1.64	0.98	0.98
D_{50} (mm) of Proposed Rip Rap Zone		300	500	800	500	500	500	500	500	300	300

PMF Routing at simulation time 1 day, 12 hours											
Simulation time (hr)	36										
Reservoir level near outlet (m)	1205										
Discharge (m3/s)	872.3										
Scenario		Sta. 13+470	Sta. 13+570	Sta. 13+625	Sta. 13+770	Sta. 13+970	Sta. 14+170	Sta. 14+270	Sta. 14+300	Sta. 14+370	Sta. 14+560
Velocity (m/s) (from 2D model)		4	4.8	5.3	4.5	5.0	4.5	4.1	3.9	3.4	2.5
Depth (m) (from 2D model		5.9	5.3	4.9	4.8	3.9	3.3	2.9	2.9	2.9	3.1
S_f , Safety Factor (determine using solver)		**1.27**	**1.30**	**1.59**	**1.49**	**1.09**	**1.36**	**1.66**	**1.88**	**1.59**	**3.49**
C_s , Stability Coefficient		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
C_v , Vertical Velocity Distribution Coefficient		1	1	1	1	1	1	1	1	1	1
C_t , Thickness Coeffcient		1	1	1	1	1	1	1	1	1	1
d , Local depth of flow (ft)		19.36	17.39	16.08	15.75	12.80	10.83	9.51	9.51	9.51	10.17
g_w , Unit weight of water (lb/ft3)		62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4
g_s , Unit weight of stone (lb/ft3)		165.36	165.36	165.36	165.36	165.36	165.36	165.36	165.36	165.36	165.36
K_1		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Θ , Angle of side slope with horizontal		0	0	0	0	0	0	0	0	0	0
, Angle of repose of riprap material (normally 40 deg)		35	35	35	35	35	35	35	35	35	35
g , Gravitational constant (ft/s2)		32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2
V , Local velocity of flow (ft/s)		13.12	15.75	17.39	14.76	16.40	14.76	13.45	12.80	11.15	8.20
D_{30} (ft)		0.79	1.31	2.10	1.31	1.31	1.31	1.31	1.31	0.79	0.79
D_{50} (ft)		0.98	1.64	2.62	1.64	1.64	1.64	1.64	1.64	0.98	0.98
D_{50} (mm) of Proposed Rip Rap Zone		300	500	800	500	500	500	500	500	300	300

8.4 Conclusions

These calculations verify that the assigned rip rap has a factor of safety Greater than 1.0 during the PMF Scenario when the Diversion Gates are left Open indicating the rip rap is sized appropriately to prevent erosion accordinng to EM 1110-2-1601.

Scour Analysis

Springbank Off-Stream Reservior Project
Alberta, Canada
Alberta Transportation Department

1. OBJECTIVE/PURPOSE

The objective of this calculation package is to determine likelihood of erosion of Mudstone at the bottom of the diversion channel.

2. CRITERIA

Stream power-erodibility index method (USBR and USACE, 2015)

3. REFERENCES

1. USBR & USACE. (2015). Best Practices in Dam and Levee Safety Risk Analysis. U.S. Department of the Interior, Bureau of Reclamation, and U.S. Army Corps of Engineers.

2.Annadale, G.W. (1995). Erodibilit. Journal Hydraulic Research, IAHR, Vol 33(4):471-494.

3. Wibowo, J.L., D.E. Yule and Villanueva (2005). Earth and Rock Surface Spillway Erosion Risk Assesment, Proceedings, 40th U.S. Symposium on Rock Mechanics, Anchorage Alaska.

4. Erodability Index Calculation

The potential for scour during a short-lived design flood event was estimated using the Erodibility Index Method (EIM) proposed by Annadale and Smith (2001). This is based off work by Annadale (1995) and Kirsten's (1992) excavation classification system. Whilst it is proposed primarily for bridge scour, it is recommended by Federal Energy Regulatory Commission (FERC) and supported by both the USACE and USBR.

This method estimates an index value based on the rock mass characteristics and intact rock strength. This is subsequently compared against the estimated stream power for a specified design event to determine the potential for scour (Figures 4 to 7 in Annadale and Smith, 2001; Figure IV-1-6 to IV-1-8 in USACE / USBR, 2015).

For the erodibility index, four different rock zones identified along the alignment of the channel were analyzed using the EIM. Based on the results of the EIM, Rock Zones 2-4 fall within the non-eroded section which suggest less than a 1% chance of erosion and therefore erosion of theses rock zones is not anticipated when conveying a flow rate of 600 m^3/sec. Rock Zone 1 has a much weaker erodibility index and is barely located below the 1% chance. Given its close proximity to the erodibility line it may erode slightly for an erosion event. It should be noted that the EIM evaluates the likelihood of erosion for a single hydraulic event. It does not consider long terms impacts that may cause scour (or more generally, loss of material) due to weathering, freeze-thaw cycles, seepage and other long-term degradation processes. Long term impacts due to weathering, may reduce the strength of the material and thereby cause erosion in the future. The geotechnical investigation showed that rock zone 1 appears at high risk for continued long term weathering. This is likely to cause maintenance issues in the rock zone and this zone may lose additional material over the years due to increased weathering.

Erodibility Index Input Parameters

Rock Cut Section	Borings	Station	Bedrock	Mass Strength Ms	RQD	Jn	Jr	Ja
1	DC1-DC10	10+000 to 11+000	40% Mudstone, 30% Shale, 20% Claystone, 10% Sandstone	1.86	20	5	1	18
2	DC18-DC21	12+300 to 13+000	30% Mudstone, 40% Siltstone, 30% Sandstone	17.7	50	4.09	1.5	13
3	DC23-DC24	13+200 to 13+600	40% Siltstone, 60% Sandstone	8.39	25	5	1.5	13
4	DC28-DC29	13+900 to 14+250	20% Claystone, 80% Sandstone	17.7	40	4.09	1.5	13

4.1 Zone 1

Mass Strength: $M_{s1} := 1.86$ MPa Based on preliminary lab testing results

Rock Quality Designation: $RQD_1 := 20$ Based on the general RQD of the top 5m of bedrock

Modified Joint Set Number: $J_{n1} := 5$ More than 5 joints sets

Particle of Fragment Size of the Rock thet form the Mass: $K_{b1} := \frac{RQD_1}{J_{n1}} = 4$

Joint Roughness: $J_{r1} := 1$ Assume worse case

Joint Alteration Numbers: $J_{a1} := 18$ Worst case for joint alteration

Interparticle Bond Shear Strength: $K_{d1} := \frac{J_{r1}}{J_{a1}} = 0.06$

Coefficient to Account for Relative Shape and Orientation: $J_{s1} := 0.5$ Worst case 85% dip against the direction of flow

Erodibility Index: $K_{h1} := M_{s1} \cdot K_{b1} \cdot K_{d1} \cdot J_{s1} = 0.207$

4.2 Zone 2

Mass Strength: $M_{s2} := 17.7$ MPa Based on preliminary lab testing results

Rock Quality Designation: $RQD_2 := 50$ Based on the general RQD of the top 5m of bedrock

Modified Joint Set Number: $J_{n2} := 4.09$ 3 joints sets

Particle of Fragment Size of the Rock thet form the Mass: $K_{b2} := \frac{RQD_2}{J_{n2}} = 12.22$

Joint Roughness: $J_{r2} := 1.5$ Assume Mudstone is smooth/slick

Joint Alteration Numbers: $J_{a2} := 13$ Worst case for joint alteration

Interparticle Bond Shear Strength: $K_{d2} := \frac{J_{r2}}{J_{a2}} = 0.12$

Coefficient to Account for Relative Shape and Orientation: $J_{s2} := 0.5$ Worst case 85% dip against the direction of flow

Erodibility Index: $K_{h2} := M_{s2} \cdot K_{b2} \cdot K_{d2} \cdot J_{s2} = 12.48$

4.3 Zone 3

Mass Strength: $M_{s3} := 8.39$ MPa Based on preliminary lab testing results

Rock Quality Designation: $RQD_3 := 25$ Based on the general RQD of the top 5m of bedrock

Modified Joint Set Number: $J_{n3} := 5$ 3 joints sets

Particle of Fragment Size of the Rock thet form the Mass: $K_{b3} := \frac{RQD_3}{J_{n3}} = 5$

Joint Roughness: $J_{r3} := 1.5$ Assume Mudstone is smooth/slick

Joint Alteration Numbers: $J_{a3} := 13$ Worst case for joint alteration

Interparticle Bond Shear Strength: $K_{d3} := \frac{J_{r3}}{J_{a3}} = 0.12$

Coefficient to Account for Relative Shape and Orientation: $J_{s3} := 0.5$

Erodibility Index: $K_{h3} := M_{s3} \cdot K_{b3} \cdot K_{d3} \cdot J_{s3} = 2.42$

4.4 Zone 4

Mass Strength: $M_{s4} := 17.7$ MPA Based on preliminary lab testing results

Rock Quality Designation: $RQD_4 := 40$ Based on the general RQD of the top 5m of bedrock

Modified Joint Set Number: $J_{n4} := 4.09$ 3 joints sets

Particle of Fragment Size of the Rock thet form the Mass: $K_{b4} := \frac{RQD_4}{J_{n4}} = 9.78$

Joint Roughness: $J_{r4} := 1.5$ Assume Mudstone is smooth/slick

Joint Alteration Numbers: $J_{a4} := 13$ Worst case for joint alteration

Interparticle Bond Shear Strength: $K_{d4} := \frac{J_{r4}}{J_{a4}} = 0.12$

Coefficient to Account for Relative Shape and Orientation: $J_{s4} := 0.5$

Erodibility Index: $K_{h4} := M_{s4} \cdot K_{b4} \cdot K_{d4} \cdot J_{s4} = 9.99$

5. Stream Power Potential

Stream Power inputs determine from hydraulic analysis. See Appendix C.

5.1 Stream Power for Surface Flow (Channel Slope = 0.001)

Unit weight of water: $\gamma_w := 9.82 \ \frac{kN}{m^3}$ Bedrock Cut Manning Value: n= 0.020

Average Velocity: $v_1 := 3.1 \ \frac{m}{s}$

Depth of Flow: $d_1 := 5.8 \ m$

Slope of Energy Grade Line: $sl := 0.001 \ \frac{m}{m}$

Hydraulic Radius: $H_{R1} := 3.966 \ m$

Shear Stress of Open Channel: $\tau_{b1} := \gamma_w \cdot sl \cdot H_{R1} = 0.04$

Stream Power Potential: $p_1 := \gamma_w \cdot v_1 \cdot d_1 \cdot sl = 0.177 \ \frac{kW}{m^2}$

5.2 Stream Power for Surface Flow (Channel Slope = 0.002)

Average Velocity: $v_2 := 3.1 \ \frac{m}{s}$

Depth of Flow: $d_2 := 5.3 \ m$

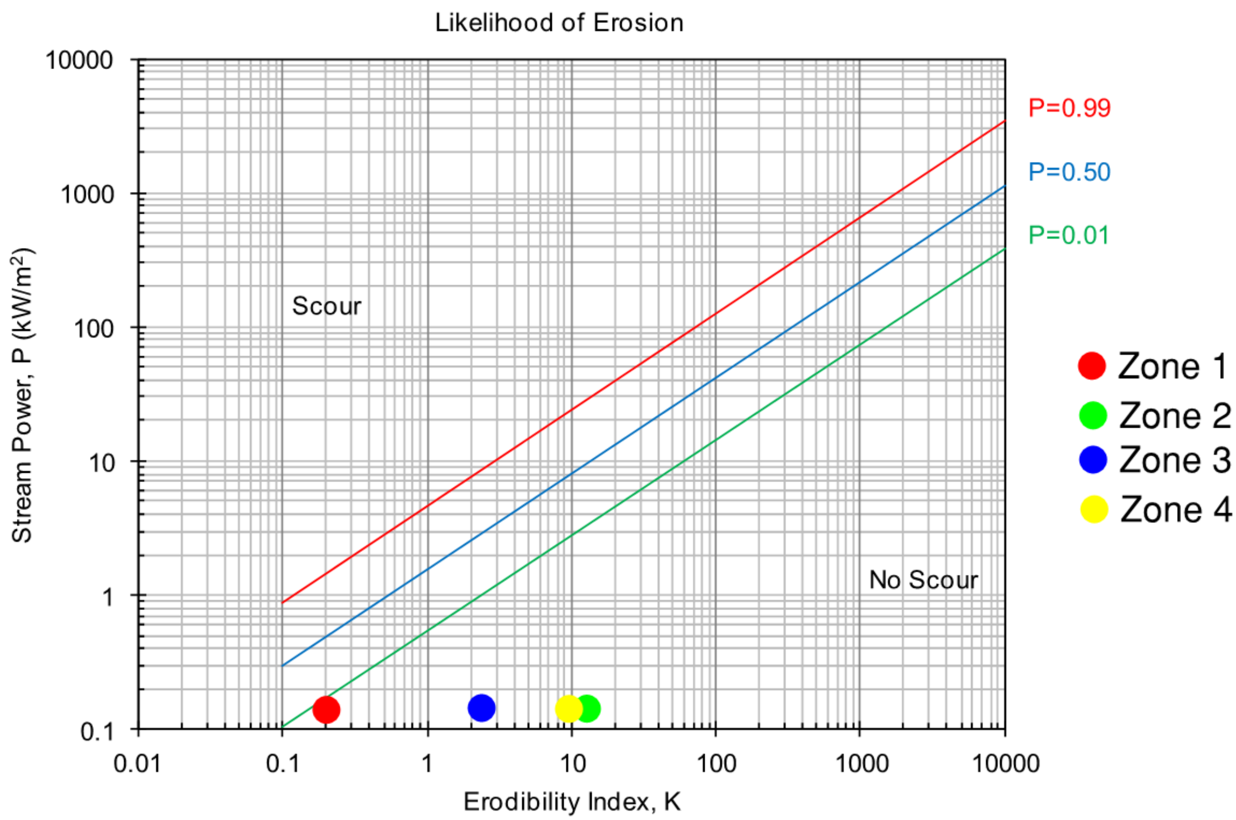
Hydraulic Radius: $H_{R2} := 3.398 \ m$

Shear Stress of Open Channel: $\tau_{b2} := \gamma_w \cdot sl \cdot H_{R2} = 0.03$

Stream Power Potential: $P := \gamma_w \cdot v_2 \cdot d_2 \cdot sl = 0.1613 \ \frac{kW}{m^2}$

6. Likelihood of Erosion

The figure shown below can be used to estimate the erosion potential based upon the Erodibility Index and Stream Power Estimate. The green line in the figure is the initial erosion threshold proposed by Annadale (1995) based on a review of 150 field observations from spillway channels and plunge pools . The blue, red and black lines on the figure represent a logical regression results obtained by Wibowo et al. (2005). The upper blue line represents a 99% change of erosion initiating, the middle red line represents a 50% chance of erosion initiating, and the bottom black line represents a 1% chance of erosion initiating.



APPENDIX F.4-3 – INLET STREAM

Riprap Sizing for Stepped Spillway Calculations

Springbank Off-Stream Storage Project
Alberta, Canada
Alberta Transportation Department

1. OBJECTIVE/PURPOSE

The objectives of this calculation package is to determine the appropriate channel lining for localized Storm Water Run-off the Diversion Channel.

2. CRITERIA

USACE EM 1110-2-1601 (1991) Method and Mark Slack Associates (2004)

3. REFERENCES

1. Alberta Transportation (2011). Erosion and Sediment Control Manual - Appendix F.

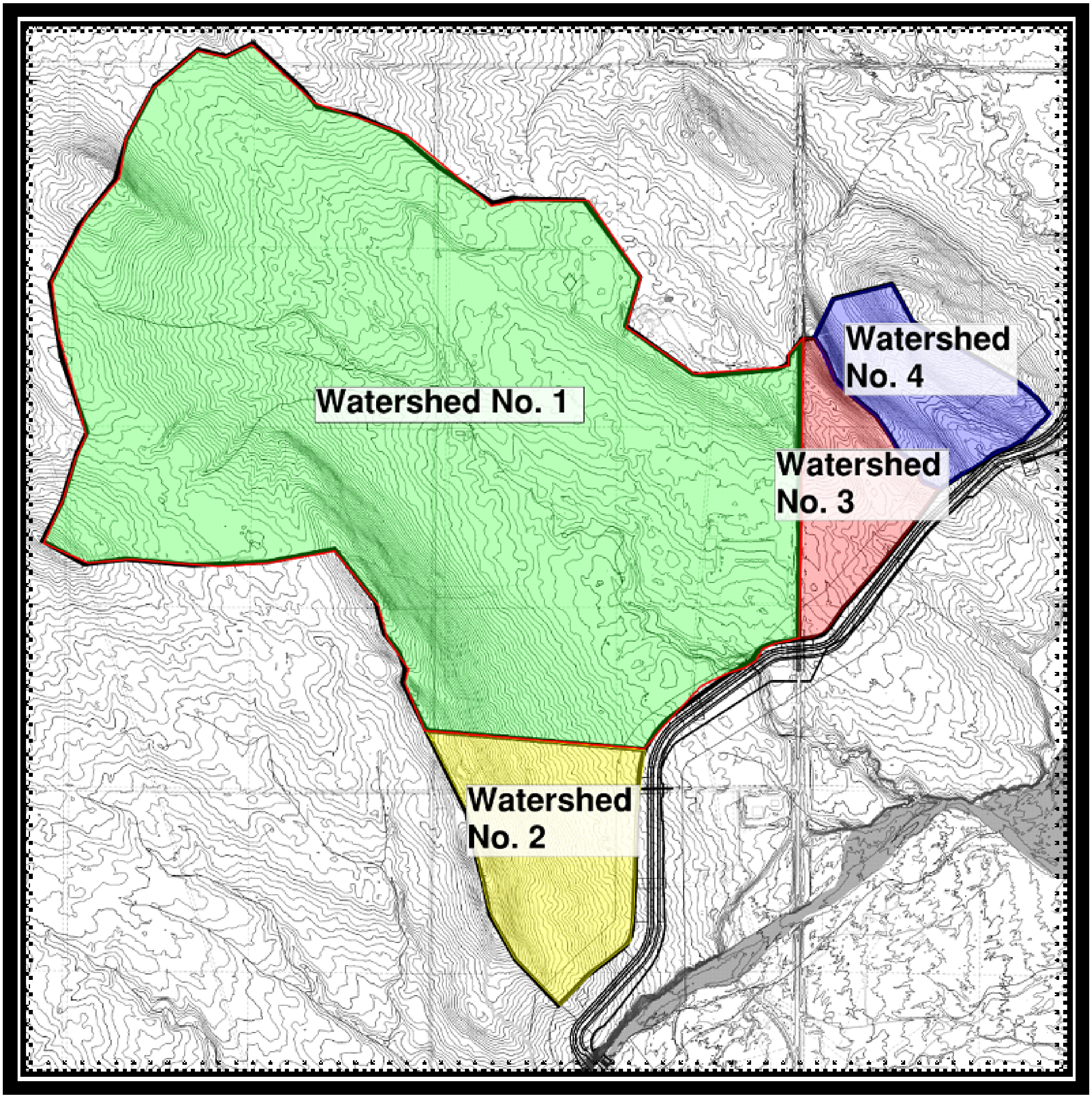
2. "Design Hydrology and Sedimentology for Small Catchments", C.T. Haan, B.J. Barfield, J.C. Hayes, Academic Pre Inc. 1994

4. Hydrologic Calculations

Calculations for the 10-year peak runoff was performed in Appendix B. A summary of the calculated 10-year peak flow a shown in Table 1 below. Figure 1 includes the drainage area of each Watershed.

Table 1. Summary of Peak Inflow

	Watershed No. 1	Watershed No. 2	Watershed No. 3	Watershed No. 4
Drainage Area (km^2)	6.83	0.75	0.46	0.48
10-yr Peak Runoff (m^3/s)	11.1	5	2.5	1.7

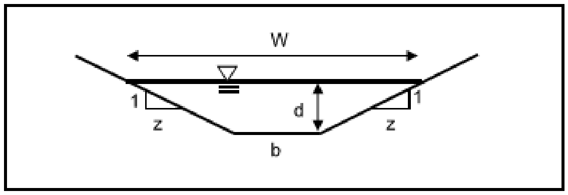

Watershed No. 1
Watershed No. 2
Watershed No. 3
Watershed No. 4

5. Ditch Analysis

WATERSHED_1_Ditch Sizing Calculations

Drainage Ditch - Channel Capacity & Depth Calculations

Channel Sketch



Channel Section 1

1. Uniform (Symmetrical) Trapezoidal Section

Input Data:

Manning's "n" value	0.043		
Longitudinal Slope - S_o	0.250	ft/ft	
Design Discharge - Q	391.9	ft^3/s - cfs	
	11.10	m^3/s - cms	

Channel Geometry Data:

Bottom Width(s)

b_1 or b	6.56168	feet	2.00 m

Side Slope(s)

z_1 or z	4.0	z H:1V	

Governing Geometry Equations

$$W = b + 2dz$$

$$A = bd + zd^2$$

$$W_P = b + 2d\sqrt{z^2 + 1}$$

plot

Calculated Depth - d	**1.64**	feet	**0.501 m**
Calculated Top Width - W	**19.71**	feet	**6.01 m**
Calculated Area - A	21.60	ft^2	
Calc. Wetted Perimeter - Wp	20.12	feet	
Calc. Hydr. Radius - R	1.07	feet	
Calculated Discharge - Q'	392.34	ft^3/s - cfs	
Convergence	0.40	ft^3/s - cfs	
Calculated Velocity	**18.17**	ft / s	
Calculated Shear Stress - τ_d	**25.65**	lb / ft^2	

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$

$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$

Note: The Mannings "n" value was referenced for Class C Vegetation

Stantec Ditch Sizing Tool

Developed by: Erman Caudill

The Resulting Velocity of 18.17 ft/sec and Calculated Shear Stress of 25.65 lb/ft^2 reflect normal depth conditions. At th flow and and shear stress is likley to cause cause significant headcutting without proper channel linining. Therefore Articulated Concrete Block has been specified to line the channel.

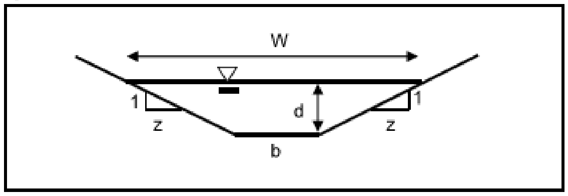
WATERSHED_2

No Ditch Calculations are required for Watershed 2, Local Storm Water runoff enters the channel via overland flow and therefore is unlikely to significantly channelize in any location. The impact of erosion are expected to be minimal.

WATERSHED_3_ Ditch Sizing Calculations

Drainage Ditch - Channel Capacity & Depth Calculations

Channel Sketch



Channel Section	1		
1. Uniform (Symmetrical) Trapezoidal Section			
Input Data:			
Manning's "n" value	0.043		
Longitudinal Slope - S_o	0.069	ft/ft	
Design Discharge - Q	88.3	ft^3/s - cfs	
	2.50	**m^3/s - cms**	
Channel Geometry Data:			
Bottom Width(s)			
b_1 or b	165.7	feet	**50.52 m**
Side Slope(s)			
z_1 or z	4.0	z H:1V	
plot			
Calculated Depth - d	**0.18**	feet	**0.055 m**
Calculated Top Width - W	**167.16**	feet	**50.96 m**
Calculated Area - A	30.29	ft^2	
Calc. Wetted Perimeter - Wp	167.20	feet	
Calc. Hydr. Radius - R	0.18	feet	
Calculated Discharge - Q'	88.55	ft^3/s - cfs	
Convergence	0.28	ft^3/s - cfs	
Calculated Velocity	**2.92**	ft / s	
Calculated Shear Stress - τ_d	**0.79**	lb / ft^2	

Governing Geometry Equations

$$W = b + 2dz$$

$$A = bd + zd^2$$

$$W_p = b + 2d\sqrt{z^2 + 1}$$

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$

$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$

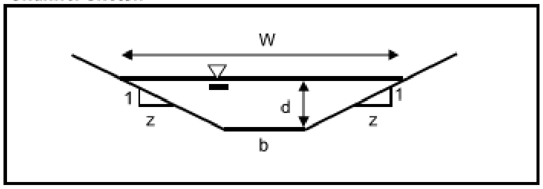
Note: The Mannings "n" value represents Class C Vegetation

Velocities do not exceed 3 ft/sec for the 10yr storm event. Given the potential steep slope at the entrance to the graded channel sideslopes of 4H:1V some erosion and headcutting may form, however this erosion is considered acceptable and is expected to have a negligible impact on the overall opeartions of the Diversion Channel overtime.

WATERSHED_4_ Ditch Sizing Calculation

Drainage Ditch - Channel Capacity & Depth Calculations

Channel Sketch



Channel Section	1	
1. Uniform (Symmetrical) Trapezoidal Section		
Input Data:		
Manning's "n" value	0.043	
Longitudinal Slope - S_o	0.131	ft/ft
Design Discharge - Q	60.0	ft^3/s - cfs
	1.70	m^3/s - cms
Channel Geometry Data:		
Bottom Width(s)		
b_1 or b	97.44	feet (29.71 m)
Side Slope(s)		
z_1 or z	4.0	z H:1V
plot		
Calculated Depth - d	0.16	feet (0.05 m)
Calculated Top Width - W	98.75	feet (30.11 m)
Calculated Area - A	16.09	ft^2
Calc. Wetted Perimeter - Wp	98.79	feet
Calc. Hydr. Radius - R	0.16	feet
Calculated Discharge - Q'	60.20	ft^3/s - cfs
Convergence	0.17	ft^3/s - cfs
Calculated Velocity	3.74	ft / s
Calculated Shear Stress - τ_d	1.34	lb / ft^2

Governing Geometry Equations

$$W = b + 2dz$$
$$A = bd + zd^2$$
$$W_P = b + 2d\sqrt{z^2 + 1}$$

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$
$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$

Note: The Mannings "n" value represents Class C Vegatation

Velocities do not exceed 3.74 ft/sec for the 10yr storm event. Given the potential steep slope at the entrance to the graded channel sideslopes of 4H:1V, some erosion and headcutting may form, however this erosion is considered acceptable and is expected to have a negligible impact on the overall opeartions of the Diversion Channel overtime.

Table F.3(g): Maximum Permissible Velocities in Channels Lined with Uniform Stands of Grass Covers, Well Maintained[1 2]

		Maximum Permissible Velocities	
Cover	**Slope Range**	**Erosion-Resistant Soils**	**Easily Eroded Soils**
	Percent	**m/s (ft/s)**	**m/s (ft/s)**
Bermuda Grass	0 – 5 5 – 10 Over 10	2.4 (8) 2.1 (7) 1.8 (6)	1.8 (6) 1.5 (5) 1.2 (4)
Buffalo Grass Kentucky bluegrass Smooth brome Blue gramma	0 – 5 5 – 10 Over 10	2.1 (7) 1.8 (6) 1.5 (5)	1.5 (5) 1.2 (4) 0.9 (3)
Grass Mixture	0 – 5[3] 5 – 10[3]	1.5 (5) 1.2 (4)	1.2 (4) 0.9 (3)
Lespedeza sericea Weeping lovegrass Yellow bluestem Kudzu Alfalfa Crabgrass	0 – 5[4]	1.1 (3.5)	0.8 (2.5)
Common lespedeza[5] Sudangrass[5]	0 – 5[4]	1.1 (3.5)	0.8 (2.5)

[1] Source: Handbook of Channel Design for Soil and Water Conservation 1954
[2] Use velocities over 1.5 m/s only where good covers and proper maintenance can be obtained
[3] Do not use on slopes steeper than 10 percent
[4] Use on slopes steeper than 10 percent is not recommended
[5] Annuals, used on mild slopes or as temporary protection until permanent covers are established.

APPENDIX F.4-4 – SADDLE DAM FILTER COMPATIBILITY CALCS

SADDLE DAM
FILTER COMPATIBILITY EVALUATION

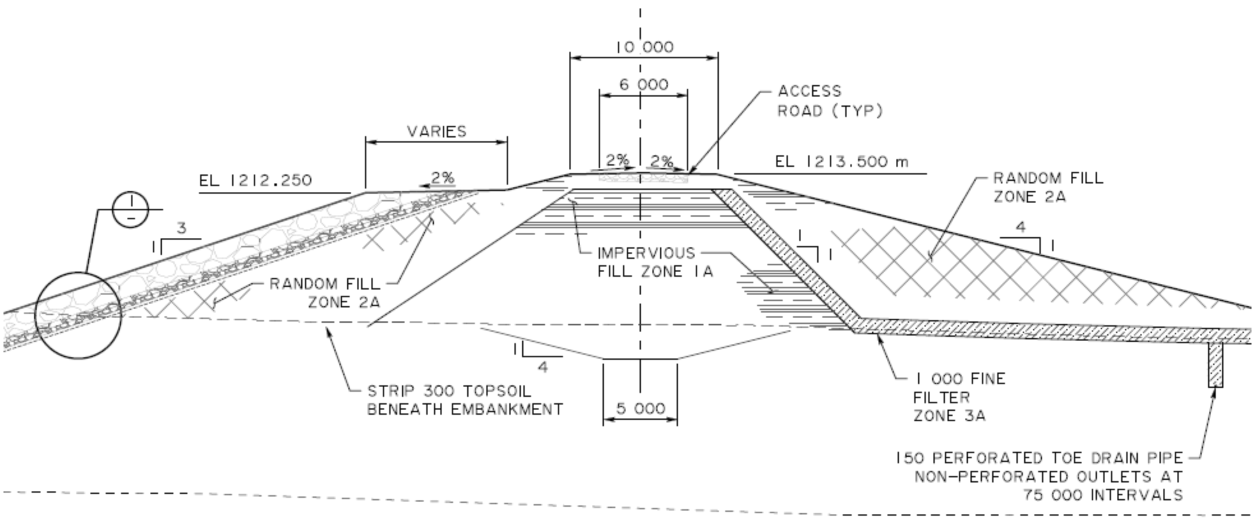
Springbank Off-Stream Reservoir Project
Alberta, Canada
Alberta Transportation Department

1. SCOPE

The scope of this analysis is to evaluate the filter compatibility of the materials that comprise the armouring layers of the saddle dam. Filter compatibility was evaluated using the design criteria described in the U.S. Army Corps of Engineers EM-1110-2-2300 (2004).

2. SADDLE DAM CONFIGURATION

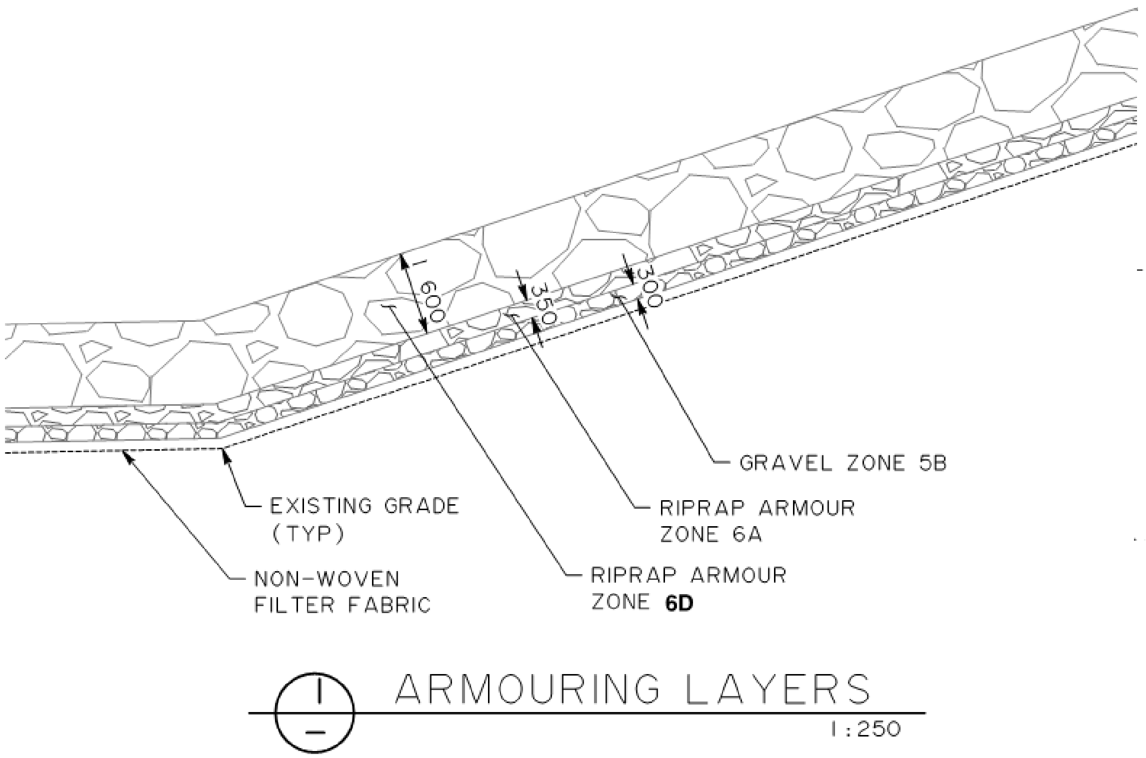
The saddle dam cross section is shown in the figure below.



The armoring layers that are subject to the filter compatibility evaluation consist of the following materials:

- Gravel Zone 5B
- Riprap Armour 6A
- Riprap Armour 6D

The configuration and dimensions of these layers are shown in the figure below.



3. GRADATIONS

The grain size distributions for the armouring materials are listed in the tables below.

Gravel Zone 5B

Sieve Size (mm)	Percent Passing
150	100
75	70 - 100
40	50 - 80
20	36 - 65
10	25 - 55
5	17 - 45
2.5	10 - 35
1.25	6 - 25
0.630	2 - 15
0.315	0 - 10
0.160	0 - 6
0.080	0 - 3

Riprap Armour 6A

Sieve Size (mm)	Percent Passing
300	100
200	50 - 80
175	20 - 50
125	0

Riprap Armour 6D

Sieve Size (mm)	Percent Passing
1,100	100
900	50 - 80
800	20 - 50
500	0

4. SUMMARY OF FILTER COMPATIBILITY EVALUATIONS

Two filter compatibility evaluations were performed. The analysis methodology outlined in the U.S. Army Corps of Engineers EM 1110-2-2300 (2004) was used for each calculation. The two evaluations are presented in the table below.

Summary of Filter Compatibility Evaluations

Evaluation No.	Base Material	Filter Material
1	Gravel Zone 5B	Riprap Armour 6A
2	Riprap Armour 6A	Riprap Armour 6D

The results of the filter evaluations are summarized in the table below. Detailed calculations are included in the attachment. The maximum particle size compatibility check is not included in this table, as the materials considered are have maximum particle sizes over 75 mm.

Summary of Filter Compatibility Evaluations

Compatibility Check	Evaluation No. 1	Evaluation No. 2
Particle Stability	Pass	Pass
Permeability	Pass	Pass[1]
Segregation	Pass	Pass
Fines Content	Pass	Pass
Plasticity Index	Pass	Pass

[1] The permeability evaluation passes on the "borderline" criterion, i.e. $D_{15,filter}/d_{15,base} > 3$. This is considered acceptable for the riprap armouring.

Project: Springbank Offstream Reservoir Project - Saddle Dam

Material Inputs

Base Soil: Zone 5 Gradations, Zone 5B

Diameter Percent Finer	Sieve Size, mm			
	Coarse Envelope		Fine Envelope	
	Unadjusted	Adjusted	Unadjusted	Adjusted
d_{85}	106.07	3.84	46.81	3.04
d_{15}	4.10	0.68	0.63	0.18

Base Soil (Fine Env., Adj.) % Passing No. 200: 6.15

Filter Soil: Zone 6 Gradations, Zone 6A

Is the interface a designed filter zone?	Yes
Is Filter Material subject to wave action?	No
Is material gap-graded?	No

Diameter Percent Finer	Filter Soil Inputs (Sieve Size, mm)	
	Coarse Envelope	Fine Envelope
D_{90}	276.63	244.95
D_{15}	160.88	138.28
D_{10}	147.90	133.70

Maximum Particle Size (Coarse Env.) (mm):	300.00
Filter Soil (Fine Env.) % Passing No. 200 Sieve:	0.00
Filter Soil Plasticity Index:	0

Results Summary

Criteria	Result
Base Soil Category	4
Particle Stability	Pass
Permeability	Pass
Segregation During Construction	Pass
Max. Particle Size	Fail
Fines Content	Pass
Plasticity Index	Pass
Gap Graded	Pass

Filter Compatibility Calculations

Base Soil:	Zone 5 Gradations, Zone 5B
Filter Soil:	Zone 6 Gradations, Zone 6A

Base Soil Designation

Base Soil Category:	4

Stability (Particle Migration) Assessment

Criteria, $D_{15} \leq$ (mm):	**234.03**
Filter (Coarse Envelope) D_{15} (mm):	160.88
Result	Pass

Permeability Assessment

Borderline Criteria, $D_{15} \geq$ (mm):	**12.31**
Preferred Criteria, $D_{15} \geq$ (mm):	**20.51**
Filter (Fine Envelope) D_{15} (mm):	138.28
Result	Pass

Segregation During Construction Assessment

Filter (Fine Envelope) D_{10} (mm)	133.70
Criteria, $D_{90} \leq$ (mm):	**Answer Not in Range**
Filter (Coarse Envelope), D_{90} (mm):	276.63
Result	Pass

Additional Criteria for Designed Filter Materials

Criteria, Max. Particle Size $\leq$ (mm)	**75**
Filter, Max. Particle Size (mm)	300
Result	Fail

Criteria, Fines Content $\leq$ (%)	**5**
Filter, Fines Content (%)	0.0
Result	Pass

Criteria, Plasticity Index	**0**
Filter, Plasticity Index	0
Result	Pass

Filter Is Not Gap-Graded	Pass

Project: Springbank Offstream Reservoir Project - Saddle Dam

Material Inputs

Base Soil: Zone 6 Gradations, Zone 6A

Diameter Percent Finer	Sieve Size, mm			
	Coarse Envelope		Fine Envelope	
	Unadjusted	Adjusted	Unadjusted	Adjusted
d_{85}	265.64	265.64	221.34	221.34
d_{15}	160.88	160.88	138.28	138.28

Base Soil (Fine Env., Adj.) % Passing No. 200: 0.00

Filter Soil: Zone 6 Gradations, Zone 6D

Is the interface a designed filter zone? Yes
Is Filter Material subject to wave action? No
Is material gap-graded? No

Diameter Percent Finer	Filter Soil Inputs (Sieve Size, mm)	
	Coarse Envelope	Fine Envelope
D_{90}	1056.73	994.99
D_{15}	711.31	575.71
D_{10}	632.46	549.28

Maximum Particle Size (Coarse Env.) (mm): 1100.00
Filter Soil (Fine Env.) % Passing No. 200 Sieve: 0.00
Filter Soil Plasticity Index: 0

Results Summary

Criteria	Result
Base Soil Category	4
Particle Stability	Pass
Permeability	Borderline
Segregation During Construction	Pass
Max. Particle Size	Fail
Fines Content	Pass
Plasticity Index	Pass
Gap Graded	Pass

Filter Compatibility Calculations

Base Soil:	Zone 6 Gradations, Zone 6A
Filter Soil:	Zone 6 Gradations, Zone 6D

Base Soil Designation

Base Soil Category:	4

Stability (Particle Migration) Assessment

Criteria, $D_{15} \leq$ (mm):	**1106.68**
Filter (Coarse Envelope) D_{15} (mm):	711.31
Result	Pass

Permeability Assessment

Borderline Criteria, $D_{15} \geq$ (mm):	**482.64**
Preferred Criteria, $D_{15} \geq$ (mm):	**804.41**
Filter (Fine Envelope) D_{15} (mm):	575.71
Result	Borderline

Segregation During Construction Assessment

Filter (Fine Envelope) D_{10} (mm)	549.28
Criteria, $D_{90} \leq$ (mm):	**Answer Not in Range**
Filter (Coarse Envelope), D_{90} (mm):	1056.73
Result	Pass

Additional Criteria for Designed Filter Materials

Criteria, Max. Particle Size $\leq$ (mm)	**75**
Filter, Max. Particle Size (mm)	1100
Result	Fail
Criteria, Fines Content $\leq$ (%)	**5**
Filter, Fines Content (%)	0.0
Result	Pass
Criteria, Plasticity Index	**0**
Filter, Plasticity Index	0
Result	Pass
Filter Is Not Gap-Graded	Pass

Design Criteria

After U.S. Army Corps of Engineers (2004). "General Design and Construction Considerations for Earth and Rock-Fill Dams." EM-1110-2-2300, July 30.

Base Soil Designation

Base Soil Category	Percent Passing No. 200	Soil Description
1	>85%	Fine silts and clays
2	40%-85%	Sands, silts, and silty and clayey sands
3	15%-39%	Silty and clayey sands and gravels
4	<15%	Sands and gravels

Stability (Particle Migration) Criteria

Base Soil Category	Criteria for Maximum D_{15} Size of the Filter Material
1	$D_{15} \leq 9 \times d_{85}$ If 9 x d85 < 0.2mm, then $D_{15} \leq 0.2$
2	$D_{15} \leq 0.7$ mm
3	$D_{15} \leq (4\text{-}A)/25 \times [((4 \times d_{85})\text{-}0.\ mm)+0.7mm]$, where A = percent passing No. 200 sieve If $4 \times d_{85} < 0.7$ mm, then $D_{15} \leq 0.7$mm
4	For filters subject to wave action: $D_{15} \leq 4 \times d_{85}$ For other filters: $D_{15} \leq 5 \times d_{85}$

Permeability Criteria

Base Soil Category	Criteria for Minimum D_{15} Size of the Filter Material
All Categories	Use the maximum d_{15} of base soil, coarse envelope unadjusted
	$D_{15} \geq [(3 \text{ to } 5) \times d_{15}]$
	If $[(3 \text{ to } 5)xd_{15}] \leq 0.1$mm, then $D_{15} \geq 0.1$ mm

Limits to Prevent Segregation During Filter Construction

If Minimum D_{10} (mm)	Then Maximum D_{90} (mm)
< 0.5	20
0.5 - 1	25
1-2	30
2-5	40
5-10	50
10-50	60

Additional Criteria for Filter Material

Maximum particle size of 3 inches
Maximum of 5% passing the No. 200 sieve
Material passing the No. 40 sieve must have PI = 0
Gap-graded filter materials are not acceptable

APPENDIX F.5 – DIVERSION CHANNEL OUTLET

APPENDIX F.5.1 – HYDRAULIC DESIGN OF RCC OVERLAY

RCC Grade Control Structure Calculations

Springbank Off-Stream Reservior Project
Alberta, Canada
Alberta Transportation Department

1. OBJECTIVE/PURPOSE

The objectives of this calculation package is to calculate the energy dissipation due to the RCC Grade Control Structu and find the depth and velocity at the toe of the structure for design of the Stilling Basin

2. CRITERIA

Relationships presented in the research paper "Simplistic Design Methods for Moderate-Sloped Stepped Chutes" (Hunt et.al,2014) were used.

3. REFERENCES

1.Hunt, S. L., Kadavy, K. C., & Hanson, G. J. (2014). Simplistic design methods for moderate-sloped stepped chutes. Journal of Hydraulic Engineering, 140(12), 04014062.

4. Calculations

Step height: $h_s := .6m$ (0.6m)

Chute slope $\theta := 10.3°$

Maximum discharge: $Q := 600 \frac{m^3}{s}$

Spillway width: $w := 150m$

Unit discharge: $q := \frac{Q}{w} = 4 \frac{m^2}{s}$

Critical Depth $d_c := \sqrt[3]{\frac{q^2}{g}} = 1.18 \cdot m$

Surface roughness: $k_s := h_s \cdot \cos(\theta) = 0.59 \cdot m$

Froude Number $F_r := \frac{q}{\sqrt{g \cdot \sin(\theta) \cdot k_s^3}} = 6.66$

Calculate the free surface inception point from Eq. 4 and 5 (Hunt et al., 2014)

$$L_i := \begin{cases} k_s \cdot 5.19 \cdot F_r^{0.89} & \text{if } (0.1 < F_r \le 28) \\ (k_s \cdot 7.48 \cdot F_r) & \text{otherwise} \end{cases} \qquad L_i = 16.56 \cdot m$$

Length of spillway: $L_s := 39.61m$ $\qquad \frac{L_s}{L_i} = 2.39$

From equation 17 and 18 (Hunt et al., 2014)

$$y := \begin{cases} d_c \cdot \left(\frac{L_s}{L_i}\right)^{-0.22} \cdot 0.34 \cdot \left(\frac{h_s}{d_c}\right)^{0.063} \cdot (\cos(\theta))^{0.063} \cdot (\sin(\theta))^{-0.18} & \text{if } \left(0.1 \le \frac{L_s}{L_i} \le 1\right) \\ \left[d_c \cdot 0.34 \cdot \left(\frac{h_s}{d_c}\right)^{0.063} \cdot (\cos(\theta))^{0.063} \cdot (\sin(\theta))^{-0.18}\right] & \text{otherwise} \end{cases}$$

$y = 0.52 \cdot m$

$v := \frac{q}{y} = 7.66 \cdot \frac{m}{s}$

Stepped Energy Loss:

$TopofRCCSteps := 1202.286m$

$BottomofRCCSteps := 1195.2m$

$H_o := TopofRCCSteps - BottomofRCCSteps + 1.5 \cdot d_c = 8.85 \cdot m$

$$\alpha := \left[1.025 \cdot \left(\frac{h_s}{d_c}\right)^{-0.128 \cdot \sin(\theta)} - 1\right] \cdot \left[\left(\frac{L_s}{L_i}\right)^{-2.37} + 0.723\right] + 1 = 1.03$$ Eq. 28 (Hunt et al., 2014)

$$H_i := y \cdot \cos(\theta) + \alpha \cdot \left(\frac{v^2}{2 \cdot g}\right) = 3.61\,m$$ Eq. 22 Notes (Hunt et al., 2014)

$\Delta H := H_o - H_i = 5.25 \cdot m$

Flow Depth at Toe:

$$F_{rs} := \left(\frac{y}{d_c}\right)^{-1.5} = 3.38$$

$$C_{mean} := 0.0645 + 0.216\cdot\left(\frac{h_s}{d_c}\right) + 0.453\cdot(\sin(\theta)) = 0.256$$

$$d_1 := \frac{y}{\left(1 - C_{mean}\right)} = 0.7\cdot m$$ y90 Depth @ Toe of Stepped Spillway

$$V_1 := \frac{q}{d_1} = 5.7\cdot\frac{m}{s}$$ V90 Velocity @ Toe of Stepped Spillway

Use a Factor of Saftey of 1.5 to set minimum wall height:

$$FS := 1.5$$

$$H_w := FS\cdot d_1 = 1.05\,m \qquad H_w = 1.053\cdot m$$

1. OBJECTIVE/PURPOSE

The objectives of this calculation is to design a natural hydraulic jump stilling basin for energy dissipation

2. CRITERIA

EM 1110-2-1603 (USACE, 1990) and USBR (1984)

3. REFERENCES

1.USACE. (1990). Hydraulic Design of Spillways. EM 1110-2-1603. US Army Corps of Engineers.

2. USBR. (1984). Hydraulic Design of Stilling Basins and Energy Dissipators, Engineering Monograph No. 25. US Department of Interior, Bureau of Reclamation (USBR).

4. Calculations

From stepped spillway analysis:

$$V_1 := v = 7.66\,\frac{m}{s} \qquad d_1 := y = 0.52\,m \qquad g = 9.81\,\frac{m}{s^2}$$

Determine sequent jump height and jump length following procedures shown is EM 110-2-1603 Section V

$$F_1 := \frac{V_1}{\sqrt[2]{g\cdot d_1}} = 3.383$$

$$d_2 := d_1\cdot 0.5\cdot\left[\sqrt[2]{\left(1 + 8\cdot F_1^{\,2}\right)} - 1\right] = 2.25\cdot m$$

Calculate energy loss due to hydraulic jump:

$$\Delta E := \frac{(d_2 - d_1)^3}{4 \cdot d_1 \cdot d_2} = 1.1\,m$$

Minimum dimensions for type I energy dissipator can be calculate by evaluating the length of the resultant hydraulic jump:

$$L_j := \begin{cases} 8 \cdot d_1 \cdot F_1 & \text{if } (F_1 > 5) \\ (3.5 \cdot d_1 \cdot F_1^{1.5}) & \text{otherwise} \end{cases} \qquad L_j = 11.38\,m$$

Determine basin length using USBR Figure 12:

$$\frac{L_I}{d_2} = \blacksquare \cdot 5.5 \qquad L_I := 5.5 \cdot d_2 = 12.38\,m$$

Use 12.5m for Final Design

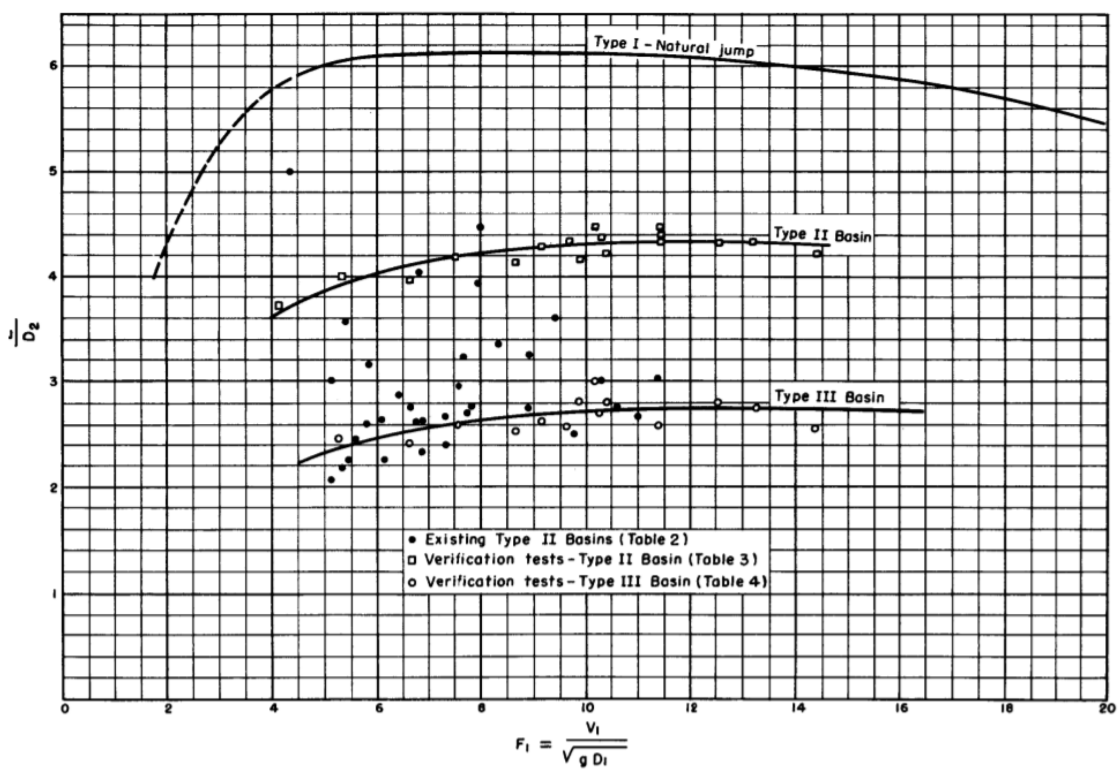


FIGURE 12.—*Length of jump on horizontal floor (Basins I, II, and III).*

APPENDIX F.6 – EMERGENCY SPILLWAY

APPENDIX F.6.1 – SPATIALLY VARIED FLOW WEIR CALCULATIONS

Stantec

Main Channel Geometry

$B = 22$ meters, $z = 4:1$ (H:V), $S_o = 0.001$ meters/meters
$N = 0.033$

// Spillway Crest = 1,206.75
$C_d = 0.7$

TRIAL/ERROR METHOD → Use Values from $\frac{\Delta X}{2}$ $(\bar{y}, \bar{Q}, \bar{A}, \bar{T})$

→ "Spatially Varied Flow Over A Side Weir In A Rectangular Channel" by P.W. France

$$\frac{dy}{dx} = \frac{S_o - S_f - \frac{Q}{gA^2}\frac{dQ}{dx}}{1 - \frac{Q^2 T}{gA^3}}$$

S_o - Channel Slope
S_f - Energy Grade Line Slope
A - Cross-Sectional Area
T - Water Surface Width
Q - Flow Rate
$\frac{dQ}{dx}$ - Discharge through Side Weir (Negative Value)

$\frac{dy}{dx}$ - Change in Flow Depth per ΔX

⇒ ⇒ Start from D/S End, y = 8 meters (1,212.0 meters), Q = 0 cms (All Diverted through Weir)

ΔX = 10 meters, Assume y_1 = 7.9 meters

	y	$\bar{y}$	$\bar{Q}$	$\bar{A}$	$\bar{P}$	$\bar{R}$	$\bar{S}_f$	$\bar{T}$	y_1
y_o	8								
		7.95	13.586	427.71	87.56	4.88	2.7×10^{-8}	63.6	7.99 ≠ 7.9
y_1	7.9								

$dQ = Q_{\bar{y}_1} = \frac{2}{3} C_d \sqrt{2g}\, L H^{3/2} = \frac{2}{3}(0.7)\sqrt{2 \cdot 9.81}(10)(7.95 - 6.75)^{3/2} = 27.172$ cms

$\bar{Q} = \frac{0 + 27.172}{2} = 13.586$

$\bar{A} = \bar{y}B + \bar{y}^2(z) = 7.95(22) + (7.95)^2(4) = 427.71\ m^2$

$\bar{R} = \frac{\bar{A}}{\bar{P}} = \frac{427.71}{87.56} = 4.88$ meters

$\bar{P} = B + 2\bar{y}(z^2+1)^{0.5} = 22 + 2(7.95)(4^2+1)^{0.5} = 87.56$ meters

$\bar{S}_f = \left(\frac{\bar{Q}N}{\bar{A}\bar{R}^{2/3}}\right)^2 = \left[\frac{(13.586)(0.033)}{(427.71)(4.88)^{2/3}}\right]^2 = 1.3\times10^{-7}$

Negative due to leaving system

$$\Rightarrow \frac{dy}{dx} = \frac{0.001 - 1.3\times10^{-7} - \frac{13.586}{(9.81)(427.71)^2}\cdot\frac{(-27.172)}{10}}{1 - \frac{13.586^2(63.6)}{9.81(427.71)^3}} = \frac{.00102}{0.999}$$

$\bar{T} = B + 2\bar{y}z = 22 + 2(7.95)(4) = 63.6$ meters

$\frac{dy}{dx} = .00102$ $dy = .00102(10) = .01$ meters

$y_1 = 8 - .01 = 7.99$ ⇒ Retry

Assume $y_1 = 7.99$ meters

		$\bar{y}$	$\bar{Q}$	$\bar{A}$	$\bar{P}$	$\bar{R}$	$\bar{T}$	$\bar{S}_f$	y_1
y_0	8								
		7.995	14.3575	43157	87.93	4.91	85.96	1.44×10^{-7}	7.99
y_1	7.99								

$dQ = Q_s = \frac{2}{3}(0.7)\sqrt{2 \times 9.81}(10)(7.995 - 6.75)^{3/2} = 28.715$ cms

$\bar{Q} = 14.3575$

$\bar{A} = 7.995(22) + 7.995^2(4) = 431.57$

$\bar{R} = 4.91$

$\bar{P} = 22 + 2(7.995)(4^2+1)^{0.5} = 87.93$

$\bar{T} = 22 + 2(7.995)(4) = 85.96$

$S_f = \left[\frac{14.3575(.033)}{431.57(4.91)^{2/3}}\right]^2 = 1.44 \times 10^{-7}$

$\frac{dy}{dx} = \frac{0.001 - 1.44 \cdot 10^{-7} - \frac{14.3575}{9.81(431.57)^2}\left(\frac{-28.715}{10}\right)}{1 - \frac{(14.3575)^2(85.96)}{(9.81)(431.57)^3}}$

$\frac{dy}{dx} = \frac{.00102}{0.99998} = .00102$ $\quad dy = .0102$ meters

$y_1 = 7.989 \approx 7.99$ ✓

PROCEED TO NEXT STEP

		$\bar{y}$	$\bar{Q}$	$\bar{A}$	$\bar{P}$	$\bar{R}$	$\bar{T}$	$\bar{S}_f$	y_2
y_1	7.99								
		7.985	28.54	430.711	87.85	4.9	85.88	5.75×10^{-7}	7.98
y_2	7.98								

$dQ = Q_y = \frac{2}{3}(0.7)\sqrt{2 \times 9.81}(10)(7.985 - 6.75)^{3/2} = 28.37$

$\bar{Q} = \frac{28.715 + 28.37}{2} = 28.54$

$\bar{A} = 7.985(22) + 7.985^2(4) = 430.711$

$\bar{P} = 22 + 2(7.985)(4^2+1)^{0.5} = 87.85$

$\bar{R} = \frac{430.711}{87.85} = 4.9$

$\bar{T} = 22 + 2(7.985)(4) = 85.88$

$S_f = \left[\frac{28.54(0.033)}{430.711(4.9)^{2/3}}\right]^2 = 5.75 \times 10^{-7}$

$\frac{dy}{dx} = \frac{.001 - 5.75 \times 10^{-7} - \frac{28.54}{9.81(430.711)^2}\left(\frac{-28.37}{10}\right)}{1 - \frac{(28.54)^2(85.88)}{9.81(430.711)^3}} = \frac{.00104}{0.9999} = .00104$ $\quad dy = .0104$ meters

$y_2 = 7.979 \approx 7.98$ ✓

Stantec

RUNGE-KUTTA – SECOND ORDER

$y_i = y_0 - (k_1 + k_2)\frac{\Delta x}{2}$ where $k_1 = F(x_i, y_i)$, $k_2 = F(x_i + \Delta x, y_i + k_1 \Delta x)$

$k = \frac{dy}{dx} = \dfrac{S_0 - S_F - \frac{Q\,dQ}{gA^2 dx}}{1 - \frac{Q^2 T}{gA^3}}$ Assume $Q_0 = 0$ cms, $y_1 = 7.99$, $\therefore Q_1 = \frac{2}{3}(0.7)\sqrt{2(9.81)}(10)(7.99-6.75)^{3/2}$ $= 28.542$

	y	Q	A	P	R	T	S_f	k	
y_0	8.0	0	432	87.97	4.91	86	0		k_1
y_1	7.99	28.542							k_2

$A_0 = y_0 B + y_0^2(z) = 8(22) + 8^2(4) = 432\ m^2$ $P_0 = B + 2y_0(z^2+1)^{0.5} = 22 + 2(8)(4^2+1)^{0.5} = 87.97$

$R_0 = \frac{A_0}{P_0} = \frac{432}{87.97} = 4.91$ $T = B + 2y_0 z = 22 + 2(8)(4) = 86$

$S_F = \left[\frac{Q_0 N}{A_0 R_0^{2/3}}\right]^2 = \left[\frac{0(0.033)}{432(4.91)^{2/3}}\right]^2 = 0$ $k_1 = \frac{.001 - 0 - 0}{1 - 0} = .001$

$y_{1x} = y_0 + k_1 \Delta x = 8 + .001(-10) = 7.99$

$A_{1x} = 7.99(22) + 7.99^2(4) = 431.14$ $P_{1x} = 22 + 2(7.99)(4^2+1)^{0.5} = 87.89$ $R_{1x} = \frac{431.14}{87.89} = 4.91$

$T_{1x} = 22 + 2(7.99)(4) = 85.92$ $S_F = \left[\frac{Q_1 N}{A_{1x} R_{1x}^{2/3}}\right]^2 = \left[\frac{28.542(0.033)}{431.14(4.91)^{2/3}}\right]^2 = 5.72 \times 10^{-7}$

$k_2 = \dfrac{.001 - 5.72\times10^{-7} - \frac{28.542(28.542)}{(9.81)(431.14)(10)}}{1 - \frac{28.542^2(85.92)}{(9.81)(431.14)^3}} = \frac{.00104}{.9999} = .00104$

$y_1 = y_0 - (k_1 + k_2)\frac{\Delta x}{2} = 8 - (.001 + .00104)\frac{10}{2} = 7.9898 \approx 7.99$ ✓ OK

Designed by: Checked by:

APPENDIX F.6.2 – HYDRAULIC DESIGN CALCULATIONS

Main Channel		Overflow Weir Geometry		NOTES:
Channel Slope	0.001 m/m	Weir Height	6.75 meters	1. Spreadsheet developed using methods outlined in "Spatially Varied Flow over a Side Weir in a Rectangular Channel" by P.W. France
Mannings N	0.033	Discharge Coeff	0.7	2.Methods applied using the Runge-Kutta Technique, 2nd Order Analysis
Bottom Width	22 meters	(2/3)*Cd*(2g)^(0.5)	2.07	3.Divides the weir length into Sub-sections (1-meter) to determine the flow for each section
Side Slopes	4 H:1V			4. Iterates depth across the weir to converge to a solution
Gravity	9.81 m/s^2			

RUNGE-KUTTA, 2ND ORDER TECHNIQUE

						k1 - Change in Weir Depth						k2 - Change in Weir Depth							
Distance From Downstream End (m)	Channel Flow (D/S of Section) (cms)	Main Channel Depth (m)	Cross-Sectional Channel Area (m2)	Flow Depth over Weir (m)	Flow Diverted via Weir (cms)	Depth of Water at D/S Section (m)	Cross-Sectional Channel Area (m2)	Wetted Perimeter (m)	Hydr Radius (m)	Friction Slope	k1	Average Depth for Section	Cross-Sectional Channel Area (m2)	Wetted Perimeter (m)	Hydr Radius (m)	Friction Slope	k2	Calculated Channel Depth at Weir (U/S Section)	Convergence Check to U/S Section
0	0.0000	8.0000	432.0000	1.2500	0.0000														
						8.0000	432.0000	87.9697	4.9108	0.0000	0.00100	7.9990	431.9140	87.9614	4.9103	5.8231E-09	0.00100	7.9990	0.0000
1	2.8854	7.9990	431.9138	1.2490	2.8854														
						7.9990	431.9138	87.9614	4.9103	0.0000	0.00100	7.9980	431.8274	87.9531	4.9097	2.3277E-08	0.00101	7.9980	0.0000
2	5.7672	7.9980	431.8272	1.2480	2.8819														
						7.9980	431.8272	87.9531	4.9097	0.0000	0.00101	7.9970	431.7405	87.9448	4.9092	5.2338E-08	0.00101	7.9970	0.0000
3	8.6456	7.9970	431.7403	1.2470	2.8784														
						7.9970	431.7403	87.9448	4.9092	0.0000	0.00101	7.9960	431.6531	87.9364	4.9087	9.2984E-08	0.00102	7.9960	0.0000
4	11.5204	7.9960	431.6530	1.2460	2.8748														
						7.9960	431.6530	87.9364	4.9087	0.0000	0.00102	7.9949	431.5654	87.9280	4.9082	1.4519E-07	0.00102	7.9949	0.0000
5	14.3917	7.9949	431.5653	1.2449	2.8713														
						7.9949	431.5653	87.9280	4.9082	0.0000	0.00102	7.9939	431.4774	87.9196	4.9076	2.0893E-07	0.00103	7.9939	0.0000
6	17.2595	7.9939	431.4772	1.2439	2.8678														
						7.9939	431.4772	87.9195	4.9076	0.0000	0.00103	7.9929	431.3889	87.9111	4.9071	2.8419E-07	0.00103	7.9929	0.0000
7	20.1237	7.9929	431.3887	1.2429	2.8642														
						7.9929	431.3887	87.9111	4.9071	0.0000	0.00103	7.9919	431.3001	87.9026	4.9066	3.7093E-07	0.00104	7.9919	0.0000
8	22.9844	7.9919	431.2999	1.2419	2.8606														
						7.9919	431.2999	87.9025	4.9066	0.0000	0.00104	7.9908	431.2109	87.8940	4.9060	4.6914E-07	0.00104	7.9908	0.0000
9	25.8414	7.9908	431.2107	1.2408	2.8571														
						7.9908	431.2107	87.8940	4.9060	0.0000	0.00104	7.9898	431.1214	87.8854	4.9055	5.7880E-07	0.00104	7.9898	0.0000
10	28.6949	7.9898	431.1212	1.2398	2.8535														
						7.9898	431.1212	87.8854	4.9055	0.0000	0.00104	7.9887	431.0315	87.8768	4.9050	6.9987E-07	0.00105	7.9887	0.0000
11	31.5447	7.9887	431.0313	1.2387	2.8498														
						7.9887	431.0313	87.8768	4.9050	0.0000	0.00105	7.9877	430.9412	87.8681	4.9044	8.3233E-07	0.00105	7.9877	0.0000
12	34.3909	7.9877	430.9410	1.2377	2.8462														
						7.9877	430.9410	87.8681	4.9044	0.0000	0.00105	7.9866	430.8506	87.8594	4.9039	9.7617E-07	0.00106	7.9866	0.0000
13	37.2335	7.9866	430.8504	1.2366	2.8426														
						7.9866	430.8504	87.8594	4.9039	0.0000	0.00106	7.9856	430.7596	87.8507	4.9033	1.1313E-06	0.00106	7.9856	0.0000
14	40.0724	7.9856	430.7594	1.2356	2.8389														
						7.9856	430.7594	87.8507	4.9033	0.0000	0.00106	7.9845	430.6683	87.8419	4.9028	1.2979E-06	0.00107	7.9845	0.0000
15	42.9077	7.9845	430.6681	1.2345	2.8353														
						7.9845	430.6681	87.8419	4.9028	0.0000	0.00107	7.9834	430.5766	87.8331	4.9022	1.4756E-06	0.00107	7.9834	0.0000
16	45.7393	7.9834	430.5764	1.2334	2.8316														
						7.9834	430.5764	87.8331	4.9022	0.0000	0.00107	7.9824	430.4845	87.8243	4.9017	1.6647E-06	0.00107	7.9824	0.0000
17	48.5672	7.9824	430.4844	1.2324	2.8279														
						7.9824	430.4844	87.8242	4.9017	0.0000	0.00107	7.9813	430.3922	87.8154	4.9011	1.8650E-06	0.00108	7.9813	0.0000
18	51.3914	7.9813	430.3920	1.2313	2.8242														
						7.9813	430.3920	87.8154	4.9011	0.0000	0.00108	7.9802	430.2994	87.8065	4.9005	2.0766E-06	0.00108	7.9802	0.0000
19	54.2119	7.9802	430.2992	1.2302	2.8205														
						7.9802	430.2992	87.8065	4.9005	0.0000	0.00108	7.9791	430.2064	87.7975	4.9000	2.2993E-06	0.00109	7.9791	0.0000
20	57.0286	7.9791	430.2062	1.2291	2.8168														
						7.9791	430.2062	87.7975	4.9000	0.0000	0.00109	7.9780	430.1130	87.7886	4.8994	2.5332E-06	0.00109	7.9780	0.0000
21	59.8416	7.9780	430.1128	1.2280	2.8130														
						7.9780	430.1128	87.7885	4.8994	0.0000	0.00109	7.9769	430.0192	87.7796	4.8989	2.7783E-06	0.00109	7.9769	0.0000
22	62.6509	7.9769	430.0190	1.2269	2.8093														
						7.9769	430.0190	87.7795	4.8989	0.0000	0.00109	7.9758	429.9251	87.7705	4.8983	3.0345E-06	0.00110	7.9758	0.0000
23	65.4564	7.9758	429.9250	1.2258	2.8055														
						7.9758	429.9250	87.7705	4.8983	0.0000	0.00110	7.9747	429.8307	87.7614	4.8977	3.3018E-06	0.00110	7.9747	0.0000
24	68.2581	7.9747	429.8305	1.2247	2.8017														
						7.9747	429.8305	87.7614	4.8977	0.0000	0.00110	7.9736	429.7360	87.7523	4.8971	3.5802E-06	0.00111	7.9736	0.0000
25	71.0560	7.9736	429.7358	1.2236	2.7979														
						7.9736	429.7358	87.7523	4.8971	0.0000	0.00111	7.9725	429.6409	87.7432	4.8966	3.8696E-06	0.00111	7.9725	0.0000
26	73.8502	7.9725	429.6407	1.2225	2.7941														
						7.9725	429.6407	87.7432	4.8966	0.0000	0.00111	7.9714	429.5455	87.7340	4.8960	4.1700E-06	0.00111	7.9714	0.0000
27	76.6405	7.9714	429.5453	1.2214	2.7903														
						7.9714	429.5453	87.7340	4.8960	0.0000	0.00111	7.9703	429.4498	87.7248	4.8954	4.4815E-06	0.00112	7.9703	0.0000
28	79.4270	7.9703	429.4496	1.2203	2.7865														
						7.9703	429.4496	87.7248	4.8954	0.0000	0.00112	7.9692	429.3537	87.7156	4.8948	4.8039E-06	0.00112	7.9692	0.0000
29	82.2096	7.9692	429.3536	1.2192	2.7827														
						7.9692	429.3536	87.7156	4.8948	0.0000	0.00112	7.9681	429.2574	87.7063	4.8943	5.1372E-06	0.00113	7.9681	0.0000
30	84.9884	7.9681	429.2572	1.2181	2.7788														

						k1 - Change in Weir Depth						k2 - Change in Weir Depth							
Distance From Downstream End (m)	Channel Flow (D/S of Section) (cms)	Main Channel Depth (m)	Cross-Sectional Channel Area (m2)	Flow Depth over Weir (m)	Flow Diverted via Weir (cms)	Depth of Water at D/S Section (m)	Cross-Sectional Channel Area (m2)	Wetted Perimeter (m)	Hydr Radius (m)	Friction Slope	k1	Average Depth for Section	Cross-Sectional Channel Area (m2)	Wetted Perimeter (m)	Hydr Radius (m)	Friction Slope	k2	Calculated Channel Depth at Weir (U/S Section)	Convergence Check to U/S Section
						7.9681	429.2572	87.7063	4.8943	0.0000	0.00113	7.9669	429.1607	87.6970	4.8937	5.4815E-06	0.00113	7.9669	0.0000
31	87.7634	7.9669	429.1605	1.2169	2.7750														
						7.9669	429.1605	87.6970	4.8937	0.0000	0.00113	7.9658	429.0637	87.6877	4.8931	5.8367E-06	0.00113	7.9658	0.0000
32	90.5345	7.9658	429.0635	1.2158	2.7711														
						7.9658	429.0635	87.6877	4.8931	0.0000	0.00113	7.9647	428.9664	87.6783	4.8925	6.2028E-06	0.00114	7.9647	0.0000
33	93.3017	7.9647	428.9662	1.2147	2.7672														
						7.9647	428.9662	87.6783	4.8925	0.0000	0.00114	7.9635	428.8688	87.6689	4.8919	6.5797E-06	0.00114	7.9635	0.0000
34	96.0650	7.9635	428.8686	1.2135	2.7633														
						7.9635	428.8686	87.6689	4.8919	0.0000	0.00114	7.9624	428.7708	87.6595	4.8913	6.9674E-06	0.00114	7.9624	0.0000
35	98.8244	7.9624	428.7707	1.2124	2.7594														
						7.9624	428.7707	87.6595	4.8913	0.0000	0.00114	7.9612	428.6726	87.6501	4.8907	7.3659E-06	0.00115	7.9612	0.0000
36	101.5799	7.9612	428.6724	1.2112	2.7555														
						7.9612	428.6724	87.6500	4.8907	0.0000	0.00115	7.9601	428.5741	87.6406	4.8901	7.7752E-06	0.00115	7.9601	0.0000
37	104.3315	7.9601	428.5739	1.2101	2.7516														
						7.9601	428.5739	87.6406	4.8901	0.0000	0.00115	7.9589	428.4752	87.6311	4.8895	8.1953E-06	0.00116	7.9589	0.0000
38	107.0791	7.9589	428.4750	1.2089	2.7476														
						7.9589	428.4750	87.6310	4.8895	0.0000	0.00116	7.9578	428.3761	87.6215	4.8889	8.6260E-06	0.00116	7.9578	0.0000
39	109.8228	7.9578	428.3759	1.2078	2.7437														
						7.9578	428.3759	87.6215	4.8889	0.0000	0.00116	7.9566	428.2766	87.6119	4.8883	9.0675E-06	0.00116	7.9566	0.0000
40	112.5626	7.9566	428.2765	1.2066	2.7397														
						7.9566	428.2765	87.6119	4.8883	0.0000	0.00116	7.9555	428.1769	87.6023	4.8877	9.5196E-06	0.00117	7.9555	0.0000
41	115.2983	7.9555	428.1767	1.2055	2.7358														
						7.9555	428.1767	87.6023	4.8877	0.0000	0.00117	7.9543	428.0769	87.5927	4.8871	9.9823E-06	0.00117	7.9543	0.0000
42	118.0301	7.9543	428.0767	1.2043	2.7318														
						7.9543	428.0767	87.5927	4.8871	0.0000	0.00117	7.9531	427.9765	87.5831	4.8865	1.0456E-05	0.00117	7.9531	0.0000
43	120.7579	7.9531	427.9764	1.2031	2.7278														
						7.9531	427.9764	87.5830	4.8865	0.0000	0.00117	7.9519	427.8759	87.5734	4.8859	1.0940E-05	0.00118	7.9519	0.0000
44	123.4818	7.9519	427.8758	1.2019	2.7238														
						7.9519	427.8758	87.5733	4.8859	0.0000	0.00118	7.9508	427.7750	87.5636	4.8853	1.1434E-05	0.00118	7.9508	0.0000
45	126.2016	7.9508	427.7749	1.2008	2.7198														
						7.9508	427.7749	87.5636	4.8853	0.0000	0.00118	7.9496	427.6739	87.5539	4.8847	1.1939E-05	0.00118	7.9496	0.0000
46	128.9174	7.9496	427.6737	1.1996	2.7158														
						7.9496	427.6737	87.5539	4.8847	0.0000	0.00118	7.9484	427.5724	87.5441	4.8841	1.2455E-05	0.00119	7.9484	0.0000
47	131.6292	7.9484	427.5722	1.1984	2.7118														
						7.9484	427.5722	87.5441	4.8841	0.0000	0.00119	7.9472	427.4707	87.5343	4.8835	1.2981E-05	0.00119	7.9472	0.0000
48	134.3369	7.9472	427.4705	1.1972	2.7077														
						7.9472	427.4705	87.5343	4.8835	0.0000	0.00119	7.9460	427.3686	87.5245	4.8828	1.3517E-05	0.00119	7.9460	0.0000
49	137.0406	7.9460	427.3685	1.1960	2.7037														
						7.9460	427.3685	87.5245	4.8828	0.0000	0.00119	7.9448	427.2663	87.5146	4.8822	1.4064E-05	0.00120	7.9448	0.0000
50	139.7402	7.9448	427.2662	1.1948	2.6996														
						7.9448	427.2662	87.5146	4.8822	0.0000	0.00120	7.9436	427.1638	87.5047	4.8816	1.4622E-05	0.00120	7.9436	0.0000
51	142.4358	7.9436	427.1636	1.1936	2.6956														
						7.9436	427.1636	87.5047	4.8816	0.0000	0.00120	7.9424	427.0609	87.4948	4.8810	1.5189E-05	0.00120	7.9424	0.0000
52	145.1273	7.9424	427.0608	1.1924	2.6915														
						7.9424	427.0608	87.4948	4.8810	0.0000	0.00120	7.9412	426.9578	87.4849	4.8804	1.5767E-05	0.00121	7.9412	0.0000
53	147.8148	7.9412	426.9577	1.1912	2.6874														
						7.9412	426.9577	87.4849	4.8804	0.0000	0.00121	7.9400	426.8545	87.4749	4.8797	1.6356E-05	0.00121	7.9400	0.0000
54	150.4981	7.9400	426.8543	1.1900	2.6833														
						7.9400	426.8543	87.4749	4.8797	0.0000	0.00121	7.9388	426.7508	87.4649	4.8791	1.6954E-05	0.00121	7.9388	0.0000
55	153.1774	7.9388	426.7507	1.1888	2.6792														
						7.9388	426.7507	87.4649	4.8791	0.0000	0.00121	7.9376	426.6469	87.4549	4.8785	1.7563E-05	0.00122	7.9376	0.0000
56	155.8525	7.9376	426.6468	1.1876	2.6751														
						7.9376	426.6468	87.4549	4.8785	0.0000	0.00122	7.9364	426.5428	87.4449	4.8778	1.8182E-05	0.00122	7.9364	0.0000
57	158.5235	7.9364	426.5426	1.1864	2.6710														
						7.9364	426.5426	87.4448	4.8778	0.0000	0.00122	7.9351	426.4384	87.4348	4.8772	1.8812E-05	0.00122	7.9351	0.0000
58	161.1904	7.9351	426.4382	1.1851	2.6669														
						7.9351	426.4382	87.4348	4.8772	0.0000	0.00122	7.9339	426.3337	87.4247	4.8766	1.9451E-05	0.00123	7.9339	0.0000
59	163.8532	7.9339	426.3335	1.1839	2.6628														
						7.9339	426.3335	87.4247	4.8766	0.0000	0.00123	7.9327	426.2288	87.4146	4.8759	2.0101E-05	0.00123	7.9327	0.0000
60	166.5118	7.9327	426.2286	1.1827	2.6586														

						k1 - Change in Weir Depth						k2 - Change in Weir Depth							
Distance From Downstream End (m)	Channel Flow (D/S of Section) (cms)	Main Channel Depth (m)	Cross-Sectional Channel Area (m2)	Flow Depth over Weir (m)	Flow Diverted via Weir (cms)	Depth of Water at D/S Section (m)	Cross-Sectional Channel Area (m2)	Wetted Perimeter (m)	Hydr Radius (m)	Friction Slope	k1	Average Depth for Section	Cross-Sectional Channel Area (m2)	Wetted Perimeter (m)	Hydr Radius (m)	Friction Slope	k2	Calculated Channel Depth at Weir (U/S Section)	Convergence Check to U/S Section
						7.9327	426.2286	87.4146	4.8759	0.0000	0.00123	7.9315	426.1236	87.4044	4.8753	2.0761E-05	0.00123	7.9314	0.0000
61	169.1663	7.9314	426.1235	1.1814	2.6545														
						7.9314	426.1235	87.4044	4.8753	0.0000	0.00123	7.9302	426.0182	87.3942	4.8747	2.1431E-05	0.00124	7.9302	0.0000
62	171.8166	7.9302	426.0180	1.1802	2.6503														
						7.9302	426.0180	87.3942	4.8747	0.0000	0.00123	7.9290	425.9125	87.3841	4.8740	2.2111E-05	0.00124	7.9290	0.0000
63	174.4628	7.9290	425.9124	1.1790	2.6462														
						7.9290	425.9124	87.3840	4.8740	0.0000	0.00124	7.9277	425.8066	87.3738	4.8734	2.2801E-05	0.00124	7.9277	0.0000
64	177.1048	7.9277	425.8065	1.1777	2.6420														
						7.9277	425.8065	87.3738	4.8734	0.0000	0.00124	7.9265	425.7005	87.3636	4.8727	2.3501E-05	0.00124	7.9265	0.0000
65	179.7426	7.9265	425.7003	1.1765	2.6378														
						7.9265	425.7003	87.3636	4.8727	0.0000	0.00124	7.9253	425.5941	87.3533	4.8721	2.4211E-05	0.00125	7.9253	0.0000
66	182.3762	7.9253	425.5939	1.1753	2.6336														
						7.9253	425.5939	87.3533	4.8721	0.0000	0.00125	7.9240	425.4875	87.3430	4.8715	2.4931E-05	0.00125	7.9240	0.0000
67	185.0056	7.9240	425.4873	1.1740	2.6294														
						7.9240	425.4873	87.3430	4.8715	0.0000	0.00125	7.9228	425.3806	87.3327	4.8708	2.5661E-05	0.00125	7.9228	0.0000
68	187.6308	7.9228	425.3805	1.1728	2.6252														
						7.9228	425.3805	87.3327	4.8708	0.0000	0.00125	7.9215	425.2735	87.3223	4.8702	2.6401E-05	0.00126	7.9215	0.0000
69	190.2518	7.9215	425.2734	1.1715	2.6210														
						7.9215	425.2734	87.3223	4.8702	0.0000	0.00126	7.9202	425.1662	87.3120	4.8695	2.7151E-05	0.00126	7.9202	0.0002
70	192.8678	7.9200	425.1456	1.1700	2.6160														
						7.9200	425.1456	87.3100	4.8694	0.0000	0.00126	7.9187	425.0382	87.2996	4.8687	2.7914E-05	0.00126	7.9187	0.0000
71	195.4796	7.9187	425.0381	1.1687	2.6118														
						7.9187	425.0381	87.2996	4.8687	0.0000	0.00126	7.9175	424.9304	87.2892	4.8681	2.8683E-05	0.00126	7.9175	0.0000
72	198.0871	7.9175	424.9303	1.1675	2.6075														
						7.9175	424.9303	87.2892	4.8681	0.0000	0.00126	7.9162	424.8224	87.2788	4.8674	2.9462E-05	0.00127	7.9162	0.0000
73	200.6904	7.9162	424.8223	1.1662	2.6033														
						7.9162	424.8223	87.2788	4.8674	0.0000	0.00127	7.9149	424.7142	87.2683	4.8668	3.0251E-05	0.00127	7.9149	0.0000
74	203.2894	7.9149	424.7141	1.1649	2.5990														
						7.9149	424.7141	87.2683	4.8668	0.0000	0.00127	7.9137	424.6058	87.2578	4.8661	3.1050E-05	0.00127	7.9137	0.0000
75	205.8842	7.9137	424.6057	1.1637	2.5948														
						7.9137	424.6057	87.2578	4.8661	0.0000	0.00127	7.9124	424.4971	87.2473	4.8654	3.1858E-05	0.00128	7.9124	0.0000
76	208.4747	7.9124	424.4970	1.1624	2.5905														
						7.9124	424.4970	87.2473	4.8654	0.0000	0.00127	7.9111	424.3883	87.2368	4.8648	3.2676E-05	0.00128	7.9111	0.0000
77	211.0610	7.9111	424.3882	1.1611	2.5863														
						7.9111	424.3882	87.2368	4.8648	0.0000	0.00128	7.9098	424.2792	87.2263	4.8641	3.3504E-05	0.00128	7.9098	0.0000
78	213.6430	7.9098	424.2791	1.1598	2.5820														
						7.9098	424.2791	87.2262	4.8641	0.0000	0.00128	7.9086	424.1699	87.2157	4.8635	3.4341E-05	0.00128	7.9086	0.0000
79	216.2207	7.9086	424.1698	1.1586	2.5777														
						7.9086	424.1698	87.2157	4.8635	0.0000	0.00128	7.9073	424.0604	87.2051	4.8628	3.5188E-05	0.00129	7.9073	0.0000
80	218.7942	7.9073	424.0603	1.1573	2.5734														
						7.9073	424.0603	87.2051	4.8628	0.0000	0.00129	7.9060	423.9507	87.1945	4.8621	3.6045E-05	0.00129	7.9060	0.0000
81	221.3633	7.9060	423.9506	1.1560	2.5691														
						7.9060	423.9506	87.1945	4.8621	0.0000	0.00129	7.9047	423.8408	87.1839	4.8615	3.6911E-05	0.00129	7.9047	0.0000
82	223.9281	7.9047	423.8407	1.1547	2.5648														
						7.9047	423.8407	87.1838	4.8615	0.0000	0.00129	7.9034	423.7307	87.1732	4.8608	3.7786E-05	0.00129	7.9034	0.0000
83	226.4887	7.9034	423.7306	1.1534	2.5605														
						7.9034	423.7306	87.1732	4.8608	0.0000	0.00129	7.9021	423.6204	87.1625	4.8601	3.8671E-05	0.00130	7.9021	0.0000
84	229.0449	7.9021	423.6203	1.1521	2.5562														
						7.9021	423.6203	87.1625	4.8601	0.0000	0.00130	7.9008	423.5100	87.1518	4.8594	3.9565E-05	0.00130	7.9008	0.0000
85	231.5968	7.9008	423.5098	1.1508	2.5519														
						7.9008	423.5098	87.1518	4.8594	0.0000	0.00130	7.8995	423.3993	87.1411	4.8588	4.0469E-05	0.00130	7.8995	0.0000
86	234.1444	7.8995	423.3992	1.1495	2.5476														
						7.8995	423.3992	87.1411	4.8588	0.0000	0.00130	7.8982	423.2884	87.1304	4.8581	4.1383E-05	0.00130	7.8982	0.0000
87	236.6877	7.8982	423.2883	1.1482	2.5433														
						7.8982	423.2883	87.1304	4.8581	0.0000	0.00130	7.8969	423.1773	87.1196	4.8574	4.2305E-05	0.00131	7.8969	0.0000
88	239.2267	7.8969	423.1772	1.1469	2.5389														
						7.8969	423.1772	87.1196	4.8574	0.0000	0.00131	7.8956	423.0661	87.1089	4.8568	4.3237E-05	0.00131	7.8956	0.0000
89	241.7613	7.8956	423.0659	1.1456	2.5346														
						7.8956	423.0659	87.1089	4.8568	0.0000	0.00131	7.8943	422.9546	87.0981	4.8561	4.4178E-05	0.00131	7.8943	0.0000
90	244.2915	7.8943	422.9545	1.1443	2.5303														

						k1 - Change in Weir Depth						k2 - Change in Weir Depth							
Distance From Downstream End (m)	Channel Flow (D/S of Section) (cms)	Main Channel Depth (m)	Cross-Sectional Channel Area (m2)	Flow Depth over Weir (m)	Flow Diverted via Weir (cms)	Depth of Water at D/S Section (m)	Cross-Sectional Channel Area (m2)	Wetted Perimeter (m)	Hydr Radius (m)	Friction Slope	k1	Average Depth for Section	Cross-Sectional Channel Area (m2)	Wetted Perimeter (m)	Hydr Radius (m)	Friction Slope	k2	Calculated Channel Depth at Weir (U/S Section)	Convergence Check to U/S Section
						7.8943	422.9545	87.0981	4.8561	0.0000	0.00131	7.8930	422.8430	87.0873	4.8554	4.5129E-05	0.00131	7.8930	0.0000
91	246.8175	7.8930	422.8429	1.1430	2.5259														
						7.8930	422.8429	87.0873	4.8554	0.0000	0.00131	7.8917	422.7312	87.0764	4.8547	4.6089E-05	0.00131	7.8917	0.0000
92	249.3390	7.8917	422.7311	1.1417	2.5216														
						7.8917	422.7311	87.0764	4.8547	0.0000	0.00131	7.8904	422.6192	87.0656	4.8540	4.7058E-05	0.00132	7.8904	0.0000
93	251.8562	7.8904	422.6191	1.1404	2.5172														
						7.8904	422.6191	87.0656	4.8540	0.0000	0.00132	7.8890	422.5070	87.0547	4.8533	4.8036E-05	0.00132	7.8890	0.0000
94	254.3691	7.8890	422.5069	1.1390	2.5128														
						7.8890	422.5069	87.0547	4.8533	0.0000	0.00132	7.8877	422.3947	87.0438	4.8527	4.9023E-05	0.00132	7.8877	0.0000
95	256.8776	7.8877	422.3946	1.1377	2.5085														
						7.8877	422.3946	87.0438	4.8527	0.0000	0.00132	7.8864	422.2822	87.0329	4.8520	5.0020E-05	0.00132	7.8864	0.0000
96	259.3817	7.8864	422.2821	1.1364	2.5041														
						7.8864	422.2821	87.0329	4.8520	0.0001	0.00132	7.8851	422.1695	87.0220	4.8513	5.1025E-05	0.00133	7.8851	0.0000
97	261.8814	7.8851	422.1694	1.1351	2.4997														
						7.8851	422.1694	87.0220	4.8513	0.0001	0.00133	7.8838	422.0567	87.0111	4.8506	5.2040E-05	0.00133	7.8837	0.0000
98	264.3768	7.8838	422.0566	1.1338	2.4954														
						7.8838	422.0566	87.0111	4.8506	0.0001	0.00133	7.8824	421.9436	87.0001	4.8499	5.3064E-05	0.00133	7.8824	0.0000
99	266.8677	7.8824	421.9436	1.1324	2.4910														
						7.8824	421.9436	87.0001	4.8499	0.0001	0.00133	7.8811	421.8305	86.9892	4.8492	5.4097E-05	0.00133	7.8811	0.0000
100	269.3543	7.8811	421.8304	1.1311	2.4866														
						7.8811	421.8304	86.9891	4.8492	0.0001	0.00133	7.8798	421.7171	86.9782	4.8485	5.5138E-05	0.00133	7.8798	0.0000
101	271.8365	7.8798	421.7171	1.1298	2.4822														
						7.8798	421.7171	86.9782	4.8485	0.0001	0.00133	7.8784	421.6036	86.9672	4.8478	5.6189E-05	0.00134	7.8784	0.0000
102	274.3143	7.8784	421.6036	1.1284	2.4778														
						7.8784	421.6036	86.9671	4.8478	0.0001	0.00134	7.8771	421.4900	86.9561	4.8472	5.7249E-05	0.00134	7.8771	0.0000
103	276.7877	7.8771	421.4899	1.1271	2.4734														
						7.8771	421.4899	86.9561	4.8472	0.0001	0.00134	7.8757	421.3762	86.9451	4.8465	5.8317E-05	0.00134	7.8757	0.0000
104	279.2567	7.8757	421.3761	1.1257	2.4690														
						7.8757	421.3761	86.9451	4.8465	0.0001	0.00134	7.8744	421.2622	86.9340	4.8458	5.9394E-05	0.00134	7.8744	0.0000
105	281.7213	7.8744	421.2622	1.1244	2.4646														
						7.8744	421.2622	86.9340	4.8458	0.0001	0.00134	7.8731	421.1481	86.9230	4.8451	6.0481E-05	0.00134	7.8731	0.0000
106	284.1814	7.8731	421.1481	1.1231	2.4602														
						7.8731	421.1481	86.9230	4.8451	0.0001	0.00134	7.8717	421.0339	86.9119	4.8444	6.1576E-05	0.00135	7.8717	0.0000
107	286.6372	7.8717	421.0338	1.1217	2.4557														
						7.8717	421.0338	86.9119	4.8444	0.0001	0.00135	7.8704	420.9195	86.9008	4.8437	6.2679E-05	0.00135	7.8704	0.0000
108	289.0885	7.8704	420.9194	1.1204	2.4513														
						7.8704	420.9194	86.9008	4.8437	0.0001	0.00135	7.8690	420.8049	86.8897	4.8430	6.3792E-05	0.00135	7.8690	0.0000
109	291.5354	7.8690	420.8049	1.1190	2.4469														
						7.8690	420.8049	86.8897	4.8430	0.0001	0.00135	7.8677	420.6903	86.8785	4.8423	6.4913E-05	0.00135	7.8677	0.0000
110	293.9779	7.8677	420.6902	1.1177	2.4425														
						7.8677	420.6902	86.8785	4.8423	0.0001	0.00135	7.8663	420.5754	86.8674	4.8416	6.6043E-05	0.00135	7.8663	0.0000
111	296.4159	7.8663	420.5754	1.1163	2.4380														
						7.8663	420.5754	86.8674	4.8416	0.0001	0.00135	7.8650	420.4605	86.8562	4.8409	6.7182E-05	0.00136	7.8650	0.0000
112	298.8495	7.8650	420.4604	1.1150	2.4336														
						7.8650	420.4604	86.8562	4.8409	0.0001	0.00136	7.8636	420.3454	86.8450	4.8402	6.8329E-05	0.00136	7.8636	0.0000
113	301.2787	7.8636	420.3454	1.1136	2.4292														
						7.8636	420.3454	86.8450	4.8402	0.0001	0.00136	7.8623	420.2302	86.8338	4.8395	6.9485E-05	0.00136	7.8623	0.0000
114	303.7034	7.8623	420.2301	1.1123	2.4247														
						7.8623	420.2301	86.8338	4.8395	0.0001	0.00136	7.8609	420.1148	86.8226	4.8388	7.0649E-05	0.00136	7.8609	0.0000
115	306.1237	7.8609	420.1148	1.1109	2.4203														
						7.8609	420.1148	86.8226	4.8388	0.0001	0.00136	7.8595	419.9993	86.8114	4.8381	7.1822E-05	0.00136	7.8595	0.0000
116	308.5396	7.8595	419.9993	1.1095	2.4159														
						7.8595	419.9993	86.8114	4.8381	0.0001	0.00136	7.8582	419.8837	86.8002	4.8374	7.3003E-05	0.00136	7.8582	0.0000
117	310.9510	7.8582	419.8837	1.1082	2.4114														
						7.8582	419.8837	86.8002	4.8374	0.0001	0.00136	7.8568	419.7680	86.7889	4.8367	7.4193E-05	0.00137	7.8568	0.0000
118	313.3580	7.8568	419.7680	1.1068	2.4070														
						7.8568	419.7680	86.7889	4.8367	0.0001	0.00137	7.8554	419.6521	86.7777	4.8359	7.5392E-05	0.00137	7.8554	0.0000
119	315.7605	7.8554	419.6521	1.1054	2.4025														
						7.8554	419.6521	86.7777	4.8359	0.0001	0.00137	7.8541	419.5361	86.7664	4.8352	7.6598E-05	0.00137	7.8541	0.0000
120	318.1585	7.8541	419.5361	1.1041	2.3980														

						k1 - Change in Weir Depth						k2 - Change in Weir Depth							
Distance From Downstream End (m)	Channel Flow (D/S of Section) (cms)	Main Channel Depth (m)	Cross-Sectional Channel Area (m2)	Flow Depth over Weir (m)	Flow Diverted via Weir (cms)	Depth of Water at D/S Section (m)	Cross-Sectional Channel Area (m2)	Wetted Perimeter (m)	Hydr Radius (m)	Friction Slope	k1	Average Depth for Section	Cross-Sectional Channel Area (m2)	Wetted Perimeter (m)	Hydr Radius (m)	Friction Slope	k2	Calculated Channel Depth at Weir (U/S Section)	Convergence Check to U/S Section
						7.8541	419.5361	86.7664	4.8352	0.0001	0.00137	7.8527	419.4200	86.7551	4.8345	7.7813E-05	0.00137	7.8527	0.0000
121	320.5521	7.8527	419.4201	1.1027	2.3936														
						7.8527	419.4201	86.7551	4.8345	0.0001	0.00137	7.8513	419.3038	86.7438	4.8338	7.9037E-05	0.00137	7.8513	0.0000
122	322.9412	7.8513	419.3039	1.1013	2.3891														
						7.8513	419.3039	86.7438	4.8338	0.0001	0.00137	7.8500	419.1875	86.7325	4.8331	8.0269E-05	0.00137	7.8500	0.0000
123	325.3259	7.8500	419.1875	1.1000	2.3847														
						7.8500	419.1875	86.7325	4.8331	0.0001	0.00137	7.8486	419.0711	86.7212	4.8324	8.1509E-05	0.00138	7.8486	0.0000
124	327.7061	7.8486	419.0711	1.0986	2.3802														
						7.8486	419.0711	86.7212	4.8324	0.0001	0.00137	7.8472	418.9545	86.7099	4.8317	8.2757E-05	0.00138	7.8472	0.0000
125	330.0818	7.8472	418.9546	1.0972	2.3757														
						7.8472	418.9546	86.7099	4.8317	0.0001	0.00138	7.8458	418.8379	86.6985	4.8310	8.4014E-05	0.00138	7.8458	0.0000
126	332.4531	7.8458	418.8379	1.0958	2.3713														
						7.8458	418.8379	86.6985	4.8310	0.0001	0.00138	7.8445	418.7212	86.6872	4.8303	8.5279E-05	0.00138	7.8445	0.0000
127	334.8199	7.8445	418.7212	1.0945	2.3668														
						7.8445	418.7212	86.6872	4.8303	0.0001	0.00138	7.8431	418.6043	86.6758	4.8295	8.6552E-05	0.00138	7.8431	0.0000
128	337.1822	7.8431	418.6043	1.0931	2.3623														
						7.8431	418.6043	86.6758	4.8295	0.0001	0.00138	7.8417	418.4873	86.6644	4.8288	8.7833E-05	0.00138	7.8417	0.0000
129	339.5401	7.8417	418.4874	1.0917	2.3579														
						7.8417	418.4874	86.6644	4.8288	0.0001	0.00138	7.8403	418.3703	86.6530	4.8281	8.9122E-05	0.00138	7.8403	0.0000
130	341.8935	7.8403	418.3704	1.0903	2.3534														
						7.8403	418.3704	86.6530	4.8281	0.0001	0.00138	7.8389	418.2531	86.6416	4.8274	9.0419E-05	0.00139	7.8389	0.0000
131	344.2424	7.8389	418.2532	1.0889	2.3489														
						7.8389	418.2532	86.6416	4.8274	0.0001	0.00138	7.8376	418.1359	86.6302	4.8267	9.1725E-05	0.00139	7.8376	0.0000
132	346.5868	7.8376	418.1360	1.0876	2.3444														
						7.8376	418.1360	86.6302	4.8267	0.0001	0.00139	7.8362	418.0186	86.6188	4.8260	9.3038E-05	0.00139	7.8362	0.0000
133	348.9268	7.8362	418.0187	1.0862	2.3400														
						7.8362	418.0187	86.6188	4.8260	0.0001	0.00139	7.8348	417.9011	86.6073	4.8252	9.4359E-05	0.00139	7.8348	0.0000
134	351.2623	7.8348	417.9012	1.0848	2.3355														
						7.8348	417.9012	86.6073	4.8252	0.0001	0.00139	7.8334	417.7836	86.5959	4.8245	9.5689E-05	0.00139	7.8334	0.0000
135	353.5933	7.8334	417.7837	1.0834	2.3310														
						7.8334	417.7837	86.5959	4.8245	0.0001	0.00139	7.8320	417.6660	86.5844	4.8238	9.7026E-05	0.00139	7.8320	0.0000
136	355.9198	7.8320	417.6661	1.0820	2.3265														
						7.8320	417.6661	86.5844	4.8238	0.0001	0.00139	7.8306	417.5484	86.5730	4.8231	9.8371E-05	0.00139	7.8306	0.0000
137	358.2418	7.8306	417.5485	1.0806	2.3220														
						7.8306	417.5485	86.5730	4.8231	0.0001	0.00139	7.8292	417.4306	86.5615	4.8224	9.9724E-05	0.00139	7.8292	0.0000
138	360.5594	7.8292	417.4307	1.0792	2.3176														
						7.8292	417.4307	86.5615	4.8224	0.0001	0.00139	7.8278	417.3128	86.5500	4.8216	1.0108E-04	0.00140	7.8278	0.0000
139	362.8724	7.8278	417.3129	1.0778	2.3131														
						7.8278	417.3129	86.5500	4.8216	0.0001	0.00139	7.8264	417.1949	86.5385	4.8209	1.0245E-04	0.00140	7.8264	0.0000
140	365.1810	7.8264	417.1950	1.0764	2.3086														
						7.8264	417.1950	86.5385	4.8209	0.0001	0.00140	7.8251	417.0769	86.5270	4.8202	1.0383E-04	0.00140	7.8251	0.0000
141	367.4851	7.8251	417.0770	1.0751	2.3041														
						7.8251	417.0770	86.5270	4.8202	0.0001	0.00140	7.8237	416.9588	86.5155	4.8195	1.0521E-04	0.00140	7.8237	0.0000
142	369.7847	7.8237	416.9589	1.0737	2.2996														
						7.8237	416.9589	86.5155	4.8195	0.0001	0.00140	7.8223	416.8407	86.5040	4.8187	1.0661E-04	0.00140	7.8223	0.0000
143	372.0799	7.8223	416.8408	1.0723	2.2951														
						7.8223	416.8408	86.5040	4.8187	0.0001	0.00140	7.8209	416.7225	86.4925	4.8180	1.0801E-04	0.00140	7.8209	0.0000
144	374.3705	7.8209	416.7226	1.0709	2.2906														
						7.8209	416.7226	86.4925	4.8180	0.0001	0.00140	7.8195	416.6042	86.4809	4.8173	1.0941E-04	0.00140	7.8195	0.0000
145	376.6567	7.8195	416.6044	1.0695	2.2862														
						7.8195	416.6044	86.4810	4.8173	0.0001	0.00140	7.8181	416.4859	86.4694	4.8166	1.1083E-04	0.00140	7.8181	0.0000
146	378.9383	7.8181	416.4860	1.0681	2.2817														
						7.8181	416.4860	86.4694	4.8166	0.0001	0.00140	7.8167	416.3675	86.4579	4.8158	1.1225E-04	0.00140	7.8167	0.0000
147	381.2155	7.8167	416.3676	1.0667	2.2772														
						7.8167	416.3676	86.4579	4.8158	0.0001	0.00140	7.8153	416.2490	86.4463	4.8151	1.1368E-04	0.00141	7.8153	0.0000
148	383.4882	7.8153	416.2492	1.0653	2.2727														
						7.8153	416.2492	86.4463	4.8151	0.0001	0.00140	7.8139	416.1305	86.4347	4.8144	1.1512E-04	0.00141	7.8139	0.0000
149	385.7564	7.8139	416.1307	1.0639	2.2682														
						7.8139	416.1307	86.4348	4.8144	0.0001	0.00141	7.8125	416.0119	86.4232	4.8137	1.1656E-04	0.00141	7.8125	0.0000
150	388.0202	7.8125	416.0121	1.0625	2.2637														

APPENDIX F.6.3 – SITES ANALYSIS

```
******************************************************************************
 SITES XEQ 03/20/2017   WATER RESOURCE SITE ANALYSIS COMPUTER PROGRAM
      VER 2005.1.05              (USER MANUAL - DATED DECEMBER 2005)
      TIME 14:05:16

 ************************** 80-80 LIST OF INPUT Data ***************************
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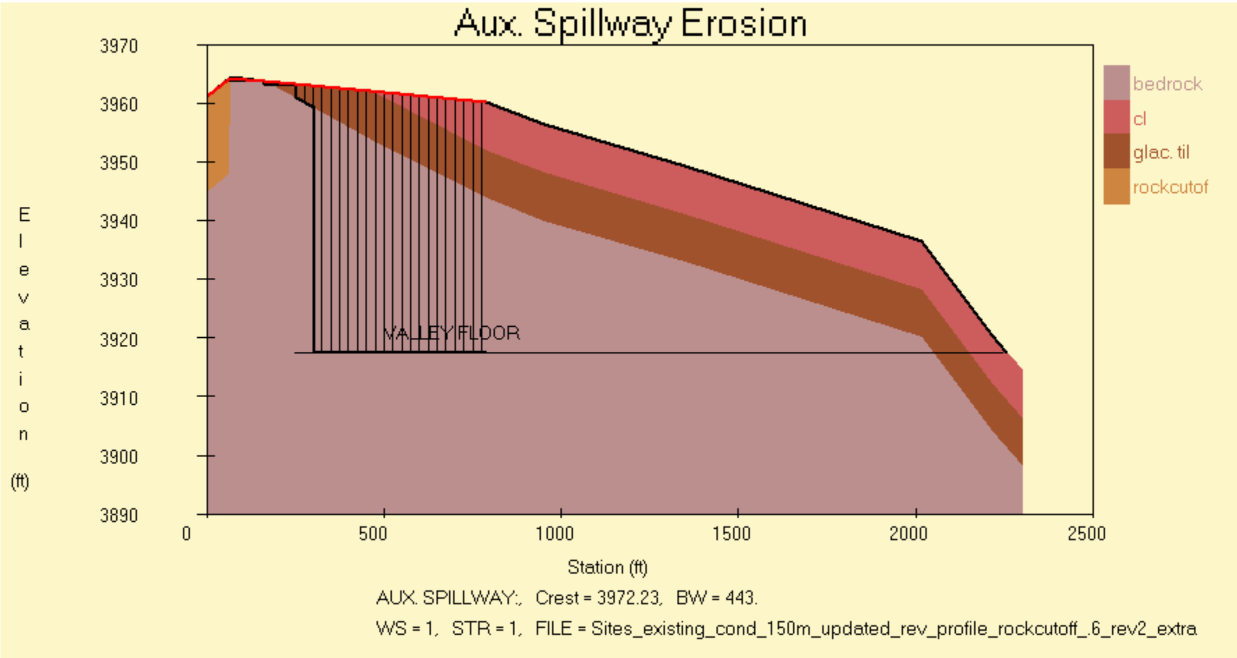


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SAVMOV    101  1                                                      1
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                     3912.40             .2         0          630
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                     3937.01             .4         0          14055
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                     3946.85             .7         0          24328
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                     3953.41             .9         0          32649
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ENDTABLE
WSDATA    2S 1               1
POOLDATA  ELEV               3896.00                       3917.5
ASSPRFL   41        0
          0         3961.0738865.616    3964.35468164      3963.8628
          460       3962.1    787       3960.1
ENDTABLE
ASSURFACE 41        787.4     1
          0         787.4     0.025     0         1
ENDTABLE
ASDATA    41                            4                            1
BTMWIDTH  FEET      442.908
ASMATERIAL
          1         0         2         0         140       10
          2         48        .000086   77        83        .16
          3         11        0.0051    11        97        .16
          4         0         2         0         140       10
ENDTABLE
ASCOORD    1        bedrock   N
          0         3944.696  49.212    3947.1566 50.212    3947.1566
          65.616    3948      66.616    3964.40030164      3963.8628
          460       3953.8848 787       3943.71844954      3939.898
          1349      3932.826192018      3919.998262215      3904.152
          2300      3898.196
ENDTABLE
ASCOORD    2        CL
          0         3944.696  49.212    3947.1566 50.212    3947.1566
          65.616    3948      66.616    3964.40030164      3963.8628
          460       3962.0868 787       3960.12244954      3956.3
          1349      3949.230192018      3936.402262215      3920.556
          2300      3914.6
ENDTABLE
ASCOORD    3        glac. till
          0         3944.696  49.212    3947.1566 50.212    3947.1566
          65.616    3948      66.616    3964.40030164      3963.8628
          460       3962.0868 787       3951.92044954      3948.098
          1349      3941.028192018      3928.200262215      3912.354
          2300      3906.398
ENDTABLE
ASCOORD    4        rockcutoff
          0         3961.07   49.212    3963.5306 50.212    3963.5806
          65.616    3964.35   66.616    3964.40030
ENDTABLE
GRAPHICS  I
GO,HYD    L                                                3972.23
SAVMOV    2    101  1                   1
ENDJOB

-------------------------------------------------------------
** CONTROL FILE SEGMENT LIST **
SAVMOV    101  1                                                     1
STRUCTURE 1         stage-storage-discharge
                    3896.00             0         0         9
                    3904.20             .1        0         84
                    3912.40             .2        0         630
                    3928.81             .3        0         7714
                    3937.01             .4        0         14055
                    3940.29             .5        0         17167
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                    3943.57             .6        0         20601
                    3946.85             .7        0         24328
                    3950.13             .8        0         28340
                    3953.41             .9        0         32649
                    3956.69             1         0         37255
                    3959.97             1.1       0         42156
                    3963.25             1.2       0         47343
                    3966.54             1.3       0         52829
                    3972.2286           1.4       0         63172.4538
                    3973.0488           1.5       780.45487 64693.96
                    3973.869            1.6       2803.9871866292.1085
                    3974.6892           1.7       5530.2820267890.2532
                    3975.5094           1.8       8793.3603 69488.3979
                    3976.3296           1.9       12497.872371086.54
ENDTABLE
HYD       9                   Storm
                    0.166667
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                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0          0          0          0
                  0          0
ENDTABLE
WSDATA    2S 1               1
POOLDATA  ELEV               3896.00                          3917.5
ASSPRFL   41        0
          0         3961.0738865.616    3964.35468164         3963.8628
          460       3962.1     787      3960.1
ENDTABLE
ASSURFACE 41        787.4      1
          0         787.4      0.025     0          1
ENDTABLE
ASDATA    41                            4                                1
BTMWIDTH  FEET      442.908
ASMATERIAL
          1         0          2          0          140        10
          2         48         .000086    77         83         .16
          3         11         0.0051     11         97         .16
          4         0          2          0          140        10
ENDTABLE
ASCOORD    1        bedrock    N
          0         3944.696   49.212     3947.1566 50.212      3947.1566
          65.616    3948       66.616     3964.40030164         3963.8628
          460       3953.8848  787        3943.71844954         3939.898
          1349      3932.826192018        3919.998262215        3904.152
          2300      3898.196
ENDTABLE
ASCOORD    2        CL
          0         3944.696   49.212     3947.1566 50.212      3947.1566
          65.616    3948       66.616     3964.40030164         3963.8628
          460       3962.0868  787        3960.12244954         3956.3
          1349      3949.230192018        3936.402262215        3920.556
          2300      3914.6
ENDTABLE
ASCOORD    3        glac. till
          0         3944.696   49.212     3947.1566 50.212      3947.1566
          65.616    3948       66.616     3964.40030164         3963.8628
```

```
          460       3962.0868 787       3951.92044954       3948.098
          1349      3941.028192018      3928.200262215      3912.354
          2300      3906.398
ENDTABLE
ASCOORD    4        rockcutoff
          0         3961.07   49.212    3963.5306 50.212    3963.5806
          65.616    3964.35   66.616    3964.40030
ENDTABLE
GRAPHICS  I
GO,HYD    L                                                 3972.23
SAVMOV    2    101  1                   1

-------------------------------------------------------------

 ******************************************************************************

 ***** MESSAGE - DEFAULT TOPSOIL FILL MATERIAL PARAMETERS USED.

 ***** MESSAGE - AUXILIARY SPILLWAY CREST ELEVATION IS SET TO  3964.35
                 FROM THE ASSPRFL RECORDS.

 ***** MESSAGE - VALUES FROM ASSURFACE, REACH  1 IMPLY NO VEGETAL COVER WITH
                 "n" OF 0.025.


1SITES -------------------------------------------------------------------------------
 XEQ 03/20/2017             SR1 Emergency Spillway                WSID= 1
 VER 2005.1.05               stage-storage-discharge                SUBW= 1
 TIME 14:05:16            SITE = 1                  PASS=    1     PART=   1


 **********************    MATERIAL PROPERTIES    ****************************
                            DRY                       PERCENT      DETACH.      REP.
      MATERIAL       PI   DENSITY        Kh         CLAY          RATE       DIAMETER
                          lbs/CuFt                             (Ft/H)/(lb/SqFt)  inches
     bedrock         0.      140.     10.00          0.0           --        2.00000
     CL             48.       83.      0.16         77.0           --        0.00009
     glac. till     11.       97.      0.16         11.0           --        0.00510
     rockcutoff      0.      140.     10.00          0.0           --        2.00000
     TS_FILL         0.      100.      0.05          0.0           --        0.05000
     GEN_FILL        0.      140.     10.00          0.0           --        2.00000

 ****************************    BASIC Data    *********************************
 HUMID- SUBHUMID CLIMATE AREA                    DESIGN CLASS  S = USER DEFINED

 FLOOD HYDROGRAPH(S) USED

 WSDATA -       CN          DA-SM         TC/L            -/H           QRF
              0.00          1.00          0.00           0.00          0.00

 SITEDATA- PERM POOL     CREST PS       FP SED       VALLEY FL        378?
              0.00       3896.00          0.00       3917.50            NO

          BASEFLOW      INITIAL EL     EXTRA VOL      SITE TYPE
              0.00          0.00          0.00       SIMULATION

 PSDATA -  NO. COND        COND L         DIA/W            -/H
              0.00          0.00          0.00           0.00

              PS N            KE         WEIR L        TW EL
             0.000          0.00          0.00           0.00

           2ND STG         ORF H          ORF L      START AUX.
              0.00          0.00          0.00       3972.23

 ASCRESTS -   AUX.1         AUX.2         AUX.3          AUX.4         AUX.5
```

```
          3964.35          0.00          0.00           0.00          0.00

AUX.Data -  REF.NO.    RETARD. Ci   TIE STATION    INLET LENGTH
                 41          0.00         65.62             65

AUX.Data - INLET N     SIDE SLOPE       EXIT N      EXIT SLOPE     ACTUAL AUX?
              0.025          4.00        0.025          0.005            NO

BTM WIDTH -    BW1           BW2           BW3            BW4           BW5
  ft        442.91          0.00          0.00           0.00          0.00


1SITES -------------------------------------------------------------------------------
 XEQ 03/20/2017            SR1 Emergency Spillway                 WSID= 1
 VER 2005.1.05              stage-storage-discharge                 SUBW= 1
 TIME 14:05:16            SITE = 1                PASS=    1     PART=   2


 INFLOW HYDROGRAPH PROVIDED IN LOCATION  9,  PEAK=  11147.44 CFS, AT  63.63 HRS.
 TITLE = Storm


 ***** WARNING - ONLY ONE CREST ELEVATION AND BOTTOM WIDTH MAY BE USED
                WITH AUXILIARY SPILLWAY RATING GIVEN IN STRUCTURE TABLE.
                ADDITIONAL AND/OR INCONSISTENT VALUES IGNORED

 CREST PS       3896.00 FT       9.0 ACFT      0.00 AC       0.0 CFS

 SED ACCUM      3896.00 FT       9.0 ACFT      0.00 AC       0.0 CFS

 AUX. CREST     3972.23 FT   63172.5 ACFT      0.00 AC       1.4 CFS

      PS STORAGE  63163.5 ACFT,  BETWEEN AUX. CREST AND SED. ACCUM ELEVATIONS.

 START ELEV     3972.23 FT   63175.2 ACFT      0.00 AC       1.4 CFS


 *******************************************************************************
 RATING TABLE DEVELOPED, SITE = 1     :
  WITH TOTAL RATING SUPPLIED BY USER.


 RATING TABLE NUMBER  2
```

	ELEV. FEET	Q-TOTAL CFS	Q-PS CFS	Q-AUX. CFS	VOLUME AC-FT	AREA ACRE
1	3896.00	0.00	0.00	0.00	9.00	0.00
2	3904.20	0.10	0.10	0.00	84.00	0.00
3	3912.40	0.20	0.20	0.00	630.00	0.00
4	3928.81	0.30	0.30	0.00	7714.00	0.00
5	3937.01	0.40	0.40	0.00	14055.00	0.00
6	3940.29	0.50	0.50	0.00	17167.00	0.00
7	3943.57	0.60	0.60	0.00	20601.00	0.00
8	3946.85	0.70	0.70	0.00	24328.00	0.00
9	3950.13	0.80	0.80	0.00	28340.00	0.00
10	3953.41	0.90	0.90	0.00	32649.00	0.00
11	3956.69	1.00	1.00	0.00	37255.00	0.00
12	3959.97	1.10	1.10	0.00	42156.00	0.00
13	3963.25	1.20	1.20	0.00	47343.00	0.00
14	3966.54	1.30	1.30	0.00	52829.00	0.00
15	3972.23	1.40	1.40	0.00	63172.45	0.00
16	3973.05	781.95	1.50	780.45	64693.96	0.00
17	3973.87	2805.59	1.60	2803.99	66292.11	0.00
18	3974.69	5531.98	1.70	5530.28	67890.25	0.00
19	3975.51	8795.16	1.80	8793.36	69488.40	0.00
20	3976.33	12499.77	1.90	12497.87	71086.54	0.00

```
 ***************************************************************************
```

SUMMARY OF AUXILIARY SPILLWAY SURFACE CONDITIONS USED IN COMPUTATIONS BY REACH

REACH	FROM STA (ft)	TO STA (ft)	SLOPE (%)	RETARDANCE CURVE INDEX@	VEGETAL COVER FACTOR	MAINT. CODE +	ROOTING DEPTH (ft)	REACH LOCATION *
1	0.	66.	-5.0	0.025	**	**	**	INLET
2	66.	164.	0.5	0.025	0.00	1		EXIT !
3	164.	460.	0.6	0.025	0.00	1		EXIT
4	460.	787.	0.6	0.025	0.00	1		EXIT

@ The program interprets retardance curve index entries of less than 1 as Manning's n values.
\+ The minimum maintenance code value of 2 is used in INTEGRITY computations (the program changes values of 1 to 2 during computation).
* Upper case indicates a reach of constructed spillway channel.
** The program does not use vegetal cover factor, maintenance code, and rooting depth for inlet and crest reaches in computations.
! Reach 2 used in computing exit channel velocities.
****

ROUTING OF STORM HYDROGRAPH STARTS AT ELEVATION 3972.23

ROUTED RESULTS	BTM WIDTH FT	MAX ELEV FT	VOL-MAX ACFT	AREA-MAX AC	AUX.-HP FT	VOL-AUX. ACFT
FLOOD HYD	442.9	3975.63	69724.2	0.0	3.40	6551.8

PEAK - CFS	Q-PS	Q-AUX.	Q-TOT.
DISCHARGE =	2.	9340.	9342.

	CRITICAL DEPTH FT	CRITICAL VELOCITY FT/SEC	CRITICAL SLOPE-Sc FT/FT	25% OF Q Sc FT/FT
AUXILIARY SPILLWAY ---	2.38	8.67	0.007	0.009

****

EROSIONALLY EFFECTIVE STRESS FOR STABILITY ANALYSIS OF AUX. EXIT CHANNEL
(Refer to Ag. Handbook 667, Chapt. 3, for allowable stresses.)
Aux. Spillway Discharge = 9340. cfs; Bottom Width = 443. ft

REACH NO.	FROM STA	TO STA	SLOPE %	MANNING`S n	VELOCITY ft/s	TOTAL STRESS lb/ft^2	EFFECTIVE STRESS lb/ft^2	
2	66.	164.	0.50	0.025	7.86	0.82	0.818	
3	164.	460.	0.60	0.025	8.29	0.92	0.924	
4	460.	787.	0.61	0.025	8.36	0.94	0.942	max.

****

INTEGRITY ANALYSIS - REACH SURFACE PERFORMANCE SUMMARY
(The auxiliary spillway began flow at time = 36.4 hours
and peaked at time = 71.0 hours.)

REACH 2: FROM STATION 66. TO 164. ON 0.5% SLOPE.
Non-vegetated conditions implied: flow concentration
assumed with minimal flow: Time = 48.6 hours.

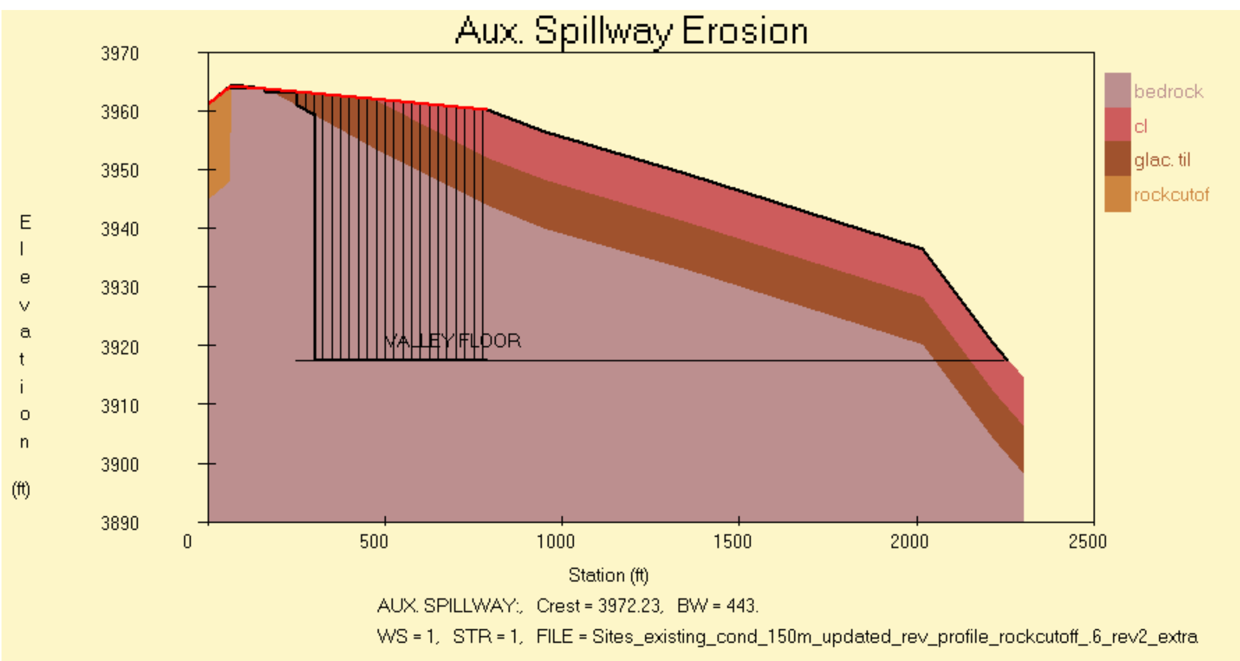
REACH 3: FROM STATION 164. TO 460. ON 0.6% SLOPE.
Non-vegetated conditions implied: flow concentration
assumed with minimal flow: Time = 47.6 hours.

REACH 4: FROM STATION 460. TO 787. ON 0.6% SLOPE.
Non-vegetated conditions implied: flow concentration
assumed with minimal flow: Time = 47.4 hours.

```
INTEGRITY ANALYSIS - HEADCUT EROSION DAMAGE SUMMARY

  Surface (vegetal) damage with a computed depth of 0.5 ft or less
  occurred up to station     66.

  The most upstream headcut began at station    460.
  and progressed upstream to station    254.
  The final height of the headcut was    2.5 ft.

  The headcut having the maximum final overfall height began
  at station    460. and progressed upstream to station   302.
  The final height of the headcut was   45.5 ft.

               DURATION    ATTACK   DIST. FROM MOST U/S
                 FLOW       OE/B    HEADCUT TO U/S EDGE
AUXILIARY         HRS     ACFT/FT     AUX. CREST, FT
SPILLWAY ---    213.3       77.7           189.

EXIT CHANNEL FLOW SUBCRITICAL: MAX VELOCITY=   7.9 FT/SEC
                               EXIT SLOPE  = 0.005 FT/FT
                               FLOW DEPTH  =   2.6 FT
```

```
 ***** MESSAGE - WITH AUX. RATING GIVEN ON STRUCTURE CONTROL, COMPUTED
                CRITICAL FLOW VALUES MAY NEED REVISION.
 -------------------------------------------------------------------------------

 Input--Storm Hyd, Peak =       9341.87 CFS at   70.97 hrs.,  Location Point
HYDOUT   1     1

1SITES....JOB NO.  1 COMPLETE.
 -------------------------------------------------------------------------------

 1             SR1 Emergency Spillway

       0 SUBWATERSHED(S) ANALYZED.

       1 STRUCTURE(S) ANALYZED.

       1 HYDROGRAPHS ROUTED AT LOWEST SITE.

       0 TRIALS TO OBTAIN BOTTOM WIDTH FOR SPECIFIED STRESS OR VELOCITY.

 *******************************************************************************


 SITES.....COMPUTATIONS COMPLETE


                             SUMMARY TABLE  1          SITES VERSION 2005.1.05
                            ----------------                DATED 01/01/2005


 WATERSHED ID                       RUN DATE                           RUN TIME
 ------------                       --------                           --------
 1                                03/20/2017                           14:05:16

 >>>   SITE   SUBWS   SUBWS DA   CURVE    TC   TOTAL DA   TYPE    STRUC    <<<
        ID      ID     (SQ MI)    NO.    (HRS)  (SQ MI)  DESIGN   CLASS
       -----   ----   --------   -----   ----   -------   -----   -----
       1        1         1.00      0.   0.00      1.00    TR60     S

 PASS  DIA./  AUX.CREST  BTM.  MAX.    MAX.    EMB.  INTEGR.*  EXIT*    TYPE
  NO.  WIDTH    ELEV    WIDTH   HP     ELEV    VOL.   DIST.     VEL.     HYD
      (IN/FT)   (FT)     (FT)  (FT)    (FT)    (CY)   (FT)    (FT/SEC)
```

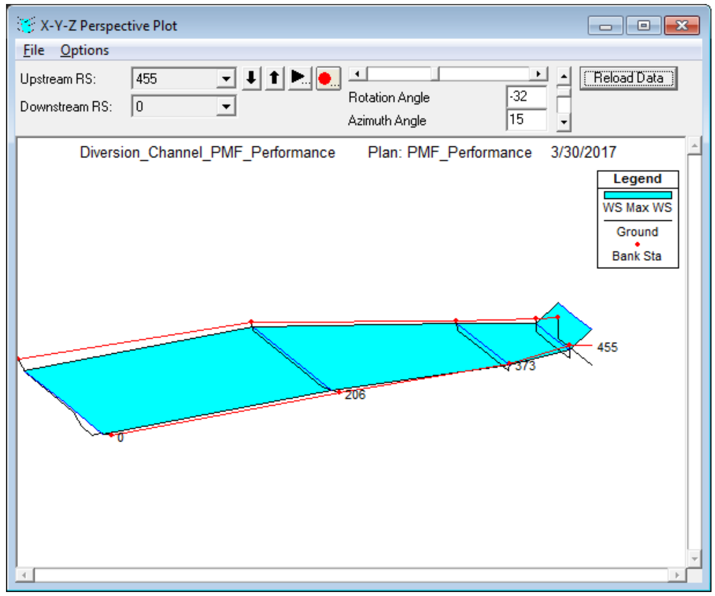
```
 ----  -----  -------  ------  ----  -------  -------  -----  ------  ---------
    1    0.0   3972.2   442.9   3.4   3975.6       0.    189.     7.9  FLOOD HYD


 *  INTEGRITY DIST. AND EXIT VEL. VALUES ARE BASED ON THE ROUTED
    HYDROGRAPH SHOWN UNDER TYPE HYD.



 SITES.......SUMMARY TABLE 1 COMPLETED.

                    NRCS  SITES    VERSION 2005.1.05 ,01/01/2005
                              1        FILES

INPUT  =
Z:\SR1\SITES3\Sites_existing_cond_150m_updated_rev_profile_rockcutoff_.6_rev2_extra.D2C
OUTPUT =
Z:\SR1\SITES3\Sites_existing_cond_150m_updated_rev_profile_rockcutoff_.6_rev2_extra.OUT
         DATED 03/20/2017 14:05:16

                         GRAPHICS FILES GENERATED

OPTION "L"  =
Z:\SR1\SITES3\Sites_existing_cond_150m_updated_rev_profile_rockcutoff_.6_rev2_extra.DRG
DATED 03/20/2017 14:05:16

OPTION "P"  =
Z:\SR1\SITES3\Sites_existing_cond_150m_updated_rev_profile_rockcutoff_.6_rev2_extra.DHY
DATED 03/20/2017 14:05:16

OPTION "E"  =
Z:\SR1\SITES3\Sites_existing_cond_150m_updated_rev_profile_rockcutoff_.6_rev2_extra.DEM
DATED 03/20/2017 14:05:16

AUX.GRAPHICS =
Z:\SR1\SITES3\Sites_existing_cond_150m_updated_rev_profile_rockcutoff_.6_rev2_extra.DG*
DATED 03/20/2017 14:05:16
```

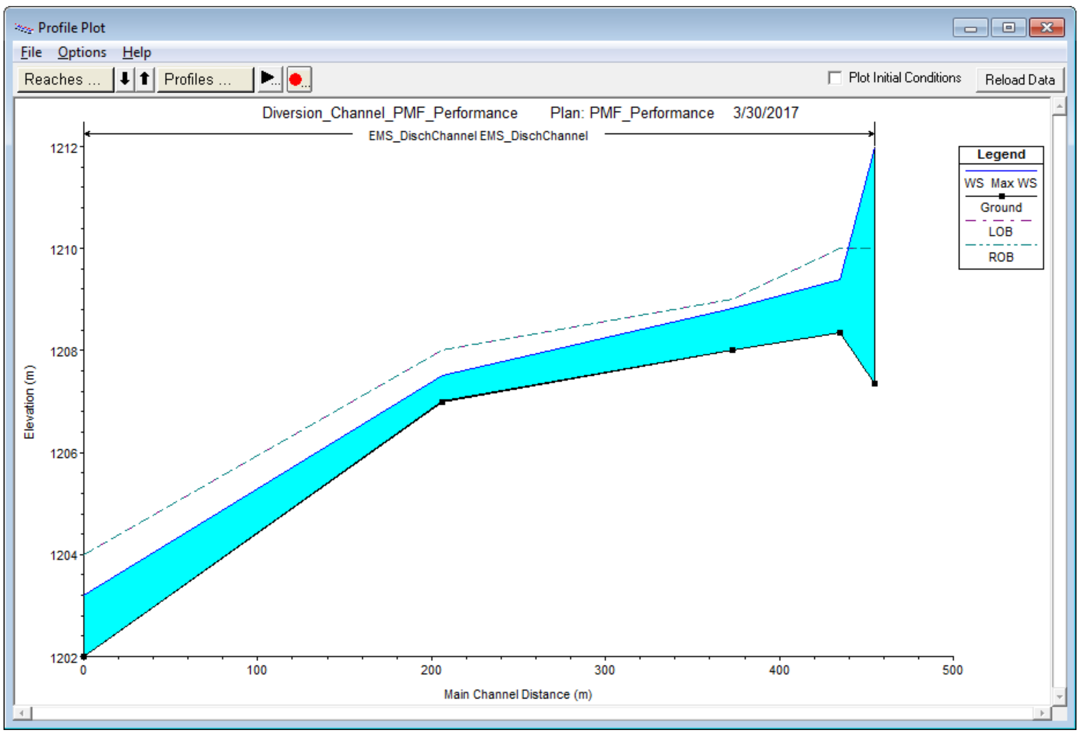


APPENDIX F.6.4 – HEC-RAS RESULTS SUMMARY

Emergency Spillway Discharge Channel
HEC-RAS 1D, Unsteady Results

Stantec
B.Lavey
March 7, 2017





Profile Output Table - Standard Table 1

File Options Std. Tables Locations Help

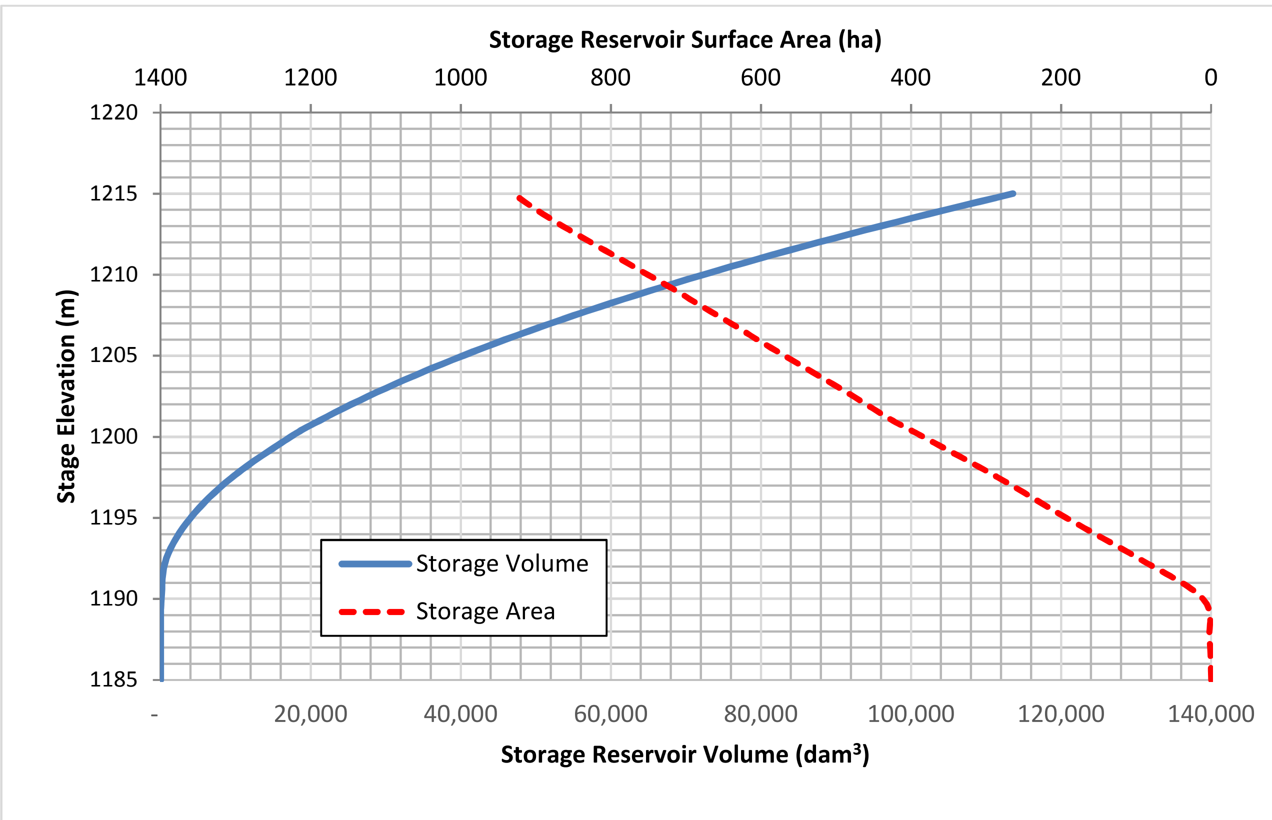
HEC-RAS Plan: PMF River: EMS_DischChannel Reach: EMS_DischChannel Profile: Max WS

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
EMS_DischChannel	455	Max WS	0.66	1207.35	1211.99		1211.99	0.000000	0.00	626.06	135.00	0.00
EMS_DischChannel	435	Max WS	-511.26	1208.35	1209.38	1209.48	1210.07	0.025555	-3.67	139.25	135.00	1.15
EMS_DischChannel	373	Max WS	382.87	1208.00	1208.83		1209.08	0.004148	2.24	170.92	210.60	0.79
EMS_DischChannel	206	Max WS	343.75	1207.00	1207.51	1207.52	1207.77	0.008734	2.28	150.95	317.40	1.05
EMS_DischChannel	0	Max WS	343.77	1202.00	1203.21	1203.26	1203.52	0.033387	2.46	139.55	316.09	1.18

APPENDIX F.7 – OFF-STREAM STORAGE DAM

APPENDIX F.7-1 – STAGE STORAGE CURVE

Storage Source	Storage Volume (dam^3)	Cumulative Storage Volume (dam^3)	Stage Elevation (m)
2013 Storm	70210	70210	1209.78
Sediment (10% of 2013 Inflow)	7021	77231	1210.66
Tributary Inflow	540	77771	1210.75



APPENDIX F.7-2 – FREEBOARD CALCULATIONS

Freeboard Requirement Calculations

Springbank Off-Stream Reservior Project
Alberta, Canada
Alberta Transportation Department

1. OBJECTIVE/PURPOSE

The objectives of this calculation package is to calculate freeboard requirements.

2. CRITERIA

Water Control Structures Selected Design Critera. Alberta Transportation (2004)

3. REFERENCES

1. USBR (1981). Freeboard Criteria and Guidelines for Computing Freeboard Allowances for Storage Dams. ACER Technical Memorandum No. 3. Assistant Commissioner-Engineering and Research. U.S. Department of the Interior Bureau of Reclamation. (USBR).
2. Canadian Dam Association (CDA). Technical Bulletin. Hydrotechnical Considerations for Dam Safety. 2007.

4. Calculations

4.1 Normal Freeboard

Wind velocity over land: $V_{wl} := 83 \frac{km}{hr}$

Wind gauage summary-estimated 1000 yr wind event @ 1200. No Adjustment to wind speed elevation-Conservative assumption.

From USBR (1981) Table 2

Wind velocity over water ratio: $R_w := 1.26$

Table 2. - Wind relationship - Water to land

Effective fetch (F_e) in miles*	0.5	1	2	3	4	5 (or more)
Wind velocity ratio (Over water)/(Over land)	1.08	1.13	1.21	1.26	1.28	1.30

Wind velocity over water: $V_{ww} := V_{wl} \cdot R_w = 29.05 \frac{m}{s}$ $V_{ww} = 64.98 \cdot \frac{mile}{hr}$

Effective Fetch Length: $F_e := 4.795\text{km}$

his Fetch length represents the full fetch length and not the "effective" fetch length. This approach is highly conservative.

$F_e = 4795\,\text{m}$

From USBR (1981), Figure 9

Significant wave height: $H_s := 4.9\text{ft}$

Heighest 10% of wave height: $H_{s10} := 1.37 \cdot H_s = 6.71 \cdot \text{ft}$

1.37 times the significant wave height to obtain to| 5% of waves

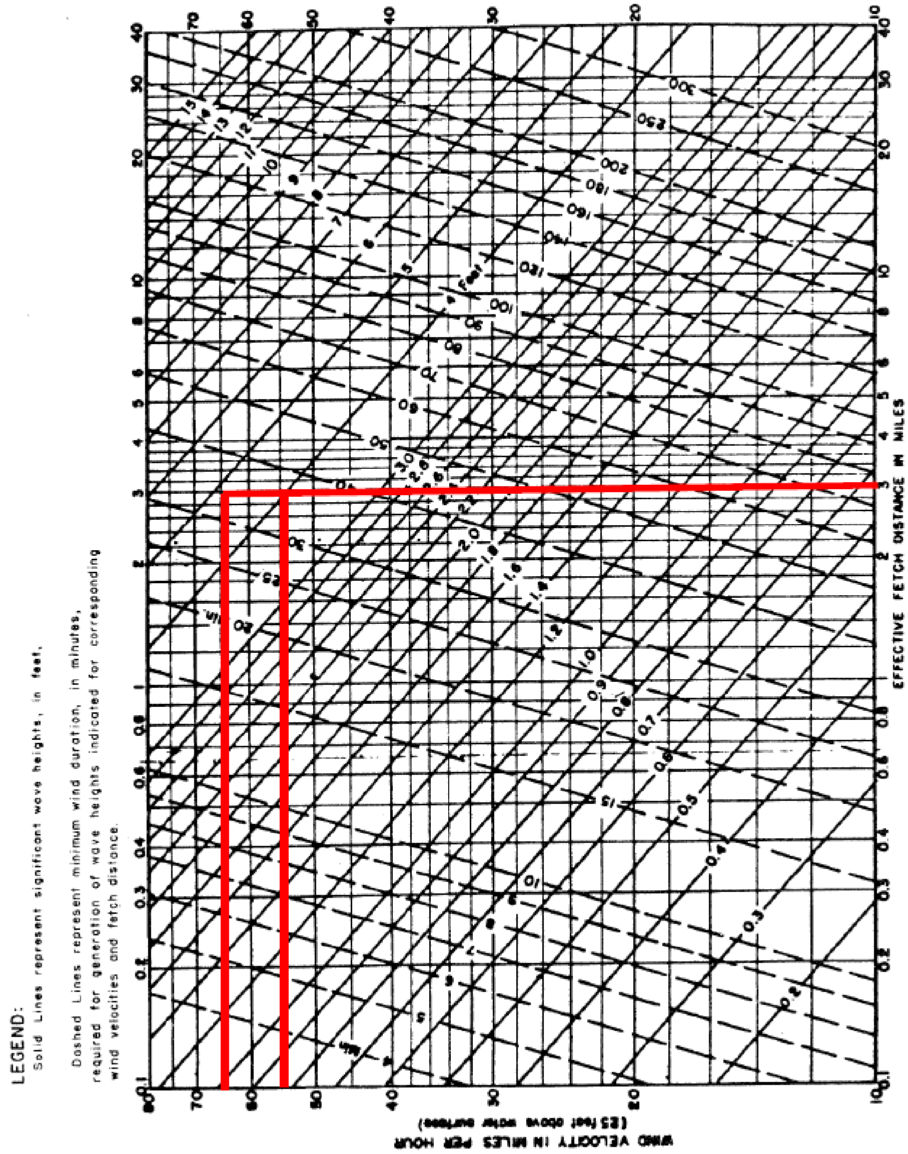


FIGURE 9. - GENERALIZED CORRELATIONS OF SIGNIFICANT WAVE HEIGHTS (H_s) WITH RELATED FACTORS -DEEP WATER CONDITIONS (FROM FIGURE 11, REF. 3)

Wave Period: $T_{wp} := 4.2s$ From USBR (1981) Figure-10

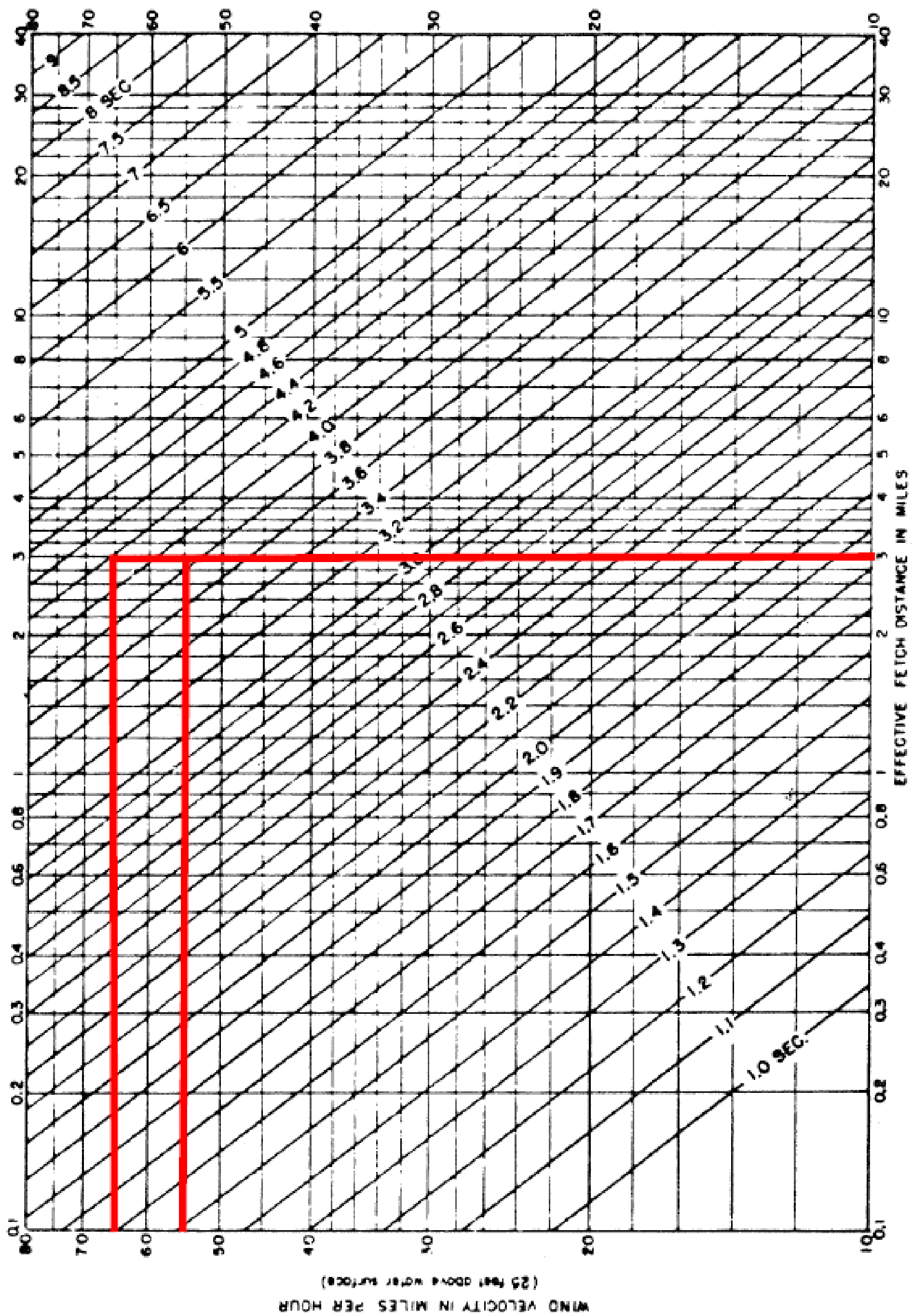


FIGURE 10.- GENERALIZED RELATIONS BETWEEN WAVE PERIODS AND RELATED FACTORS -DEEP WATER CONDITIONS (FROM FIGURE 12, REF. 3)

Deep water length: $L_{dw} := 5.12 \frac{ft}{s^2} \cdot T_{wp}^{\ 2} = 90.32 \cdot ft$ Equation 2: USBR (1981)

Angle of upstream face of dam with horizonatal: $\theta := 15.94°$ Based on 3.5H:1V slope

Runup: $$R_s := \frac{H_{s10}}{0.4 + \left(\frac{H_{s10}}{L_{dw}}\right)^{0.5} \left(\frac{1}{\tan(\theta)}\right)} = 4.96 \cdot ft$$ *USBR (1981): Equation 3*

Runup correction Factor: $F_R := 1.4$ For embankment dam with smooth upstream face-criteria recommends a mixmum correction factor o 1.5

Wave runup correction factor: $F_{WR} := 1.0$ Based on direction of wave propagation normal to the embankment. Use 1 as conservative estimate.

Final wave run up: $R_{sf} := R_s \cdot F_R \cdot F_{WR} = 6.94 \cdot ft$

Average water depth along central radius: $D := 42.3ft$ **Input:Calculated from AutoCAD**

Manual calcs due to imperical equation

Wind velocity over water in miles per hour:

$D_1 := 42.3$ ft $V_{ww1} := 64.98$ mph $F_{e1} := 3$ miles **Input: Refer to results above**

$R_{sf1} := 6.94$ 1 referes to unitless to match USBR (1981) equation 4

Wind setup: $$S_s := \frac{V_{ww1}^{\ 2} \cdot (2 \cdot F_{e1})}{1400 \cdot D_1} = 0.43$$

Final Runup plus wind setup: $S_f := S_s + R_{sf1} = 7.37$ ft Normal Freeboard

$S_{fn} := 7.37 \cdot 0.3048 = 2.25$ m Normal Freeboard in meters

4.2 Minimum Freeboard

Wind velocity over land: $V_{wlm} := 70\frac{km}{hr}$

Input: Wind gauage summary-estimated 1000 yr wind even 1200. No Adjustment to wind speed elevation-Conservative assumption.

From USBR (1981) Table 2 (Refer Section 4.1)

Wind velocity over water ratio: $R_w = 1.26$

Wind velocity over water: $V_{wwm} := V_{wlm} \cdot R_w = 24.5\frac{m}{s}$ $V_{wwm} = 54.8 \cdot \frac{mile}{hr}$

Effective Fetch Length: $F_e = 4.8 \cdot km$

This Fetch length represents the full fetch length a the "effective" fetch length. This approach is highl conservative.

$F_e = 4795\,m$

From USBR (1981), Figure 9 (Refere section 4.1)

Significant wave height: $H_{sm} := 4 \cdot ft$

Wave height: $H_{sms} := H_{sm} = 4 \cdot ft$

Wave Period: $T_{wpm} := 3.85s$

Input: From USBR (1981) Figure-10 (Refer section 4.1)

Deep water length: $L_{dwm} := 5.12\frac{ft}{s^2} \cdot T_{wpm}{}^2 = 75.89 \cdot ft$ Equation 2: USBR (1981)

Runup:

$$R_{sm} := \frac{H_{sms}}{0.4 + \left(\frac{H_{sms}}{L_{dwm}}\right)^{0.5}\left(\frac{1}{\tan(\theta)}\right)} = 3.32 \cdot ft$$

USBR (1981): Equation 3

Final wave run up: $R_{sfm} := R_{sm} \cdot F_R \cdot F_{WR} = 4.65 \cdot ft$

Average water depth along central radius: $D_m := 45.2ft$ **Input:Calculated from AutoCAD**

Manual calcs due to imperical equation

Wind velocity over water in miles per hour:

$D_{m1} := 45.2$ ft $V_{wwm1} := 54.8$ mph $F_{e1} = 3$ mph   **Input: Refer results above**

$R_{sfm1} := 4.65$ 1 refers to a unitless number to match USBR (1981) equation 4

Wind setup: $S_{sm} := \frac{V_{wwm1}^{2} \cdot (F_{e1})}{1400 \cdot D_{m1}} = 0.14$ Equation 4: USBR (1981)

Final Runup plus wind setup: $S_{fmi} := R_{sfm1} + S_{sm} = 4.79$ ft   Normal Freeboard in Feet

$S_{fm1} := S_{fmi} \cdot 0.3048 = 1.46$ m   Normal Freeboard in meters

$S_{fm} := 1.46$ m   Input: Sfm1=Sfm in m

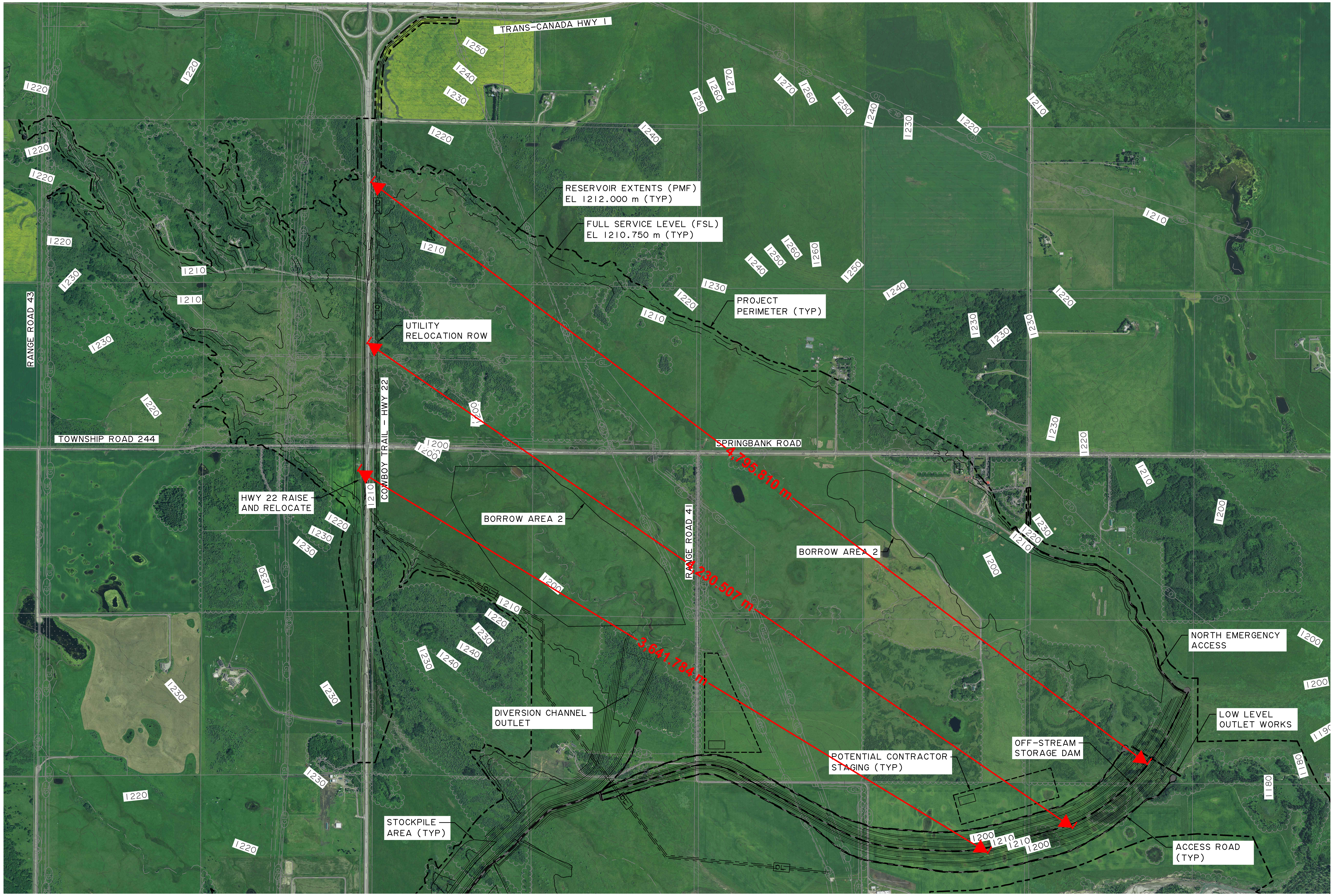
Design Pool: $D_p := 1210.75$

PMF Pool Elevation: $I_p := 1212$ PMF Pool Height Used instead of IDF Pool Height-Conservative

Crest Height for "Normal Freeboard": $H_n := D_p + S_{fn} = 1213.00$

Crest Height for "Minimum Freeboard": $H_m := I_p + S_{fm} = 1213.46$

Final Crest Elevation = 1213.5



N

PLAN
1:10 000

0 400 800 Metres

THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc) ARE BASED ON 22" X 34" FORMAT DRAWINGS

THINK SAFETY FIRST

DEPARTMENT BAR CODE

Stantec

Project No.: 110773396
200 - 325 25th Street SE
Calgary AB Canada T2A 7H8
Tel. 403.716.8000
www.stantec.com

REV	DATE	REVISIONS	BY
6			
5			
4			
3			
2			
1	-	-	-

NOT FOR CONSTRUCTION
DRAFT
For Review Only

DESIGNER
DATE

CHECKER
DATE

Alberta Transportation

SPRINGBANK OFF-STREAM STORAGE PROJECT
SR1

OFF-STREAM STORAGE DAM
RESERVOIR OVERVIEW
PLAN

DATE	ALBERTA ENVIRONMENT AND PARKS CAPITAL PROJECTS NUMBER	SITE	SHEET	CONSULTANT DRAWING	TRANSPORTATION DRAWING
2017-02-03	-	-	1 OF ?	73396C-401	?????-P

PlotDate: 2017.01.20 10:35 AM Login: White, Jarred TENDER No. ?
AUTOCAD FILE No. U:\110773396\CAD\water\c_civil\sheet_files\400_ossd\73396C-401.dwg

Station	Difference in Length	Elevation	Length	Water Depth (1212)	Water Depth (1210.75)	Grade Ahead	Grade Back
0		1212.466	5.811	-2.707926	-14.329926	-0.84%	0.84%
5.811	5.811	1212.417	2.227	-0.928659	-5.382659	-1.49%	1.49%
8.038	2.227	1212.384	2.385	-0.91584	-5.68584	-4.20%	4.20%
10.423	2.385	1212.284	1.71	-0.48564	-3.90564	2.47%	-2.47%
12.133	1.71	1212.326	0.703	-0.229178	-1.635178	0.94%	-0.94%
12.836	0.703	1212.333	3.634	-1.210122	-8.478122	-0.78%	0.78%
16.47	3.634	1212.304	12.2	-3.7088	-28.1088	-0.32%	0.32%
28.67	12.2	1212.266	4.039	-1.074374	-9.152374	-0.45%	0.45%
32.709	4.039	1212.248	2.247	-0.557256	-5.051256	-1.55%	1.55%
34.956	2.247	1212.213	2.406	-0.512478	-5.324478	-0.52%	0.52%
37.362	2.406	1212.2	2.199	-0.4398	-4.8378	-3.54%	3.54%
39.561	2.199	1212.122	12.28	-1.49816	-26.05816	-2.52%	2.52%
51.841	12.28	1211.813	16.318	3.051466	-29.584534	-1.46%	1.46%
68.159	16.318	1211.574	3.613	1.539138	-5.686862	-1.09%	1.09%
71.772	3.613	1211.534	4.993	2.326738	-7.659262	0.35%	-0.35%
76.765	4.993	1211.552	2.037	0.912576	-3.161424	-1.45%	1.45%
78.802	2.037	1211.522	12.083	5.775674	-18.390326	-0.42%	0.42%
90.886	12.084	1211.471	0.833	0.440657	-1.225343	-0.16%	0.16%
91.718	0.832	1211.47	5.98	3.1694	-8.7906	-2.08%	2.08%
97.698	5.98	1211.346	3.27	2.13858	-4.40142	-0.86%	0.86%
100.968	3.27	1211.317	0.919	0.627677	-1.210323	-3.61%	3.61%
101.887	0.919	1211.284	0.548	0.392368	-0.703632	3.60%	-3.60%
102.436	0.549	1211.304	4.837	3.366552	-6.307448	0.46%	-0.46%
107.272	4.836	1211.326	5.648	3.806752	-7.489248	-2.26%	2.26%
112.921	5.649	1211.199	0.787	0.630387	-0.943613	5.02%	-5.02%
113.707	0.786	1211.238	10.094	7.691628	-12.496372	-0.08%	0.08%
123.801	10.094	1211.23	9.23	7.1071	-11.3529	0.38%	-0.38%
133.031	9.23	1211.265	3.27	2.40345	-4.13655	-3.10%	3.10%
136.301	3.27	1211.163	5.687	4.760019	-6.613981	-0.87%	0.87%
141.988	5.687	1211.114	8.686	7.695796	-9.676204	-1.89%	1.89%
150.674	8.686	1210.95	3.596	3.7758	-3.4162	-0.67%	0.67%
154.27	3.596	1210.926	4.96	5.32704	-4.59296	-2.21%	2.21%
159.231	4.961	1210.816	4.063	4.810592	-3.315408	-1.90%	1.90%
163.294	4.063	1210.739	5.679	7.161219	-4.196781	-2.09%	2.09%
168.973	5.679	1210.62	2.49	3.4362	-1.5438	-0.59%	0.59%
171.463	2.49	1210.606	6.548	9.127912	-3.968088	-1.19%	1.19%
178.011	6.548	1210.528	10.025	14.7568	-5.2932	0.47%	-0.47%
188.036	10.025	1210.574	3.398	4.845548	-1.950452	-0.07%	0.07%
191.434	3.398	1210.572	7.165	10.23162	-4.09838	-1.44%	1.44%
198.599	7.165	1210.469	5.271	8.069901	-2.472099	-1.14%	1.14%
203.87	5.271	1210.409	3.987	6.343317	-1.630683	-1.56%	1.56%
207.857	3.987	1210.346	0.839	1.387706	-0.290294	0.20%	-0.20%
208.696	0.839	1210.348	6.913	11.420276	-2.405724	0.45%	-0.45%
215.609	6.913	1210.38	2.248	3.64176	-0.85424	0.13%	-0.13%
217.857	2.248	1210.382	1.367	2.211806	-0.522194	0.87%	-0.87%
219.224	1.367	1210.394	7.529	12.091574	-2.966426	-2.12%	2.12%
226.753	7.529	1210.235	6.395	11.287175	-1.502825	-1.17%	1.17%
233.148	6.395	1210.16	1.609	2.96056	-0.25744	-3.19%	3.19%
234.757	1.609	1210.109	0.86	1.62626	-0.09374	-2.84%	2.84%
235.617	0.86	1210.084	0.338	0.647608	-0.028392	0.52%	-0.52%
235.955	0.338	1210.086	0.154	0.294756	-0.013244	-11.81%	11.81%
236.11	0.155	1210.068	0.819	1.582308	-0.055692	-0.12%	0.12%
236.928	0.818	1210.067	4.34	8.38922	-0.29078	-6.57%	6.57%
241.269	4.341	1209.781	1.338	2.969022	0.293022	-0.67%	0.67%
242.607	1.338	1209.772	9.099	20.272572	2.074572	1.19%	-1.19%
251.706	9.099	1209.881	14.379	30.469101	1.711101	-0.76%	0.76%
266.085	14.379	1209.771	2.194	4.890426	0.502426	0.05%	-0.05%
268.279	2.194	1209.773	1.732	3.857164	0.393164	0.24%	-0.24%
270.011	1.732	1209.777	6.609	14.691807	1.473807	-0.42%	0.42%
276.621	6.61	1209.749	19.304	43.453304	4.845304	-0.33%	0.33%
295.924	19.303	1209.685	10.721	24.819115	3.377115	1.00%	-1.00%
306.645	10.721	1209.792	7.354	16.237632	1.529632	-0.36%	0.36%
313.999	7.354	1209.766	13.077	29.214018	3.060018	1.08%	-1.08%
327.076	13.077	1209.907	5.119	10.714067	0.476067	1.34%	-1.34%
332.195	5.119	1209.976	7.374	14.924976	0.176976	3.56%	-3.56%
339.569	7.374	1210.238	12.296	21.665552	-2.926448	2.55%	-2.55%
351.865	12.296	1210.552	7.483	10.835384	-4.130616	-1.33%	1.33%
359.348	7.483	1210.452	6.635	10.27098	-2.99902	-9.04%	9.04%
365.983	6.635	1209.852	1.327	2.850396	0.196396	-11.61%	11.61%
367.309	1.326	1209.698	0.867	1.995834	0.261834	-16.55%	16.55%
368.176	0.867	1209.554	2.109	5.158614	0.940614	21.23%	-21.23%

370.285	2.109	1210.002	2.731	5.456538	-0.005462	16.88%	-16.88%
373.016	2.731	1210.463	0.269	0.413453	-0.124547	8.63%	-8.63%
373.286	0.27	1210.486	0.325	0.49205	-0.15795	-0.94%	0.94%
373.61	0.324	1210.483	0.076	0.115292	-0.036708	1.76%	-1.76%
373.686	0.076	1210.485	1.33	2.01495	-0.64505	3.22%	-3.22%
375.017	1.331	1210.527	0.223	0.328479	-0.117521	1.80%	-1.80%
375.24	0.223	1210.531	18.874	27.725906	-10.022094	-0.37%	0.37%
394.114	18.874	1210.462	0.518	0.796684	-0.239316	1.30%	-1.30%
394.631	0.517	1210.469	3.615	5.534565	-1.695435	-0.80%	0.80%
398.246	3.615	1210.44	2.753	4.29468	-1.21132	-0.68%	0.68%
400.999	2.753	1210.422	0.156	0.246168	-0.065832	-2.16%	2.16%
401.155	0.156	1210.418	4.202	6.647564	-1.756436	-7.31%	7.31%
405.358	4.203	1210.111	0.511	0.965279	-0.056721	-8.66%	8.66%
405.869	0.511	1210.067	0.397	0.767401	-0.026599	-15.23%	15.23%
406.266	0.397	1210.006	3.063	6.107622	-0.018378	-23.27%	23.27%
409.33	3.064	1209.293	0.755	2.043785	0.533785	-11.96%	11.96%
410.085	0.755	1209.203	0.576	1.611072	0.459072	-4.19%	4.19%
410.66	0.575	1209.179	4.139	11.676119	3.398119	-1.58%	1.58%
414.799	4.139	1209.114	4.243	12.245298	3.759298	-12.17%	12.17%
419.042	4.243	1208.598	0.466	1.585332	0.653332	-11.51%	11.51%
419.508	0.466	1208.544	4.345	15.01632	6.32632	-2.11%	2.11%
423.852	4.344	1208.452	16.139	57.261172	24.983172	-3.18%	3.18%
439.991	16.139	1207.939	3.613	14.672393	7.446393	-1.25%	1.25%
443.604	3.613	1207.893	10.4	42.7128	21.9128	-1.72%	1.72%
454.004	10.4	1207.715	2.908	12.46078	6.64478	-2.56%	2.56%
456.912	2.908	1207.641	11.416	49.762344	26.930344	-0.70%	0.70%
468.328	11.416	1207.561	1.555	6.902645	3.792645	-1.01%	1.01%
469.883	1.555	1207.545	0.141	0.628155	0.346155	-1.21%	1.21%
470.024	0.141	1207.543	5.288	23.568616	12.992616	1.57%	-1.57%
475.312	5.288	1207.627	5.943	25.988739	14.102739	2.43%	-2.43%
481.255	5.943	1207.771	15.411	65.173119	34.351119	0.78%	-0.78%
496.666	15.411	1207.891	0.251	1.031359	0.529359	0.61%	-0.61%
496.916	0.25	1207.893	11.326	46.515882	23.863882	-0.94%	0.94%
508.243	11.327	1207.787	9.889	41.662357	21.884357	-0.18%	0.18%
518.131	9.888	1207.768	6.67	28.22744	14.88744	-1.25%	1.25%
524.801	6.67	1207.685	3.166	13.66129	7.32929	-1.82%	1.82%
527.967	3.166	1207.627	6.474	28.310802	15.362802	-2.17%	2.17%
534.441	6.474	1207.487	3.422	15.443486	8.599486	-1.94%	1.94%
537.862	3.421	1207.421	1.153	5.279587	2.973587	-2.91%	2.91%
539.016	1.154	1207.387	2.657	12.256741	6.942741	-2.47%	2.47%
541.673	2.657	1207.322	0.993	4.645254	2.659254	-2.02%	2.02%
542.665	0.992	1207.301	8.297	38.987603	22.393603	-2.57%	2.57%
550.962	8.297	1207.088	3.809	18.709808	11.091808	-0.89%	0.89%
554.771	3.809	1207.054	23.349	115.484154	68.786154	-0.96%	0.96%
578.12	23.349	1206.831	3.531	18.251739	11.189739	-5.50%	5.50%
581.651	3.531	1206.637	6.527	35.004301	21.950301	-0.70%	0.70%
588.178	6.527	1206.591	2.935	15.875415	10.005415	-2.36%	2.36%
591.113	2.935	1206.521	3.402	18.639558	11.835558	1.04%	-1.04%
594.515	3.402	1206.557	6.895	37.529485	23.739485	0.46%	-0.46%
601.41	6.895	1206.589	0.797	4.312567	2.718567	0.89%	-0.89%
602.207	0.797	1206.596	8.008	43.275232	27.259232	-0.57%	0.57%
610.215	8.008	1206.55	4.951	26.98295	17.08095	2.03%	-2.03%
615.167	4.952	1206.65	7.788	41.6658	26.0898	0.54%	-0.54%
622.954	7.787	1206.693	8.3	44.0481	27.4481	-0.20%	0.20%
631.254	8.3	1206.676	5.871	31.257204	19.515204	-1.51%	1.51%
637.126	5.872	1206.587	2.01	10.88013	6.86013	2.14%	-2.14%
639.136	2.01	1206.63	9.15	49.1355	30.8355	-2.33%	2.33%
648.285	9.149	1206.417	13.734	76.676922	49.208922	-2.21%	2.21%
662.019	13.734	1206.112	1.812	10.669056	7.045056	-3.79%	3.79%
663.831	1.812	1206.044	1.832	10.911392	7.247392	-1.84%	1.84%
665.663	1.832	1206.01	11.247	67.36953	44.87553	0.71%	-0.71%
676.91	11.247	1206.09	1.272	7.51752	4.97352	1.25%	-1.25%
678.182	1.272	1206.106	1.536	9.053184	5.981184	0.66%	-0.66%
679.718	1.536	1206.116	9.711	57.139524	37.717524	1.40%	-1.40%
689.429	9.711	1206.252	2.307	13.260636	8.646636	2.07%	-2.07%
691.735	2.306	1206.3	20.729	118.1553	76.6973	-0.63%	0.63%
712.464	20.729	1206.168	5.493	32.035176	21.049176	-0.03%	0.03%
717.957	5.493	1206.167	4.795	27.969235	18.379235	-2.81%	2.81%
722.752	4.795	1206.032	4.561	27.220048	18.098048	-2.66%	2.66%
727.313	4.561	1205.911	1.283	7.812187	5.246187	1.50%	-1.50%
728.596	1.283	1205.93	1.798	10.91386	7.31786	2.06%	-2.06%
730.394	1.798	1205.967	11.312	68.245296	45.621296	1.26%	-1.26%

741.706	11.312	1206.11	1.078	6.34942	4.19342	-0.84%	0.84%
742.785	1.079	1206.101	3.342	19.714458	13.030458	-1.04%	1.04%
746.126	3.341	1206.066	5.137	30.482958	20.208958	0.02%	-0.02%
751.263	5.137	1206.067	5.266	31.243178	20.711178	0.36%	-0.36%
756.529	5.266	1206.086	1.563	9.243582	6.117582	-0.62%	0.62%
758.092	1.563	1206.077	3.974	23.538002	15.590002	1.77%	-1.77%
762.067	3.975	1206.147	9.51	55.66203	36.64203	0.54%	-0.54%
771.577	9.51	1206.198	6.387	37.057374	24.283374	-1.16%	1.16%
777.964	6.387	1206.124	1.275	7.4919	4.9419	0.38%	-0.38%
779.24	1.276	1206.129	7.893	46.339803	30.553803	-0.86%	0.86%
787.133	7.893	1206.061	3.153	18.725667	12.419667	-0.81%	0.81%
790.287	3.154	1206.036	6.958	41.497512	27.581512	-0.58%	0.58%
797.245	6.958	1205.995	4.982	29.91691	19.95291	-1.85%	1.85%
802.227	4.982	1205.903	1.916	11.681852	7.849852	1.73%	-1.73%
804.143	1.916	1205.936	12.242	74.235488	49.751488	1.80%	-1.80%
816.384	12.241	1206.156	8.724	50.983056	33.535056	1.32%	-1.32%
825.108	8.724	1206.271	3.937	22.555073	14.681073	1.65%	-1.65%
829.045	3.937	1206.336	5.954	33.723456	21.815456	0.30%	-0.30%
834.999	5.954	1206.354	8.509	48.041814	31.023814	-0.30%	0.30%
843.508	8.509	1206.328	3.924	22.256928	14.408928	1.31%	-1.31%
847.433	3.925	1206.38	3.508	19.71496	12.69896	-1.52%	1.52%
850.941	3.508	1206.327	1.317	7.471341	4.837341	0.32%	-0.32%
852.258	1.317	1206.331	2.269	12.862961	8.324961	0.50%	-0.50%
854.526	2.268	1206.342	4.048	22.903584	14.807584	0.07%	-0.07%
858.575	4.049	1206.345	4.912	27.77736	17.95336	0.39%	-0.39%
863.487	4.912	1206.364	0.358	2.017688	1.301688	-0.92%	0.92%
863.844	0.357	1206.361	1.374	7.747986	4.999986	1.99%	-1.99%
865.219	1.375	1206.388	6.567	36.854004	23.720004	-0.10%	0.10%
871.786	6.567	1206.382	6.072	34.112496	21.968496	1.41%	-1.41%
877.858	6.072	1206.467	2.742	15.171486	9.687486	1.12%	-1.12%
880.6	2.742	1206.498	2.175	11.96685	7.61685	0.00%	0.00%
882.775	2.175	1206.498	7.416	40.802832	25.970832	2.00%	-2.00%
890.191	7.416	1206.646	0.209	1.118986	0.700986	1.48%	-1.48%
890.4	0.209	1206.649	0.098	0.524398	0.328398	0.09%	-0.09%
890.498	0.098	1206.649	0.788	4.216588	2.640588	0.77%	-0.77%
891.286	0.788	1206.655	3.501	18.712845	11.710845	0.42%	-0.42%
894.787	3.501	1206.67	0.182	0.97006	0.60606	1.75%	-1.75%
894.969	0.182	1206.673	0.291	1.550157	0.968157	3.83%	-3.83%
895.26	0.291	1206.684	3.926	20.870616	13.018616	-0.30%	0.30%
899.186	3.926	1206.673	12.725	67.786075	42.336075	-0.19%	0.19%
911.911	12.725	1206.649	4.806	25.716906	16.104906	-1.07%	1.07%
916.717	4.806	1206.598	5.981	32.309362	20.347362	-0.57%	0.57%
922.698	5.981	1206.564	1.349	7.333164	4.635164	-0.67%	0.67%
924.047	1.349	1206.555	5.795	31.553775	19.963775	2.80%	-2.80%
929.842	5.795	1206.717	3.607	19.055781	11.841781	1.97%	-1.97%
933.45	3.608	1206.788	7.044	36.713328	22.625328	1.49%	-1.49%
940.494	7.044	1206.893	2.345	11.975915	7.285915	-1.74%	1.74%
942.839	2.345	1206.852	14.824	76.313952	46.665952	-2.50%	2.50%
957.663	14.824	1206.481	7.748	42.761212	27.265212	-3.02%	3.02%
965.411	7.748	1206.247	1.332	7.662996	4.998996	-1.64%	1.64%
966.743	1.332	1206.225	18.398	106.24845	69.45245	-1.12%	1.12%
985.141	18.398	1206.018	0.654	3.912228	2.604228	-1.68%	1.68%
985.795	0.654	1206.008	6.735	40.35612	26.88612	0.67%	-0.67%
992.53	6.735	1206.053	13.287	79.017789	52.443789	-0.55%	0.55%
1005.818	13.288	1205.979	0.859	5.172039	3.454039	0.21%	-0.21%
1006.676	0.858	1205.981	1.221	7.349199	4.907199	-1.10%	1.10%
1007.897	1.221	1205.967	6.324	38.152692	25.504692	-1.31%	1.31%
1014.221	6.324	1205.884	1.402	8.574632	5.770632	3.45%	-3.45%
1015.623	1.402	1205.933	5.27	31.97309	21.43309	-0.59%	0.59%
1020.893	5.27	1205.902	8.066	49.186468	33.054468	0.47%	-0.47%
1028.959	8.066	1205.94	2.959	17.93154	12.01354	-0.31%	0.31%
1031.918	2.959	1205.931	8.079	49.031451	32.873451	-0.86%	0.86%
1039.997	8.079	1205.862	1.85	11.3553	7.6553	-2.56%	2.56%
1041.847	1.85	1205.814	4.219	26.098734	17.660734	-0.05%	0.05%
1046.067	4.22	1205.812	2	12.376	8.376	1.57%	-1.57%
1048.067	2	1205.843	11.551	71.119507	48.017507	-0.73%	0.73%
1059.618	11.551	1205.759	2.555	15.945755	10.835755	-0.64%	0.64%
1062.173	2.555	1205.743	0.638	3.991966	2.715966	-0.12%	0.12%
1062.811	0.638	1205.742	0.869	5.438202	3.700202	-0.06%	0.06%
1063.68	0.869	1205.742	7.962	49.826196	33.902196	0.08%	-0.08%
1071.642	7.962	1205.748	6.873	42.969996	29.223996	-0.26%	0.26%
1078.514	6.872	1205.73	3.721	23.33067	15.88867	-0.94%	0.94%

1082.236	3.722	1205.696	1.597	10.067488	6.873488	-1.23%	1.23%
1083.833	1.597	1205.676	8.54	54.00696	36.92696	0.03%	-0.03%
1092.373	8.54	1205.679	3.436	21.718956	14.846956	-0.57%	0.57%
1095.809	3.436	1205.659	4.235	26.854135	18.384135	-2.42%	2.42%
1100.044	4.235	1205.557	4.657	30.005051	20.691051	-1.31%	1.31%
1104.701	4.657	1205.496	5.478	35.628912	24.672912	-0.43%	0.43%
1110.179	5.478	1205.472	3.405	22.22784	15.41784	-1.65%	1.65%
1113.584	3.405	1205.416	1.412	9.296608	6.472608	-1.92%	1.92%
1114.996	1.412	1205.389	6.23	41.18653	28.72653	-1.35%	1.35%
1121.226	6.23	1205.305	2.797	18.725915	13.131915	0.97%	-0.97%
1124.023	2.797	1205.332	1.976	13.175968	9.223968	-0.58%	0.58%
1125.999	1.976	1205.32	2.256	15.07008	10.55808	-0.68%	0.68%
1128.255	2.256	1205.305	0.891	5.965245	4.183245	4.94%	-4.94%
1129.146	0.891	1205.349	1.908	12.690108	8.874108	1.42%	-1.42%
1131.054	1.908	1205.376	2.164	14.334336	10.006336	-0.71%	0.71%
1133.218	2.164	1205.361	7.567	50.237313	35.103313	-1.51%	1.51%
1140.785	7.567	1205.247	6.345	42.847785	30.157785	-0.80%	0.80%
1147.13	6.345	1205.196	0.614	4.177656	2.949656	-3.18%	3.18%
1147.744	0.614	1205.176	2.77	18.90248	13.36248	-0.03%	0.03%
1150.514	2.77	1205.176	1.351	9.219224	6.517224	-0.19%	0.19%
1151.865	1.351	1205.173	0.992	6.772384	4.788384	-2.01%	2.01%
1152.857	0.992	1205.153	3.329	22.793663	16.135663	-0.62%	0.62%
1156.186	3.329	1205.133	1.805	12.394935	8.784935	2.16%	-2.16%
1157.991	1.805	1205.172	5.954	40.653912	28.745912	-0.81%	0.81%
1163.945	5.954	1205.124	3.335	22.93146	16.26146	-0.16%	0.16%
1167.28	3.335	1205.118	1.517	10.439994	7.405994	-0.09%	0.09%
1168.797	1.517	1205.117	14.812	101.950996	72.326996	0.57%	-0.57%
1183.609	14.812	1205.202	1.213	8.245974	5.819974	-1.57%	1.57%
1184.822	1.213	1205.183	1.254	8.548518	6.040518	-1.36%	1.36%
1186.075	1.253	1205.166	6.135	41.92659	29.65659	-1.97%	1.97%
1192.211	6.136	1205.045	1.104	7.67832	5.47032	-0.67%	0.67%
1193.315	1.104	1205.037	2.611	18.180393	12.958393	-0.29%	0.29%
1195.926	2.611	1205.03	6.266	43.67402	31.14202	-0.44%	0.44%
1202.192	6.266	1205.002	0.374	2.617252	1.869252	0.40%	-0.40%
1202.566	0.374	1205.004	3.571	24.982716	17.840716	0.27%	-0.27%
1206.137	3.571	1205.013	7.297	50.984139	36.390139	0.10%	-0.10%
1213.434	7.297	1205.021	9.092	63.453068	45.269068	0.02%	-0.02%
1222.526	9.092	1205.023	1.898	13.242346	9.446346	2.11%	-2.11%
1224.424	1.898	1205.063	0.384	2.663808	1.895808	-0.94%	0.94%
1224.808	0.384	1205.059	12.73	88.35893	62.89893	-1.14%	1.14%
1237.538	12.73	1204.914	6.086	43.125396	30.953396	-0.25%	0.25%
1243.624	6.086	1204.899	2.839	20.159739	14.481739	1.83%	-1.83%
1246.464	2.84	1204.951	0.217	1.529633	1.095633	-1.64%	1.64%
1246.681	0.217	1204.947	3.807	26.850771	19.236771	-0.41%	0.41%
1250.488	3.807	1204.932	1.785	12.61638	9.04638	-0.89%	0.89%
1252.274	1.786	1204.916	8.127	57.571668	41.317668	-1.68%	1.68%
1260.401	8.127	1204.779	2.023	14.608083	10.562083	-1.13%	1.13%
1262.424	2.023	1204.756	1.954	14.154776	10.246776	-0.53%	0.53%
1264.378	1.954	1204.746	11.491	83.355714	60.373714	-1.11%	1.11%
1275.869	11.491	1204.618	2.411	17.798002	12.976002	-1.92%	1.92%
1278.28	2.411	1204.572	6.046	44.909688	32.817688	-1.70%	1.70%
1284.326	6.046	1204.469	7.345	55.315195	40.625195	-0.81%	0.81%
1291.671	7.345	1204.409	11.61	88.13151	64.91151	-0.93%	0.93%
1303.281	11.61	1204.302	2.767	21.300366	15.766366	-1.83%	1.83%
1306.048	2.767	1204.251	5.712	44.262288	32.838288	-1.27%	1.27%
1311.759	5.711	1204.178	0.529	4.137838	3.079838	-2.56%	2.56%
1312.288	0.529	1204.165	7.604	59.57734	44.36934	-1.01%	1.01%
1319.892	7.604	1204.088	3.822	30.239664	22.595664	0.90%	-0.90%
1323.714	3.822	1204.122	1.36	10.71408	7.99408	-1.38%	1.38%
1325.074	1.36	1204.103	1.429	11.284813	8.426813	-1.92%	1.92%
1326.503	1.429	1204.076	5.167	40.943308	30.609308	-1.04%	1.04%
1331.67	5.167	1204.023	3.5	27.9195	20.9195	-1.37%	1.37%
1335.17	3.5	1203.975	0.96	7.704	5.784	1.03%	-1.03%
1336.13	0.96	1203.984	12.446	99.767136	74.875136	0.65%	-0.65%
1348.577	12.447	1204.065	0.825	6.546375	4.896375	0.64%	-0.64%
1349.402	0.825	1204.071	0.348	2.759292	2.063292	-0.34%	0.34%
1349.75	0.348	1204.069	5.217	41.376027	30.942027	-1.92%	1.92%
1354.967	5.217	1203.969	10.825	86.935575	65.285575	-0.87%	0.87%
1365.791	10.824	1203.875	4.171	33.889375	25.547375	-0.99%	0.99%
1369.962	4.171	1203.834	0.373	3.045918	2.299918	-0.53%	0.53%
1370.335	0.373	1203.832	3.226	26.349968	19.897968	1.70%	-1.70%
1373.56	3.225	1203.887	1.06	8.59978	6.47978	0.98%	-0.98%

1374.62	1.06	1203.897	5.493	44.509779	33.523779	-0.13%	0.13%
1380.113	5.493	1203.89	3.9	31.629	23.829	0.78%	-0.78%
1384.013	3.9	1203.921	4.636	37.454244	28.182244	-0.55%	0.55%
1388.649	4.636	1203.895	6.873	55.705665	41.959665	0.27%	-0.27%
1395.521	6.872	1203.913	4.855	39.262385	29.552385	0.81%	-0.81%
1400.376	4.855	1203.953	6.397	51.476659	38.682659	-0.28%	0.28%
1406.773	6.397	1203.935	2.974	23.98531	18.03731	-0.91%	0.91%
1409.747	2.974	1203.908	13.736	111.151712	83.679712	-1.35%	1.35%
1423.483	13.736	1203.722	7.268	60.164504	45.628504	-1.27%	1.27%
1430.752	7.269	1203.63	0.932	7.80084	5.93684	-1.47%	1.47%
1431.684	0.932	1203.617	0.978	8.198574	6.242574	0.72%	-0.72%
1432.662	0.978	1203.624	6.868	57.526368	43.790368	-1.42%	1.42%
1439.531	6.869	1203.526	0.961	8.143514	6.221514	-2.42%	2.42%
1440.491	0.96	1203.503	12.401	105.371297	80.569297	-1.71%	1.71%
1452.892	12.401	1203.291	1.754	15.275586	11.767586	-0.78%	0.78%
1454.647	1.755	1203.277	7.774	67.812602	52.264602	-1.53%	1.53%
1462.421	7.774	1203.158	7.467	66.023214	51.089214	-1.31%	1.31%
1469.888	7.467	1203.061	1.159	10.360301	8.042301	-3.33%	3.33%
1471.047	1.159	1203.022	0.943	8.466254	6.580254	-0.13%	0.13%
1471.99	0.943	1203.021	10.539	94.629681	73.551681	0.20%	-0.20%
1482.529	10.539	1203.041	8.109	72.648531	56.430531	0.89%	-0.89%
1490.638	8.109	1203.114	13.352	118.645872	91.941872	0.05%	-0.05%
1503.99	13.352	1203.12	10.07	89.4216	69.2816	0.12%	-0.12%
1514.06	10.07	1203.132	8.641	76.628388	59.346388	-0.24%	0.24%
1522.701	8.641	1203.111	2.377	21.129153	16.375153	-2.57%	2.57%
1525.078	2.377	1203.05	0.971	8.69045	6.74845	-1.14%	1.14%
1526.049	0.971	1203.039	0.741	6.640101	5.158101	-0.61%	0.61%
1526.79	0.741	1203.035	6.107	54.749255	42.535255	-0.45%	0.45%
1532.897	6.107	1203.007	11.294	101.566942	78.978942	-0.17%	0.17%
1544.192	11.295	1202.987	1.682	15.159866	11.795866	0.99%	-0.99%
1545.873	1.681	1203.004	3.838	34.526648	26.850648	-0.15%	0.15%
1549.711	3.838	1202.998	6.941	62.482882	48.600882	-1.92%	1.92%
1556.653	6.942	1202.865	1.134	10.35909	8.09109	-0.58%	0.58%
1557.786	1.133	1202.858	5.518	50.445556	39.409556	-0.52%	0.52%
1563.304	5.518	1202.83	3.508	32.16836	25.15236	-0.65%	0.65%
1566.812	3.508	1202.807	0.995	9.147035	7.157035	-0.52%	0.52%
1567.806	0.994	1202.802	2.286	21.026628	16.454628	-0.86%	0.86%
1570.092	2.286	1202.782	9.596	88.455928	69.263928	-1.17%	1.17%
1579.688	9.596	1202.67	1.048	9.77784	7.68184	-1.19%	1.19%
1580.736	1.048	1202.658	0.227	2.120634	1.666634	-1.12%	1.12%
1580.963	0.227	1202.655	0.94	8.7843	6.9043	-2.44%	2.44%
1581.903	0.94	1202.632	11.454	107.301072	84.393072	-2.58%	2.58%
1593.357	11.454	1202.336	8.33	80.50112	63.84112	0.51%	-0.51%
1601.687	8.33	1202.379	15.692	150.972732	119.588732	-1.34%	1.34%
1617.379	15.692	1202.169	8.803	86.542293	68.936293	0.48%	-0.48%
1626.182	8.803	1202.211	12.727	124.584603	99.130603	-1.97%	1.97%
1638.908	12.726	1201.96	0.521	5.23084	4.18884	-0.95%	0.95%
1639.429	0.521	1201.956	0.419	4.208436	3.370436	-1.72%	1.72%
1639.848	0.419	1201.948	0.259	2.603468	2.085468	-0.72%	0.72%
1640.107	0.259	1201.946	2.644	26.582776	21.294776	0.02%	-0.02%
1642.751	2.644	1201.947	5.479	55.080387	44.122387	0.08%	-0.08%
1648.23	5.479	1201.951	1.058	10.631842	8.515842	-2.00%	2.00%
1649.288	1.058	1201.93	0.315	3.17205	2.54205	-1.90%	1.90%
1649.603	0.315	1201.924	1.969	19.839644	15.901644	0.69%	-0.69%
1651.573	1.97	1201.938	3.498	35.196876	28.200876	1.25%	-1.25%
1655.071	3.498	1201.982	9.495	95.12091	76.13091	0.38%	-0.38%
1664.566	9.495	1202.018	0.79	7.88578	6.30578	-0.77%	0.77%
1665.356	0.79	1202.012	0.397	3.965236	3.171236	0.07%	-0.07%
1665.753	0.397	1202.012	2.255	22.52294	18.01294	0.72%	-0.72%
1668.008	2.255	1202.028	6.875	68.5575	54.8075	0.12%	-0.12%
1674.883	6.875	1202.036	7.048	70.226272	56.130272	-0.80%	0.80%
1681.93	7.047	1201.98	4.951	49.60902	39.70702	-0.49%	0.49%
1686.882	4.952	1201.956	3.994	40.115736	32.127736	-0.73%	0.73%
1690.876	3.994	1201.927	5.106	51.432738	41.220738	-0.87%	0.87%
1695.982	5.106	1201.882	5.887	59.564666	47.790666	-0.81%	0.81%
1701.869	5.887	1201.835	8.181	83.159865	66.797865	0.44%	-0.44%
1710.05	8.181	1201.871	3.534	35.795886	28.727886	0.50%	-0.50%
1713.584	3.534	1201.889	2.983	30.161113	24.195113	0.38%	-0.38%
1716.567	2.983	1201.9	22.442	226.6642	181.7802	-1.24%	1.24%
1739.009	22.442	1201.622	0.935	9.70343	7.83343	-0.77%	0.77%
1739.944	0.935	1201.614	1.889	19.619154	15.841154	-0.34%	0.34%
1741.833	1.889	1201.608	0.674	7.004208	5.656208	-0.42%	0.42%

1742.507	0.674	1201.605	1.91	19.85445	16.03445	0.86%	-0.86%
1744.417	1.91	1201.621	17.25	179.03775	144.53775	0.74%	-0.74%
1761.667	17.25	1201.748	3.205	32.85766	26.44766	-0.04%	0.04%
1764.871	3.204	1201.747	3.532	36.213596	29.149596	2.53%	-2.53%
1768.404	3.533	1201.837	3.954	40.184502	32.276502	1.52%	-1.52%
1772.358	3.954	1201.897	5.518	55.748354	44.712354	0.83%	-0.83%
1777.876	5.518	1201.943	5.67	57.02319	45.68319	-1.76%	1.76%
1783.546	5.67	1201.843	1.048	10.644536	8.548536	-0.51%	0.51%
1784.594	1.048	1201.837	5.369	54.565147	43.827147	-2.56%	2.56%
1789.963	5.369	1201.7	6.166	63.5098	51.1778	-3.17%	3.17%
1796.129	6.166	1201.505	15.135	158.841825	128.571825	1.23%	-1.23%
1811.263	15.134	1201.692	1.715	17.67822	14.24822	-2.65%	2.65%
1812.979	1.716	1201.646	1.212	12.549048	10.125048	-1.53%	1.53%
1814.19	1.211	1201.628	17.435	180.83582	145.96582	-3.47%	3.47%
1831.625	17.435	1201.023	2.223	24.401871	19.955871	-0.70%	0.70%
1833.848	2.223	1201.008	9.248	101.654016	83.158016	-4.37%	4.37%
1843.096	9.248	1200.603	1.627	18.542919	15.288919	1.63%	-1.63%
1844.722	1.626	1200.63	0.683	7.76571	6.39971	-3.44%	3.44%
1845.406	0.684	1200.606	0.86	9.79884	8.07884	-2.50%	2.50%
1846.266	0.86	1200.585	5.88	67.1202	55.3602	-2.14%	2.14%
1852.146	5.88	1200.459	1.081	12.475821	10.313821	-1.48%	1.48%
1853.227	1.081	1200.443	8.897	102.822629	85.028629	0.64%	-0.64%
1862.124	8.897	1200.501	6.146	70.672854	58.380854	-0.91%	0.91%
1868.27	6.146	1200.445	3.556	41.08958	33.97758	-3.10%	3.10%
1871.826	3.556	1200.335	5.257	61.322905	50.808905	-5.05%	5.05%
1877.083	5.257	1200.069	2.827	33.728937	28.074937	-1.13%	1.13%
1879.91	2.827	1200.037	6.286	75.199418	62.627418	-1.17%	1.17%
1886.196	6.286	1199.964	6.658	80.135688	66.819688	-1.04%	1.04%
1892.854	6.658	1199.895	7.431	89.952255	75.090255	0.20%	-0.20%
1900.284	7.43	1199.91	0.016	0.19344	0.16144	3.25%	-3.25%
1900.3	0.016	1199.91	4.143	50.08887	41.80287	-0.02%	0.02%
1904.444	4.144	1199.91	13.77	166.4793	138.9393	-2.46%	2.46%
1918.213	13.769	1199.571	11.617	144.387693	121.153693	2.83%	-2.83%
1929.83	11.617	1199.9	1.168	14.1328	11.7968	2.00%	-2.00%
1930.998	1.168	1199.923	0.797	9.625369	8.031369	-0.72%	0.72%
1931.795	0.797	1199.917	1.39	16.79537	14.01537	-0.08%	0.08%
1933.184	1.389	1199.916	24.792	299.586528	250.002528	-0.08%	0.08%
1957.977	24.793	1199.898	0.342	4.138884	3.454884	-1.60%	1.60%
1958.318	0.341	1199.892	0.59	7.14372	5.96372	-0.88%	0.88%
1958.908	0.59	1199.887	10.116	122.535108	102.303108	-1.48%	1.48%
1969.024	10.116	1199.737	2.351	28.830313	24.128313	-1.42%	1.42%
1971.375	2.351	1199.704	0.079	0.971384	0.813384	1.86%	-1.86%
1971.454	0.079	1199.705	0.174	2.13933	1.79133	-0.49%	0.49%
1971.628	0.174	1199.704	9.684	119.074464	99.706464	0.89%	-0.89%
1981.312	9.684	1199.79	5.753	70.24413	58.73813	6.45%	-6.45%
1987.065	5.753	1200.161	2.383	28.212337	23.446337	3.06%	-3.06%
1989.448	2.383	1200.234	2.706	31.838796	26.426796	8.51%	-8.51%
1992.154	2.706	1200.464	10.236	118.082496	97.610496	3.40%	-3.40%
2002.39	10.236	1200.812	15.245	170.56106	140.07106	3.03%	-3.03%
2017.635	15.245	1201.274	1.456	15.617056	12.705056	0.17%	-0.17%
2019.091	1.456	1201.276	3.044	32.643856	26.555856	3.49%	-3.49%
2022.135	3.044	1201.383	9.224	97.931208	79.483208	-7.67%	7.67%
2031.359	9.224	1200.675	5.807	65.764275	54.150275	-10.78%	10.78%
2037.166	5.807	1200.049	9.677	115.649827	96.295827	-8.15%	8.15%
2046.843	9.677	1199.261	1.377	17.541603	14.787603	2.69%	-2.69%
2048.221	1.378	1199.298	10.031	127.413762	107.351762	1.34%	-1.34%
2058.252	10.031	1199.432	9.1	114.3688	96.1688	2.36%	-2.36%
2067.352	9.1	1199.647	4.153	51.302009	42.996009	2.03%	-2.03%
2071.505	4.153	1199.732	3.417	41.919756	35.085756	-0.65%	0.65%
2074.922	3.417	1199.709	1.555	19.112505	16.002505	-1.11%	1.11%
2076.477	1.555	1199.692	1.731	21.305148	17.843148	-0.13%	0.13%
2078.208	1.731	1199.69	7.977	98.19687	82.24287	-1.17%	1.17%
2086.184	7.976	1199.597	1.424	17.661872	14.813872	-1.05%	1.05%
2087.609	1.425	1199.582	2.261	28.077098	23.555098	0.27%	-0.27%
2089.869	2.26	1199.588	7.915	98.24098	82.41098	1.44%	-1.44%
2097.784	7.915	1199.702	12.222	150.306156	125.862156	0.44%	-0.44%
2110.006	12.222	1199.755	1.371	16.787895	14.045895	-1.49%	1.49%
2111.377	1.371	1199.735	0.643	7.886395	6.600395	-3.53%	3.53%
2112.02	0.643	1199.712	12.94	159.00672	133.12672	-2.20%	2.20%
2124.96	12.94	1199.427	4.271	53.699283	45.157283	0.75%	-0.75%
2129.231	4.271	1199.459	13.351	167.434891	140.732891	0.35%	-0.35%
2142.582	13.351	1199.506	2.87	35.85778	30.11778	0.67%	-0.67%

2145.453	2.871	1199.525	1.285	16.030375	13.460375	-1.24%	1.24%
2146.738	1.285	1199.509	2.352	29.378832	24.674832	2.40%	-2.40%
2149.09	2.352	1199.565	2.613	32.492655	27.266655	1.71%	-1.71%
2151.703	2.613	1199.61	4.492	55.65588	46.67188	3.43%	-3.43%
2156.195	4.492	1199.764	7.231	88.478516	74.016516	3.33%	-3.33%
2163.426	7.231	1200.005	0.334	4.00633	3.33833	1.07%	-1.07%
2163.76	0.334	1200.008	1.687	20.230504	16.856504	9.07%	-9.07%
2165.447	1.687	1200.161	2.104	24.909256	20.701256	0.39%	-0.39%
2167.552	2.105	1200.17	2.203	26.06149	21.65549	3.14%	-3.14%
2169.755	2.203	1200.239	2.87	33.75407	28.01407	-2.04%	2.04%
2172.625	2.87	1200.18	10.272	121.41504	100.87104	-2.17%	2.17%
2182.897	10.272	1199.957	5.133	61.816719	51.550719	-5.65%	5.65%
2188.03	5.133	1199.667	3.351	41.327883	34.625883	-5.69%	5.69%
2191.381	3.351	1199.477	4.977	62.326971	52.372971	-1.71%	1.71%
2196.358	4.977	1199.392	11.659	146.996672	123.678672	0.84%	-0.84%
2208.017	11.659	1199.49	4.116	51.49116	43.25916	0.70%	-0.70%
2212.133	4.116	1199.519	1.49	18.59669	15.61669	3.88%	-3.88%
2213.623	1.49	1199.577	0.904	11.230392	9.422392	6.07%	-6.07%
2214.527	0.904	1199.631	19.917	246.353373	206.519373	-1.04%	1.04%
2234.444	19.917	1199.424	1.104	13.883904	11.675904	-0.59%	0.59%
2235.548	1.104	1199.418	0.116	1.459512	1.227512	7.16%	-7.16%
2235.664	0.116	1199.426	1.459	18.345466	15.427466	-0.40%	0.40%
2237.124	1.46	1199.42	1.955	24.5939	20.6839	0.13%	-0.13%
2239.079	1.955	1199.423	3.421	43.025917	36.183917	-0.17%	0.17%
2242.5	3.421	1199.417	4.163	52.383029	44.057029	2.32%	-2.32%
2246.663	4.163	1199.514	11.873	148.246278	124.500278	-3.50%	3.50%
2258.536	11.873	1199.098	0.478	6.167156	5.211156	-1.68%	1.68%
2259.014	0.478	1199.09	5.104	65.89264	55.68464	-1.14%	1.14%
2264.118	5.104	1199.032	5.676	73.606368	62.254368	-1.84%	1.84%
2269.794	5.676	1198.928	2.555	33.39896	28.28896	3.16%	-3.16%
2272.349	2.555	1199.009	5.3	68.8523	58.2523	0.80%	-0.80%
2277.649	5.3	1199.051	3.747	48.519903	41.025903	-9.61%	9.61%
2281.396	3.747	1198.691	5.725	76.194025	64.744025	-1.37%	1.37%
2287.121	5.725	1198.612	8.462	113.289256	96.365256	7.55%	-7.55%
2295.584	8.463	1199.251	1.869	23.827881	20.089881	3.41%	-3.41%
2297.453	1.869	1199.315	0.515	6.532775	5.502775	-2.48%	2.48%
2297.968	0.515	1199.302	3.551	45.090598	37.988598	-3.95%	3.95%
2301.519	3.551	1199.162	2.129	27.332102	23.074102	-3.86%	3.86%
2303.649	2.13	1199.08	13.781	178.05052	150.48852	-4.89%	4.89%
2317.43	13.781	1198.406	12.826	174.356644	148.704644	-0.75%	0.75%
2330.256	12.826	1198.309	3.362	46.029142	39.305142	-2.68%	2.68%
2333.618	3.362	1198.219	3.419	47.117239	40.279239	-3.01%	3.01%
2337.037	3.419	1198.116	3.597	49.940748	42.746748	-4.14%	4.14%
2340.634	3.597	1197.967	16.456	230.927048	198.015048	0.80%	-0.80%
2357.09	16.456	1198.098	1.899	26.399898	22.601898	-1.04%	1.04%
2358.989	1.899	1198.079	1.144	15.925624	13.637624	0.40%	-0.40%
2360.133	1.144	1198.083	3.861	53.733537	46.011537	-0.24%	0.24%
2363.995	3.862	1198.074	13.682	190.535532	163.171532	-1.58%	1.58%
2377.676	13.681	1197.857	4.127	58.368161	50.114161	-0.87%	0.87%
2381.804	4.128	1197.822	6.24	88.47072	75.99072	-0.15%	0.15%
2388.044	6.24	1197.812	4.297	60.965836	52.371836	0.16%	-0.16%
2392.341	4.297	1197.819	2.548	36.133188	31.037188	-1.00%	1.00%
2394.889	2.548	1197.794	2.956	41.992936	36.080936	2.50%	-2.50%
2397.845	2.956	1197.868	1.057	14.937524	12.823524	-1.29%	1.29%
2398.901	1.056	1197.854	4.091	57.871286	49.689286	-2.72%	2.72%
2402.993	4.092	1197.743	8.479	120.885103	103.927103	-2.15%	2.15%
2411.471	8.478	1197.56	6.915	99.8526	86.0226	-2.87%	2.87%
2418.387	6.916	1197.362	15.483	226.640154	195.674154	-3.20%	3.20%
2433.87	15.483	1196.867	0.198	2.996334	2.600334	-4.03%	4.03%
2434.069	0.199	1196.859	0.223	3.376443	2.930443	-1.79%	1.79%
2434.292	0.223	1196.855	0.948	14.35746	12.46146	-2.15%	2.15%
2435.239	0.947	1196.835	12.691	192.459015	167.077015	-1.72%	1.72%
2447.93	12.691	1196.617	5.603	86.190949	74.984949	-1.86%	1.86%
2453.533	5.603	1196.512	13.188	204.255744	177.879744	-1.73%	1.73%
2466.721	13.188	1196.285	0.96	15.0864	13.1664	-2.17%	2.17%
2467.681	0.96	1196.264	0.74	11.64464	10.16464	0.40%	-0.40%
2468.421	0.74	1196.267	8.905	140.102365	122.292365	0.25%	-0.25%
2477.327	8.906	1196.289	8.024	126.065064	110.017064	-1.39%	1.39%
2485.351	8.024	1196.177	5.349	84.637227	73.939227	0.29%	-0.29%
2490.699	5.348	1196.193	2.085	32.957595	28.787595	5.99%	-5.99%
2492.785	2.086	1196.318	14.027	219.971414	191.917414	-0.88%	0.88%
2506.812	14.027	1196.195	5.835	92.222175	80.552175	-0.80%	0.80%

2512.646	5.834	1196.148	3.343	52.993236	46.307236	0.40%	-0.40%
2515.989	3.343	1196.162	6.158	97.530404	85.214404	-0.69%	0.69%
2522.147	6.158	1196.119	17.943	284.952783	249.066783	-1.62%	1.62%
2540.089	17.942	1195.828	6.894	111.489768	97.701768	-1.59%	1.59%
2546.983	6.894	1195.719	5.873	95.618313	83.872313	0.87%	-0.87%
2552.856	5.873	1195.77	10.022	162.65706	142.61306	-1.19%	1.19%
2562.878	10.022	1195.651	3.477	56.845473	49.891473	-0.32%	0.32%
2566.355	3.477	1195.64	2.555	41.7998	36.6898	-0.32%	0.32%
2568.91	2.555	1195.632	11.36	185.94048	163.22048	0.60%	-0.60%
2580.271	11.361	1195.7	1.005	16.3815	14.3715	-1.68%	1.68%
2581.275	1.004	1195.683	5.051	82.417167	72.315167	-1.75%	1.75%
2586.326	5.051	1195.595	0.639	10.482795	9.204795	-3.90%	3.90%
2586.965	0.639	1195.57	4.304	70.71472	62.10672	-0.89%	0.89%
2591.27	4.305	1195.532	3.112	51.248416	45.024416	0.30%	-0.30%
2594.382	3.112	1195.541	1.954	32.160886	28.252886	-0.81%	0.81%
2596.336	1.954	1195.525	3.709	61.105775	53.687775	-1.00%	1.00%
2600.045	3.709	1195.488	2.832	46.761984	41.097984	-1.24%	1.24%
2602.877	2.832	1195.453	13.709	226.842823	199.424823	-0.01%	0.01%
2616.587	13.71	1195.452	5.928	98.096544	86.240544	-6.06%	6.06%
2622.514	5.927	1195.093	1.363	23.044241	20.318241	-0.75%	0.75%
2623.877	1.363	1195.083	9.047	153.048099	134.954099	-2.18%	2.18%
2632.924	9.047	1194.886	4.448	76.123072	67.227072	0.41%	-0.41%
2637.372	4.448	1194.904	1.828	31.251488	27.595488	0.91%	-0.91%
2639.199	1.827	1194.92	11.169	190.76652	168.42852	1.61%	-1.61%
2650.369	11.17	1195.1	3.687	62.3103	54.9363	0.27%	-0.27%
2654.055	3.686	1195.11	8.322	140.55858	123.91458	-0.06%	0.06%
2662.377	8.322	1195.105	8.626	145.73627	128.48427	3.00%	-3.00%
2671.004	8.627	1195.363	8.789	146.222593	128.644593	0.21%	-0.21%
2679.793	8.789	1195.382	1.517	25.209506	22.175506	-0.64%	0.64%
2681.309	1.516	1195.372	1.276	21.217328	18.665328	-2.41%	2.41%
2682.585	1.276	1195.341	7.056	117.545904	103.433904	-1.52%	1.52%
2689.641	7.056	1195.234	14.299	239.737034	211.139034	-1.30%	1.30%
2703.941	14.3	1195.048	1.859	31.513768	27.795768	-0.57%	0.57%
2705.8	1.859	1195.037	0.973	16.504999	14.558999	-0.25%	0.25%
2706.773	0.973	1195.035	0.178	3.01977	2.66377	1.41%	-1.41%
2706.951	0.178	1195.038	8.276	140.377512	123.825512	-0.24%	0.24%
2715.227	8.276	1195.018	7.784	132.187888	116.619888	0.21%	-0.21%
2723.011	7.784	1195.034	2.756	46.758296	41.246296	-0.70%	0.70%
2725.767	2.756	1195.015	13.495	229.212575	202.222575	-0.47%	0.47%
2739.262	13.495	1194.952	5.68	96.83264	85.47264	-1.73%	1.73%
2744.942	5.68	1194.853	7.006	120.131882	106.119882	-2.24%	2.24%
2751.948	7.006	1194.696	5.266	91.122864	80.590864	0.40%	-0.40%
2757.215	5.267	1194.717	1.825	31.541475	27.891475	-2.21%	2.21%
2759.04	1.825	1194.677	3.3	57.1659	50.5659	-1.42%	1.42%
2762.34	3.3	1194.63	0.522	9.06714	8.02314	1.95%	-1.95%
2762.862	0.522	1194.64	12.154	210.99344	186.68544	1.45%	-1.45%
2775.016	12.154	1194.817	9.916	170.386628	150.554628	0.87%	-0.87%
2784.932	9.916	1194.903	3.378	57.753666	50.997666	0.84%	-0.84%
2788.31	3.378	1194.931	0.411	7.015359	6.193359	-0.87%	0.87%
2788.721	0.411	1194.928	0.484	8.262848	7.294848	0.72%	-0.72%
2789.206	0.485	1194.931	2.571	43.884399	38.742399	-0.75%	0.75%
2791.776	2.57	1194.912	1.891	32.313408	28.531408	1.71%	-1.71%
2793.668	1.892	1194.944	0.337	5.747872	5.073872	0.29%	-0.29%
2794.005	0.337	1194.945	2.324	39.63582	34.98782	-1.22%	1.22%
2796.329	2.324	1194.917	2.673	45.662859	40.316859	-1.61%	1.61%
2799.002	2.673	1194.874	1.122	19.215372	16.971372	2.97%	-2.97%
2800.123	1.121	1194.907	7.466	127.616338	112.684338	1.32%	-1.32%
2807.589	7.466	1195.006	2.709	46.036746	40.618746	1.91%	-1.91%
2810.298	2.709	1195.058	7.316	123.947672	109.315672	4.79%	-4.79%
2817.614	7.316	1195.408	9.787	162.385904	142.811904	2.78%	-2.78%
2827.401	9.787	1195.68	4.427	72.24864	63.39464	2.86%	-2.86%
2831.827	4.426	1195.806	10.952	177.356688	155.452688	1.32%	-1.32%
2842.779	10.952	1195.95	9.655	154.96275	135.65275	4.50%	-4.50%
2852.435	9.656	1196.385	0.637	9.946755	8.672755	4.03%	-4.03%
2853.072	0.637	1196.41	5.747	89.59573	78.10173	-0.67%	0.67%
2858.818	5.746	1196.372	7.203	112.568484	98.162484	2.45%	-2.45%
2866.021	7.203	1196.548	11.77	181.87004	158.33004	-0.76%	0.76%
2877.792	11.771	1196.458	0.74	11.50108	10.02108	-1.00%	1.00%
2878.532	0.74	1196.451	0.461	7.168089	6.246089	-1.22%	1.22%
2878.993	0.461	1196.445	0.423	6.579765	5.733765	-0.61%	0.61%
2879.417	0.424	1196.443	0.229	3.562553	3.104553	-1.10%	1.10%
2879.645	0.228	1196.44	5.038	78.39128	68.31528	-1.00%	1.00%

2884.683	5.038	1196.39	21.807	340.40727	296.79327	-1.06%	1.06%
2906.49	21.807	1196.159	8.822	139.749302	122.105302	1.43%	-1.43%
2915.311	8.821	1196.285	0.785	12.336275	10.766275	-0.60%	0.60%
2916.097	0.786	1196.281	4.091	64.306429	56.124429	0.67%	-0.67%
2920.188	4.091	1196.308	5.033	78.977836	68.911836	0.31%	-0.31%
2925.221	5.033	1196.324	0.764	11.976464	10.448464	-0.45%	0.45%
2925.985	0.764	1196.32	0.348	5.45664	4.76064	-0.71%	0.71%
2926.333	0.348	1196.318	22.617	354.679794	309.445794	-0.81%	0.81%
2948.951	22.618	1196.134	1.828	29.003048	25.347048	1.26%	-1.26%
2950.779	1.828	1196.157	5.077	80.434911	70.280911	-0.58%	0.58%
2955.856	5.077	1196.128	1.824	28.950528	25.302528	-2.77%	2.77%
2957.68	1.824	1196.077	6.307	100.426361	87.812361	-1.68%	1.68%
2963.987	6.307	1195.972	5.621	90.093388	78.851388	-1.60%	1.60%
2969.608	5.621	1195.882	6.286	101.317748	88.745748	-1.31%	1.31%
2975.894	6.286	1195.799	5.458	88.425058	77.509058	-0.77%	0.77%
2981.352	5.458	1195.757	4.239	68.854077	60.376077	-0.47%	0.47%
2985.592	4.24	1195.737	2.558	41.600754	36.484754	2.25%	-2.25%
2988.149	2.557	1195.794	4.35	70.4961	61.7961	1.01%	-1.01%
2992.5	4.351	1195.839	1.098	17.744778	15.548778	1.40%	-1.40%
2993.598	1.098	1195.854	2.909	46.968714	41.150714	-1.79%	1.79%
2996.507	2.909	1195.802	11.711	189.694778	166.272778	-1.42%	1.42%
3008.218	11.711	1195.636	0.76	12.43664	10.91664	-1.08%	1.08%
3008.978	0.76	1195.627	4.765	78.017345	68.487345	-0.38%	0.38%
3013.743	4.765	1195.609	5.374	88.085234	77.337234	-1.30%	1.30%
3019.118	5.375	1195.539	1.52	25.02072	21.98072	-2.01%	2.01%
3020.638	1.52	1195.509	1.57	25.89087	22.75087	-1.38%	1.38%
3022.208	1.57	1195.487	1.705	28.154665	24.744665	0.62%	-0.62%
3023.913	1.705	1195.498	0.675	11.13885	9.78885	-3.03%	3.03%
3024.588	0.675	1195.477	6.425	106.160275	93.310275	-2.33%	2.33%
3031.013	6.425	1195.328	10.204	170.121088	149.713088	-1.54%	1.54%
3041.217	10.204	1195.171	5.406	90.977574	80.165574	-3.47%	3.47%
3046.623	5.406	1194.983	5.031	85.612527	75.550527	-1.60%	1.60%
3051.654	5.031	1194.903	7.633	130.501401	115.235401	-2.04%	2.04%
3059.287	7.633	1194.747	8.016	138.300048	122.268048	-1.23%	1.23%
3067.303	8.016	1194.649	10.637	184.562587	163.288587	-1.82%	1.82%
3077.94	10.637	1194.456	1.658	29.087952	25.771952	-2.83%	2.83%
3079.599	1.659	1194.409	0.796	14.002436	12.410436	-1.11%	1.11%
3080.395	0.796	1194.4	1.828	32.1728	28.5168	-1.10%	1.10%
3082.223	1.828	1194.38	14.358	252.98796	224.27196	-1.26%	1.26%
3096.581	14.358	1194.199	3.655	65.062655	57.752655	-1.49%	1.49%
3100.236	3.655	1194.145	2.782	49.67261	44.10861	-2.88%	2.88%
3103.017	2.781	1194.065	3.4	60.979	54.179	-3.94%	3.94%
3106.417	3.4	1193.931	1.551	28.025019	24.923019	-3.14%	3.14%
3107.969	1.552	1193.882	13.138	238.034284	211.758284	-4.74%	4.74%
3121.107	13.138	1193.26	3.709	69.50666	62.08866	-4.18%	4.18%
3124.816	3.709	1193.105	1.669	31.535755	28.197755	-4.19%	4.19%
3126.485	1.669	1193.035	9.579	181.665735	162.507735	-2.77%	2.77%
3136.064	9.579	1192.769	1.741	33.481171	29.999171	0.62%	-0.62%
3137.805	1.741	1192.78	2.841	54.60402	48.92202	1.96%	-1.96%
3140.646	2.841	1192.836	1.738	33.307032	29.831032	6.43%	-6.43%
3142.384	1.738	1192.948	9.092	173.220784	155.036784	1.63%	-1.63%
3151.476	9.092	1193.096	9.679	182.971816	163.613816	-1.52%	1.52%
3161.155	9.679	1192.949	2.392	45.569992	40.785992	-1.03%	1.03%
3163.547	2.392	1192.924	0.707	13.486732	12.072732	-1.70%	1.70%
3164.254	0.707	1192.912	10.827	206.665776	185.011776	-3.48%	3.48%
3175.081	10.827	1192.536	0.401	7.805064	7.003064	-2.73%	2.73%
3175.483	0.402	1192.525	0.779	15.171025	13.613025	-2.46%	2.46%
3176.261	0.778	1192.506	13.818	269.368092	241.732092	-0.06%	0.06%
3190.079	13.818	1192.497	1.19	23.20857	20.82857	0.28%	-0.28%
3191.269	1.19	1192.501	3.081	60.076419	53.914419	0.20%	-0.20%
3194.351	3.082	1192.507	1.128	21.988104	19.732104	1.53%	-1.53%
3195.478	1.127	1192.524	5.02	97.76952	87.72952	0.67%	-0.67%
3200.498	5.02	1192.557	9.778	190.113654	170.557654	0.15%	-0.15%
3210.276	9.778	1192.572	5.859	113.828652	102.110652	0.23%	-0.23%
3216.136	5.86	1192.585	14.388	279.34302	250.56702	0.38%	-0.38%
3230.524	14.388	1192.64	15.93	308.4048	276.5448	-0.20%	0.20%
3246.454	15.93	1192.608	0.365	7.07808	6.34808	-2.58%	2.58%
3246.819	0.365	1192.598	11.637	225.781074	202.507074	-1.97%	1.97%
3258.456	11.637	1192.369	4.434	87.043854	78.175854	-1.42%	1.42%
3262.89	4.434	1192.307	1.254	24.695022	22.187022	1.93%	-1.93%
3264.144	1.254	1192.331	1.971	38.767599	34.825599	-3.98%	3.98%
3266.114	1.97	1192.252	8.423	166.337404	149.491404	-4.23%	4.23%

3274.538	8.424	1191.896	7.509	150.960936	135.942936	-1.54%	1.54%
3282.046	7.508	1191.78	3.155	63.7941	57.4841	0.91%	-0.91%
3285.201	3.155	1191.809	6.367	128.556097	115.822097	1.34%	-1.34%
3291.567	6.366	1191.895	1.49	29.95645	26.97645	1.69%	-1.69%
3293.058	1.491	1191.92	12.459	250.17672	225.25872	2.00%	-2.00%
3305.516	12.458	1192.169	3.439	68.198809	61.320809	3.75%	-3.75%
3308.955	3.439	1192.297	6.308	124.286524	111.670524	1.06%	-1.06%
3315.263	6.308	1192.364	6.262	122.960632	110.436632	-1.09%	1.09%
3321.525	6.262	1192.296	6.15	121.1796	108.8796	-0.46%	0.46%
3327.675	6.15	1192.268	2.633	51.954356	46.688356	-4.68%	4.68%
3330.308	2.633	1192.145	3.805	75.548275	67.938275	-1.16%	1.16%
3334.113	3.805	1192.101	8.048	160.147152	144.051152	-0.91%	0.91%
3342.161	8.048	1192.028	6.088	121.589536	109.413536	0.07%	-0.07%
3348.249	6.088	1192.032	6.695	133.68576	120.29576	0.38%	-0.38%
3354.945	6.696	1192.058	1.265	25.22663	22.69663	-1.51%	1.51%
3356.209	1.264	1192.038	9.397	187.582914	168.788914	-0.37%	0.37%
3365.607	9.398	1192.003	10.322	206.409034	185.765034	0.31%	-0.31%
3375.928	10.321	1192.035	0.98	19.5657	17.6057	2.05%	-2.05%
3376.908	0.98	1192.055	0.353	7.040585	6.334585	-0.48%	0.48%
3377.261	0.353	1192.053	5.868	117.048996	105.312996	2.34%	-2.34%
3383.129	5.868	1192.19	8.974	177.77494	159.82694	0.83%	-0.83%
3392.103	8.974	1192.265	1.111	21.925585	19.703585	1.93%	-1.93%
3393.214	1.111	1192.287	3.663	72.208719	64.882719	0.37%	-0.37%
3396.878	3.664	1192.3	1.091	21.4927	19.3107	-0.55%	0.55%
3397.968	1.09	1192.294	4.133	81.444898	73.178898	0.07%	-0.07%
3402.101	4.133	1192.297	12.572	247.706116	222.562116	-0.61%	0.61%
3414.673	12.572	1192.221	0.131	2.591049	2.329049	-0.45%	0.45%
3414.804	0.131	1192.22	2.558	50.59724	45.48124	1.94%	-1.94%
3417.361	2.557	1192.27	1.455	28.70715	25.79715	-0.25%	0.25%
3418.816	1.455	1192.266	4.425	87.32295	78.47295	-0.12%	0.12%
3423.241	4.425	1192.261	6.775	133.731725	120.181725	-0.61%	0.61%
3430.016	6.775	1192.22	0.556	10.99768	9.88568	-0.09%	0.09%
3430.572	0.556	1192.219	1.069	21.145889	19.007889	-0.60%	0.60%
3431.641	1.069	1192.213	1.847	36.546589	32.852589	-0.17%	0.17%
3433.489	1.848	1192.21	6.241	123.50939	111.02739	0.42%	-0.42%
3439.73	6.241	1192.236	1.428	28.222992	25.366992	-1.76%	1.76%
3441.158	1.428	1192.211	1.077	21.312753	19.158753	-2.19%	2.19%
3442.235	1.077	1192.187	1.281	25.380453	22.818453	-0.58%	0.58%
3443.516	1.281	1192.18	7.544	149.52208	134.43408	-1.68%	1.68%
3451.06	7.544	1192.053	17.98	358.64706	322.68706	-1.76%	1.76%
3469.04	17.98	1191.736	3.071	62.230744	56.088744	1.10%	-1.10%
3472.112	3.072	1191.77	1.714	34.67422	31.24622	-1.30%	1.30%
3473.825	1.713	1191.747	8.019	162.408807	146.370807	0.82%	-0.82%
3481.844	8.019	1191.813	3.008	60.722496	54.706496	2.42%	-2.42%
3484.852	3.008	1191.886	1.45	29.1653	26.2653	1.09%	-1.09%
3486.302	1.45	1191.901	3.57	71.75343	64.61343	-0.78%	0.78%
3489.872	3.57	1191.873	8.001	161.036127	145.034127	0.90%	-0.90%
3497.872	8	1191.946	3.681	73.818774	66.456774	-2.02%	2.02%
3501.554	3.682	1191.871	9.299	187.179571	168.581571	-1.94%	1.94%
3510.853	9.299	1191.691	0.646	13.119614	11.827614	-4.97%	4.97%
3511.498	0.645	1191.659	3.961	80.570701	72.648701	1.42%	-1.42%
3515.46	3.962	1191.715	9.23	187.23055	168.77055	1.29%	-1.29%
3524.69	9.23	1191.835	0.873	17.604045	15.858045	0.37%	-0.37%
3525.563	0.873	1191.838	4.758	95.930796	86.414796	0.13%	-0.13%
3530.321	4.758	1191.844	0.346	6.973976	6.281976	0.03%	-0.03%
3530.667	0.346	1191.844	1.569	31.624764	28.486764	-0.25%	0.25%
3532.236	1.569	1191.84	3.327	67.07232	60.41832	-0.03%	0.03%
3535.563	3.327	1191.839	1.947	39.253467	35.359467	-0.08%	0.08%
3537.51	1.947	1191.837	5.332	107.509116	96.845116	0.29%	-0.29%
3542.842	5.332	1191.853	3.406	68.620682	61.808682	1.38%	-1.38%
3546.249	3.407	1191.9	2.548	51.2148	46.1188	-1.01%	1.01%
3548.797	2.548	1191.874	18.541	373.156166	336.074166	-0.07%	0.07%
3567.337	18.54	1191.862	3.581	72.114178	64.952178	0.41%	-0.41%
3570.919	3.582	1191.876	3.434	69.105816	62.237816	-0.76%	0.76%
3574.352	3.433	1191.85	2.354	47.4331	42.7251	0.70%	-0.70%
3576.706	2.354	1191.867	6.156	123.938748	111.626748	-1.58%	1.58%
3582.863	6.157	1191.77	15.817	319.97791	288.34391	0.32%	-0.32%
3598.679	15.816	1191.82	0.174	3.51132	3.16332	-1.52%	1.52%
3598.854	0.175	1191.817	15.056	303.875248	273.763248	-0.14%	0.14%
3613.91	15.056	1191.795	0.215	4.344075	3.914075	0.75%	-0.75%
3614.125	0.215	1191.797	0.466	9.414598	8.482598	1.15%	-1.15%
3614.591	0.466	1191.802	5.129	103.595542	93.337542	0.46%	-0.46%

3619.721	5.13	1191.826	2.558	51.605092	46.489092	-0.62%	0.62%
3622.279	2.558	1191.81	1.23	24.8337	22.3737	-0.26%	0.26%
3623.509	1.23	1191.807	3.047	61.528071	55.434071	0.79%	-0.79%
3626.555	3.046	1191.831	5.317	107.238573	96.604573	0.20%	-0.20%
3631.873	5.318	1191.841	1.039	20.945201	18.867201	-0.03%	0.03%
3632.912	1.039	1191.841	5.639	113.676601	102.398601	-1.22%	1.22%
3638.551	5.639	1191.772	1.204	24.354512	21.946512	-0.18%	0.18%
3639.755	1.204	1191.77	2.682	54.25686	48.89286	-0.01%	0.01%
3642.437	2.682	1191.77	6.598	133.47754	120.28154	0.38%	-0.38%
3649.035	6.598	1191.795	7.646	154.48743	139.19543	-1.10%	1.10%
3656.681	7.646	1191.711	5.064	102.743496	92.615496	-1.01%	1.01%
3661.745	5.064	1191.66	5.081	103.34754	93.18554	0.74%	-0.74%
3666.826	5.081	1191.698	8.063	163.695026	147.569026	0.64%	-0.64%
3674.889	8.063	1191.75	1.612	32.643	29.419	-3.14%	3.14%
3676.501	1.612	1191.699	4.101	83.254401	75.052401	-2.33%	2.33%
3680.602	4.101	1191.603	3.99	81.38403	73.40403	-0.31%	0.31%
3684.592	3.99	1191.591	2.445	49.900005	45.010005	-4.37%	4.37%
3687.037	2.445	1191.484	1.626	33.359016	30.107016	1.54%	-1.54%
3688.663	1.626	1191.509	2.83	57.98953	52.32953	-1.10%	1.10%
3691.493	2.83	1191.478	19.464	399.440208	360.512208	0.72%	-0.72%
3710.957	19.464	1191.618	2.298	46.837836	42.241836	0.50%	-0.50%
3713.254	2.297	1191.629	7.374	150.215754	135.467754	-3.27%	3.27%
3720.628	7.374	1191.388	3.484	71.812208	64.844208	1.15%	-1.15%
3724.112	3.484	1191.428	7.958	163.711976	147.795976	0.39%	-0.39%
3732.07	7.958	1191.459	1.823	37.446243	33.800243	-12.75%	12.75%
3733.893	1.823	1191.227	0.501	10.407273	9.405273	0.96%	-0.96%
3734.394	0.501	1191.231	1.035	21.495915	19.425915	3.45%	-3.45%
3735.429	1.035	1191.267	6.428	133.271724	120.415724	4.42%	-4.42%
3741.858	6.429	1191.551	3.303	67.543047	60.937047	-1.74%	1.74%
3745.161	3.303	1191.494	1.089	22.331034	20.153034	-1.89%	1.89%
3746.25	1.089	1191.473	1.214	24.919778	22.491778	0.57%	-0.57%
3747.464	1.214	1191.48	7.786	159.76872	144.19672	-3.13%	3.13%
3755.25	7.786	1191.236	1.922	39.908408	36.064408	-4.20%	4.20%
3757.172	1.922	1191.155	2.047	42.669715	38.575715	2.48%	-2.48%
3759.219	2.047	1191.206	13.216	274.813504	248.381504	2.71%	-2.71%
3772.436	13.217	1191.564	1.446	29.550456	26.658456	-0.35%	0.35%
3773.882	1.446	1191.559	2.286	46.728126	42.156126	-1.28%	1.28%
3776.168	2.286	1191.53	2.15	44.0105	39.7105	-1.80%	1.80%
3778.318	2.15	1191.491	12.969	265.981221	240.043221	-1.66%	1.66%
3791.287	12.969	1191.275	0.83	17.20175	15.54175	-1.36%	1.36%
3792.116	0.829	1191.264	7.895	163.71072	147.92072	-0.30%	0.30%
3800.012	7.896	1191.24	1.164	24.16464	21.83664	1.25%	-1.25%
3801.176	1.164	1191.255	8.945	185.564025	167.674025	-0.92%	0.92%
3810.121	8.945	1191.173	7.48	155.78596	140.82596	-0.30%	0.30%
3817.601	7.48	1191.15	3.105	64.73925	58.52925	-5.20%	5.20%
3820.706	3.105	1190.989	4.011	84.275121	76.253121	4.40%	-4.40%
3824.717	4.011	1191.165	11.154	232.39359	210.08559	1.01%	-1.01%
3835.87	11.153	1191.277	2.775	57.506325	51.956325	-1.55%	1.55%
3838.645	2.775	1191.234	2.582	53.617812	48.453812	-0.84%	0.84%
3841.227	2.582	1191.212	6.206	129.010328	116.598328	-5.58%	5.58%
3847.433	6.206	1190.866	8.715	184.18281	166.75281	-1.66%	1.66%
3856.148	8.715	1190.722	0.155	3.29809	2.98809	-3.68%	3.68%
3856.303	0.155	1190.716	0.254	5.406136	4.898136	2.40%	-2.40%
3856.557	0.254	1190.722	0.384	8.170752	7.402752	-5.31%	5.31%
3856.941	0.384	1190.702	13.351	284.349598	257.647598	-0.28%	0.28%
3870.292	13.351	1190.665	1.206	25.73001	23.31801	-2.30%	2.30%
3871.498	1.206	1190.637	7.531	160.884753	145.822753	0.91%	-0.91%
3879.029	7.531	1190.705	2.357	50.192315	45.478315	-2.91%	2.91%
3881.386	2.357	1190.637	3.534	75.496842	68.428842	15.23%	-15.23%
3884.92	3.534	1191.175	2.206	45.93995	41.52795	-6.71%	6.71%
3887.126	2.206	1191.027	4.381	91.882713	83.120713	-3.02%	3.02%
3891.508	4.382	1190.895	18.748	395.67654	358.18054	1.58%	-1.58%
3910.255	18.747	1191.191	2.568	53.437512	48.301512	5.97%	-5.97%
3912.823	2.568	1191.345	2.058	42.50799	38.39199	-1.85%	1.85%
3914.881	2.058	1191.307	5.486	113.521798	102.549798	-1.43%	1.43%
3920.367	5.486	1191.228	3.018	62.689896	56.653896	-0.20%	0.20%
3923.386	3.019	1191.222	2.162	44.922036	40.598036	-0.29%	0.29%
3925.548	2.162	1191.216	4.554	94.650336	85.542336	-0.65%	0.65%
3930.102	4.554	1191.187	17.603	366.371239	331.165239	0.86%	-0.86%
3947.705	17.603	1191.338	0.216	4.462992	4.030992	-3.18%	3.18%
3947.921	0.216	1191.331	1.214	25.092166	22.664166	-4.82%	4.82%
3949.135	1.214	1191.272	3.651	75.677928	68.375928	-6.71%	6.71%

3952.786	3.651	1191.028	0.416	8.724352	7.892352	-0.39%	0.39%
3953.202	0.416	1191.026	0.71	14.89154	13.47154	-7.54%	7.54%
3953.912	0.71	1190.972	2.16	45.42048	41.10048	-0.60%	0.60%
3956.071	2.159	1190.959	1.413	29.730933	26.904933	-6.15%	6.15%
3957.484	1.413	1190.873	11.577	244.587279	221.433279	-3.60%	3.60%
3969.061	11.577	1190.456	4.981	107.310664	97.348664	-1.66%	1.66%
3974.042	4.981	1190.373	1.471	31.813317	28.871317	5.96%	-5.96%
3975.513	1.471	1190.461	1.564	33.686996	30.558996	3.67%	-3.67%
3977.077	1.564	1190.518	14.097	302.831754	274.637754	5.29%	-5.29%
3991.174	14.097	1191.263	3.013	62.480581	56.454581	-0.30%	0.30%
3994.187	3.013	1191.254	7.407	153.665622	138.851622	-1.17%	1.17%
4001.594	7.407	1191.167	9.862	205.455046	185.731046	0.12%	-0.12%
4011.456	9.862	1191.18	1.356	28.23192	25.51992	-1.10%	1.10%
4012.812	1.356	1191.165	12.9	268.7715	242.9715	-0.76%	0.76%
4025.712	12.9	1191.066	8.075	169.04205	152.89205	-0.77%	0.77%
4033.787	8.075	1191.004	1.416	29.730336	26.898336	-0.66%	0.66%
4035.204	1.417	1190.994	6.442	135.320652	122.436652	0.09%	-0.09%
4041.646	6.442	1191	0.147	3.087	2.793	-0.25%	0.25%
4041.792	0.146	1191	4.082	85.722	77.558	-2.37%	2.37%
4045.874	4.082	1190.903	4.436	93.586292	84.714292	-2.36%	2.36%
4050.31	4.436	1190.799	0.587	12.444987	11.270987	-0.40%	0.40%
4050.897	0.587	1190.796	1.468	31.127472	28.191472	1.18%	-1.18%
4052.366	1.469	1190.814	19.371	410.394006	371.652006	1.30%	-1.30%
4071.736	19.37	1191.065	2.131	44.612485	40.350485	-1.43%	1.43%
4073.867	2.131	1191.034	2.025	42.45615	38.40615	-1.51%	1.51%
4075.892	2.025	1191.004	0.885	18.58146	16.81146	-0.99%	0.99%
4076.777	0.885	1190.995	4.616	96.95908	87.72708	-0.85%	0.85%
4081.393	4.616	1190.956	10.855	228.43262	206.72262	-0.46%	0.46%
4092.248	10.855	1190.906	5.495	115.91153	104.92153	-0.32%	0.32%
4097.742	5.494	1190.889	3.289	69.434079	62.856079	-0.52%	0.52%
4101.031	3.289	1190.871	8.857	187.139553	169.425553	0.01%	-0.01%
4109.888	8.857	1190.872	9.449	199.638472	180.740472	-0.27%	0.27%
4119.337	9.449	1190.847	3.369	71.264457	64.526457	-0.87%	0.87%
4122.706	3.369	1190.818	11.194	237.111308	214.723308	-1.06%	1.06%
4133.9	11.194	1190.699	6.503	138.520403	125.514403	-5.36%	5.36%
4140.403	6.503	1190.351	8.94	193.54206	175.66206	-4.08%	4.08%
4149.342	8.939	1189.985	6.626	145.87139	132.61939	6.32%	-6.32%
4155.968	6.626	1190.404	0.709	15.311564	13.893564	4.06%	-4.06%
4156.677	0.709	1190.433	1.45	31.27215	28.37215	1.14%	-1.14%
4158.127	1.45	1190.449	21.146	455.717446	413.425446	-0.37%	0.37%
4179.274	21.147	1190.37	5.724	123.81012	112.36212	2.64%	-2.64%
4184.998	5.724	1190.521	9.924	213.157596	193.309596	2.81%	-2.81%
4194.922	9.924	1190.8	7.502	159.0424	144.0384	0.71%	-0.71%
4202.423	7.501	1190.854	2.26	47.78996	43.26996	-3.29%	3.29%
4204.683	2.26	1190.779	0.668	14.175628	12.839628	15.11%	-15.11%
4205.351	0.668	1190.88	1.263	26.67456	24.14856	-3.70%	3.70%
4206.614	1.263	1190.833	14.424	305.312808	276.464808	-2.79%	2.79%
4221.038	14.424	1190.432	6.654	143.513472	130.205472	-1.77%	1.77%
4227.691	6.653	1190.314	2.761	59.875046	54.353046	-0.11%	0.11%
4230.452	2.761	1190.311	7.799	169.152511	153.554511	0.98%	-0.98%
4238.251	7.799	1190.387	5.326	115.110838	104.458838	1.95%	-1.95%
4243.577	5.326	1190.491	1.712	36.823408	33.399408	0.23%	-0.23%
4245.288	1.711	1190.495	10.088	216.94244	196.76644	-0.93%	0.93%
4255.376	10.088	1190.401	0.463	10.000337	9.074337	-5.08%	5.08%
4255.839	0.463	1190.377	5.54	119.79142	108.71142	2.04%	-2.04%
4261.379	5.54	1190.49	10.961	235.77111	213.84911	1.92%	-1.92%
4272.34	10.961	1190.701	3.947	84.067153	76.173153	24.70%	-24.70%
4276.287	3.947	1191.676	2.616	53.167584	47.935584	8.45%	-8.45%
4278.902	2.615	1191.897	7.819	157.185357	141.547357	7.38%	-7.38%
4286.721	7.819	1192.474	1.681	32.823206	29.461206	-2.84%	2.84%
4288.402	1.681	1192.426	3.801	74.400774	66.798774	-1.86%	1.86%
4292.204	3.802	1192.356	5.42	106.47048	95.63048	-1.07%	1.07%
4297.624	5.42	1192.298	4.682	92.244764	82.880764	-4.07%	4.07%
4302.306	4.682	1192.107	2.439	48.519027	43.641027	1.76%	-1.76%
4304.745	2.439	1192.15	5.968	118.4648	106.5288	-6.04%	6.04%
4310.713	5.968	1191.789	11.715	236.771865	213.341865	-6.72%	6.72%
4322.428	11.715	1191.002	1.29	27.08742	24.50742	-6.23%	6.23%
4323.718	1.29	1190.922	0.173	3.646494	3.300494	-4.15%	4.15%
4323.891	0.173	1190.914	1.194	25.176684	22.788684	-6.64%	6.64%
4325.085	1.194	1190.835	2.202	46.60533	42.20133	-11.49%	11.49%
4327.287	2.202	1190.582	5.285	113.19413	102.62413	-5.98%	5.98%
4332.573	5.286	1190.266	0.812	17.648008	16.024008	-5.77%	5.77%

4333.384	0.811	1190.219	7.986	173.943066	157.971066	-3.68%	3.68%
4341.37	7.986	1189.925	0.076	1.6777	1.5257	-4.32%	4.32%
4341.446	0.076	1189.922	0.075	1.65585	1.50585	-2.21%	2.21%
4341.521	0.075	1189.92	0.11	2.4288	2.2088	-4.93%	4.93%
4341.631	0.11	1189.915	5.1	112.6335	102.4335	-4.98%	4.98%
4346.731	5.1	1189.661	8.369	186.955091	170.217091	-6.43%	6.43%
4355.099	8.368	1189.123	10.978	251.143706	229.187706	-2.28%	2.28%
4366.078	10.979	1188.873	8.765	202.708155	185.178155	7.54%	-7.54%
4374.843	8.765	1189.533	0.885	19.883295	18.113295	7.90%	-7.90%
4375.728	0.885	1189.603	0.145	3.247565	2.957565	0.72%	-0.72%
4375.873	0.145	1189.604	0.969	21.701724	19.763724	4.61%	-4.61%
4376.841	0.968	1189.649	6.371	142.398221	129.656221	4.59%	-4.59%
4383.212	6.371	1189.941	0.756	16.676604	15.164604	1.88%	-1.88%
4383.968	0.756	1189.955	16.418	361.93481	329.09881	0.20%	-0.20%
4400.386	16.418	1189.988	1.584	34.867008	31.699008	0.36%	-0.36%
4401.97	1.584	1189.993	0.596	13.116172	11.924172	0.76%	-0.76%
4402.567	0.597	1189.998	0.217	4.774434	4.340434	-0.20%	0.20%
4402.784	0.217	1189.997	4.106	90.344318	82.132318	0.41%	-0.41%
4406.89	4.106	1190.014	4.544	99.904384	90.816384	0.32%	-0.32%
4411.433	4.543	1190.029	0.822	18.060162	16.416162	0.16%	-0.16%
4412.255	0.822	1190.03	14.381	315.95057	287.18857	-0.19%	0.19%
4426.636	14.381	1190.003	0.075	1.649775	1.499775	3.90%	-3.90%
4426.711	0.075	1190.006	0.479	10.535126	9.577126	-3.49%	3.49%
4427.191	0.48	1189.989	0.796	17.520756	15.928756	-6.91%	6.91%
4427.986	0.795	1189.934	15.247	336.440302	305.946302	-4.94%	4.94%
4443.233	15.247	1189.181	7.383	168.472677	153.706677	-2.50%	2.50%
4450.616	7.383	1188.996	2.493	57.348972	52.362972	-3.33%	3.33%
4453.109	2.493	1188.913	4.57	105.50759	96.36759	-5.53%	5.53%
4457.679	4.57	1188.66	3.625	84.6075	77.3575	-0.58%	0.58%
4461.304	3.625	1188.64	1.56	36.4416	33.3216	7.35%	-7.35%
4462.864	1.56	1188.754	3.841	89.287886	81.605886	-21.59%	21.59%
4466.705	3.841	1187.925	4.811	115.824825	106.202825	3.87%	-3.87%
4471.516	4.811	1188.112	7.719	184.391472	168.953472	3.34%	-3.34%
4479.235	7.719	1188.369	9.854	232.859874	213.151874	3.25%	-3.25%
4489.089	9.854	1188.69	6.376	148.62456	135.87256	1.45%	-1.45%
4495.465	6.376	1188.782	4.761	110.540898	101.018898	-0.87%	0.87%
4500.226	4.761	1188.741	1.75	40.70325	37.20325	13.61%	-13.61%
4501.976	1.75	1188.979	16.399	377.521379	344.723379	22.75%	-22.75%
4518.375	16.399	1192.709	7.102	137.004682	122.800682	6.09%	-6.09%
4525.478	7.103	1193.142	7.196	135.702168	121.310168	1.73%	-1.73%
4532.673	7.195	1193.267	1.366	25.589278	22.857278	4.23%	-4.23%
4534.039	1.366	1193.325	0.573	10.700775	9.554775	5.52%	-5.52%
4534.612	0.573	1193.356	7.733	144.174052	128.708052	0.14%	-0.14%
4542.345	7.733	1193.367	3.364	62.681412	55.953412	-0.69%	0.69%
4545.709	3.364	1193.343	0.803	14.981571	13.375571	0.34%	-0.34%
4546.512	0.803	1193.346	1.49	27.79446	24.81446	-0.50%	0.50%
4548.002	1.49	1193.339	0.174	3.247014	2.899014	-6.45%	6.45%
4548.176	0.174	1193.327	6.206	115.884638	103.472638	-1.80%	1.80%
4554.383	6.207	1193.216	2.593	48.706912	43.520912	-1.07%	1.07%
4556.975	2.592	1193.188	4.124	77.580688	69.332688	-0.83%	0.83%
4561.1	4.125	1193.154	8.974	169.124004	151.176004	-1.47%	1.47%
4570.074	8.974	1193.022	5.686	107.908908	96.536908	-2.94%	2.94%
4575.759	5.685	1192.855	5.862	112.22799	100.50399	-4.81%	4.81%
4581.622	5.863	1192.573	7.293	141.681111	127.095111	-1.13%	1.13%
4588.915	7.293	1192.491	0.466	9.091194	8.159194	0.48%	-0.48%
4589.38	0.465	1192.493	0.294	5.735058	5.147058	-4.29%	4.29%
4589.674	0.294	1192.481	2.785	54.360415	48.790415	-5.77%	5.77%
4592.459	2.785	1192.32	2.604	51.24672	46.03872	-9.70%	9.70%
4595.063	2.604	1192.068	9.826	195.851832	176.199832	-12.99%	12.99%
4604.889	9.826	1190.791	2.08	44.11472	39.95472	-13.48%	13.48%
4606.969	2.08	1190.511	1.762	37.863618	34.339618	-17.25%	17.25%
4608.73	1.761	1190.207	12.266	267.312938	242.780938	-32.47%	32.47%
4620.996	12.266	1186.225	5.487	141.427425	130.453425	13.49%	-13.49%
4626.483	5.487	1186.965	3.302	82.66557	76.06157	11.96%	-11.96%
4629.785	3.302	1187.36	13.872	341.80608	314.06208	-0.69%	0.69%
4643.657	13.872	1187.264	3.514	86.922304	79.894304	-2.00%	2.00%
4647.171	3.514	1187.194	0.704	17.463424	16.055424	8.72%	-8.72%
4647.875	0.704	1187.256	11.219	277.602936	255.164936	0.50%	-0.50%
4659.094	11.219	1187.311	10.607	261.876223	240.662223	1.83%	-1.83%
4669.701	10.607	1187.505	6.22	152.3589	139.9189	2.14%	-2.14%
4675.921	6.22	1187.639	8.226	200.393586	183.941586	-0.48%	0.48%
4684.146	8.225	1187.599	0.917	22.375717	20.541717	1.79%	-1.79%

4685.064	0.918	1187.616	1.801	43.915584	40.313584	6.47%	-6.47%
4686.864	1.8	1187.732	2.929	71.080972	65.222972	3.67%	-3.67%
4689.793	2.929	1187.84	11.948	288.66368	264.76768	2.26%	-2.26%
4701.741	11.948	1188.109	9.941	237.500431	217.618431	-0.18%	0.18%
4711.682	9.941	1188.091	4.532	108.355588	99.291588	2.99%	-2.99%
4716.214	4.532	1188.226	3.703	88.035122	80.629122	2.62%	-2.62%
4719.917	3.703	1188.323	8.418	199.312986	182.476986	1.93%	-1.93%
4728.335	8.418	1188.486	4.86	114.27804	104.55804	1.69%	-1.69%
4733.195	4.86	1188.568	6.165	144.45828	132.12828	-1.15%	1.15%
4739.361	6.166	1188.497	6.389	150.160667	137.382667	0.17%	-0.17%
4745.75	6.389	1188.508	7.088	166.511296	152.335296	2.84%	-2.84%
4752.838	7.088	1188.709	3.419	79.631929	72.793929	5.53%	-5.53%
4756.257	3.419	1188.898	0.735	16.97997	15.50997	-0.30%	0.30%
4756.992	0.735	1188.896	1.123	25.945792	23.699792	1.38%	-1.38%
4758.116	1.124	1188.911	2.166	50.010774	45.678774	-4.01%	4.01%
4760.281	2.165	1188.824	16.602	384.767952	351.563952	-4.02%	4.02%
4776.883	16.602	1188.157	1.802	42.965086	39.361086	-4.85%	4.85%
4778.685	1.802	1188.07	3.966	94.90638	86.97438	-3.79%	3.79%
4782.652	3.967	1187.919	9.883	237.992523	218.226523	-4.80%	4.80%
4792.535	9.883	1187.445	2.425	59.545875	54.695875	-2.17%	2.17%
4794.96	2.425	1187.393	13.742	338.149394	310.665394	-4.54%	4.54%
4808.702	13.742	1186.77	4.777	120.52371	110.96971	3.87%	-3.87%
4813.48	4.778	1186.955	3.411	85.428495	78.606495	3.31%	-3.31%
4816.89	3.41	1187.068	6.989	174.249748	160.271748	-3.00%	3.00%
4823.88	6.99	1186.858	5.703	143.384826	131.978826	-1.30%	1.30%
4829.583	5.703	1186.784	8.494	214.184704	197.196704	-2.91%	2.91%
4838.077	8.494	1186.537	7.17	182.56971	168.22971	-0.27%	0.27%
4845.248	7.171	1186.518	9.214	234.791148	216.363148	-1.44%	1.44%
4854.462	9.214	1186.385	4.823	123.541145	113.895145	2.10%	-2.10%
4859.285	4.823	1186.486	4.007	102.234598	94.220598	6.88%	-6.88%
4863.292	4.007	1186.762	3.951	99.715338	91.813338	5.35%	-5.35%
4867.243	3.951	1186.973	8.72	218.23544	200.79544	5.57%	-5.57%
4875.963	8.72	1187.459	6.452	158.338532	145.434532	3.82%	-3.82%
4882.415	6.452	1187.706	2.046	49.705524	45.613524	3.38%	-3.38%
4884.461	2.046	1187.775	0.681	16.497225	15.135225	-23.10%	23.10%
4885.142	0.681	1187.618	3.966	96.699012	88.767012	-24.45%	24.45%
4889.108	3.966	1186.648	3.379	85.664408	78.906408	-26.33%	26.33%
4892.487	3.379	1185.758	1.488	39.048096	36.072096	-28.26%	28.26%
4893.975	1.488	1185.337	1.055	28.129465	26.019465	-4.30%	4.30%
4895.031	1.056	1185.292	7.11	189.89388	175.67388	-2.17%	2.17%
4902.141	7.11	1185.138	0.772	20.737464	19.193464	-0.90%	0.90%
4902.912	0.771	1185.131	1.347	36.192543	33.498543	-65.59%	65.59%
4904.259	1.347	1184.248	0.493	13.681736	12.695736	-49.63%	49.63%
4904.752	0.493	1184.003	3.683	103.112951	95.746951	1.46%	-1.46%
4908.435	3.683	1184.056	2.849	79.612456	73.914456	0.16%	-0.16%
4911.284	2.849	1184.061	1.325	37.019175	34.369175	25.72%	-25.72%
4912.609	1.325	1184.402	1.165	32.15167	29.82167	15.18%	-15.18%
4913.774	1.165	1184.578	1.793	49.167646	45.581646	5.11%	-5.11%
4915.567	1.793	1184.67	1.369	37.41477	34.67677	3.25%	-3.25%
4916.936	1.369	1184.714	6.927	189.010122	175.156122	1.38%	-1.38%
4923.863	6.927	1184.81		0	0		
			Subtotal	67875.08363	58321.57012		
		Average Depth		13.8	12.9		

Table 2 – Wind Gauge Summary Data

Long	Lat	Gauge	Yrs	Loc	Elev	Dir	Wavg	Wsd	Wmx	W100	W1000
-113.883	52.167	3025480	53	RED DEER A	905	NW	75	3.4	84	85	92
-114.017	51.100	3031093	53	CALGARY INT'L A	1084	NW	79	4.1	89	92	99
-112.800	49.617	3033880	53	LETHBRIDGE A	929	W	100	4.6	113	115	123
-110.717	50.017	3034480	53	MEDICINE HAT A	717	W	73	3.2	80	83	89
-111.217	56.650	3062693	53	FORT MCMURRAY A	369	W	52	3.6	63	63	70
-118.883	55.167	3072920	53	GRANDE PRAIRIE A	669	W	72	1.8	77	78	81
-113.517	53.567	3012208	52	EDMONTON CITY CENTR	671	NW	64	2.1	68	70	74
-110.267	54.417	3081680	52	COLD LAKE A	541	NW	66	3.2	72	76	82
-113.467	53.667	3012210	51	EDMONTON NAMAO A	688	NW	74	2.9	80	83	89
-117.450	56.217	3075040	51	PEACE RIVER A	571	W	56	1.9	61	62	66
-113.567	53.317	3012205	45	EDMONTON INT'L A	723	NW	69	2.7	76	77	82
-118.067	52.867	3053520	43	JASPER	1062	NE	48	4.0	56	60	67
-111.450	52.067	3011880	41	CORONATION A	791	NW	69	3.1	77	79	85
-115.567	51.167	3050520	40	BANFF	1384	SW	53	5.2	64	69	79
-112.017	54.767	3063685	40	LAC LA BICHE (AUT)	567	W	57	6.9	76	78	91
-111.117	58.767	3072658	39	FORT CHIPEWYAN A	232	W	54	3.2	61	64	69
-111.167	50.267	3036240	38	SUFFIELD A	770	SW	70	1.8	74	75	79
-117.150	58.617	3073146	36	HIGH LEVEL A	338	NW	47	2.0	52	54	58
-110.817	53.350	3016800	29	VERMILION A	619	NW	60	2.7	64	69	73
-115.783	54.133	3067372	28	WHITECOURT A	782	NW	49	2.7	56	58	62
-116.467	53.567	3062244	26	EDSON A	927	NW	55	1.8	58	60	64
-111.450	52.067	3011885	25	CORONATION (AUT)	791	NW	64	2.0	69	70	74
-114.917	52.367	3015520	25	ROCKY MTN HOUSE	1015	NW	49	2.5	56	57	62
-114.767	55.300	3066001	25	SLAVE LAKE A	581	W	70	2.6	76	78	83
-115.667	54.117	3067370	25	WHITECOURT	741	NW	53	3.2	61	63	68
-110.067	53.300	3013961	24	LLOYDMINSTER A	668	NW	61	4.7	74	76	85
-113.967	49.517	3035206	24	PINCHER CREEK (AUT)	1190	W	97	3.4	104	107	113
-114.900	52.417	3015523	23	ROCKY MTN HOUSE (AU	988	NW	44	1.1	46	48	50
-114.367	51.100	303F0PP	22	SPRINGBANK A	1201	W	70	2.6	74	78	83
-113.950	49.500	3035201	19	PINCHER CREEK	1155	W	115	4.4	122	129	137
-113.617	50.000	3031640	18	CLARESHOLM	1012	W	89	4.3	98	103	111
-112.050	49.117	3044533	18	MILK RIVER	1050	W	77	2.7	82	85	90
-115.067	51.067	3050778	18	BOW VALLEY	1298	W	52	1.4	54	56	59
-118.017	52.917	3053536	18	JASPER WARDEN	1020	N	36	1.7	39	41	44
-114.967	55.350	3066920	18	WAGNER	584	W	61	2.0	64	67	71
-114.667	51.767	3026KNQ	18	SUNDRE A	1114	NW	52	2.0	56	59	62
-111.850	50.550	3030QLP	18	BROOKS	747	NW	63	1.5	67	67	70
-112.100	53.517	3016GF0	17	VEGREVILLE	639	NW	62	2.6	67	70	75
-114.917	52.417	3015522	16	ROCKY MTN HOUSE A	988	NW	47	2.0	52	53	57
-115.267	56.550	3075488	16	RED EARTH	546	W	40	1.6	44	45	48
-112.667	51.417	30221LG	16	DRUMHELLER EAST	678	NW	49	2.2	52	56	60
-114.000	49.517	3035202	15	PINCHER CREEK A	1190	SW	105	2.4	109	112	117
-110.467	49.117	3044923	15	ONEFOUR CDA	935	NW	76	1.4	78	80	82
-115.567	51.167	3050521	15	BANFF (AUT)	1397	SW	34	1.0	35	37	38
-113.750	52.450	3023722	14	LACOMBE CDA 2	860	NW	56	1.7	59	61	64
-114.217	51.067	3031875	14	COP UPPER	1235	NW	66	4.7	76	80	89
-110.200	51.667	301B460	14	ESTHER 1	707	NW	63	1.5	65	67	70
-114.467	49.617	3051R4R	14	CROWSNEST	1303	W	53	1.4	56	58	60
-112.867	53.667	3012275	13	ELK ISLAND NAT PARK	716	SE	41	1.7	43	46	49
-114.467	53.450	3013247	13	HIGHVALE	747	NW	62	1.7	65	67	70
-111.450	49.717	3030768	13	BOW ISLAND	817	W	70	2.4	74	78	82
-111.900	50.567	3030838	13	BROOKS	755	SW	57	1.0	59	61	62
-111.550	57.033	3064528	13	MILDRED LAKE	310	NW	47	2.4	52	54	59
-116.050	58.367	3072730	13	FORT VERMILION	283	W	46	1.4	48	50	53
-118.350	53.383	306GE70	13	WILLOW CREEK 1	1402	N	26	0.7	28	29	30
-113.867	58.700	307KPFP	13	GARDEN RIVER	241	W	32	1.4	35	37	39
-112.817	53.017	3011240	12	CAMROSE	739	NW	57	0.5	57	58	59
-113.200	51.817	3026479	12	THREE HILLS	907	NW	68	1.7	70	73	76
-113.267	49.200	3031322	12	CARDSTON	1136	W	55	1.2	57	59	61
-112.767	49.700	3033890	12	LETHBRIDGE CDA	921	W	68	1.1	70	71	73
-113.800	49.117	3056214	12	WATERTON PARK GATE	1296	SW	87	1.6	89	92	95
-116.467	53.600	3062242	12	EDSON A	925	W	46	0.9	48	49	51
-114.767	55.267	3065999	12	SLAVE LAKE A	583	W	67	1.7	70	73	76
-111.100	52.817	301S001	11	WAINWRIGHT CFB AIRFII	686	NW	56	1.7	59	62	65
-113.867	50.167	3036099	10	STAVELY AAFC	1364	W	90	2.2	93	97	101
-116.417	53.567	3062241	10	EDSON	924	NW	70	4.6	80	85	93
-110.050	54.750	3065304	10	PRIMROSE LAKE DND	702	NW	41	2.6	44	49	54

APPENDIX F.7.3 – DITCH SIZING FOR STORM RUNOFF CALCULATIONS

Storage Dam Surface Runoff

Springbank Off-Stream Reservior Project
Alberta, Canada
Alberta Transportation Department

1. OBJECTIVE

The objectives of this calculation package are to calculate peak runoff from the Off-Stream Storage Dam and to size the ditch for the 100-year storm runoff.

2. CRITERIA

Rational Method (AT, 2011)

3. REFERENCES

1. AT (2011). Erosion and Sediment Control Manual. Government of Alberta Transportation (AT).

2. USACE (2011). AED Design Requirements: Hydrology Studies, Various Locations, Afganistan. US Army Corps of Engineers, Afghanistan Enigeer District.

3. AEP (1999). Stormwater Management Guidelines for the Province of Alberta.Alberta Environmental Protection. Edmonton, Alberta.

4. VDOT. (2002). Chapter 6-Hydrology (Revesion 2017). Drainge Manual. Location and Design Division. Virginia Department of Transportation.

5. Rainfall Intensity. Calgary Internation Airport, AB 3031093. Return Interval Rainfall Data.

4. CALCULATIONS

Rational Method: Q = 0.00278 C x I x A

Where,

Q = Peak flow (cms)

C = Dimensionless runoff coefficient

I = Rainfall intensity (mm/hr)

A = Drainage area (square km)

Runoff Coefficient

For Earth embankments at 10-year storm frequency, USACE (2011) reported runoff coefficient as 0.6. For 100-year frequency, runoff coefficient is generally multiplied by a factor of 1.25 (AEP, 1999, VDOT 2002). Therefore, the runoff coefficient was selected as 0.6 * 1.25 = 0.75 for 100-year runoff event.

Runoff Coefficient: $C_o := 0.75$

Rainfall Intensity: Calgary Airport, AB 3031093

1 Hour Duration

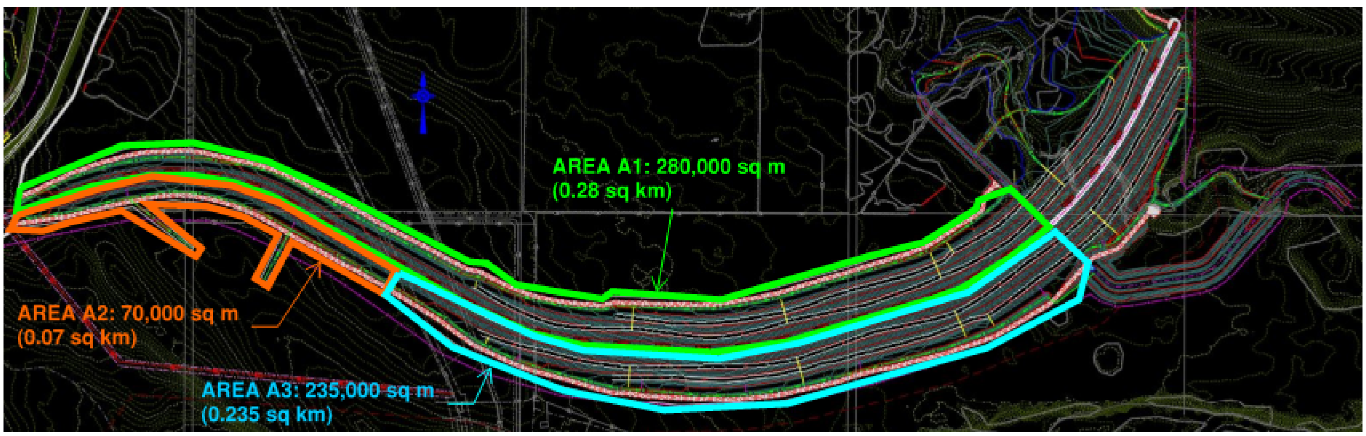
100-Year Rainfall Intensity: $i_{100} := 42 \frac{mm}{hr}$

25-Year Rainfall Intensity: $i_{25} := 34 \frac{mm}{hr}$

10-Year Rainfall Intensity: $i_{10} := 26 \frac{mm}{hr}$

Dam Selection

Runoff Area - From AutoCAD Civil 3D



The Ditch is sized for the larger of the areas:

$A_1 := 28 \text{ hectare}$

Peak Discharge Calculation

100-Year Peak Discharge: $Q_{p100} := 0.00278 \cdot C_o \cdot i_{100} \cdot A_1 = 2.45 \frac{m^3}{s}$

The ditch grades from elevation 1213.0 m to elevation 1188.0 m and is approximately 2,600 m in length.

Elevations of ditch: $El_{start} := 1213.0m$ $El_{end} := 1188.0m$

Length of ditch: $L_{ditch} := 2600m$

Average Slope of Ditch: $S_o := \frac{El_{start} - El_{end}}{L_{ditch}} = 0.00962$

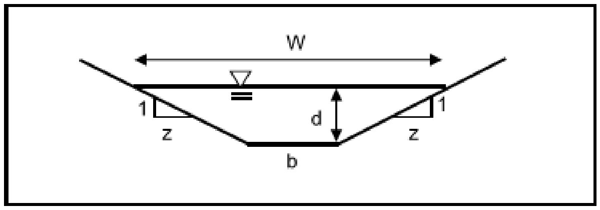
Ditch Sizing Calculations

Bench Ditch Hydraulic Capacity w/ Stable Lining System

Client	Alberta Transportation		
Project Name	Springbank Off-Stream Storage Project		
	1, 24-Hour Design Storm	**Prepared By:**	DMB
Location	Alberta, Canada		
Date	11/22/2019	**Reviewed By:**	JLG
Stantec Project Number	110773396		

Drainage Ditch - Channel Capacity & Depth Calculations

Channel Sketch



Channel Section 1

1. Uniform (Symmetrical) Trapezoidal Section

Input Data:

Manning's "n" value	0.027	
Longitudinal Slope - S_o	0.010	ft/ft
Design Discharge - Q	86.5	ft^3/s - cfs
	2.45	**m^3/s - cms**

Channel Geometry Data:

Bottom Width(s)			
b_1 or b	3.28084	feet	**1.00 m**
Side Slope(s)			
z_1 or z	3.0	z H:1V	

Governing Geometry Equations

$$W = b + 2dz$$

$$A = bd + zd^2$$

$$W_p = b + 2d\sqrt{z^2 + 1}$$

plot

Calculated Depth - d	**1.77**	feet	**0.539 m**
Calculated Top Width - W	**13.89**	feet	**4.236 m**
Calculated Area - A	15.19	ft^2	
Calc. Wetted Perimeter - Wp	14.47	feet	
Calc. Hydr. Radius - R	1.05	feet	
Calculated Discharge - Q'	86.61	ft^3/s - cfs	
Convergence	0.11	ft^3/s - cfs	
Calculated Velocity	**5.70**	ft / s	
Calculated Shear Stress - τ_d	**1.10**	lb / ft^2	

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$

$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$

Note: The Mannings "n" value was referenced from "Open Channel Hydraulics" by Ven Te Chow, PhD. Table 5-6 lists a Manning's "n" value of 0.027 for an excavated or dredged channel - "with short grass, few weeds."

Based upon the low calculated velocities and calculated shear stress, a channel lining of vegetation is sufficient.

APPENDIX F.7-4 – CHUTE SIZING AND ARMOURING CALCULATIONS

Storage Dam Surface Runoff

Springbank Off-Stream Reservoir Project
Alberta, Canada
Alberta Transportation Department

1. OBJECTIVE/PURPOSE

The objectives of this calculation package is to calculate runoff for storage dam surface.

2. CRITERIA

Rational Method (AT, 2011)

3. REFERENCES

1. AT (2011). Erosion and Sediment Control Manual. Government of Alberta Transportation (AT).

2. USACE (2011). AED Design Requirements: Hydrology Studies, Various Locations, Afaganistan. US Army Corps of Engineers, Afghanistan Enigeer District.

3. AEP (1999). Stormwater Management Guidelines for the Province of Alberta.Alberta Environmental Protection. Edmonton, Alberta.

4. VDOT. (2002). Chapter 6-Hydrology (Revesion 2017). Drainge Manual. Location and Design Division. Virginia Department of Transportation.

5. Rainfall Intensity....

4. Calculations

Rational Method: Q = 0.278 C x I x A

Where,

Q = Peak flow (cms)

C = Dimensionless runoff coefficient

I = Rainfall intensity (mm/hr)

A = Drainage area (square km)

Runoff Coefficient

Earth embankments at 10-year storm frequency, USACE ( ) reported runoff coefficient as 0.6. For 100-yea frequency, runoff coefficient is generally multiplied by a factor 1.25 (AEP, 1999, VDOT 2002). Therefore, th runoff coefficient was selected as 0.6 * 1.25 = 0.75 for 100-Year runoff event.

Runoff Coefficient: $C_o := 0.75$

Rainfall intensity: Calgary Airport, AB 3031093

1 Hour Duration

100-Year Rainfall Intensity: $i_{100} := 42 \ \frac{mm}{yr}$

25-Year Rainfall Intensity: $i_{25} := 34 \ \frac{mm}{yr}$

10-Year Rainfall Intesity: $i_{10} := 26 \ \frac{mm}{yr}$

Dam Selection

Maximum width: $w_{max} := 50 \ m$

Length: $L_1 := 400 \ m$ $L_2 := 800 \ m$

$$A_1 := \frac{w_{max}}{1000} \cdot \frac{L_1}{1000} = 0.02 \ km^2 \qquad A_2 := \frac{L_2}{1000} \cdot \frac{w_{max}}{1000} = 0.04 \ km^2$$

Peak Discharge Calculation

100-Year Peak Discharge: $Q_{p100A1} := 0.278 \cdot C_o \cdot i_{100} \cdot A_1 = 0.1751 \ \frac{m^3}{s}$ For A1

100-Year Peak Discharge: $Q_{p100A2} := 0.278 \cdot C_o \cdot i_{100} \cdot A_2 = 0.3503 \ \frac{m^3}{s}$ For A2

Ditch Sizing:

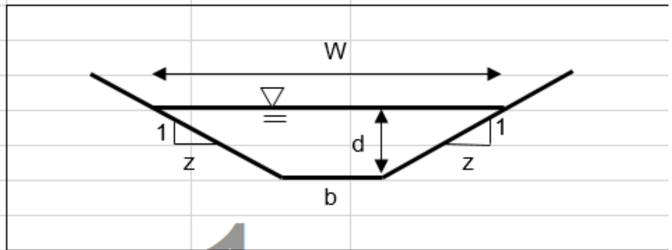
$Q_p := Q_{p100A2} = 0.35028 \ \frac{m^3}{s}$ $Q := 0.35028 \frac{m^3}{s}$ Note: Manual

Assume Slope OF Chutes = 0.286
ft/ft

Drainage Ditch - Channel Capacity & Depth Calculations

Update Geometry

Channel Sketch



Channel Section	1			
1. Uniform (Symmetrical) Trapezoidal Section				
Input Data:				
Manning's "n" value	0.027			
Longitudinal Slope - S_o	0.286	ft/ft		
Design Discharge - Q	12.4	ft^3/s - cfs		
	0.35	**m^3/s - cms**		
Channel Geometry Data:				
Bottom Width(s)				
b_1 or b	3.28084	feet	**1.00**	**m**
Side Slope(s)				
z_1 or z	3.0	z H:1V		

Governing Geometry Equations

$$W = b + 2dz$$

$$A = bd + zd^2$$

$$W_P = b + 2d\sqrt{z^2 + 1}$$

plot				
Calculated Depth - d	**0.28**	feet	**0.08**	**m**
Calculated Top Width - W	**4.94**	feet	**1.51**	**m**
Calculated Area - A	1.14	ft^2		
Calc. Wetted Perimeter - Wp	5.03	feet		
Calc. Hydr. Radius - R	0.23	feet		
Calculated Discharge - Q'	12.48	ft^3/s - cfs		
Convergence	0.08	ft^3/s - cfs		
Calculated Velocity	**10.95**	ft / s		
Calculated Shear Stress - τ_d	**4.94**	lb / ft^2		

Solve for Correct Depth & Update Calculations GO!

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$

$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$

Note: The Mannings "n" value was referenced from "Open Channel Hydraulics" by Ven Te Chow, PhD. Table 5-6 lists a Manning's "n" value of 0.027 for an excavated or dredged channel - "with short grass, few weeds."

Velocity = 10.95 ft/s = 3.3 m/s

1. OBJECTIVE/PURPOSE

The objectives of this section is to size the appropriate rip rap for protection of the off stream storage dams chutes.

2. CRITERIA

USACE EM 1110-2-1601 (1991) Method and Mark Slack Associates (2004)

3. REFERENCES

1. USACE. (1991). Hydraulic Design of Flood Control Channels. U.S. Army Corps of Engineers.

2. Mark Slack Associates (2004). Water Control Structures Selected Design Guidelines. Submitted to: Alberta Transportation Department. Calgary, Alberta.

4. Riprap Size Calculations

4.1 Calculations

Using equation 3-3 of USACE (1994):

$$D_{30} = S_f C_S C_V C_T d \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{1/2} \frac{V}{\sqrt{K_1 g d}} \right]^{2.5}$$

Where

Saftey Factor: $S_f := 1.0$

Stability coefficient for incipient failure: $C_s := 0.3$ (Angular rock)

Vertical velocity distribution coefficient: $C_v := 1$ (For straight channels)

Thickness coefficient $C_T := 1$ [For thickness 1D100(max) or 1.5D50(max)]

Velocity: $v := 3.33 \frac{m}{s}$ (From Figure 1)

Local depth of flow: $d := .08m$ (From Figure 2)

Unit weight of water $\gamma_w := 1000 \frac{kg}{m^3}$

Unit weight of stone: $\gamma_s := 2643 \frac{kg}{m^3}$

Side slope correction factor:

Currently the downstream chutes is anticipated to have a side slope of 3:1. Therefore, a 14 percent angle of the side slope has been included to conservatory account for any potential side slope which may result from final grading of the channel.

Angle of side slope with horizontal: $\theta := 14°$

Angle of repose of riprap material: $\varphi := 35°$

Side slope correction factor: $K_1 := \sqrt{1 - \frac{(\sin(\theta))^2}{(\sin(\varphi))^2}} = 0.91$

Gravitational Constant: $g = 9.81 \frac{m}{s^2}$

4.2.1 Riprap sizing (D30)

$$D_{30} := S_f \cdot C_s \cdot C_v \cdot C_T \cdot d \cdot \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{0.5} \frac{v}{\sqrt{K_1 \cdot g \cdot d}} \right]^{2.5} = 400 \cdot mm$$

5.0 Riprap sizing (D50)

$$D_{50} := 1.25 \cdot D_{30} = 500 \cdot mm$$

6.0 Select Appropriate Alberta Transportation Riprap Class

$D_{30} = 400 \cdot mm$

$D_{50} = 500 \cdot mm$

From Figure 3, the Alberta Transportation Class 2 Riprap has a D50 of 500 mm and D100 of 800 mm which matched the required D50 of 500 mm and therefore appropriate for this application.

Assume riprap layer thickness of larger of 2X D50 or D100, which in this case 1600 mm (2 x D50)

		CLASS			
		1M	1	2	3
Nominal Mass (kg) **Nominal Diameter (mm)**		**7** **175**	**40** **300**	**200** **500**	**700** **800**
None greater than:	kg or mm	40 300	130 450	700 800	1800 1100
20% to 50%	kg or mm	10 200	70 350	300 600	1100 900
50% to 80%	kg or mm	7 175	40 300	200 500	700 800
100% greater than:	kg or mm	3 125	10 200	40 300	200 500

Figure 3. Alberta Transportation-Typical Rip Rap Gradations

APPENDIX F.8 – LOW LEVEL OUTLET WORKS

APPENDIX F.8-1 – OUTLET CHANNEL ARMOURING

LLOW Riprap Sizing
Exit Channel at CSU Basin

Springbank Off-Stream Storage Project (SR1)
Rocky View, Alberta, Canada
Government of Alberta - Transportation

PURPOSE

Determine the recommended riprap size for use in the CSU Basin exit channel to prevent erosion in the downstream natural channel.

CRITERIA

1. Use HEC-14, Section 10.3 Riprap Aprons After Energy Dissipators, to determine the median rock size required for riprap.

REFERENCE

1. FHWA (2006). Hydraulic Design of Energy Dissipators for Culverts and Channels. Hydraulic Engineering Circular No. 14 (HEC-14), 3rd Edition, July 2006. United States Department of Transportation (USDOT), Federal Highway Administration (FHWA).

DATA PROVIDED

Conditions at CSU Basin outlet.

Specific gravity of riprap: $S_g := 2.65$

Acceleration due to gravity: $g = 9.81 \frac{m}{s^2}$

Exit velocity: $V_b := 3.60 \frac{m}{s}$ (Based on tailwater depth; see CSU Basin calculations)

CALCULATIONS

Median rock size: $D_{50} := \frac{0.692}{S_g - 1} \cdot \left(\frac{V_b^2}{2g} \right) = 0.28\,m$ (Eqn 10.6, pg 10-19, HEC-14)

$D_{50} = 0.91 \cdot ft$

$D_{50} = 10.91 \cdot in$

The length of riprap protection will be based on the magnitude of the exit velocity compared to the natural channel velocity.

Low Level Outlet
Channel Lining Design Calculations

Springbank Off-Stream Reservoir Project
Alberta, Canada
Alberta Transportation Department

1. OBJECTIVE/PURPOSE

The objective of this calculation package is to size the appropriate riprap downstream of the low level outlet works.

2. CRITERIA

USACE EM 1110-2-1601 (1991) Method.

3. REFERENCES

1. USACE. (1991). Hydraulic Design of Flood Control Channels. EM 1110-2-1601, 1 July 1991. U.S. Army Corps of Engineers (USACE), Washington, D.C.

4. RIPRAP SIZING CALCULATIONS

4.1 Channel Design

The LLO discharge channel was sized for the design peak discharge of 27 cms based on the full reservoir condition. Although the Off-Stream Storage Dam toe ditch also drains into the LLO discharge channel, these flows would not likely combine during a major storm event as it would be anticipated that the LLO gates would be closed while the runoff from the toe ditch drained into the LLO discharge channel.

Manning's n value selected as 0.035 for Class 2 (Zone 6B) riprap.

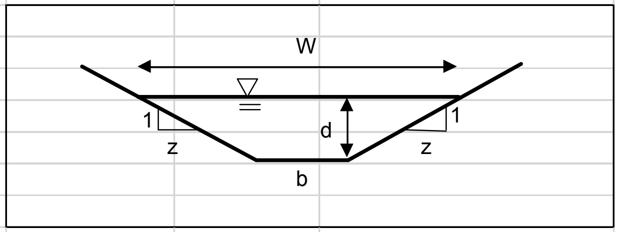
Normal depth has been assumed for design.

Drainage Ditch - Channel Capacity & Depth Calculations

Channel Section	1			
1. Uniform (Symmetrical) Trapezoidal Section				
Input Data:				
Manning's "n" value	0.035			
Longitudinal Slope - S_o	0.020	ft/ft		
Design Discharge - Q	953.4	ft^3/s - cfs		
	27.00	**m^3/s - cms**		
Channel Geometry Data:				
Bottom Width(s)				
b_1 or b	32.8	feet	**10.00**	**m**
Side Slope(s)				
z_1 or z	3.0	z H:1V		
plot				
Calculated Depth - d	**2.45**	feet	**0.748**	**m**
Calculated Top Width - W	**47.52**	feet	**14.49**	**m**
Calculated Area - A	98.51	ft^2		
Calc. Wetted Perimeter - Wp	48.31	feet		
Calc. Hydr. Radius - R	2.04	feet		
Calculated Discharge - Q'	953.64	ft^3/s - cfs		
Convergence	0.24	ft^3/s - cfs		
Calculated Velocity	**9.68**	ft / s	2.951	
Calculated Shear Stress - τ_d	**3.06**	lb / ft^2		

Update Geometry

Channel Sketch



Governing Geometry Equations

$$W = b + 2dz$$

$$A = bd + zd^2$$

$$W_P = b + 2d\sqrt{z^2 + 1}$$

Solve for Correct Depth & Update Calculations GO!

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$

$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$

Note: The Mannings "n" value was referenced from "Open Channel Hydraulics" by Ven Te Chow, PhD. Table 5-6 lists a Manning's "n" value of 0.027 for an excavated or dredged channel - "with short grass, few weeds."

4.2 Calculations

Using Equation 3-3 of USACE (1994):

$$D_{30} = S_f C_S C_V C_T d \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{1/2} \frac{V}{\sqrt{K_1 g d}} \right]^{2.5}$$

Where

Safety Factor: $S_f := 1.3$

Stability coefficient for incipient failure: $C_S := 0.3$ (Angular rock)

Vertical velocity distribution coefficient: $C_V := 1$ (For straight channels)

Thickness coefficient: $C_T := 1$ [For thickness 1D100(max) or 1.5D50(max)]

Velocity: $v := 2.9 \frac{m}{s}$

Local depth of flow: $d := .75m$

Unit weight of water: $\gamma_w := 1000 \frac{kg}{m^3}$

Unit weight of stone: $\gamma_s := 2643 \frac{kg}{m^3}$

Side slope correction factor:

Currently the riprap apron is not anticipated to have a significant side slope. However, final grading of the area may include partial side slopes. Therefore, an 18.435 degree angle of the side slope has been included to account for any potential side slope which may result from final grading of the channel.

Angle of side slope with horizontal: $\theta := 18.435°$

Angle of repose of riprap material: $\varphi := 35°$

Side slope correction factor: $K_1 := \sqrt{1 - \frac{(\sin(\theta))^2}{(\sin(\varphi))^2}} = 0.83$

Gravitational Constant: $g = 9.81 \frac{m}{s^2}$

4.2.1 Riprap sizing (D30)

$$D_{30} := S_f \cdot C_s \cdot C_v \cdot C_T \cdot d \cdot \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{0.5} \frac{v}{\sqrt{K_1 \cdot g \cdot d}} \right]^{2.5} = 233 \cdot mm$$

5.0 Riprap sizing (D50)

$$D_{50} := 1.25 \cdot D_{30} = 291 \cdot mm$$

6.0 Select Appropriate Alberta Transportation Riprap Class

$D_{30} = 233 \cdot mm$

$D_{50} = 291 \cdot mm$

From Figure 3, the Alberta Transportation Class 1 Riprap has a D50 of 300 mm and D100 of 450 mm which exceeds the required D50 of 291 mm and therefore is appropriate for this application.

Assume riprap layer thickness of the larger of 2 x D50 or D100, which in this case is 600 mm (2 x D50).

		CLASS			
		1M	**1**	**2**	**3**
Nominal Mass (kg)		**7**	**40**	**200**	**700**
Nominal Diameter (mm)		**175**	**300**	**500**	**800**
None greater than:	kg or mm	40 300	130 450	700 800	1800 1100
20% to 50%	kg or mm	10 200	70 350	300 600	1100 900
50% to 80%	kg or mm	7 175	40 300	200 500	700 800
100% greater than:	kg or mm	3 125	10 200	40 300	200 500

Figure 3 - Alberta Transportation Typical Riprap Gradations

APPENDIX F.8-2 – LLO OUTLET CHANNEL SCOUR PROTECTION

Net Potential Scour and Riprap Size Calculations for Floodplain Berm Armouring and Head-Cut Prevention

Springbank Off-Stream Storage Project

Alberta, Canada

Alberta Transportation Department

1. OBJECTIVE/PURPOSE

The objectives of this calculation package are to assess the net potential scour at the end of the Low level outlet works discharge channel.

Computations include calculations of riprap size for nested riprap to serve as head-cut prevention. launching

2. CRITERIA

- Use scour equations that are relevant to mobile bed gravel and cobble rivers.

3. REFERENCES

Lacey, G, 1930. Stable Channels in Alluvium. *Proceedings of the Institution of Civil Engineers,* 229: 259-292.

Blench, T, 1969. *Mobile-bed Fluviology.* Edmonton: The University of Alberta Press.

National Engineering Handbook, 2007, *Technical Supplement 14B, (*Pemberton and Lara equations)

U.S Department of the Interior, 1984. *Computing Degradation and Local Scour, Technical Guideline for Bureau of Reclamation*

Neill, C.R., Kellerhalls, R. and D.I. Bray, 1972. "Hydraulic and Geomorphic Characteristics of Rivers in Alberta." River Engineering and Surface Hydrology Report 72-1, Research Council of Alberta.

Hudson, R. Henry, "Hydrology and Sediment Transport in the Elbow River Basin SW Alberta", University of Alberta 1983.

National Engineering Handbook, 2007, *Technical Supplement 14C "Stone Sizing Criteria"*

3. ASSESSMENT BASIS

3.1 Hydraulic Parameters

The LLO discharge channel was sized for the design peak discharge of 27 cms based on the full reservoir condition. Although the Off-Stream Storage Dam toe ditch also drains into the LLO discharge channel, these flows would not likely combine during a major storm event as it would be anticipated that the LLO gates would be closed while the runoff from the toe ditch drained into the LLO discharge channel.

Manning's n value selected as 0.033 for Class 1M riprap. The proposed riprap lining will only extend to Station 30+500.

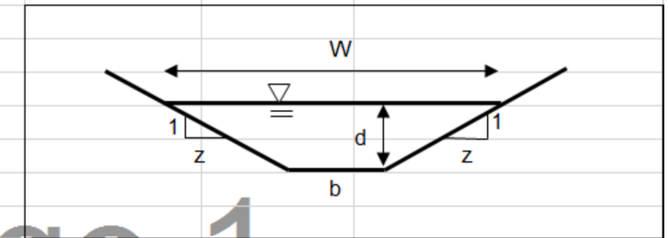
Normal depth has been assumed for design. Hydraulic Parameters are shown below.

Drainage Ditch - Channel Capacity & Depth Calculations

Channel Section	1			
1. Uniform (Symmetrical) Trapezoidal Section				
Input Data:				
Manning's "n" value	0.033			
Longitudinal Slope - S_o	0.005	ft/ft		
Design Discharge - Q	953.4	ft^3/s - cfs		
	27.00	m^3/s - cms		
Channel Geometry Data:				
Bottom Width(s)				
b_1 or b	17.7	feet	5.40	m
Side Slope(s)				
z_1 or z	3.0	z H:1V		
plot				
Calculated Depth - d	4.53	feet	1.381	m
Calculated Top Width - W	44.88	feet	13.68	m
Calculated Area - A	141.74	ft^2		
Calc. Wetted Perimeter - Wp	46.35	feet		
Calc. Hydr. Radius - R	3.06	feet		
Calculated Discharge - Q'	953.44	ft^3/s - cfs		
Convergence	0.04	ft^3/s - cfs		
Calculated Velocity	6.73	ft / s	2.05	
Calculated Shear Stress - τ_d	1.41	lb / ft^2		

Update Geometry

Channel Sketch



Governing Geometry Equations

$$W = b + 2dz$$

$$A = bd + zd^2$$

$$W_p = b + 2d\sqrt{z^2 + 1}$$

Solve for Correct Depth & Update Calculations GO!

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S_o^{\frac{1}{2}} \qquad R = \frac{A}{W_p}$$

$$\tau_d = \gamma d S \qquad V = \frac{Q}{A}$$

3.2 Channel Properties Use for Assessment

3.2.1 Grain of Alluvial Material in Floodplain

A D_{50} of 40 mm was used for all computations. This is the smallest D_{50} for floodplain alluvial gravels in the Elbow River obtained from: Stantec's site investigations of River Bed substrate: D_{50}=50mm, and in basin specific available literature (Hudson 1983: D_{50} = 64 mm, Kellerhalls 1972: D_{50} = 41 mm).

3.2.2 Channel Slope and Width

A channel slope of 0.005 m/m was used for all computation in accordance with the project's channel design slope from the LLO.

A bank full width of 13.68 m as determined through normal depth calculations.

3.2.3 Regime Channel Discharge

Using the normal depth calculations, an estimate of flow in the regime channel was made for the design event. The design flow is 27 cms per the design discharge of the LLO structure.

4. Net Potential Scour Methods and Parameters

The methods described herein refer to factors applied to estimate local scour from general scour using their respective methods. The suite of available factors is provided in Table 1 for reference in this section.

Table 1: Local Scour Factors Applied to General Net Potential Scour

Reach Descriptors	Z Factors for Max Original Blench and Lacey Equations (Method 1 and 2)	US Bureau of Reclamation Factors for Lacey Equation	US Bureau of Reclamation Factors for Blench Equation	Z Factors for Pemberton and Lara adjusted Equations
Moderate Bend	1.50	0.50	0.6	1.50

In addition, reference is made to channel reach factors. In this application all applied factors are for a moderate bend as shown in Table 2.

4.1 Original Lacey (Method 1)

The Lacey equation (Lacey, 1930) calculates the regime (mean) potential scour depth from the water surface during a flood event. In order to predict the maximum local scour an adjustment factor (Z-factor) is applied. The factor applied is dependent on the reach geometry (straight or bend). In order to calculate the potential scour depth below the channel, the depth of water is then subtracted from the regime or maximum scour depth.

$$d_m = 0.47 * (\frac{Q}{f})^{1/3}$$

$$f = 1.76 * {D_m}^{1/2}$$

d_m = Mean depth at design discharge = 0.63 m

Q = Design discharge = 27 m^3/s

f = Lacey's silt factor

D_m = mean grain size of bed material = 40 mm

In order to predict the maximum local scour an adjustment factor (Z-factor) is applied (Table 1). In order to calculate the general potential scour depth below the channel invert, the depth of water (1.38 m) is then subtracted from the regime or maximum scour depth. The factor applied is dependent on the reach geometry (straight or bend). Here, a factor of 1.5 is applied to the general scour estimate of 0.63 m for a total net potential scour of 0.95 m suggesting aggradation could occur.

4.2 Original Blench (Method 2)

The Blench equation was developed based on gravel bed rivers in Alberta and, like the Lacey method, calculates the regime (mean) potential scour depth from the water surface during a flood event.

$$d_{fo} = \frac{{q_f}^{\frac{2}{3}}}{{F_{bo}}^{1/3}}$$

d_{fo} = Depth for zero bed sediment transport

q_f = Design flood discharge per unit width = 5 m^2/s (27 m^3/s / 13.68 m)

F_{bo} = Blench's "zero bed factor" from figure in document (for C = 1.0) = 1.35

The design flood water depth (1.38 m) is then subtracted from the depth for zero bed sediment transport (1.42m) to produce the general net potential scour of 0.04 m. Maximum local scour is added by multiplying an adjustment factor (Z-factor of 1.5 for moderate bend) (Table 1) to the general scour estimate of 0.04m for a total net potential scour estimate of 0.06 m.

4.3 USBR (Method 3)

The USBR method takes the regime scour depth as calculated by the Lacey and Blench equations and applies different adjustment factors to each to produce general potential scour computed from the channel invert downwards.

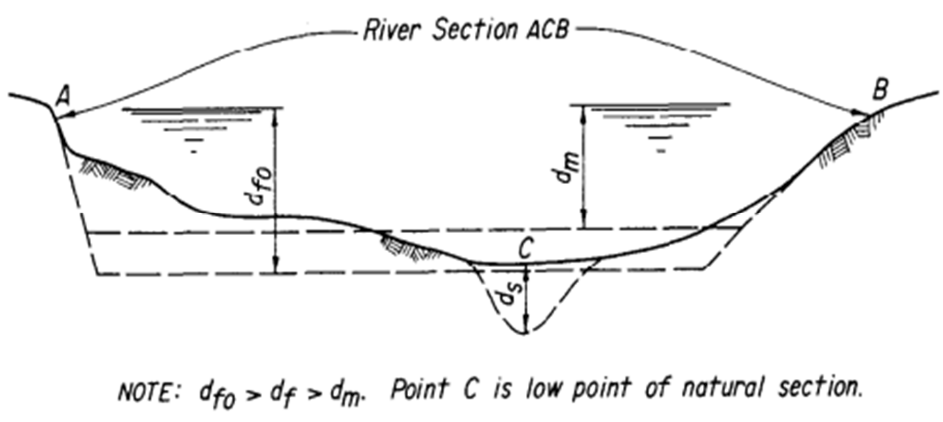
USBR Lacey $d_S = Z * d_m$ = 0.5*0.63 m = 0.32 m where Z = 0.5

USBR Blench $d_S = Z * d_{fo}$ = 0.6*1.42 m = 0.85 m where Z = 0.6

USBR Mean Depth = $d * Z_L$ d = mean depth of flow = 1.38 m, Z_L = 0.5 = 0.69 m

The results of these three equations are then averaged to provide a computed net potential scour depth of = 0.62 m

1/ Z value selected by USBR for use on bends in river.



NOTE: $d_{fo} > d_f > d_m$. Point C is low point of natural section.

Figure 10. - Sketch of natural channel scour by regime method.

4.4 Pemberton and Lara (Method 4)

Pemberton and Lara modified the Lacey and Blench equations to measure potential scour from the thalweg elevation using different adjustment factors to the USBR. These factors are built into the modified equations as exponents.

$$z_t = K * Q_d^a * W_f^b * D_{50}{}^c$$

z_t = maximum scour depth at the cross-section or reach (m)

K = coefficient

Q_d = design discharge = 27 m^3/s

W_f = flow width at design discharge = 13.68 m

D_{50} = median stone diameter (mm) = 40 mm

a,b,c = exponents shown in Table 2.

Table 2: Coefficients and Exponents for Pemberton and Lara Method 4

	Lacey				Blench			
	K	a	b	c	K	a	b	c
Moderate Bend	0.059	1/3	0	-1/6	0.162	2/3	-2/3	-0.1092

Pemberton and Lara's method for Lacey and Blench equations computes net potential scour at 0.10 m and 0.14 m respectively.

5. Summary of Net Potential Scour Results and Recommendation

A summary of the results from the various scour equations is provided in Table 3.

Table 3: Summary of Net Potential Scour Results

Net Potential Scour Assessment Method	
1.Original Lacey	-1.13 m
2.Original Blench	1.91 m
3.USBR	0.62 m
4.Pemberton and Lara	0.0.10 m Lacey and 0.14 Blench

It is very common for the results from these methods to vary and all results are presented for information. Selection of a result to use in design often comes to the strengths and weaknesses of the various methods, and the given application. In review of the results we recommend the design should account for up to 2.5 m of net potential scour below the transposed thalweg, should bedrock not be encountered

6. Riprap Sizing for Berm Armour Methods and Parameters

Riprap sizing was determined using the methods summarized in the National Engineering Handbook Technical Specification 14C.

6.1 USACE Maynord Method (TS14C-5)

$$D_{30} = FS * C_s * C_v * C_T * d * [\left(\frac{\gamma_w}{\gamma_s - \gamma_w}\right)^{0.5} * \frac{V}{\sqrt{K_1 * g * d}}]^{2.5}$$

$$D_{50} = D_{30} * 1.15$$

D_{30} = stone size in ft; m percent finer by weight

D_{50} = stone size in ft; m percent finer by weight

d = water depth (ft) = 5 m or 16.4 ft

FS = Factor of safety = 1.2

C_s = stability coefficient = 0.3

C_V = velocity distribution coefficient =1.26 for bend

C_T = thickness coefficient = 1.0

γ_s = stone density (lb/ft^3) = 165 lb/ft^3

γ_w = water density (lb/ft^3) = 62.4 lb/ft^3

V = local velocity (ft/s) = 3.6 m/s or 11.81 ft/s

g = gravity = 32.2 ft/s^2

$K_1 = \sqrt{1 - (\,sin^2\theta \;/\; sin^2\emptyset)}$

θ = angle of rock from horizontal = 27^o (2H:1V side slope)

$\emptyset$ = angle of repose = 40^o

Result is a D_{50} of 0.54 m, suggesting a Class II riprap

6.2 ASCE Method (Isbash Method Modified for Bank Slope)

$$D_{50} = (\frac{6 * W}{\pi * \gamma_s})^{1/3}$$

$$W = \frac{0.000041 * G_s * V^6}{(G_s - 1)^3 * cos^3\theta}$$

θ = arctan(1/m) = arctan(1/2) = ← assume that launch profile will be at 2:1 and not berm design grade of 3:1 H:V

D_{50} = median stone diameter (ft)

W = weight of stone modified for bank slope (lbs) = 135 lb/ft^3

γ_s = stone density (lb/ft^3) = 165 lb/ft^3

V = velocity (ft/s) = 3.6 m or 11.81 ft/s

G_S = specific gravity of stone = 2.4

Result is a D_{50} of 0.35 m, suggesting a Class I riprap. It is our experience that this method underestimates required riprap size.

6.3 USBR Method

$$D_{50} = 0.0122 * V^{2.06}$$

D_{50} = median stone diameter (ft)

V = average channel velocity (ft/s) = 3.6 m or 11.81 ft/s

Result is a D_{50} of 0.60 m, suggesting a Class II riprap is required.

6.4 Isbash Method

$$Vc = C * \left(2 * g * \frac{\gamma_s - \gamma_w}{\gamma_w}\right)^{0.5} * (D_{50})^{0.5}$$

Vc = critical velocity (ft/s) = V *1.2 = 3 m/s*1.2 = 3.6 m/s or 11.81 ft/s

C = coefficient for turbulent flow = 0.86

g = gravity = 32.2 ft/s^2

γ_s = stone density (lb/ft^3) = 165 lb/ft^3

γ_w = water density (lb/ft^3) = 62.4 lb/ft^3

Result is a D_{50} of 1.78 ft = 0.54 m suggesting a riprap of Class 2.

7. Riprap Sizing for Berm Armour Results and Recommendations

A table summarizing the computed riprap sizes is above.

Table 4: Riprap Sizing for Berm Revetment and Apron

Method	**D_{50} of Stone**	**Riprap Type**
USACE Maynord Method	0.54 m	Rip Rap Class 2 (Zone 6C)
ASCE Method	0.35 m	Rip Rap Class 1 (Zone 6B)
USBR Method	0.60 m	Rip Rap Class 2 (Zone 6C)
Isbash	0.54 m	Rip Rap Class 2 (Zone 6C)

In review of the results from the various method. Class 3 riprap meeting AT standards for Heavy Rock riprap is recommended for the outlet of the discharge channel of the LLO armouring and its launching apron.

8. Riprap Sizing for Head-Cut Prevention

The Isbash method (National Engineering Handbook, Technical Supplement 14c, Eq. TS14C-1) was used to estimate the required riprap size for the head-cut prevention. The Isbash method was developed by dropping rock into moving water and measuring their travel and was deemed conservative in its application to sizing the rocks for the head-cut prevention over weir crest rock sizing and similar equations.

$$Vc = C * \left(2 * g * \frac{\gamma_s - \gamma_w}{\gamma_w}\right)^{0.5} * (D_{50})^{0.5}$$

Vc = critical velocity (ft/s) = V *1.2 = 2.05 m/s*1.2 = 2.46 m/s or 8.07 ft/s

C = 0.86 coefficient for turbulent flow

g = gravity (32.2 ft/s^2) – 9.81 m/s^2

γ_s = stone density (lb/ft^3) -165 lb/ft^3 - equation assembly converted to SG of 2.4

γ_w = water density (lb/ft^3) – 62.4 lb/ft^3 - equation assembly converted to SG of 1

The proposed head-cut prevention is nested riprap and the computed velocity over that riprap when launched and assumed velocity of 3 m/s estimated by the model as for floodplain flow at this location with consideration for avulsion. The computations for 2 m/s and 4 m/s were also considered for information and result in a riprap size with a D_{50} between 0.64 m and 1.13 m. Table 4 identifies the results from varying the velocity and suggests a Class III riprap is appropriate. As information a velocity of 3.36 m/s is the threshold estimated by the Isbash method for which Class III riprap may mobilize in free flow.

Table 4: Riprap Size for Head-Cut Prevention with Varying Velocity

Velocity Estimate	D_{50} of Stone	Comment
2.05 m/s	0.527 m	Approximate Type 2 Rip Rap Class 2 (Zone 6C)
3.36 m/s	0.80 m	D_{50} of Class 3 Riprap

Rip Rap Gradation Information

		Zone 6A	Zone 6B	Zone 6C	Zone 6D
Nominal Mass (kg)		**7**	**40**	**200**	**700**
Nominal Diameter (mm)		**175**	**300**	**500**	**800**
None greater than:	kg or mm	40 300	130 450	700 800	1800 1100
20% to 50%	kg or mm	10 200	70 350	300 600	1100 900
50% to 80%	kg or mm	7 175	40 300	200 500	700 800
100% greater than:	kg or mm	3 125	10 200	40 300	200 500

APPENDIX F.9 – ROADWAY AND BRIDGE DESIGN

APPENDIX F.9.1 – HIGHWAY 22 AND SPRINGBANK ROAD REPORT

Springbank Off-Stream Reservoir Project (SR1) - Highway 22 and Springbank Road Preliminary Report

Final Report

Prepared for:
Alberta Transportation

Prepared by:
Stantec Consulting Ltd.

September 15, 2017

Revision	Description	Author		Quality Check		Independent Review	
0	Draft	DP	2017-02-03	RS	2017-02-08	RS	2017-02-08
0.1	Draft	DP	2017-03-24	RS	2017-03-24	RS	2017-03-24
0.2	Final	DP	2017-09-15	RS	2017-09-15	RS	2017-09-15

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Reviewed by ___________________________________
(signature)

Rhonda Shewchuk, P.Eng

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1.0 INTRODUCTION

1.1 BACKGROUND

In June 2013, parts of southern Alberta experienced a significant rainfall event that caused widespread flood damage in several communities along the Bow River, Elbow River and the Oldman River basins. In Calgary flooding necessitated the evacuation of over 75,000 residents and caused an estimated total damage to infrastructure at over $5 Billion.

Following the June 2013 floods, the Government of Alberta (GoA) initiated the Southern Alberta Flood Recovery Task force (SAFRTF) to evaluate stormwater management options and identify flood mitigation measures. Several strategies were developed and evaluated through this study including the Springbank Off-Stream Reservoir (SR1) located west of Calgary, approximately 20km upstream of the Glenmore Reservoir.

The SR1 Project consists of the construction and operation of an off-stream storage reservoir to divert portions of the Elbow River flow during an event and release the flow after the threat of flood has subsided.

The SR1 Project is to be designed to protect against a flood having a magnitude of at least the 2013 flood magnitude (TOR0015997). Flood mitigation operation is expected to occur for events both larger and smaller than the 2013 design event.

Operation of the SR1 Project will commence when the discharge in the Elbow River exceeds the capacity of the Glenmore Reservoir low level outlet (160 m^3/s). Flood diversion will continue until the off-stream reservoir is full or the discharge in the Elbow River falls below the 160 m^3/s threshold. The design flood diversion operation discharge is 480 m^3/s. The maximum diversion operation discharge is 600 m^3/s.

The threshold for operation (160 m^3/s) has a recurrence interval slightly more frequent than once every 10 years. Under planned operations, Springbank Road would begin to overtop for a flood event having a return interval of 1:50 years. The Full Service Level (El. 1210.75 m) has been set at the required diversion storage for the 2013 design event (approximately 1:200 year return interval). As a result, sections of Highway 22 and Springbank Road will be impacted.

The following plan illustrates the overall area of impact, which encompasses about 3.0 km of Hwy 22 from South of Hwy1 Interchange to North of Elbow River, together with the at-grade intersection at Springbank Road/TWP RD 244.

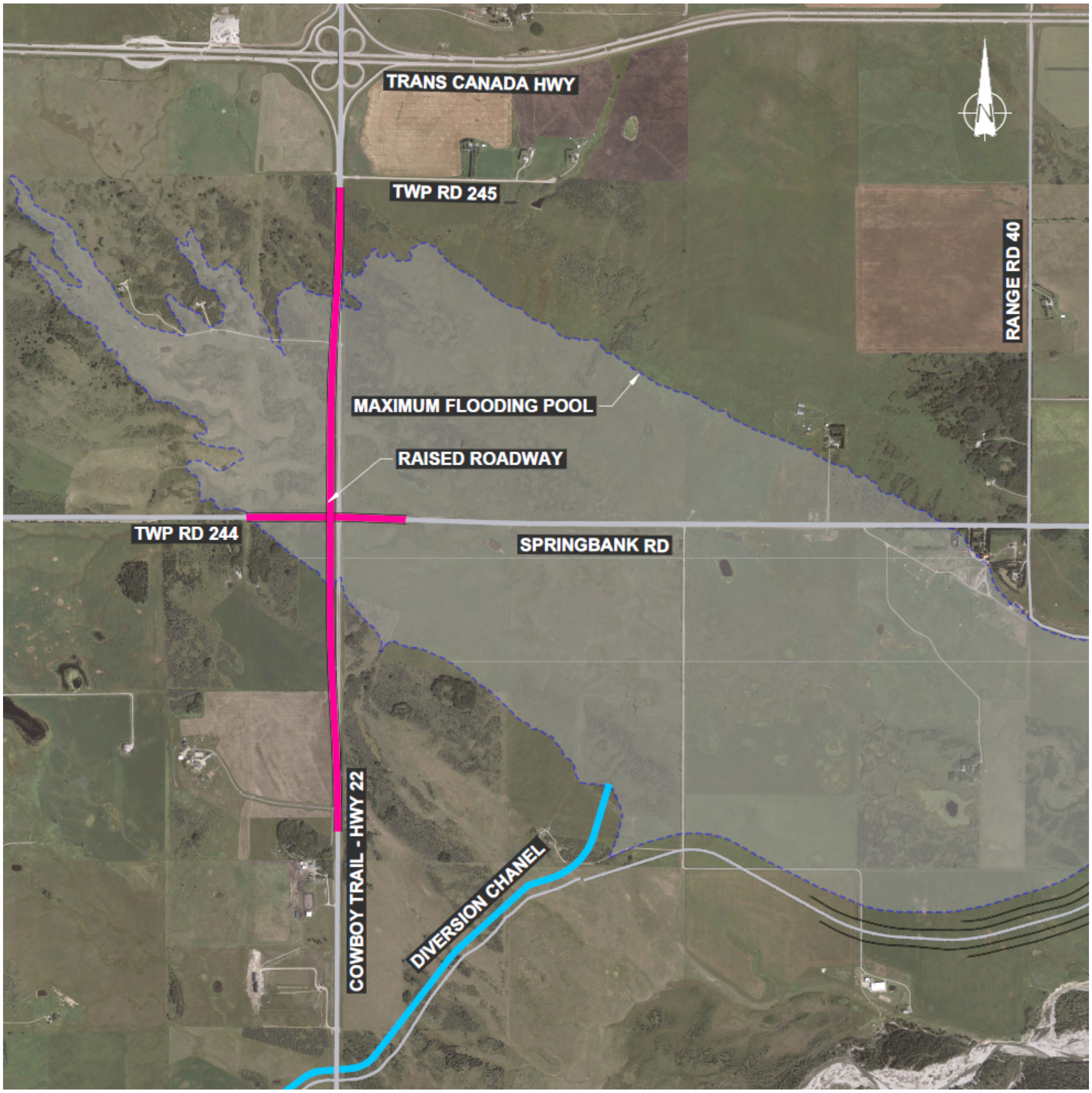


Figure A-1 Area of flood impact

2.0 EXISTING ROADWAYS

2.1 HIGHWAY 22

Highway 22, the "Cowboy Trail", is a key north/south arterial highway in the western part of the province that connects the communities of Black Diamond, Turner Valley, Priddis, Bragg Creek and Redwood Meadows west of Calgary. It is also a major truck route in Alberta connecting Highway 1, Highway 22X, Highway 8 and various other provincial highways.

Within the study area, Highway 22 is a two-lane undivided rural highway, the lane width are 3.7 m with 3.0 m shoulders. The posted speed limit along Highway 22 is 100 km/h.

2.2 SPRINGBANK Road/ Twp Rd 244

Springbank Road is an east/west roadway in Rocky View County (RVC) located south of Highway 1 that provides access to existing properties within the area. East of Highway 22, Springbank Road is a two-lane paved roadway and is identified as a Regional Collector. It has a posted speed of 80 km/h and functions as a parallel network to the provincial highway system allowing traffic to travel short distance trips without accessing Highway 1.

West of Highway 22, Twp Rd 244 functions as a two-lane gravel roadway, with a posted speed of 80km/h. The intersection of Highway 22 and Springbank Road/ Twp Rd 244 is a Type IVb configuration with a southbound left turn and northbound right turn.

3.0 RECOMMENDED PLAN

3.1 DESIGN CRITERIA

Hwy 22 ultimate classification as per Alberta Transportation classification is RAD-616.6-120, Springbank Road and Twp Rd 244 are County roads. The design criteria used to develop the preliminary design were based on:

-Alberta Transportation Highway Geometric Design Guide (1995-updated 1999)

-The Transportation Association of Canada (TAC) Geometric Design Guide for Canadian Roads-1999 edition

-Rocky View County Servicing Standards -2013 Edition

The following **Table 3-1 Design criteria table.** summarizes the minimum geometric standards used for preliminary design.

Description	Hwy 22:14	Springbank Road	TWP RD 244
Road Classification	Arterial(RAD-616.6-120 - ultimate configuration)	Regional Collector- MD of Rockyview	Regional Moderate Volume- MD of Rockyview
Design Speed; Horizontal (km/h)	120	90	90
Posted Speed (km/h)	100	80	80
Super Elevation (Max.) (%)	6.0	6.0	6.0
Min. Curve Radius	750	300	300
Max. Grade %	5.0	6.0	8.0
Min. Grade %	0	0.6	0.6
Desirable Decision Sight Distance (m)	360 - 470	280-360	280-360
Minimum Stopping Sight Distance	270	170	170
Crest Vertical Curves (Min.) (K)	130	55	55
Sag Vertical Curves (K)(Headlight Control)	70	40	40
Lane Width (m)	3.7	3.7	4.0
Right/Left Turn Lane Width (m)	3.5	N/A	N/A
Outside Shoulder Widths (Min.) (m)	3.0	0.8	0
Inside Shoulder Widths (Min.) (m)	2.5	0	0
Standard Median Width (m)	25.2	N/A	N/A
Median Type	Depressed	N/A	N/A
Ditch Width, m	4	2.5	0

Description	Hwy 22:14	Springbank Road	TWP RD 244
Fill Sideslope Ratio	6:1(up to 2.5m fill); 5:1(2.5m to 4.0m fill); 4:1(more than 4m fill); 3:1(guardrail protection)	4:1	3:1
Backslope Ratio (Maximum)	3:1	4:1	3:1
Backslope Ratio (Desirable)	5:1	4:1	3:1
Barrier Shy Distance	3.2	2.2	2.2
Design Vehicle	WB36	WB23	WB23

Table 3-1 Design criteria table

3.2 HIGHWAY 22 ROAD GEOMETRY

The proposed horizontal alignment of Hwy 22 follows the ultimate alignment of SB lanes for about 2 km, from about 1.5 km South of Springbank Road intersection to north of the intersection. The north section of the alignment transition from the ultimate SB lanes alignment and ties into existing road just South of the Highway 1 interchange. In order to keep the crowned section of the road, large radius curves of 8,000m were used for the alignment transition.

The vertical profile of the road was raised in Option 1 up to 12m above the existing road grade to accommodate the reservoir maximum elevation of 1210.75m and provide a minimum of 1m between the road top of subgrade and reservoir maximum elevation. In Option 2 a minimum of one meter is provided from the top of pavement to the maximum reservoir elevation. The recommended option is Option 1 which provides a better separation between the top of road and water levels in case of flooding.

The proposed cross section for the road is as per standard cross section for RAU-213.4-120 with one 3.7 m lane per direction and 3.0m shoulders which matches the existing road cross section. The subgrade and the pavement will have to be built wider initially to accommodate for two future overlays as per AT requirements. The east shoulder, which in the ultimate 6 lane highway configuration will be a future lane, will be built 3.7m wide to avoid any future longitudinal joints inside the lane; this applies just for the 2 km south section of road which follows the ultimate highway alignment. Most of the highway will be in fill; the sideslope will vary with the height of the embankment, but will be flatter than 4:1 to eliminate the need for guardrails. The north and south tie-ins will be built in cut sections with 4m ditches and flatter slopes.

It is anticipated that the traffic can be maintained on existing road during the construction of new road alignment. The east sideslope of the embankment will have to be built initially with a stepper slope in some areas and will be flattened to the standards after the traffic will be moved on new highway lanes.

3.3 SPRINGBANK ROAD GEOMETRY

Springbank road requires reconstruction for the section of the road approaching Hwy 22 intersection from the east. Hwy 22 and the intersection are raised about 6 m above the existing ground; therefore, about 400m of the road east of the intersection will require reconstruction. Springbank Road is classified accordingly to Rocky View County Servicing Standards as a Regional Collector paved road with 90km/h design speed and 80km/h posted speed.

The vertical profile matches Hwy 22 grade at proposed intersection and it is maintained at the highway grade for a short distance east of the intersection. The profile was designed to accommodate future twinning of Hwy 22 without having to reconstruct Springbank Road. Further to the east a relatively steep 4% grade is used to tie into existing road which will minimize the length of road being reconstructed and hence the construction costs.

The cross section as per County Servicing Standard is a 9.0m top road with 2x3.7m lanes and 2x0.8m shoulders.

Springbank Road will be completely closed for traffic during the reconstruction of the road. Traffic to and from Hwy 22 will be detoured on Range Road 40 and Township Road 250.

3.4 TOWNSHIP ROAD 244 GEOMETRY

West of Hwy 22 intersection the existing road is Twp Rd 244 which is classified as a Regional Moderate Volume gravel road with a design speed of 90 km/h and posted speed of 80 km/h. Due to the raise of the intersection, this road will be reconstructed for about 300m.

The profile was raised at the intersection to match Hwy 22 grade and will tie into the existing road to the west. A low point was created about 240m west of intersection which coincides with existing road low point.

The road is 8m wide with a gravel finished surface as per Rocky View County Servicing Standards.

3.5 HIGHWAY 22/SPRINGBANK ROAD INTERSECTION

The existing intersection was built in 2004 and it matches the configuration for a Type IVb intersection treatment as classified in AT Highway Geometric Design Guide with deceleration lane and taper for NB-EB right turn movement, acceleration taper for WB-NB right turn and a bypass lane for SB. The intersection has to be relocated along the new alignment of Hwy 22 and raised to match the raised grade of the road. The proposed configuration of the intersection will be similar with existing to meet the Type IVb configuration for 120km/h design speed. The existing intersection and AT type IVb standard intersection layout are presented at the end of the report.

3.6 STORMWATER DRAINAGE

The new alignment of the highway will be raised above the existing ground. No formal ditches will be provided along the highway alignment, the stormwater drainage will run overland along the toe of the road following the natural drain path. Culverts are provided at approximate same locations as existing to cross the highway from west to east and to bring the water south of Springbank Road.

There are several existing culverts along the existing Hwy 22 which will require replacement or modifications due to the change in horizontal and vertical geometry of the highway.

BF 9026 is located approximately 300 m north of the intersection of Highway 22 and Springbank Road at WSW 26-24-4-W5. This structure is located along a tributary to the Elbow River. The existing structure consists of a 3.35 m diameter SPCSP culvert with an invert length of 42 m and plate thickness of 3.0 mm. The recommended improvement strategy for the Highway 22 at this site is to raise Hwy 22 above the FSL in the location of the future southbound twinning lanes, west of existing Hwy 22. This improvement would increase the elevation of the existing Highway 22 at BF 9026 by approximately 8 m resulting in a height of cover over the existing culvert of approximately 10 m. Since the proposed height of cover exceed the maximum value for this type of structure, a new structure is recommended at this site. A 3.67 m diameter SPCSP is recommended based on the hydraulic assessment carried out.

The culvert at BF 943 is located approximately 300 m east of the intersection of Highway 22 and Springbank Road at SSW 26-24-4-W5. This structure is located approximately 900 m downstream of the BF 9026 proposed crossing along the tributary to the Elbow River. The existing structure consists of a 3.00 m in diameter CSP culvert with an invert length of 31 m, 125 mm x 26 mm corrugations and a wall thickness of 2.8 mm. The raised intersection would increase the elevation of the existing Springbank Road at BF 943 by approximately 4 m resulting in a height of cover over the existing culvert being approximately 5 m. Based on the corrugations and wall thickness of the existing structure, the existing culvert can be maintained. At the crossing, a culvert extension of 33 m will be required at this site based on 9.0 m roadway surface width and 4:1 sideslopes.

For the conceptual stormwater plan, a total culvert length of approximately 145 m will be required at 3 locations along Highway 22.

4.0 PAVEMENT DESIGN

This section provides the pavement analysis and design recommendations for the reconstruction of Highway 22 between Highway 8, and Highway 1.

Pavement design was completed using the American Association of State Highway and Transportation Officials (AASHTO) 1993 Design Method in accordance to Alberta Transportation's Pavement Design Manual, June 1997. Relevant traffic information was extracted from the report titled: "Springbank Off-Stream Reservoir Project (SR1) – Highway 22 and Springbank Road Planning Study – Draft Report", dated January 13, 2017 completed by Stantec Consulting Ltd.

4.1 TRAFFIC

4.1.1 Traffic Information

As noted above, traffic data was extracted from the Stantec report. Projected traffic volumes and vehicle composition information was provided in Section 1.0 of the aforementioned report. The daily volumes are presented in Table 4-1 below. Traffic growth rates were backcalculated between 2015 and 2030, and 2050 and 2030. It is understood that the highway may be twinned in the future, however the timeline is unspecified. For pavement design it was assumed that the highway will remain two lanes undivided for the design life of 20 years.

Table 4-1: Highway 22 - Daily Vehicle Volumes

Horizon	Two-Way Daily Volumes (VPD)
2015	12,140
2030	15,200
2050 – Scenario 1*	20,000
2050 – Scenario 2	22,000

*Note: Scenario 1 was not used, as Scenario 2 provided a conservative volume.

The vehicle composition is presented in Table 4-2 below.

Table 4-2: Highway 22 - Vehicle Composition

Vehicle Type	Composition (%)
Passenger Vehicle	81.8
Recreational Vehicle (RV)	1.9
Bus	1.3
Single Unit Trailer (SUT)	4.0
Tractor Trailer Combo (TTC)	11.0

4.1.2 Equivalent Single Axle Loads (ESALs)

The AASHTO 93 design method uses the Equivalent Single Axle Loads (ESALs) concept to determine the required structural capacity for the pavement. ESALs relate different configurations of axles and loads to a uniform 18-kip (80 kN) single axle load. Load Equivalency Factors (LEFs) are calculated based on average axles weights, and loads. Alberta Transportation standard LEFs have been used for the analysis and are presented in Table 4-3 below.

Table 4-3: Load Equivalency Factors

Vehicle Category	Load Equivalency Factor
Recreational Vehicle (RV)*	0.881
Bus	3.0
Single Unit Trailer (SUT)	0.881
Tractor Trailer Combo (TTC)	2.073

* RVs are categorized under Federal Highway Administration as Single Unit Trucks

The Alberta Transportation Pavement Design Manual indicates a design period of 20 years. ESALs were calculated for 2018 through 2038. The design ESAL was calculated to be 18,300,000.

4.2 SUBGRADE

It is understood that the elevation of Highway 22 will be raised to accommodate for the Springbank Off-Stream Reservoir. Hence subgrade information was not available at the time this document was prepared. It was assumed that an engineered fill material will be placed. A subgrade CBR of 3.0 was assumed.

4.3 PAVEMENT DESIGN

AASHTO 93 parameters used for pavement design were extracted from Alberta Transportations Pavement Design Manual, June 1997 and are presented in Table 4-4 below.

Table 4-4: AASHTO 93 Parameters

Parameter	Value
Design Life (Years)	20
Reliability	95%
Standard Deviation	0.45
Initial Serviceability	4.2
Terminal Serviceability	2.5
Subgrade Resilient Modulus (CBR)	3.0
Material Layer Coefficients Asphalt Concrete (ACP) Granular Base Course (GBC) Granular Subbase Course (GSBC)	 0.40 0.14 0.10
Drainage Coefficient	1.0

4.4 RECOMMENDATIONS

A Required Structural Number (SN_{REQ}) of 168.89 was calculated. Based on the required SN_{REQ}, the pavement structure presented in Table 4-5 below provides an SN of 171.0. Recommended lift thicknesses of the ACP, and material types are presented in the same table.

Table 4-5: Highway 22 - Recommended Pavement Structure

Material	Thickness (mm)
Asphalt Concrete	
H1 PG 64-34	50
H1 PG 64-34	60
H1 PG 64-34	70
H1 PG 64-34	70
Granular Base Course	
Des. 2 Class 25	150
Granular Subbase Course	
Des. 6 Class 80	500
Total Thickness	**900**

5.0 OPINION OF PROBABLE COST

A type 'B'Estimate is provided below for the two profile options. The estimated cost for Option 1 is **$15,883,000** and for Option 2 is **$15.527,000** and includes the construction, 10% contingency and engineering cost. It has been assumed that all property acquisition and utility impacts costs will be dealt with as part of the overall SR1 project. There are construction savings of $356,000 between Option 2 and 1, but Stantec's recommendation is Option 1 which can minimize any future maintenance and repair costs due to the potential of water saturating the subgrade and weakening the pavement structure in case of flooding.

The grading cost was estimated taking in consideration the earth available from the other components of SR1 project.

The pavement structure for Hwy 22 used for this estimate is 250mm ACP, 150mm GBC, 500mm GSBC as detailed in section **4. Pavement Design**. The assumed pavement structure for Springbank Road and TWR244 is based on Rocky View County Servicing Standards for each road classification, namely, 120mm ACP, 100mm GBC and 300mm GSBC for Springbank Road (Regional Collector) and 100mm GBC and 250mm GSBC for Twp Rd 244(Regional Moderate Volume).

TYPE 'B' ESTIMATE OPTION 1 (BASED ON ESTIMATED UNIT PRICES)

	Unit of Measure	Estimated Quantity	Unit Price Averages*	Estimated Unit Price	Estimated Cost (nearest 1000)
Existing Features					
Surface Removal	m2	55,400	$ 25.33	$ 25.00	$ 1,385,000
Grading					
Borrow Excavatioin - Contractor's Supply	m3	212,615	$ 31.91	$ 4.50	$ 957,000
Common Excavation	m3	265,600	$ 3.54	$ 5.50	$ 1,461,000
Topsoil Placement	m2	119,000	$ 0.84	$ 0.90	$ 107,000
Drill Seeding	hectares	12	$ 1,256.00	$ 1,260.00	$ 15,000
Surfacing					
Preparing Subgrade Surface (First Layer)	m2	78,000	$ 1.45	$ 1.00	$ 78,000
Supply of Aggregate - No Option	t	148,600	$ 1.18	$ 0.60	$ 89,000
Granular Base Course	t	23,600	$ 23.57	$ 24.00	$ 566,000
Granular SubBase Course	t	91,500	$ 20.63	$ 24.00	$ 2,196,000
Asphalt Concrete Pavement (EPS Mix Type H1)	t	33,500	$ 77.21	$ 65.00	$ 2,178,000
Drainage					
Bridge culvert at BF 9026	ls	1		$ 2,500,000.00	$ 2,500,000
Bridge culvert extension at BF 943	ls	1		$ 300,000.00	$ 300,000
New or existing culverts extension	ls	1		$ 200,000.00	$ 200,000
Subtotal					$ 12,032,000
Mobilization 10%)					$ 1,203,000
Subtotal - Construction (Contract Costs)					$ 13,235,000
Contingency (10%)					$ 1,324,000
Engineering (10%)					$ 1,324,000
		"B" ESTIMATE TOTAL			$ 15,883,000

* Unit Price Averages were based on Southern Region average unit prices(Aug 2016 to June 2017) where available and the Provincial Averages(Aug 2016 to June 2017) where no Region average exists

TYPE 'B' ESTIMATE OPTION 2 (BASED ON ESTIMATED UNIT PRICES)

	Unit of Measure	Estimated Quantity	Unit Price Averages*	Estimated Unit Price	Estimated Cost (nearest 1000)
Existing Features					
Surface Removal	m2	55,400	$ 25.33	$ 25.00	$ 1,385,000
Grading					
Borrow Excavatioin - Contractor's Supply	m3	151,629	$ 31.91	$ 4.50	$ 682,000
Common Excavation	m3	266,730	$ 3.54	$ 5.50	$ 1,467,000
Topsoil Placement	m2	119,000	$ 0.84	$ 0.90	$ 107,000
Drill Seeding	hectares	12	$ 1,256.00	$ 1,260.00	$ 15,000
Surfacing					
Preparing Subgrade Surface (First Layer)	m2	78,000	$ 1.45	$ 1.00	$ 78,000
Supply of Aggregate - No Option	t	148,600	$ 1.18	$ 0.60	$ 89,000
Granular Base Course	t	23,600	$ 23.57	$ 24.00	$ 566,000
Granular SubBase Course	t	91,500	$ 20.63	$ 24.00	$ 2,196,000
Asphalt Concrete Pavement (EPS Mix Type H1)	t	33,500	$ 77.21	$ 65.00	$ 2,178,000
Drainage					
Bridge culvert at BF 9026	ls	1		$ 2,500,000.00	$ 2,500,000
Bridge culvert extension at BF 943	ls	1		$ 300,000.00	$ 300,000
New or existing culverts extension	ls	1		$ 200,000.00	$ 200,000
Subtotal					$ 11,763,000
Mobilization 10%)					$ 1,176,000
Subtotal - Construction (Contract Costs)					$ 12,939,000
Contingency (10%)					$ 1,294,000
Engineering (10%)					$ 1,294,000
		"B" ESTIMATE TOTAL			$ 15,527,000

* Unit Price Averages were based on Southern Region average unit prices(Aug 2016 to June 2017) where available and the Provincial Averages(Aug 2016 to June 2017) where no Region average exists

Table 5-1 Type "B" Estimate Option 1 & 2

LEGEND

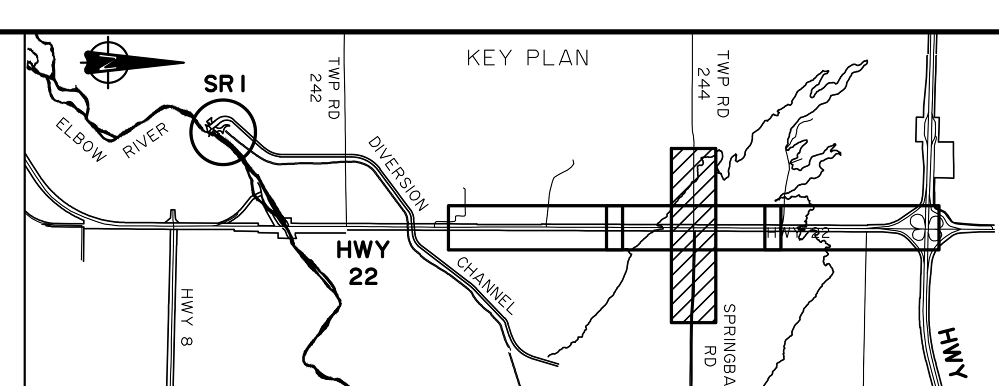
DRAINAGE FLOW DIRECTION

D PROPOSED DITCH

HORIZONTAL: 100m

VERTICAL: 5m

KEY PLAN



CONSULTANT

Stantec

200-325 25th Street SE
Calgary AB
www.stantec.com

JOB NO. 110773396

DESIGNER

CHECKER

DATE

REV	DATE	REVISION	BY
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Alberta Transportation

HWY 22:00 AND SPRINGBANK ROAD
PRELIMINARY DESIGN
PLAN PROFILE - SPRINGBANK RD/TWP 244
STA 53+000 TO STA 54+700

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
2017-05-01	SE27-24-4-5		12345	HWY 22:14	1 OF 7	Figure 1.1

DRAWING Figure 1.1

HIGHWAY HWY 22:14

CONTRACT 12345

DESCRIPTION HWY 22:00 AND SPRINGBANK ROAD PRELIMINARY DESIGN

PHOTO

DATE

BY

SURVEYED

DEPARTMENT BAR CODE

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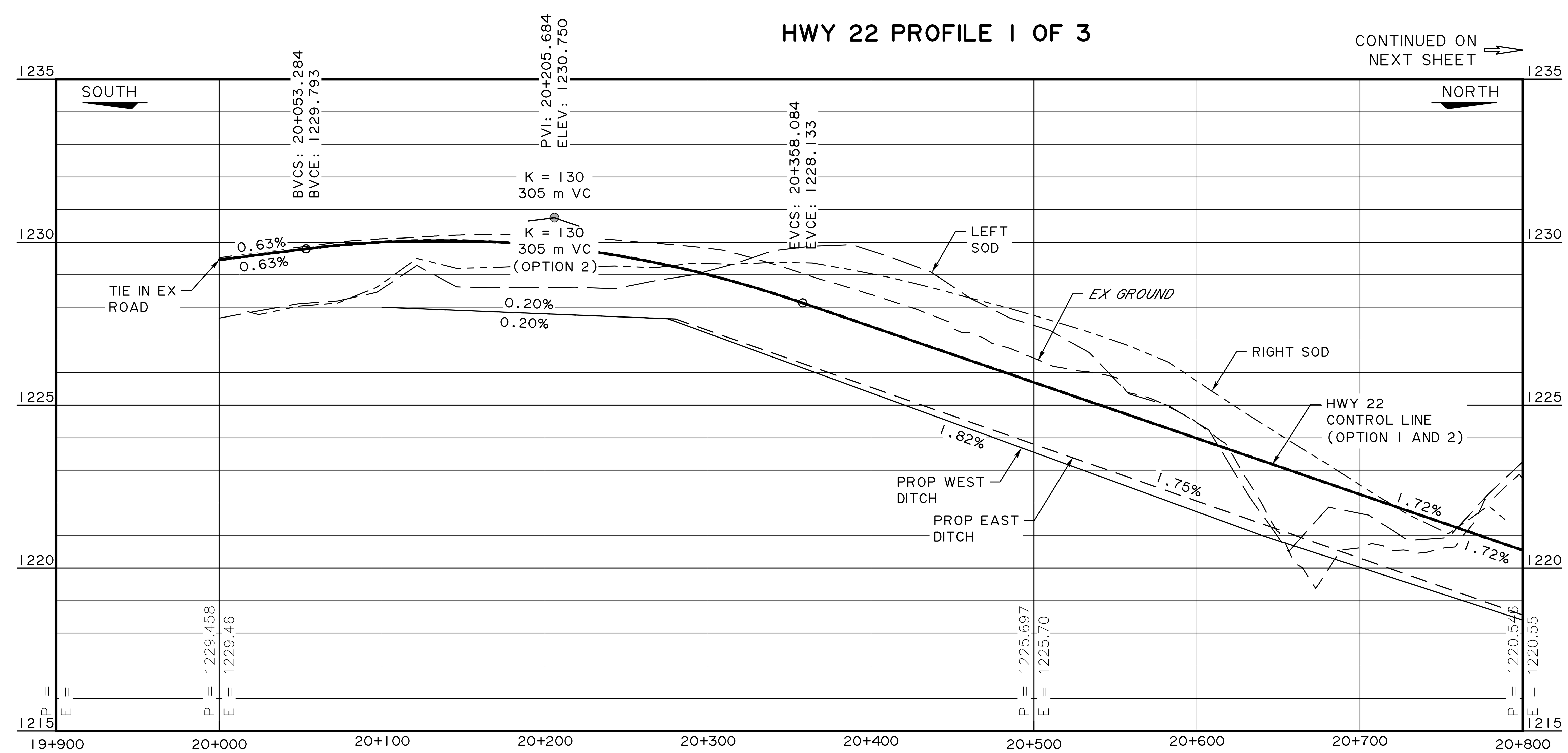
2017-06-14 9:21am By: mrusu

DRAWING Figure 1.2
HIGHWAY HWY 22:14
CONTRACT 12345
DESCRIPTION HWY 22:00 AND SPRINGBANK ROAD PRELIMINARY DESIGN
PHOTO
DATE
BY
SURVEYED
DEPARTMENT BAR CODE

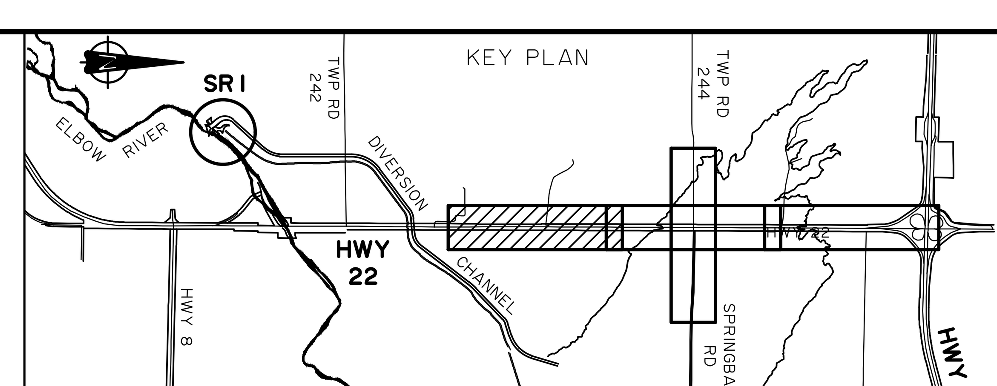
HWY 22 PROFILE 1 OF 3



LEGEND
DRAINAGE FLOW DIRECTION
D PROPOSED DITCH

HORIZONTAL: 100m
VERTICAL: 5m

KEY PLAN



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DESIGNER
DATE

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DATE

REV	DATE	REVISION	BY
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DATE	LOCATION	SITE
2017-05-01	SE22-24-4-5	

Alberta Transportation

HWY 22:00 AND SPRINGBANK ROAD
PRELIMINARY DESIGN
PLAN PROFILE - HWY 22
STA 19+900 TO STA 20+800

CONTRACT	HIGHWAY	SHEET	DRAWING
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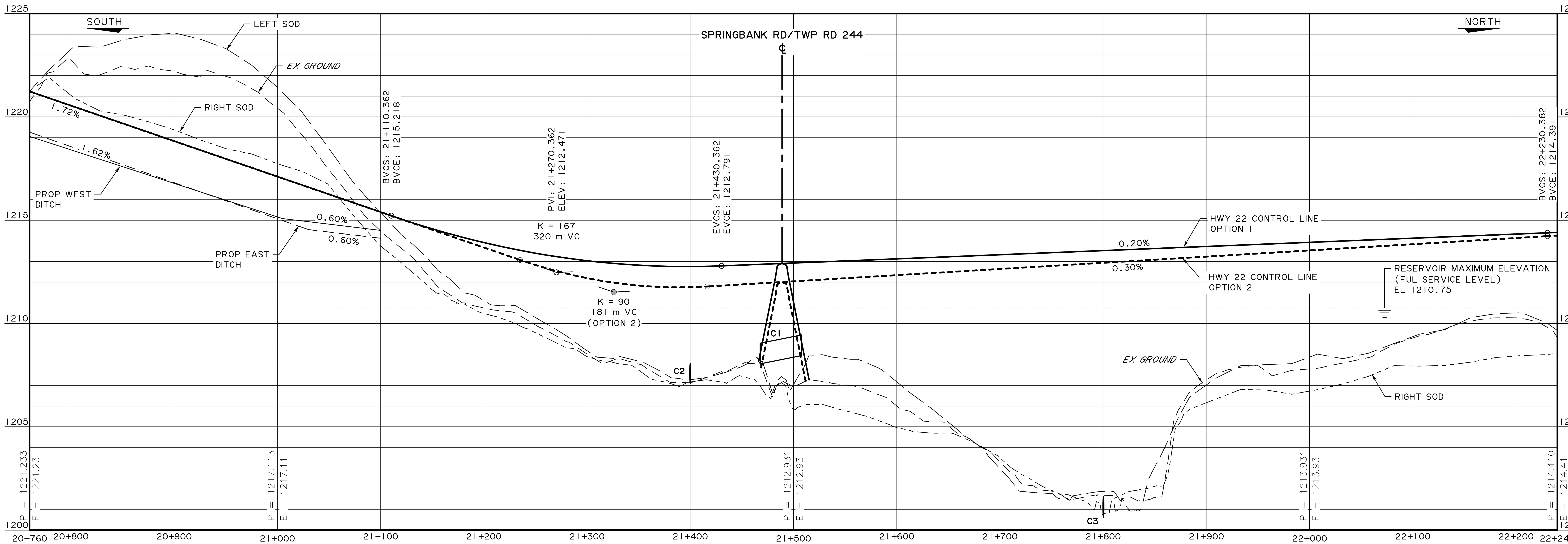
2017-06-14 9:21am By: mrusu

DRAWING: Figure 1.3
HIGHWAY: HWY 22:14
CONTRACT: 12345
DESCRIPTION: HWY 22:00 AND SPRINGBANK ROAD PRELIMINARY DESIGN

HWY 22 PROFILE 2 OF 3

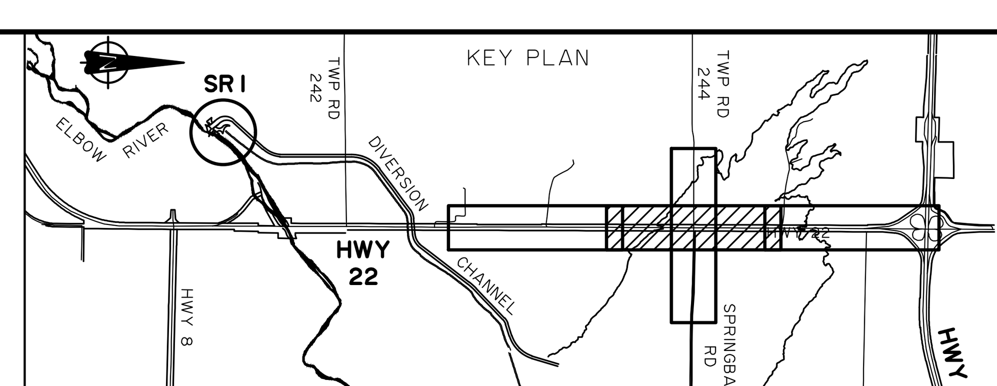
CONTINUED ON PREVIOUS SHEET
CONTINUED ON NEXT SHEET



LEGEND
- DRAINAGE FLOW DIRECTION
- D — PROPOSED DITCH

HORIZONTAL: 100m
VERTICAL: 5m

KEY PLAN



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DESIGNER
DATE

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Alberta Transportation

HWY 22:00 AND SPRINGBANK ROAD
PRELIMINARY DESIGN
PLAN PROFILE - HWY 22
STA 20+760 TO STA 22+240

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
2017-05-01	NE22-24-4-5		12345	HWY 22:14	3 OF 7	Figure 1.3

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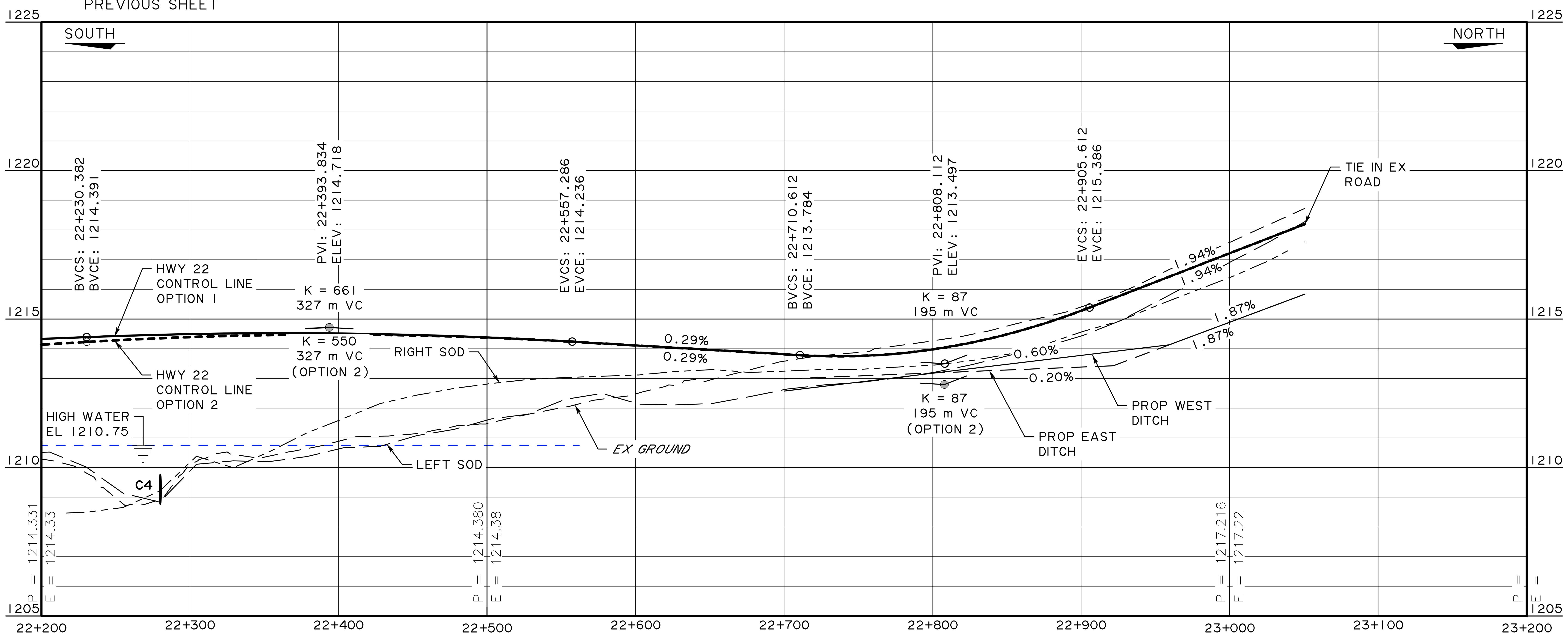
HWY 22 PROFILE 3 OF 3



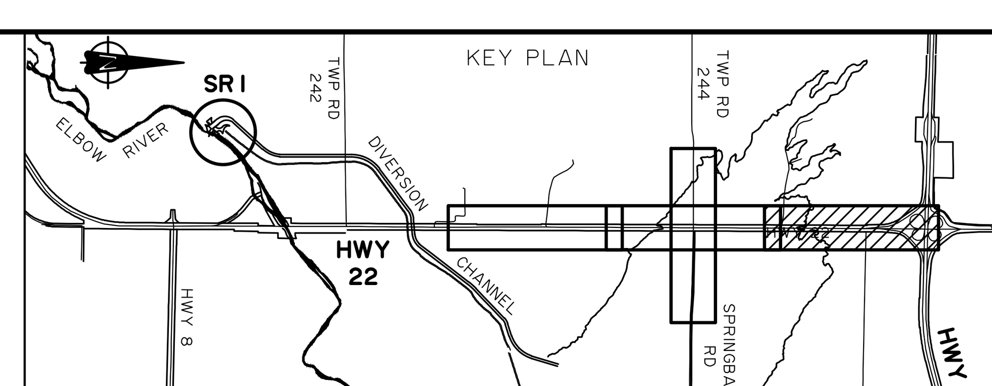
LEGEND

DRAINAGE FLOW DIRECTION

D — PROPOSED DITCH

HORIZONTAL: 100m
VERTICAL: 5m

KEY PLAN



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DESIGNER

DATE

CHECKER

DATE

REV	DATE	REVISION	BY
5			
4			
3			
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DATE	LOCATION	SITE
2017-05-01	NE27-24-4-5	

Alberta Transportation

HWY 22:00 AND SPRINGBANK ROAD
PRELIMINARY DESIGN
PLAN PROFILE – HWY 22
STA 22+200 TO STA23+300

CONTRACT	HIGHWAY	SHEET	DRAWING
12345	HWY 22:14	4 OF 7	Figure 1.4

DRAWING Figure 1.4
HIGHWAY HWY 22:14
CONTRACT 12345
DESCRIPTION HWY 22:00 AND SPRINGBANK ROAD PRELIMINARY DESIGN
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DATE
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DEPARTMENT BAR CODE

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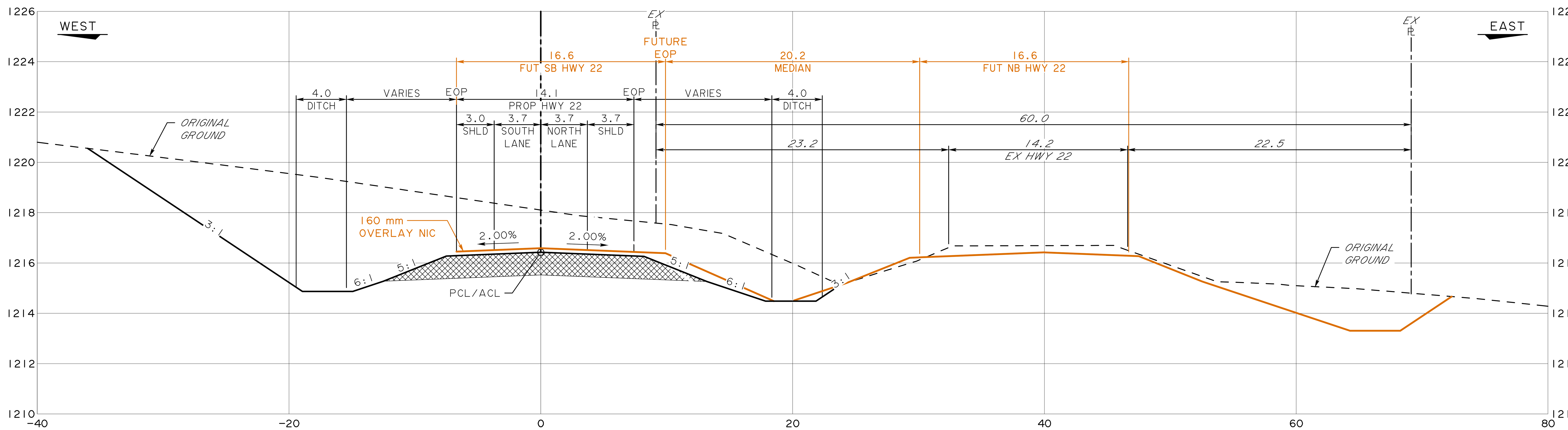
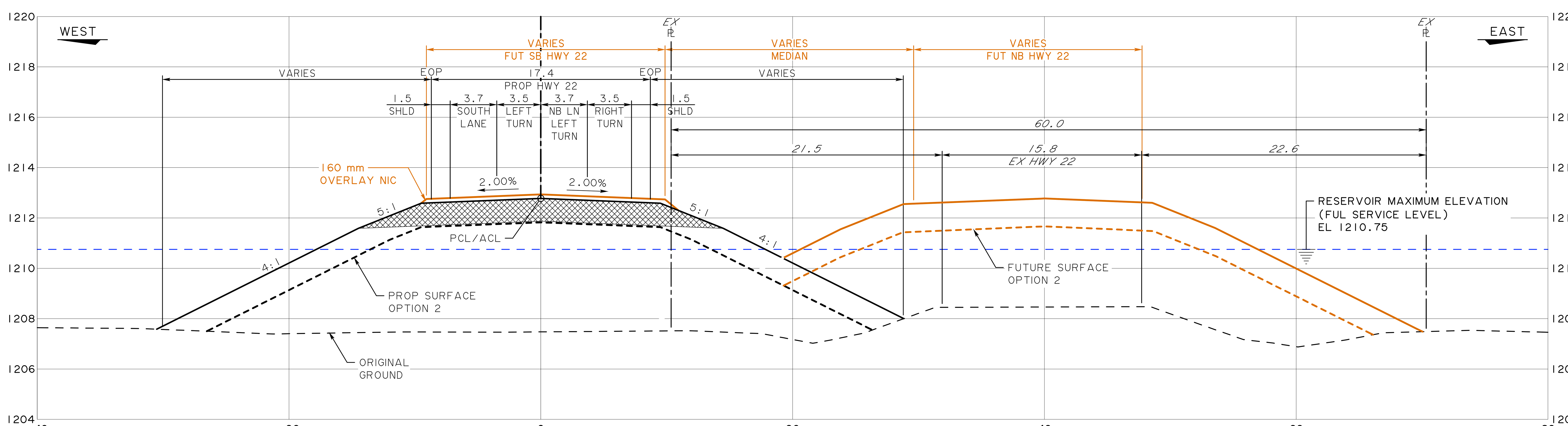


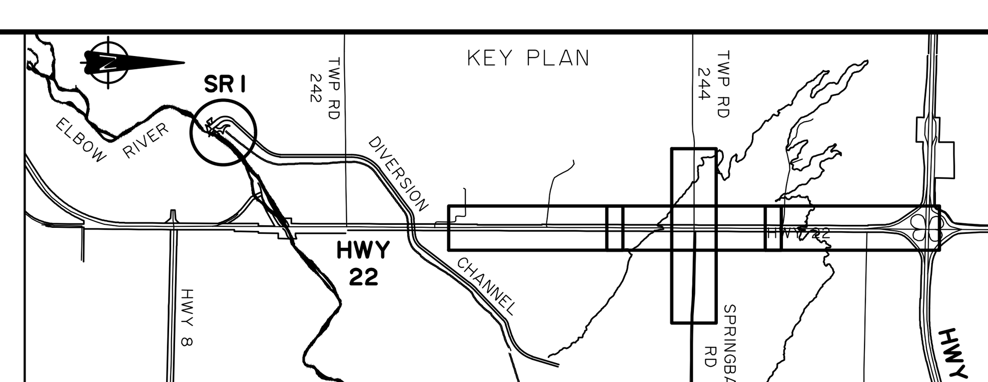
A HIGHWAY 22
1.3 STA 21+040
H 1:200
V 1:100



B HIGHWAY 22
1.3 STA 21+420
H 1:200
V 1:100

LEGEND

KEY PLAN



CONSULTANT

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JOB NO. 110773396

DESIGNER DATE

CHECKER DATE

REV	DATE	REVISION	BY
5			
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2			
1			

DATE	LOCATION	SITE
2017-05-01		

Alberta Transportation

HWY 22:00 AND SPRINGBANK ROAD PRELIMINARY DESIGN TYPICAL SECTIONS A AND B

CONTRACT	HIGHWAY	SHEET	DRAWING
12345	HWY 22:14	5 OF 7	Figure 2.1

DRAWING Figure 2.1
HIGHWAY HWY 22:14
CONTRACT 12345
DESCRIPTION HWY 22:00 AND SPRINGBANK ROAD PRELIMINARY DESIGN
PHOTO
DATE
BY
SURVEYED
DEPARTMENT BAR CODE

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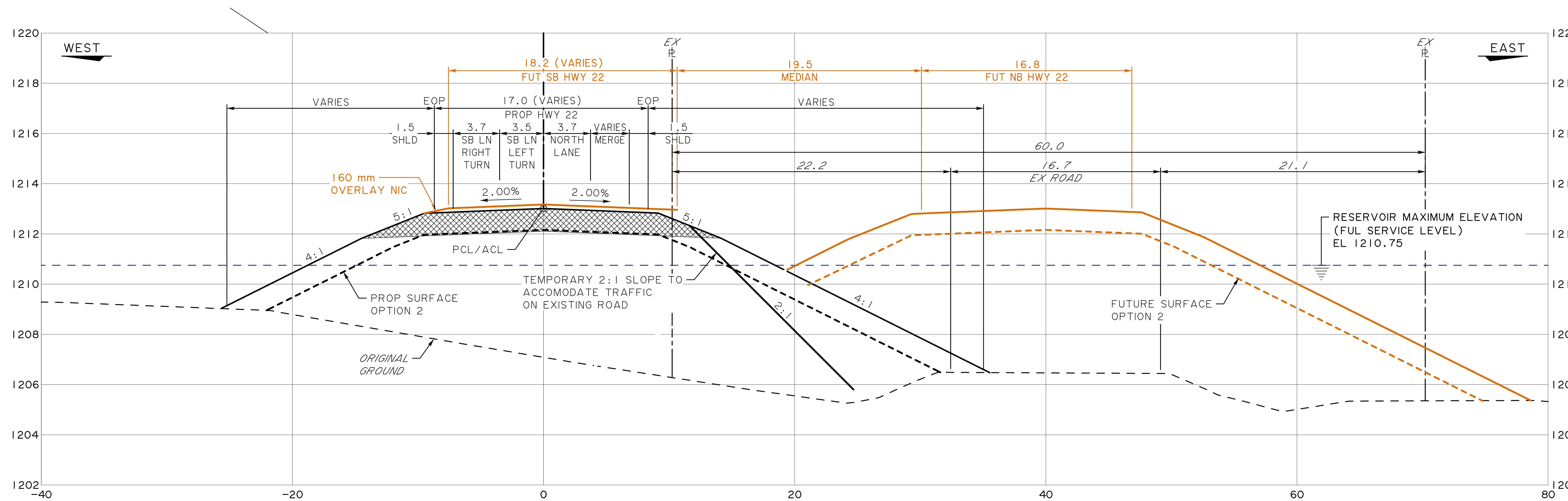
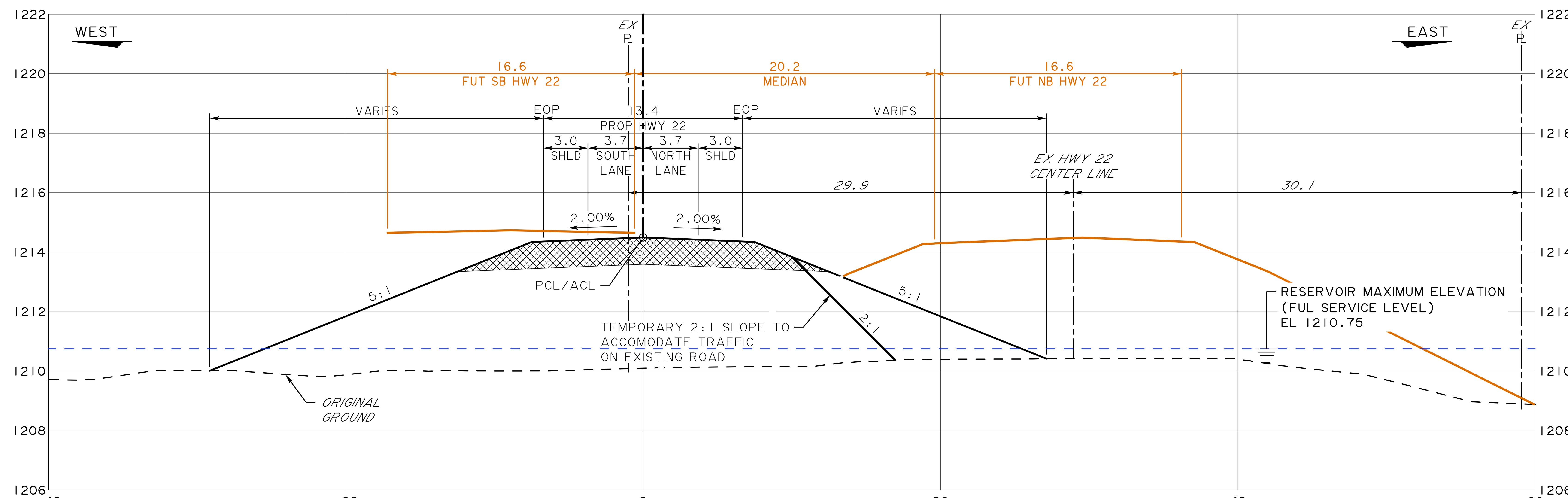
2017-06-14 9:22am By: mrusu



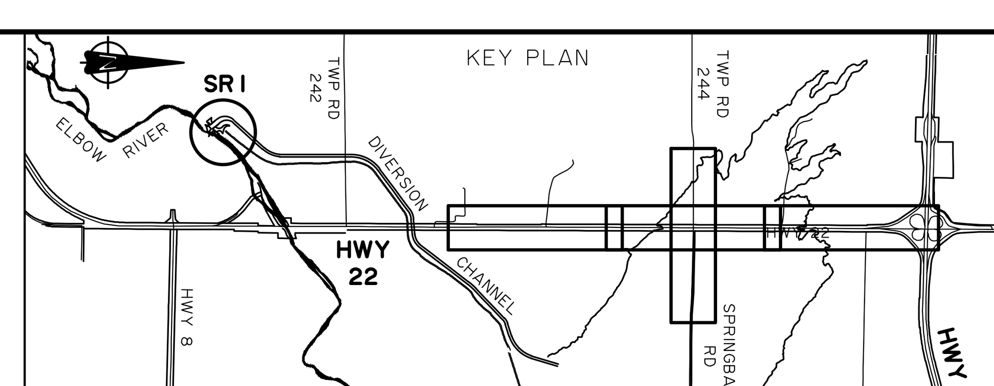
C 1.3 HIGHWAY 22
STA 21+540 H 1:200 V 1:100



D 1.4 HIGHWAY 22
STA 22+300 H 1:200 V 1:100

LEGEND

KEY PLAN



CONSULTANT

Stantec
200-325 25th Street SE
Calgary AB
www.stantec.com

JOB NO. 110773396

DESIGNER DATE

CHECKER DATE

REV	DATE	REVISION	BY
5			
4			
3			
2			
1			

DATE	LOCATION	SITE
2017-05-01		

Alberta Transportation

HWY 22:00 AND SPRINGBANK ROAD
PRELIMINARY DESIGN
TYPICAL SECTIONS
C AND D

CONTRACT	HIGHWAY	SHEET	DRAWING
12345	HWY 22:14	6 OF 7	Figure 2.2

DRAWING Figure 2.2
HIGHWAY HWY 22:14
CONTRACT 12345
DESCRIPTION HWY 22:00 AND SPRINGBANK ROAD PRELIMINARY DESIGN
PHOTO
DATE
BY
SURVEYED
DEPARTMENT BAR CODE

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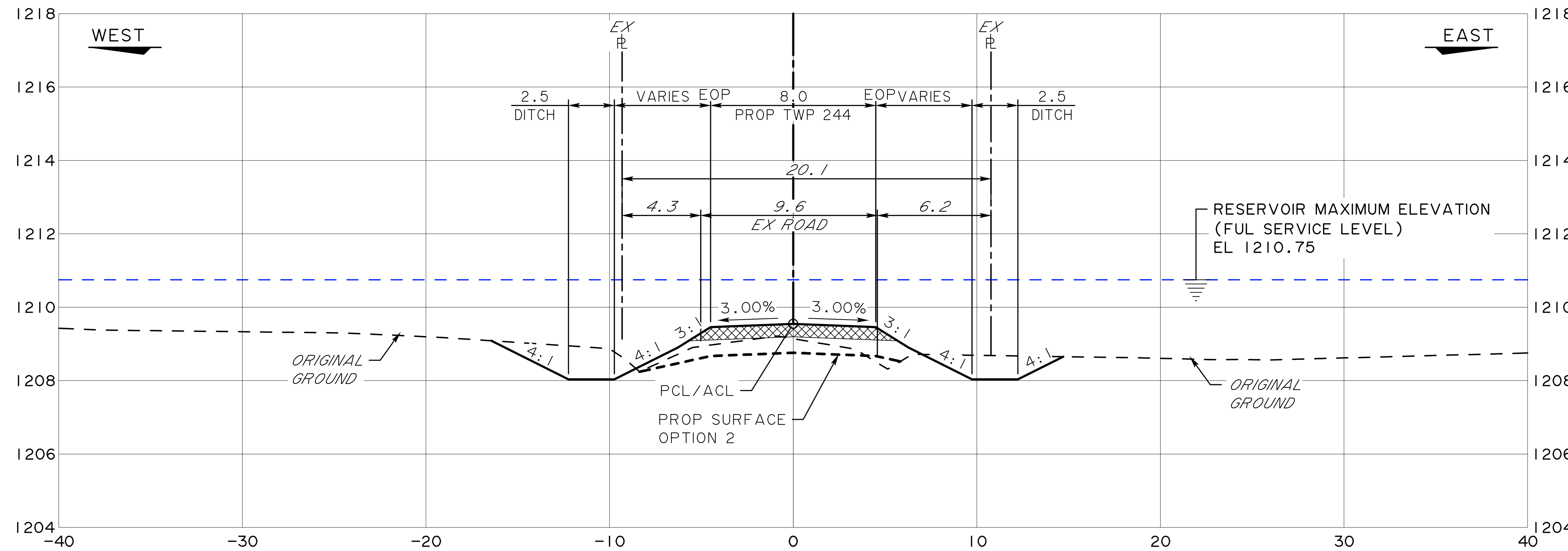
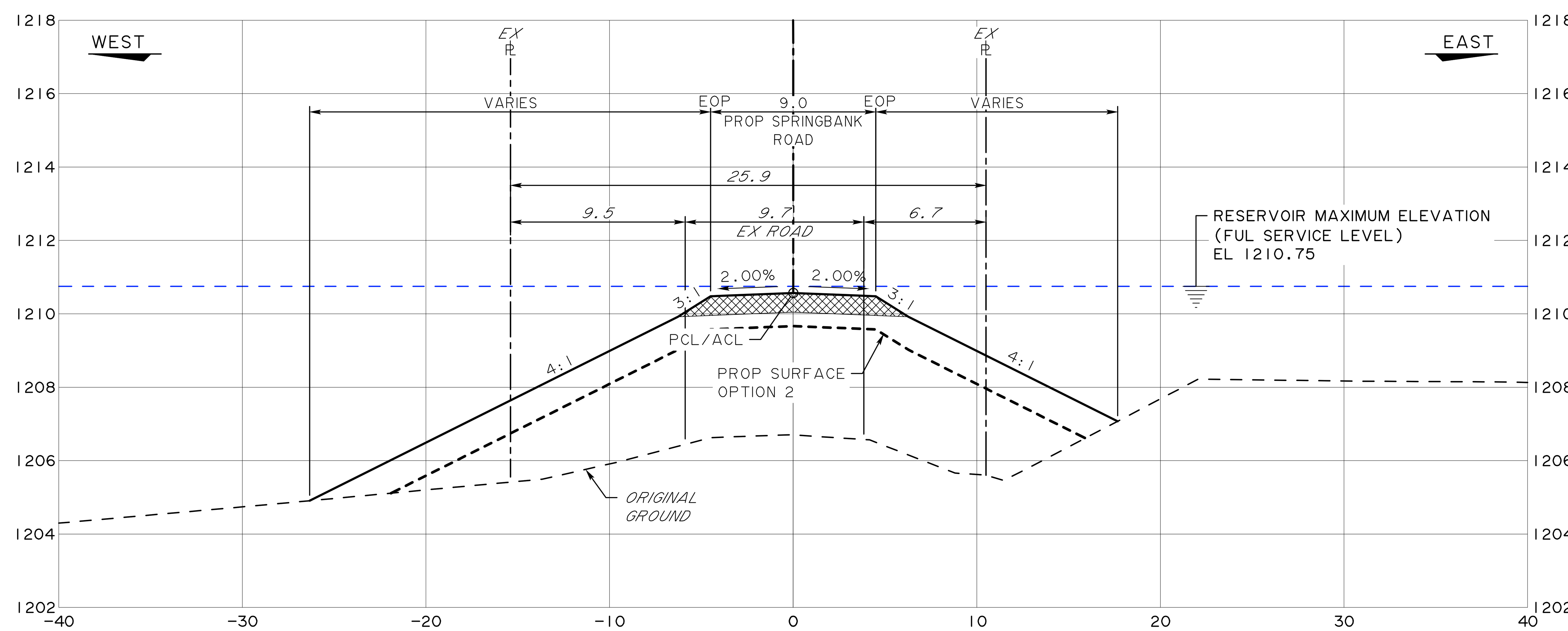
2017-06-14 9:22am By: mrusu



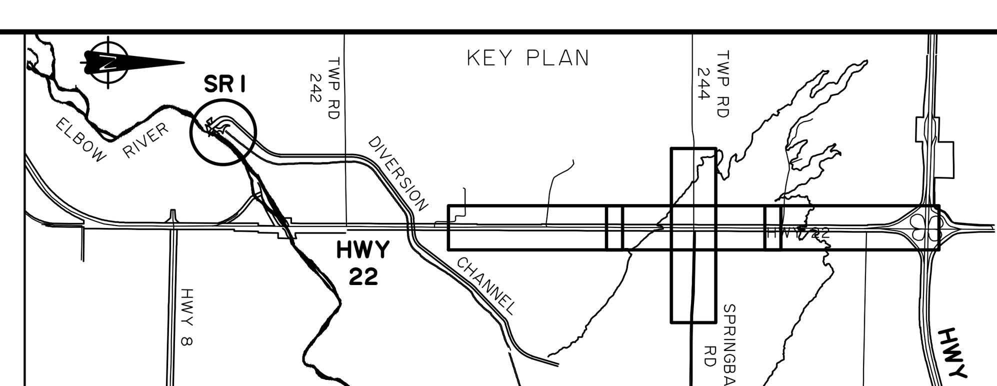
E / 1.1 TOWNSHIP ROAD 244
STA 53+700
H 1:200
V 1:100



F / 1.1 SPRINGBANK ROAD
STA 54+000
H 1:200
V 1:100

LEGEND

KEY PLAN



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DESIGNER DATE

CHECKER DATE

REV	DATE	REVISION	BY
5			
4			
3			
2			
1			

DATE	LOCATION	SITE
2017-05-01		

Alberta Transportation

HWY 22:00 AND SPRINGBANK ROAD PRELIMINARY DESIGN TYPICAL SECTIONS E AND F

CONTRACT	HIGHWAY	SHEET	DRAWING
12345	HWY 22:14	7 OF 7	Figure 2.3

DRAWING Figure 2.3
HIGHWAY HWY 22:14
CONTRACT 12345
DESCRIPTION HWY 22:00 AND SPRINGBANK ROAD PRELIMINARY DESIGN
PHOTO
DATE
BY
SURVEYED
DEPARTMENT BAR CODE

\\CD1002-F04\shared_projects\110773396\CAD\transportation\sheet_files\92_figure\01_roads_0-999\73396_fig-02.dwg
2017-06-14 9:22am By: mrusu

2-CENTERED CURVE DATA (REFER TO FIGURE D-5.2b)	
Δ	85°47'02"
Δ_1	23°53'35"
Δ_2	61°53'28"
R_1	75.0
R_2	16.0
T_a	33.402
T_b	19.959

3-CENTERED CURVE DATA (REFER TO FIGURE D-5.2a)	
Δ	89°36'22"
Δ_1	18°55'29"
Δ_2	51°45'25"
R_1	55.0
R_2	18.0
P	2.000
X	2.973
T	31.863
T_1	19.863
T_2	14.025

NOTE:
DIMENSIONS SHOWN ARE FINISHED SURFACE PAVEMENT WIDTHS. ADDITIONAL SUBGRADE WIDTHS TO BE PROVIDED TO ALLOW FOR DEPTH OF BASE COURSE AND PAVEMENT, EXCEPT WHERE OTHERWISE SPECIFIED

DATE	BY	PROCESS
		TO IDMS
		TO GIS
		MICROFILMED

PLAN DESCRIPTION
INT 2450
HWY. 22:14 & SPRINGBANK RD.
NORTH OF BRAGG CR.

BAR CODE

PLAN No.	IN-2450-1-C
PLAN LOCATION	HWY. 22:14
CONTRACT No.	6452/03
GRAPHICS FILE	

COORDINATE DATA
LOCAL
BASE LONGITUDE

	BY	DATE	No.	REVISIONS	BY	DATE
						/ /
						/ /
TITLE SEARCH DATE						/ /
						/ /
						/ /
SURVEYED						/ /
DESIGNED						/ /
CHECKED	K.J.B.	11/03				/ /
DRAWN	D.J.F.	11/03				

CONSULTANT

JOB No.	PLAN No.

EAGLE ENGINEERING CORP.

PERMIT TO PRACTICE

DESIGNER
P ENG
DATE

CHECKER
P ENG
DATE

PLAN SHOWING
INTERSECTIONAL TREATMENT
AT
JCT. HWY. 22:14 & SPRINGBANK RD.
NORTH OF BRAGG CREEK

REGION	PLAN No.	PROJECT	CONTRACT No.	SHEET
SOUTHERN	IN-2450-1-C	HWY. 22:14	6452/03	1 of 1

Alberta
TRANSPORTATION

10m 0 20m
HORIZONTAL

TABLE 3: RIGHT TURN LANE

HIGHWAY DESIGN SPEED (km/h)	LENGTH AND TAPER RATIO "TR" OF RIGHT TURN TAPER (m)	LENGTH OF PARALLEL LANE "PI" ** (m)		LENGTH AVAILABLE FOR DECELERATION: LANE + TAPER	DECELERATION LENGTH REQUIRED BASED ON DESIGN SPEED	STORAGE LENGTH PROVIDED BY STANDARD TREATMENT
		RIGHT TURN LANE NOT + WARRANTED	RIGHT TURN LANE + WARRANTED			
50	87.5 at 25:1	0	0	87.5	70	17.5
60	87.5 at 25:1	0	10	97.5	90	7.5
70	87.5 at 25:1	0	35	122.5	110	12.5
80	87.5 at 25:1	10	50	137.5	130	7.5
90	87.5 at 25:1	10	65	152.5	150	2.5
100	87.5 at 25:1	10	85	172.5	170	2.5
110	140.0 at 40:1	20	100	240 △	190	50
120	140.0 at 40:1	20	100	240	210	30
130	140.0 at 40:1	30	110	250	215	35

** ADJUST PARALLEL LANE LENGTH FOR GRADE EFFECT.
+ SEE RIGHT TURN LANE REQUIREMENTS IN SECTION D.7.7

TABLE 2: LEFT TURN LANE

HIGHWAY DESIGN SPEED km/h	LENGTH AND TAPER RATIO "TB" OF BYPASS LANE (m)	PARALLEL DECELERATION LANE "P2" ** (m)	LENGTH AVAILABLE FOR DECELERATION ½ TAPER+LANE	DECELERATION LENGTH REQUIRED BASED ON DESIGN SPEED	STORAGE LENGTH PROVIDED BY STANDARD TREATMENT
50	140 at 40:1	20	90	70	20
60	140 at 40:1	35	105	90	15
70	140 at 40:1	55	125	110	15
80	140 at 40:1	80	150	130	20
90	210 at 60:1	70	175	150	25
100	210 at 60:1	85	190	170	20
110	210 at 60:1	100	205	190	15
120	210 at 60:1	120	225	210	15
130	210 at 60:1	125	230	215	15

TABLE 1

HIGHWAY DESIGNATION	LANE*/SHOULDER WIDTHS (m)	SHOULDER WIDTH "W" AT INTERSECTION (m)
RAU-213.4	3.7/3.0	1.5
RAU-211.8	3.7/2.2	1.5
RAU-210.0	3.5/1.5	1.5
RAU-209.0	3.5/1.0	1.0
RAU-208.0	3.5/0.5	0.5
RAU-207.0	3.5/0	0

* AUXILIARY LANE WILL BE 3.5m
BYPASS LANE WIDTH WILL BE THE SAME AS THROUGH LANE.

NOTES:

1. DIMENSIONS SHOWN ARE FINISHED SURFACE PAVEMENT WIDTHS. ADDITIONAL SUBGRADE WIDTHS TO BE PROVIDED TO ALLOW FOR DEPTH OF BASE COURSE AND PAVEMENT.
2. THE DESIGNER MUST COMPLETE "INTERSECTION ANALYSIS" PROCEDURE TO JUSTIFY TYPE IV TREATMENT.
That is, exclusive left turn lane must be warranted for the movement shown ⊗

No.		BY	DATE
△			
△	TABLE 3: CHANGED DECEL LANE TAPER	R.M.	05/96

Alberta INFRASTRUCTURE

FIGURE D-7k

Date: APRIL 1995

INTERSECTION TREATMENT TYPE IVb (TWO-LANE HIGHWAY)

Prepared By: R.T. Checked By: B.K. Scale: N.T.S.

Graphics File: debd7k.man

APPENDIX F.9.2
STRUCTURE ALTERNATIVES REPORT
HIGHWAY 22 BRIDGE
OVER SPRINGBANK DIVERSION CHANNEL

Structure Alternatives Report Alberta Transportation, Highway 22 over Springbank Diversion Channel

Stantec

Prepared for:
Alberta Transportation

Prepared by:
Stantec Consulting Ltd.

December 19, 2018

Revision	Description	Author		Quality Check		Independent Review	
0.1	Draft	C. Smit	7/18/2018	K. Karvinen	7/18/2018	K. Karvinen	7/18/2018
0.2	Draft	C. Smit	11/8/2018	K. Karvinen	11/8/2018	K. Karvinen	11/8/2018
1.0	Final	C. Smit	12/19/2018	K. Karvinen	12/19/2018	K. Karvinen	12/19/2018

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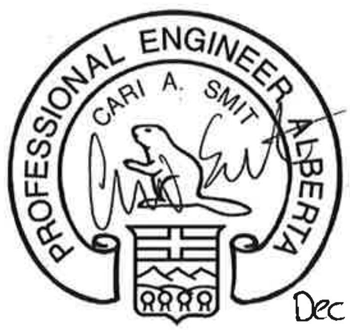
Sign-off Sheet

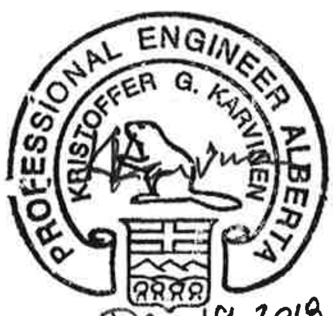
This document entitled Structure Alternatives Report Alberta Transportation, Highway 22 over Springbank Diversion Channel was prepared by Stantec Consulting Ltd. ("Stantec") for the account of Alberta Transportation (AT) (the "Client"). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.



Prepared by ______________ Dec 19/2018

(signature)

Cari Smit, P.Eng.



Reviewed by ______________ Dec 19, 2018

(signature)

Kristoffer Karvinen, M.A.Sc., PMP, P.Eng.

Stantec

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1.0 INTRODUCTION

The purpose of this report is to summarize design options for a new structure that will carry Highway 22 over a new flood diversion channel near Springbank. The diversion channel is part of a larger flood mitigation project that will see flood water from the Elbow River diverted into an off-stream storage reservoir.

2.0 BACKGROUND DESIGN INFORMATION

The proposed Springbank Off-Stream Reservoir Project (SR1), located west of Calgary approximately 20 km upstream of the Glenmore Reservoir, will capture flood flow from the Elbow River in an off-stream storage reservoir. The storage reservoir will temporarily contain flood water until the water is released back into the Elbow River. A diversion channel is required to convey water from the Elbow River to the storage reservoir. This channel will intersect both Highway 22 and Township Road 242, both locations require a new bridge crossing.

2.1 ROADWAY DESIGN INFORMATION

Highway 22's current profile, at the proposed bridge location, consists of a 2.1% gradient at the south transitioning to a crest vertical curve over the structure. The horizontal alignment is a tangent. The current profile will be maintained for the proposed structure. Further details on the design of Highway 22 can be found in the report *Springbank Off-Stream Reservoir Project (SR1) – Highway 22 and Springbank Road Planning Study*. The other road information is presented in Table 2-1.

Table 2-1: Highway 22 Design Parameters

Design Parameter	Value
Cross Slope	2%
Number of Lanes	2
Lane Widths	3.7 m
Shoulder Widths	3.0
Posted Speed	100 km/hr
Design Speed	120 km/hr
AADT (2015)	12,140
Commercial Vehicles (2015)	16.3 %

2.2 DIVERSION CHANNEL HYDROTECHNICAL DESIGN INFORMATION

The diversion channel's proposed geometry at the Highway 22 crossing is:

- A 5°12' RHF skew relative to the bridge,
- Design high water elevation of 1210.4 m,
- A 1 m freeboard, providing a minimum bottom flange elevation of 1211.4m, and
- 600 mm thick Class 1 heavy rock riprap to protect the channel banks.

Additional channel data is presented in Table 2-2.

Table 2-2: Channel Design Parameters

Design Parameter	Value
Side Slope	3H:1V
Long. Slope	0.1%
Peak Flow	600 m^3/s
Mean Velocity	2 m/s

The channel is intended to be used only in high water scenarios and will be dry through the winter months; therefore, ice is not considered in design.

2.2.1 Channel Debris

Stantec, using a scale model, carried out testing on the entrance of the diversion channel. A portion of the testing related to debris/inlet interaction. A debris barrier will be designed at the channel inlet to prevent debris in the channel. A 1 m freeboard provides adequate protection for the superstructure and there is minimal concern of debris impact on the piers.

2.3 GEOTECHNICAL INFORMATION

The geotechnical memo issued to the bridge design team is provided in Appendix D. The following is a summary. Four boreholes were drilled near the proposed bridge to a depth of 30 m. Typical soil conditions consist of:

- Topsoil, overlaying clay and silt, overlaying clay glacial till, overlaying sedimentary bedrock.
- The bedrock encountered includes: sandstone, siltstone, and mudstone.
- A weak layer of sedimentary rock was encounter at an elevation of approximately 1208 m, which is between 6.1 to 8.4 m below the existing ground and approximately 2 m above the proposed bottom of channel.

2.3.1 Foundation Recommendation Summary

The foundation design will present a unique challenge due to the fractured rock layers and channel side slopes. Because of this, the foundation design will be an iterative process between the bridge design team, and the geotechnical engineering team. After preliminary foundation systems are designed, they will be reviewed by the geotechnical team for a refinement of their recommendations, that may in turn revise the structural design.

Table 2-3 outlines preliminary design parameters for both cast-in-place piles and H-piles.

Table 2-3: Preliminary Pile Design Parameters

Pile Type	Location	Depth (m)	Unfactored Shaft Resistance at ULS (kPa)	Unfactored Toe Resistance at ULS (kPa)
Cast-in-Place	Hwy 22 Abutments	0.0 to 2.0	0	Neglect
		2.0 to 6.0	18	Neglect
		>6.0	220	1000
	Hwy 22 Piers	0.0 to 2.0	0	Neglect
		>6.0	220	1000
H-Piles	Hwy 22 Abutments	0.0 to 2.0	0	Neglect
		2.0 to 6.0	20	Neglect
		>6.0	100	1000
	Hwy 22 Piers	0.0 to 2.0	0	Neglect
		>6.0	100	1000

The modulus of subgrade reaction (k_s) was given as:

$$k_s = \frac{E_s}{d}$$

Where:

d = External diameter of pile (m)
E_s = Modulus of elasticity

Table 2-4: Pile Design Parameters for Lateral Loads

Location	Depth (m)	k_s (kPa/mm)[1]
Hwy 22 Abutments	1.0 to 6.0	6/d
	>6.0	30/d
Hwy 22 Piers	>1.0	30/d

2.3.2 Seismic

Highway 22 is considered a Level 2 roadway as per the provincial highway classification system, which is deemed a 'major-route bridge'. The site is site class 'C'. Therefore, it is considered seismic performance category 2 and force-based seismic design is required.

2.4 DESIGN STANDARDS

The design will meet the following requirements:

- Canadian Highway Bridge Design Code CAN/CSA S6-14 (CHBDC)
- Alberta Transportation Bridge Structures Design Criteria (BSDC), Version 8, 2017
- Alberta Transportation Standard Specifications for Bridge Construction, Edition 16, 2017
- Alberta Transportation Roadside Design Guide, November 2007, Revision 8
- Alberta Transportation Highway Geometric Design Guide, 1999

3.0 CONSTRUCTION ISSUES

3.1 SITE ACCESS

Highway 22 is a major north-south corridor that needs to remain open throughout construction. The Contractor will be required to install an onsite detour. No other site access issues are expected. The temporary detour will be specified to have the following parameters:

- 9 m road width,
- Pavement road surfacing,
- 60 km/hr detour design speed,
- 50 km/hr posted speed,
- 120 m minimum radius,
- 3:1 side slope,
- Max 5% superelevation,
- 21.5 m horizontal distance between centre line of the road to centre line of the detour, and
- The detour will be east of the existing road to avoid the underground utilities.

3.2 CONSTRUCTION METHODS

The contractor could consider a top-down construction method, since the new bridge is being constructed to match the existing grade of Highway 22, and the diversion channel will be cut into existing grade. Abutment construction would involve installing piles from existing grade to design cut-off elevation, then casting the abutment seat. The piers could be constructed in trenches

4.0 TENDER ISSUES

No issues noted at this time.

5.0 GEOMETRY AND SPAN CONFIGURATION

As stated in the *Bridge Conceptual Design Report*, a three span option allows for a reduced girder depth, while keeping the piers out of the center of the channel. The proposed bridge geometry is as follows;

- 3 – spans: 22 m – 30 m – 26 m,
- No skew between road and bridge,
- Maintain the current vertical and horizontal alignment of the road,
- Overall width of 14.35 m,
- 2 – 3.7 m wide lanes,
- 3.0 m shoulders,
- 0.475 m barriers on both sides,
- Longitudinal slope ranging from 1.5% to 2.1%, and
- Crossfall of 2% away from crown.

6.0 STRUCTURE ALTERNATIVES

6.1 EXPOSURE CLASS

As per AT's *BSDC, Appendix C,* with an AADT of 12,140 and a deck area of 1292 m^2, the bridge is exposure class 1. Therefore, stainless steel reinforcing bars will be used for:

- The deck,
- Barriers,
- Approach slabs,
- Sleeper slabs, and
- Top 300 mm of the wingwalls, backwalls and diaphragms.

6.2 FOUNDATIONS

As recommended in *Springbank Off-Stream Storage Project Bridge Structure Foundation Design Memorandum – Township Road 242 and Highway 22 over Springbank Diversion Channel,* both cast-in-place piles and H-piles are potential options. However, the mechanics of cast-in-place pile foundations in weak bedrock are better understood. There are several risks associated with driven steel piles that need to be considered.

6.2.1 Cast-in-Place Concrete Piles

Based on preliminary geometry and soil parameters listed in Table 2-3 it is estimated that five 1.2 m diameter piles spaced at 3.6 m are sufficient for the piers and five 0.9 m diameter piles spaced at 2.7 m are sufficient for the abutments.

6.2.2 H-Piles

The bedrock is anticipated to be approximately 3 m below the abutment and 2 m above the pier foundation. Given the shallow depth of bedrock and the complicated mechanics of driven piles in the expected ground conditions, there is a risk that the steel piles will not sufficiently be able to penetrate the bedrock layer. If a pile is damaged in the process, the Contractor would need to remove the pile. Additional equipment may be required to remove the damaged piles and to bore through the strong bedrock layer, if necessary. If this is encountered, there will be delays to construction and additional construction cost.

Some ways to minimize the potential for damage to the piles is by using a large section size, such as HP 360x132 and by using steel driving shoes.

A summary of the soil parameters are listed in Table 2-3.

6.3 ABUTMENTS

Three abutment configurations have been considered for this structure: fully integral, semi-integral with sliding bearings, and conventional.

6.3.1 Conventional

As per AT's *Best Practice Guidelines* and AT's BSDC, *Appendix A*, conventional abutments should only be considered if integral abutments cannot be used. With proper design considerations, such as longitudinal restraints at the piers, acceptable thermal spans can be achieve making integral or semi-integral abutments feasible. For these reasons conventional abutments were not considered further.

6.3.2 Fully Integral

A fully integral abutment would eliminate the need for sliding bearings and deck joints, reducing the life cycle costs of the structure. A single row of driven steel piles would be required at the abutments, to provide the flexibility required to accommodate movement of the structure. To reduce the risk of driven steel piles, concrete piles could be used at the piers, however this would increase the cost, as a second piling rig would need to be mobilized.

Due to the risks of additional cost and construction delays associated with driven steel piles, discussed in the foundation section, a fully integral abutment is not the recommended option.

6.3.3 Semi-Integral

Semi-integral abutments can be constructed using cast-in-place concrete piles, while removing the need for traditional deck joints. Differential movement between the superstructure and substructure will be accommodated by a type C2 joints located at the ends of the approach slabs and reinforced elastomeric bearings. A concrete abutment diaphragm will retain fill behind the abutment as well as provide support for the approach slabs. A compressible material is required between the moving diaphragm and the stationary abutment seat.

The overall cost of a semi-integral bridge is anticipated to be approximately $300,000 more than an integral bridge. However, the risks associated with damaged steel piles, including potential construction delays and cost, are undesirable and therefore semi-integral abutments are recommended.

6.3.4 Wingwalls

On conventional abutments, the wingwall are connected to the backwall and abutment seat. For semi-integral abutments, the wingwall are typically connected to the diaphragm and are required to move.

6.3.4.1 Stationary

The challenge with a stationary wingwall for semi-integral abutments, is that a joint is required between the barrier on the overhang and the barrier on the wingwall. One of the benefits of semi-integral abutments is the elimination of joints near the bearings. Compared to a moving wingwall, a stationary wall requires additional reinforcing steel for a long cantilever or the addition of piles to limit the cantilever. For this reason, a stationary wingwall is not recommended.

6.3.4.2 Moving

When wingwalls are connected to the diaphragm they must be designed to accommodate longitudinal movement of the superstructure. Compressible material is required between the wingwall and abutment seat. The approach slab will move independently of the wingwalls. Moving wingwalls have successfully been used on Northeast Anthony Henday and Southeast Stoney Trail. Moving wingwalls are recommended for this structure.

6.3.5 Approach slab

The approach slabs will be cast-in-place 6.0 m long and 300 mm thick.

6.3.6 Slope Protection

At the bridge location, the channel slopes will consist of 600 mm deep, Class 1 riprap. It will extend up to the face of the abutment seat to prevent erosion. Outside the bridge footprint, it will extend up to 1 m above the design high water elevation.

6.4 PIERS

The piers are within the highwater line. It is assumed that the debris mitigation measures will prevent any large debris from the channel. Debris and ice loads on the piers will not be designed for.

As the piers are not within the splash zone, the rebar will consist of standard carbon steel and the concrete will be Class C (35 MPa). Generally, the public will not be able to see the piers, so aesthetics will be a minor consideration.

6.4.1 Multi-Shaft Pier

A two-shaft pier would reduce the amount of concrete and steel required. However, a multi-shaft pier may cause more disruption to the flow. In addition, a multi-shaft configuration is prone to the accumulation of small debris, resulting in additional loading on the piers and an increase in maintenance cost. Multi-shaft piers are not recommended for this structure.

6.4.2 T-Shaped Piers

T-shaped piers are recommended as a single solid shaft is easier to construct, will reduce the amount of concrete within the channel and will reduce the likelihood of debris accumulation. The preliminary pier size is 6 m by 1.8 m.

6.5 GIRDERS

Two girder types were considered; precast 1200 mm deep NU girders and steel plate girders. The depth of both girder systems are restricted to allow the profile of Highway 22 to be maintained while allowing a 1 m freeboard during a flood event. The girder options will be discussed further in the cost estimate and recommendations section.

6.5.1 Precast Concrete 1200 NU Girders

The NU girder option consists of:

- 5 girder lines,
- 1200 mm deep precast NU girders,
- 2900 mm spacing,
- 70 MPa high performance concrete, and
- No post-tensioning.

Intermediate steel diaphragms are required to increase lateral stability during erection. Cast-in-place concrete diaphragms are required at the abutments and piers.

6.5.2 Steel Plate Girders

The steel girder option consists of:

- 5 girder lines,
- 1320 mm deep welded steel plate girders, and
- 2900 mm spacing.

The steel plates are grade 350 AT category 3 weathering steel. The approximate weight of each girder (including diaphragms) is 479 kg/m. Based on preliminary design no longitudinal or transverse stiffeners are required. It is anticipated that eleven intermediate weathering steel diaphragms are required, including at the piers and abutments. Lateral bracing is not required.

6.6 DECK

The deck will have a longitudinal slope ranging from approximately 1.5% to 2.1% with a 2% crossfall away from the crown. Based on preliminary calculations, deck drains are not required

Precast panels were not considered as schedule is expected to have minimal impact on the public, making precast panels unnecessary. A standard 45 MPa, 225 mm thick cast-in-place concrete deck system is recommended. Since the bridge is exposure class 1, solid stainless steel reinforcement is required.

The standard deck protection system is recommended. Consisting of two 40 mm courses of hot-mix asphalt concrete pavement, 3.2 mm protection board, and a 5 mm thick asphalt waterproofing membrane with wick drains, as per AT standard drawing S-1838-17 to S-1840-17.

6.6.1 Drain Trough

The water will be directed to both barriers via the crossfall and flow to the south due to the longitudinal grade. At the ends of the bridge the water will be directed, via a drain trough, into the diversion channel. Runoff is not expected to encroach on the travel lanes.

6.7 BARRIERS

The barrier exposure index is 38, therefore TL-5 barriers are required on both sides of the structure. Cyclists and pedestrians will not be considered in the design of the barriers.

6.7.1 TL-5 Barrier

The recommended barrier type is the standard Alberta Transportation TL-5 barrier, as per drawing S-1702-17 with a transition detail as per S-1703-17. The standard TL-5 barrier consists of a 600 mm high single slope barrier with a double tube rail on top. The transition section will consist of a thrie-beam approach rail.

6.7.2 Utilities

A power line and Telus line are currently running along the edge of Highway 22. It is proposed that the utilities use the bridge as a crossing by providing ducts in the barriers.

6.8 JOINTS AND BEARINGS

The proposed arrangement will consist of expansion bearings at the abutments and fixed supports at the piers. The transverse restrain will be provided via shear blocks. Based on preliminary load calculations all bearing will be steel reinforced elastomeric bearings.

According to AT's BSDC *Appendix A*, the maximum thermal span for concrete and steel girder systems is 60 m and 45 m, respectively. It is assumed that the thermal fixity of the superstructure is located at the centre of the structure.

According to CAN/CSA S6-14 the maximum and minimum mean daily temperatures, for this area, are +28°C and -38°C, respectively. The expected thermal movement is dependent on the superstructure type. Assuming the piers provide no restriction to longitudinal movement, the following thermal movement can be expected:

- For the concrete girder system, the structure is classified as a type C structure according to clause 3.9 of CAN/CSA S6-14. The estimated thermal movement, based on a maximum thermal span of 41 m, is 28 mm.
- For the steel girder system, the structure is classified as a type B structure according to clause 3.9 of CAN/CSA S6-14. The estimated thermal movement, based on a maximum thermal span of 41m, is 40 mm.
- These movements require a type C2 cycle control joint.

7.0 COST ESTIMATE

The opinions of probable cost assembled in this report are based only on major structural components and the minimum extents of fills required to achieve stability. It does not provide for any cost of elements such as, roadway construction, detour construction, utility placement or relocation, electrical distribution, smaller secondary items, excavation, or channel riprap. The cost of the temporary detour, excavation and riprap placement are included in civil works. This methodology is consistent with providing the owner with comparative costs to identify preferable options.

For comparison purposes, an initial capital cost (Class B) estimate for a steel plate girder system and a NU girder system is summarized in the table below and further details can be found in Appendix B. the costs include construction cost plus a 10% contingency and engineering fees. It is noted that the level of accuracy of the estimate at this stage is within ± 20%. All figures have been rounded up to the nearest $10-thousand value.

Table 7-1: Estimated Initial Capital Cost (Class B)

Option	Structure Type	Initial Capital Cost (±20%)	Cost per m²
1	1200 mm deep NU girder	$ 5.42 M	$ 4,100.00
2	1320 mm deep steel plate girder	$ 5.51 M	$ 4,100.00

The two cost estimates provided are based on the recommended alternatives stated above. It has been assumed that a semi-integral abutment with 5 cast-in-place concrete piles per abutment/pier and reinforced elastomeric bearings are used. As well, the estimates assume a cast-in-place concrete deck and TL-5 single slope concrete barriers with double tube railings.

The cost estimate is based on a structure with a total width of 14.35 m. The estimated unit cost values were derived from the 2018 Unit Prices Average Reports, recent experience, and presumed escalation. It is noted that these values are assumed based on construction in today's market, however, if the tender is postponed, the estimates may fluctuate due to changes in the market and inflation.

7.1 LIFE CYCLE COST ESTIMATE

Table 7-2: Estimated Life Cycle Cost

Option	Structure Type	Life Cycle Cost Estimate
1	1200 mm deep NU girder	$ 6.22 M
2	1320 mm deep steel plate girder	$ 6.38 M

The life cycle cost estimate includes major rehabilitation items that present potentially expensive future cost liabilities; these include items such as deck rehabilitation, sealer and paint applications, and bearing replacements. The life cycle costs do not include the user costs associated with future maintenance work. Depending on the maintenance work required, the structure may be partially or fully closed temporarily. The user delays associated with maintenance for all options presented are assumed to be equivalent, as maintenance techniques will be similar.

To determine the dollar value of future maintenance, an assumed (long term) interest rate of 4% was used, and an estimate of when future maintenance work would be required.

8.0 DESIGN DECISIONS AND RECOMMENDATIONS

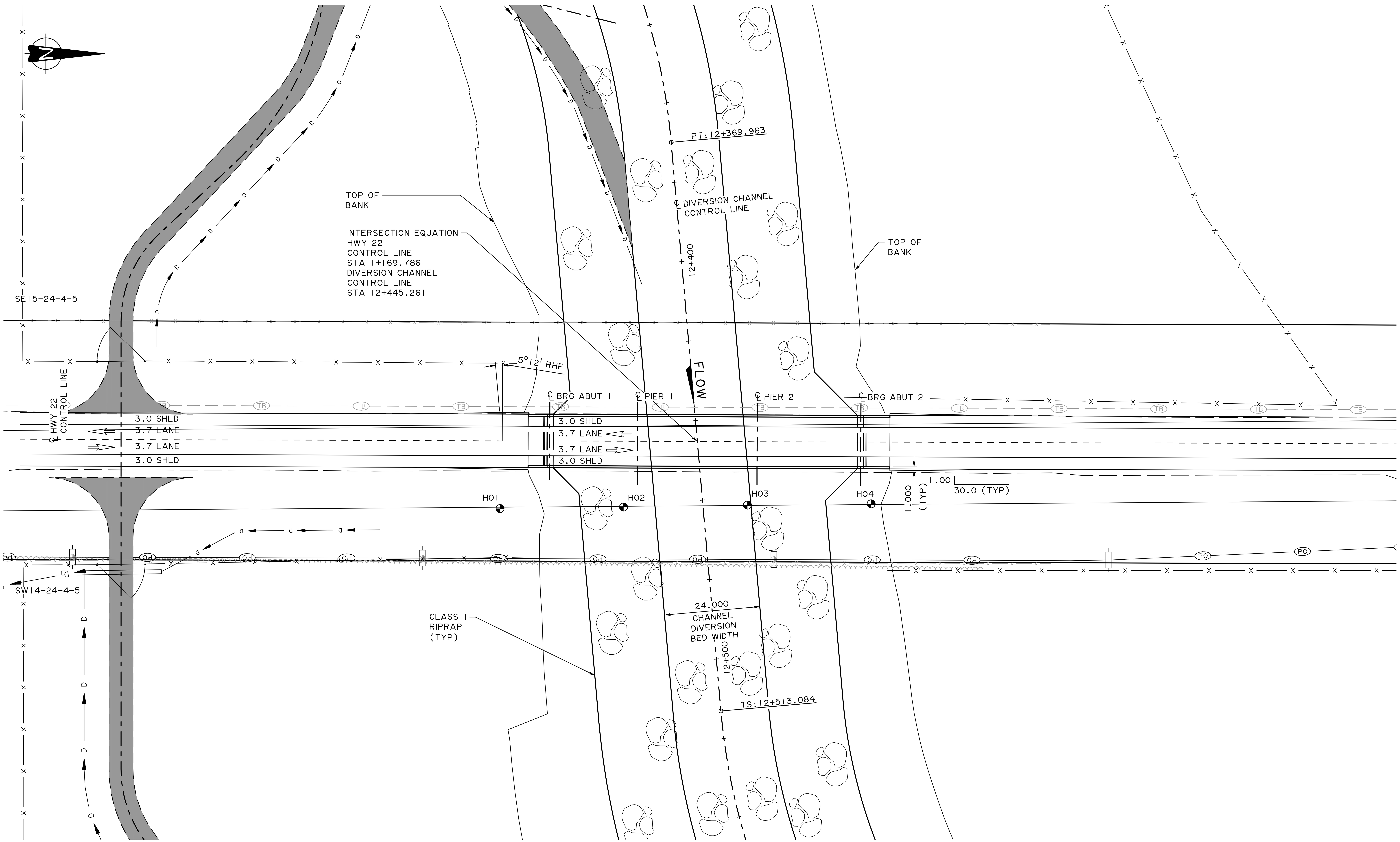
After a review of the alternatives presented in this report, a 3 span 1200 mm deep prestressed concrete NU girder structure is recommended, with:

- Semi-integral abutments,
- Moving wingwalls,

- Concrete piles,
- Concrete T-shaped pier shafts,
- TL-5 barriers,
- Type C2 deck joints, and
- Reinforced elastomeric bearings.

The structure has the lowest initial capital cost and life cycle cost. A summary of the recommended structure can be found in the Bridge Choose Design Form in Appendix C.

Appendix A SKETCHES



PLAN

1:500

LEGEND	KEY PLAN	CONSULTANT	DESIGNER	CHECKER
		JOB NO. 110773396	DATE	DATE

REV	DATE	REVISION	BY

Alberta Transportation

SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
HWY 22 BRIDGE OVER DIVERSION CHANNEL
SITE PLAN

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
2017-10-19	WSW14-24-4-5	BF 968	-	HWY 22	1 OF 7	SK-1008

DRAWING SK-1008
HIGHWAY
CONTRACT
DESCRIPTION SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
PHOTO
DATE
BY
SURVEYED
DEPARTMENT BAR CODE

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2018-10-19 11:05am By: jlo

DRAWING SK-1009

HIGHWAY

CONTRACT

DESCRIPTION SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)

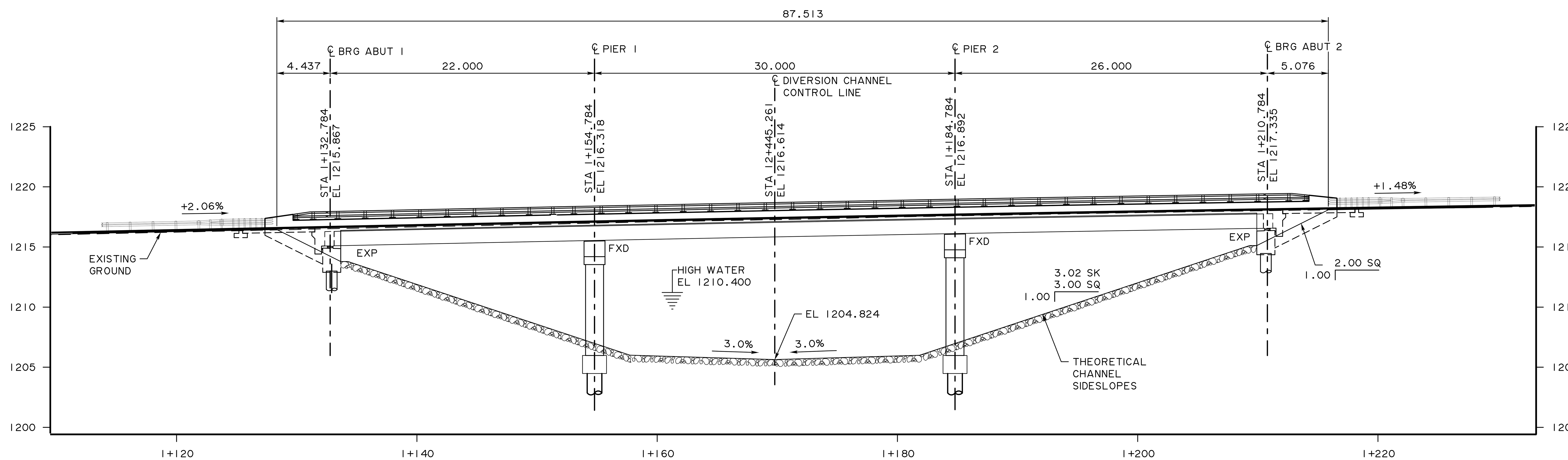
PHOTO

DATE

BY

SURVEYED

DEPARTMENT BAR CODE



ELEVATION

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LEGEND	KEY PLAN	CONSULTANT	DESIGNER	CHECKER
		JOB NO. 110773396	DATE	DATE

REV	DATE	REVISION	BY

DATE	LOCATION	SITE
2017-10-19	WSW14-24-4-5	BF 968

Alberta Transportation

SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
HWY 22 BRIDGE OVER DIVERSION CHANNEL
ELEVATION

CONTRACT	HIGHWAY	SHEET	DRAWING
-	HWY 22	2 OF 7	SK-1009

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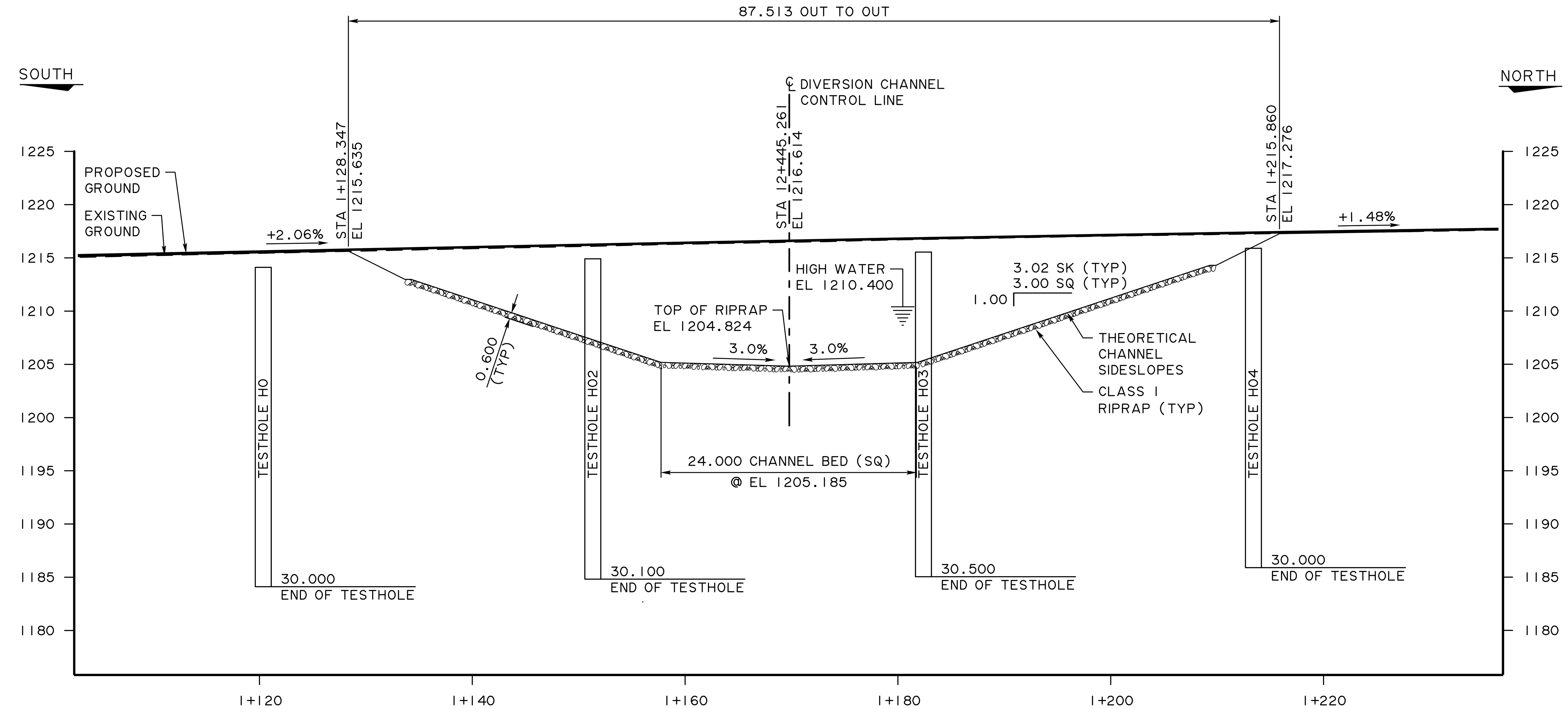

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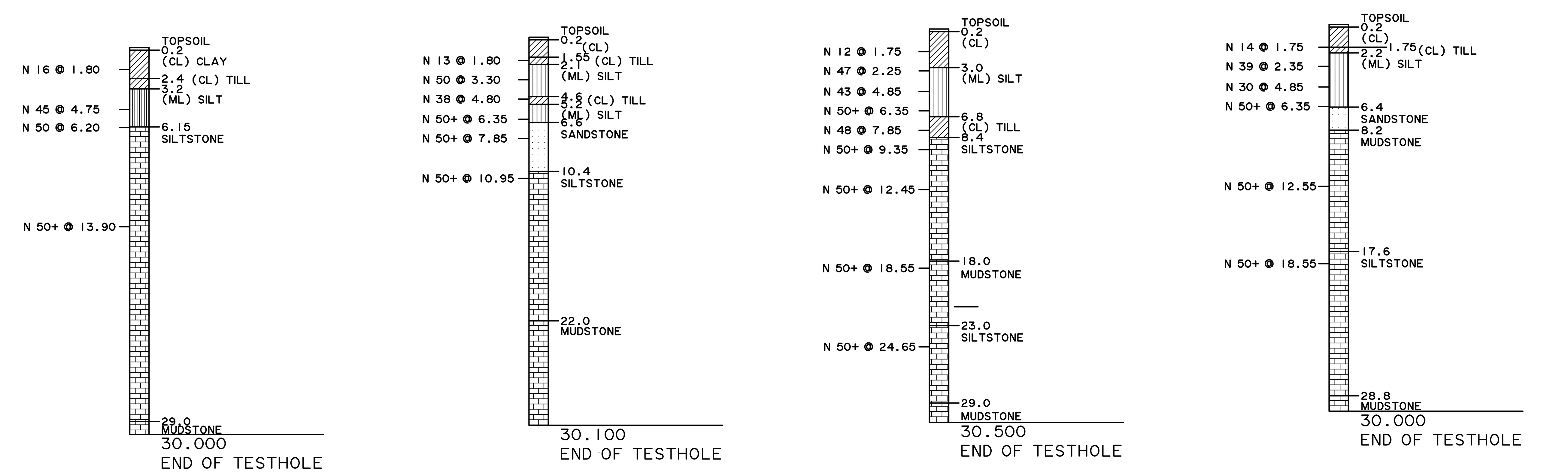

TESTHOLE H01
STA 1+120.350, 16.993 m RT OF ℄
TOP EL 1214.111 (APPROX)
N 5656426.618, E -32712.635
DEPTH 30.000 m
2016-08-24

TESTHOLE H02
STA 1+151.331, 16.506 m RT OF ℄
TOP EL 1214.914 (APPROX)
N 5656457.601, E -32713.018
DEPTH 30.100 m
2016-08-26

TESTHOLE H03
STA 1+182.399, 15.908 m RT OF ℄
TOP EL 1215.550 (APPROX)
N 5656488.671, E -32713.511
DEPTH 30.500 m
2016-08-27

TESTHOLE H04
STA 1+213.418, 15.484 m RT OF ℄
TOP EL 1215.903 (APPROX)
N 5656519.691, E -32713.830
DEPTH 30.000 m
2016-08-24

GEOTECHNICAL NOTES

- ALL GEOTECHNICAL INFORMATION PROVIDED FOR THIS PROJECT HAS BEEN COMPILED FOR ALBERTA TRANSPORTATION FOR DESIGN PURPOSES ONLY. INFORMATION WAS COMPILED FROM STANTEC CONSULTING LTD. MEMORANDUM, "SPRINGBANK OFF-STREAM STORAGE PROJECT BRIDGE STRUCTURE FOUNDATION DESIGN MEMORANDUM -" JULY 2018 AND REPORT, "SPRINGBANK OFF-STREAM STORAGE PROJECT GEOTECHNICAL INVESTIGATION REPORT" DECEMBER 2016. ADDITIONAL INFORMATION IS AVAILABLE IN THE REPORT AND SHOULD BE EXAMINED AND SUPPLEMENTED AS REQUIRED. ALL DISCLAIMERS IN THIS REPORT ARE APPLICABLE AND IN CASE OF DISCREPANCY, THE GEOTECHNICAL REPORT GOVERNS.
- GEOTECHNICAL LIMITATION: WHILE THE GEOTECHNICAL INFORMATION PROVIDED FOR THIS PROJECT IS BELIEVED TO CORRECTLY REPRODUCE OR SUMMARIZE OBSERVATIONS MADE DURING TESTING, IT IS VALID ONLY FOR THE PRECISE LOCATION(S) SHOWN, AND IT IS NOT TO BE CONSTRUED AS GUARANTEEING THE ACTUAL MATERIALS AND CONDITIONS EXISTING THROUGHOUT THE SITE. THE TESTING METHODS USED MAY NOT HAVE DETERMINED THE PRESENCE, ABSENCE OR EXTENT OF BOULDERS, HARD OR SOFT FORMATIONS, WATER TABLES, ARTESIAN CONDITIONS AND OTHER VARIABLES. IT IS THE RESPONSIBILITY OF OTHERS USING THIS INFORMATION TO ENSURE THAT IT IS ADEQUATE FOR THEIR PURPOSES, OR TO SUPPLEMENT IT WITH ADDITIONAL INFORMATION.
- THE PROPOSED BRIDGE GRADELINE WILL BE FINALIZED AFTER THE ROADWAY SURVEY IS AVAILABLE
- ALL CHANNEL ELEVATIONS AND DIMENSIONS ARE TO TOP OF ROCK RIPRAP

UNIFIED SOIL CLASSIFICATION SYSTEM (MODIFIED BY PFRA)

COARSE GRAINED SOILS 50%+ RETAINED ON AN 80 MICRON SIEVE			FINE GRAINED SOILS 50%+ PASSING AN 80 MICRON SIEVE		
GROUP SYM	LOG SYM	TYPICAL NAMES	GROUP SYM	LOG SYM	TYPICAL NAMES
GW		WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	CL		INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
GP		POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	CI		INORGANIC CLAYS OF MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS
GM d / u		SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CH		INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
GC		CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES	ML		INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
SW		WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	MH		INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS
SP		POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	OL		ORGANIC SILTS AND ORGANIC SILTY CLAYS OR LOW PLASTICITY
SM d / u		SILTY SANDS: SAND-SILT MIXTURES	OH		ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
SC		CLAYEY SANDS, SAND-CLAY MIXTURES	Pt		PEAT AND OTHER HIGHLY ORGANIC SOILS
OTHER SYMBOLS					
		BEDROCK (UNCLASSIFIED)			CONGLOMERATE
		SANDSTONE			COAL
		SHALE			OVERBURDEN
		SILTSTONE			TOPSOIL

LEGEND	KEY PLAN	CONSULTANT	DESIGNER	CHECKER
		JOB NO. 110773396	DATE	DATE

REV	DATE	REVISION	BY

Alberta Transportation

SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
HWY 22 BRIDGE OVER DIVERSION CHANNEL
GEOTECHNICAL INFORMATION

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
2017-10-19	SSE15-24-4-5	BF 968	-	HWY 22	3 OF 7	SK-1010

DRAWING SK-1010 | HIGHWAY | CONTRACT | DESCRIPTION SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1) | PHOTO | DATE | BY | SURVEYED | DEPARTMENT BAR CODE

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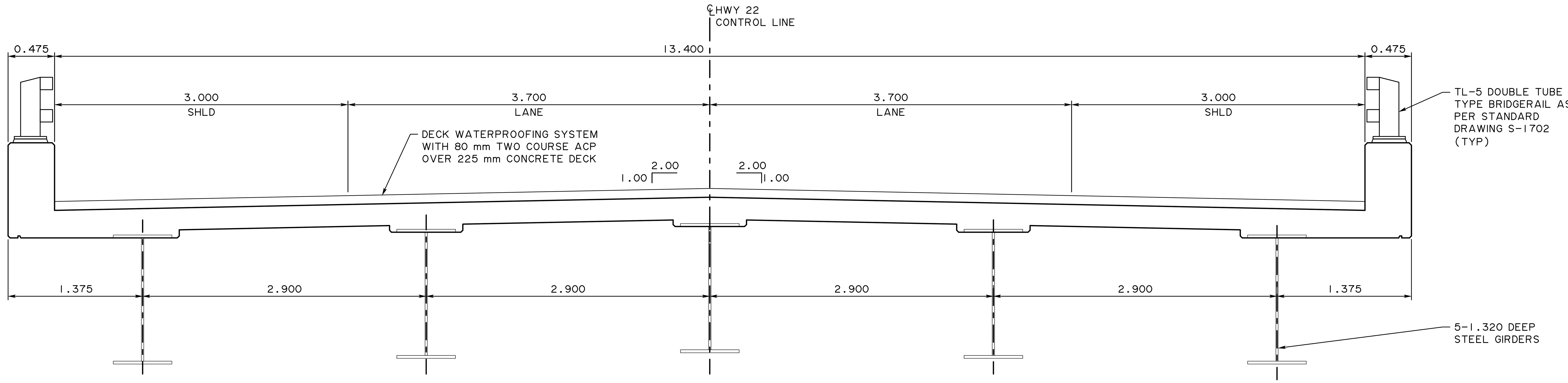
PHOTO
DATE
BY
SURVEYED
DEPARTMENT BAR CODE



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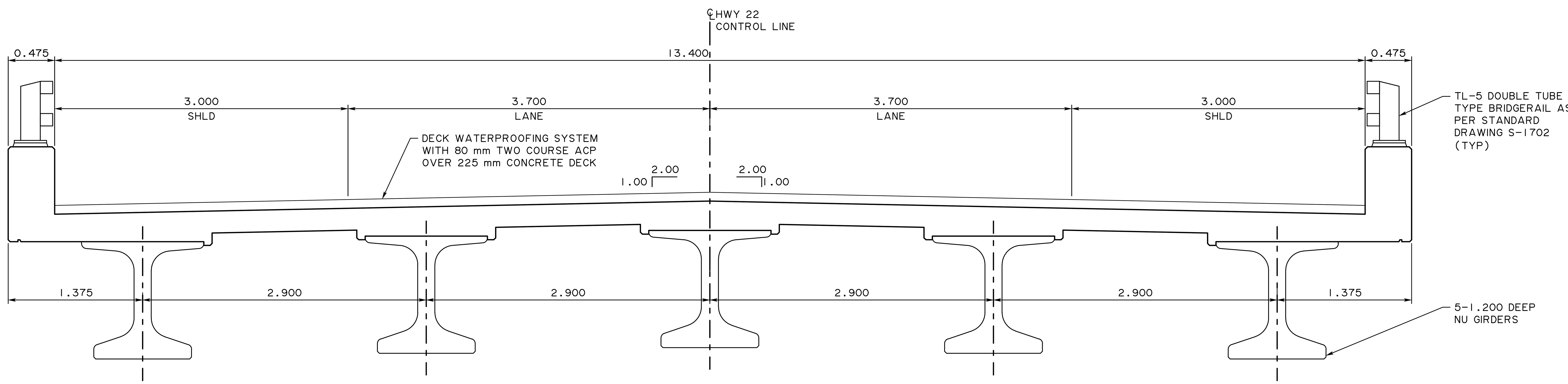

C NU GIRDER OPTION
1:25

LEGEND	KEY PLAN	CONSULTANT		DESIGNER	CHECKER
		JOB NO.	110773396	DATE	DATE

REV	DATE	REVISION	BY

Alberta Transportation

SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
HWY 22 BRIDGE OVER DIVERSION CHANNEL
GIRDER OPTIONS

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
2017-10-19	WSW14-24-4-5	BF 968	-	HWY 22	4 OF 7	SK-1011

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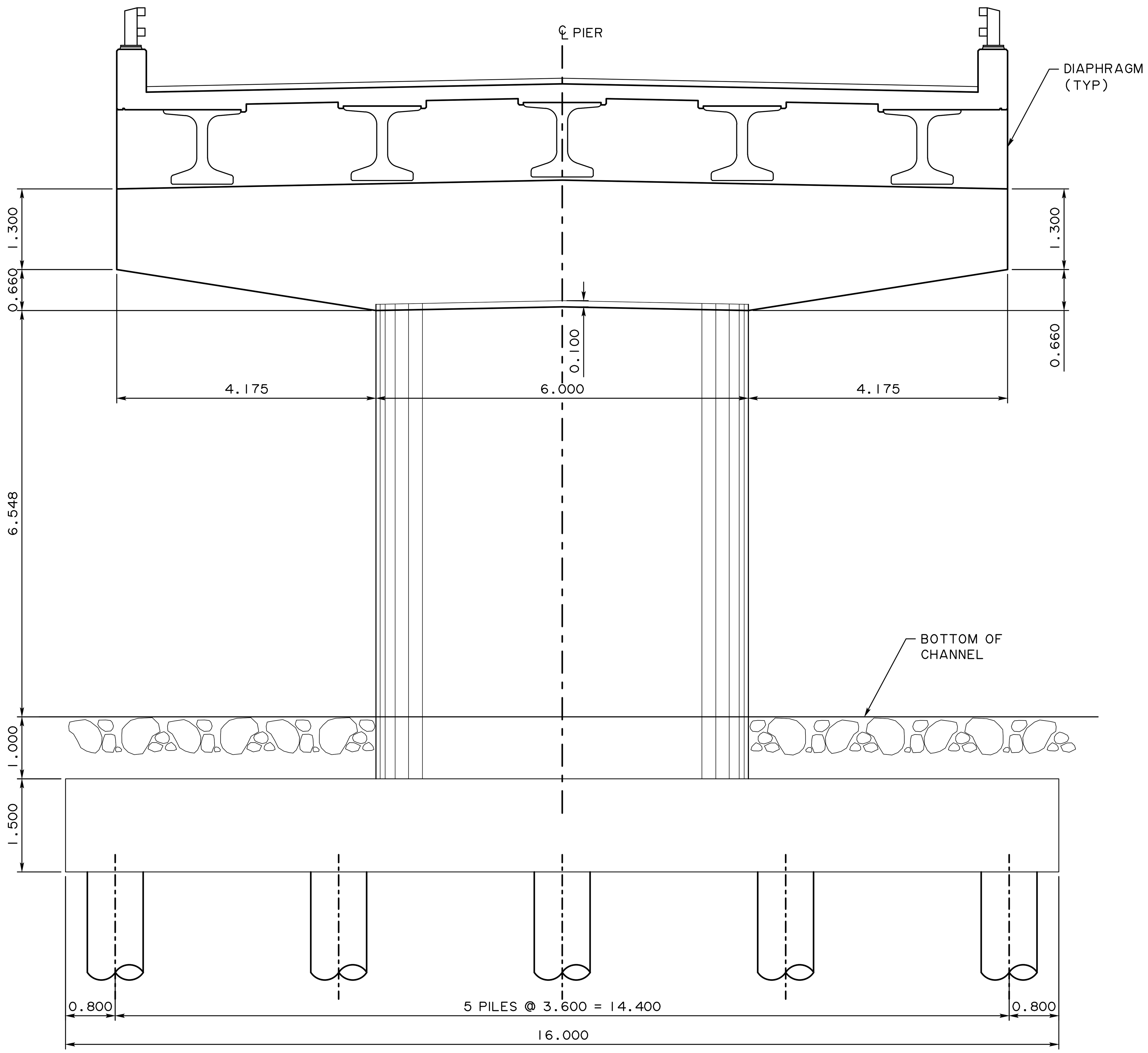

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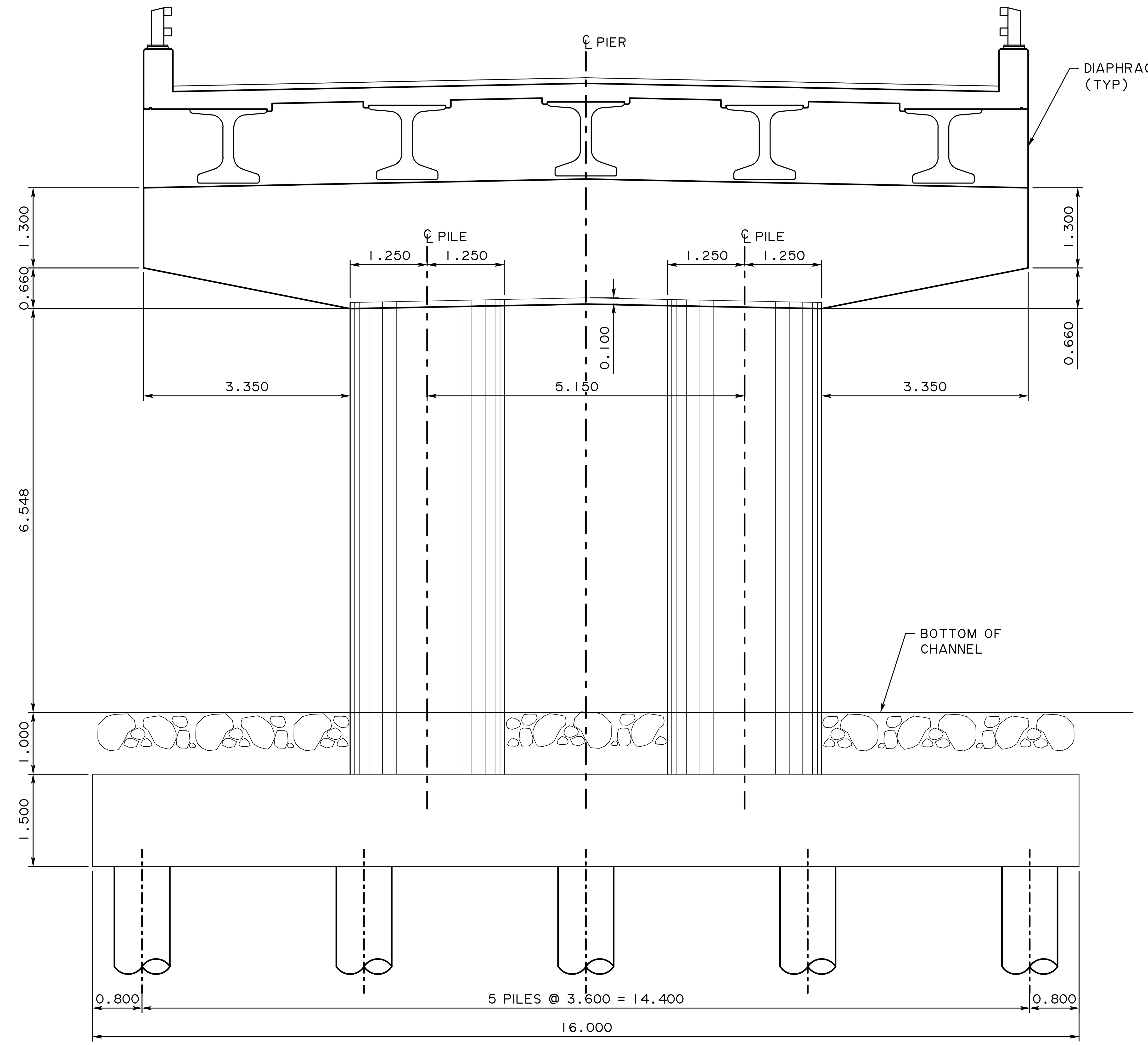

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		JOB NO. 110773396	DATE	DATE

REV	DATE	REVISION	BY

DATE	LOCATION	SITE
2017-10-19	WSW14-24-4-5	BF 968

Alberta Transportation

SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
HWY 22 BRIDGE OVER DIVERSION CHANNEL
PIER OPTION

CONTRACT	HIGHWAY	SHEET	DRAWING
-	HWY 22	5 OF 7	SK-1012

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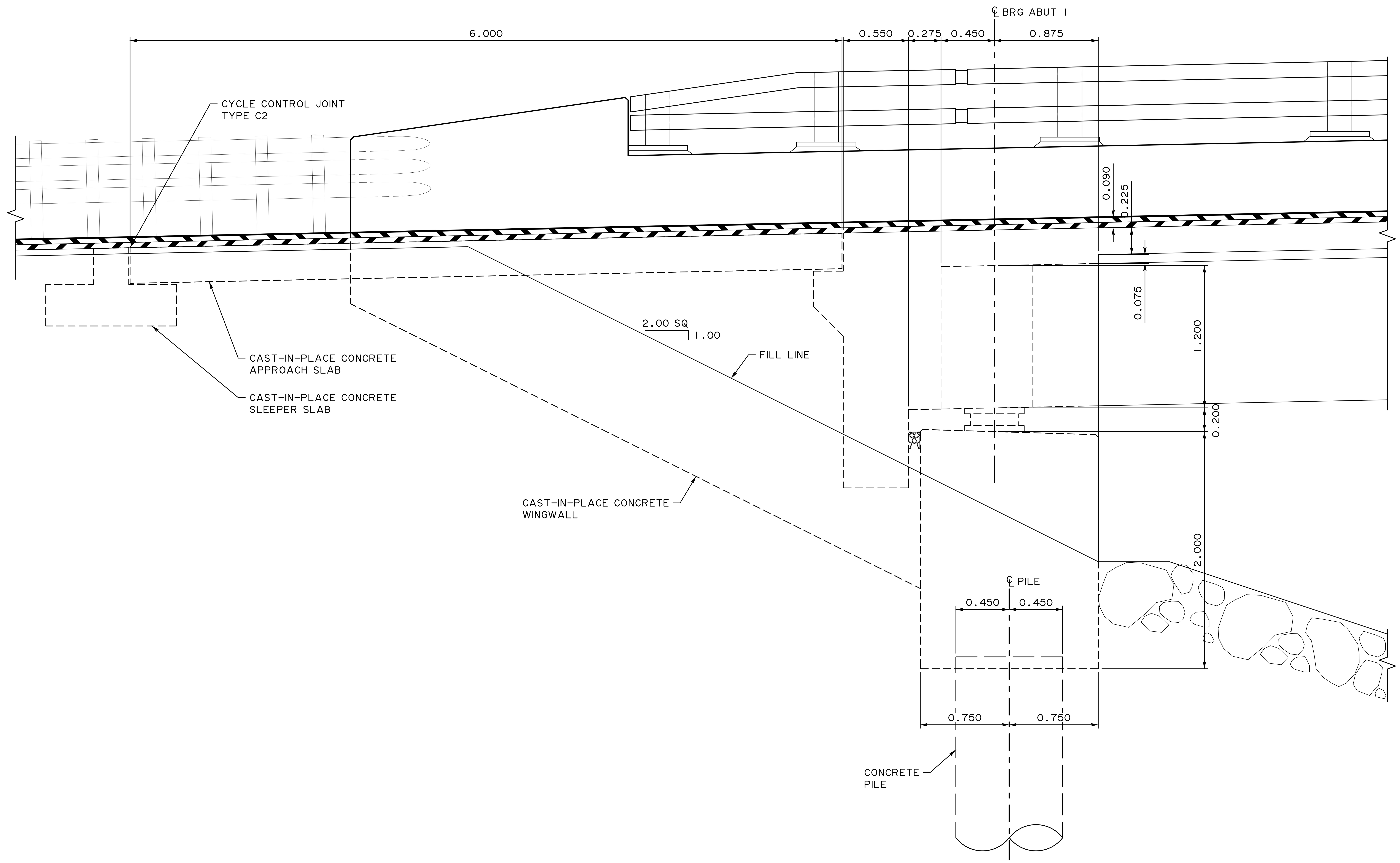

A SEMI-INTEGRAL ABUTMENT

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LEGEND	KEY PLAN	CONSULTANT	DESIGNER	CHECKER
		JOB NO. 110773396	DATE	DATE

REV	DATE	REVISION	BY
	2017-10-19	LOCATION SSE15-24-4-5	SITE BF 968

Alberta Transportation

SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
HWY 22 BRIDGE OVER DIVERSION CHANNEL
ABUTMENT 1 DETAIL

CONTRACT	HIGHWAY	SHEET	DRAWING
-	HWY 22	6 OF 7	SK-1013

DRAWING SK-1013 | HIGHWAY | CONTRACT | DESCRIPTION SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1) | PHOTO | DATE | BY | SURVEYED | DEPARTMENT BAR CODE

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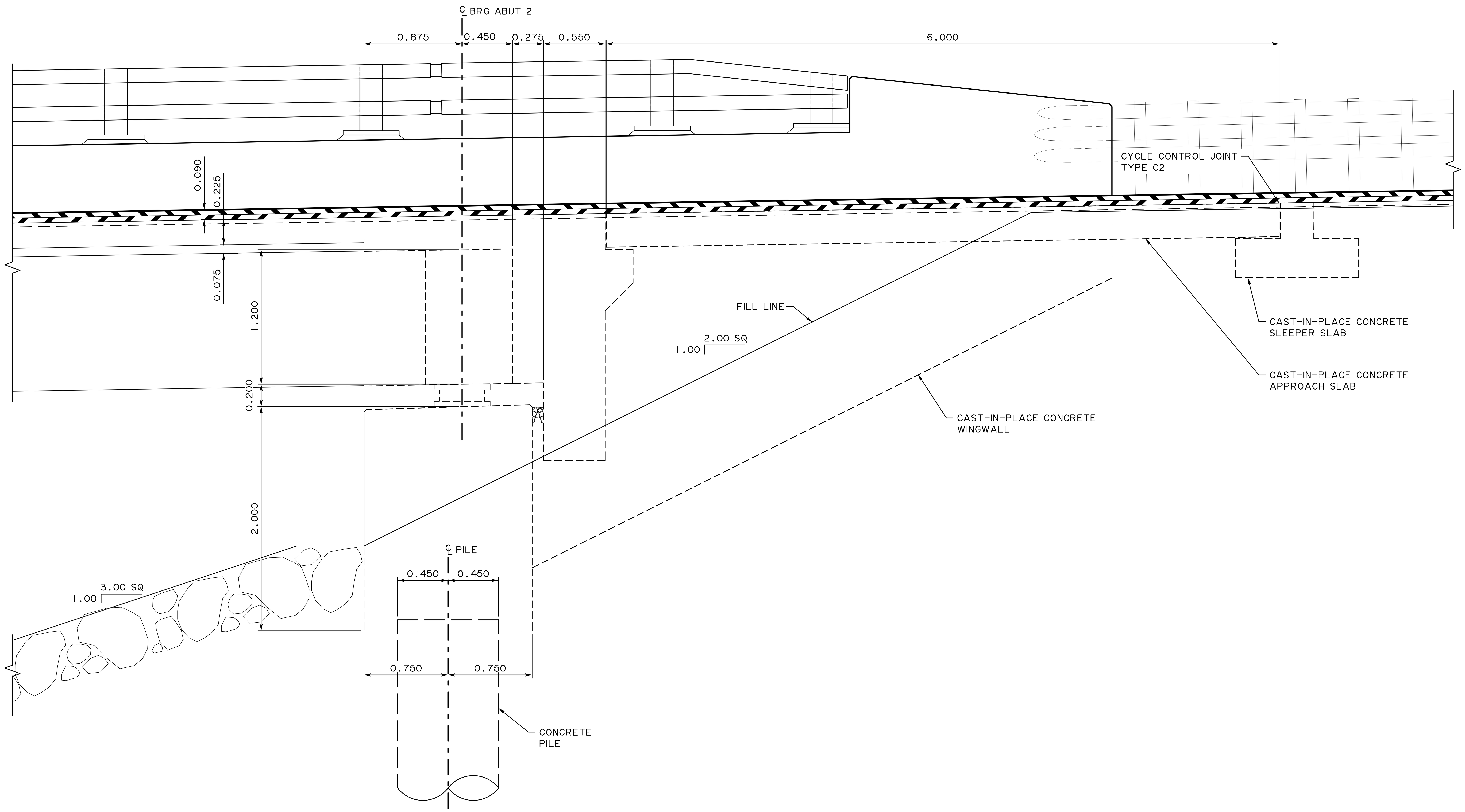

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		JOB NO.	110773396	DATE	DATE

REV	DATE	REVISION	BY

Alberta Transportation

SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
HWY 22 BRIDGE OVER DIVERSION CHANNEL
ABUTMENT 2 DETAIL

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
2017-10-19	SSE15-24-4-5	BF 968	-	HWY 22	7 OF 7	SK-1014

DRAWING SK-1014 · HIGHWAY · CONTRACT · DESCRIPTION SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1) · PHOTO · DATE · BY · SURVEYED · DEPARTMENT BAR CODE

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2018-10-19 10:38am By: jito

Appendix B COST ESTIMATE (CLASS B)

Stantec

19-Oct-18
Bridge File: TBD
Estimated Length (m): 78
Estimated Width (m): 14.35
Deck Area (m2): 1119
Total Area (m2): 1230

Cost Estimate B
SR1 - Highway 22
1200 mm Deep Precast NU - Option 1

Item No.	AT Code	Bid Item Description	Estimated Quantity	Unit	Estimated Unit Price	Estimated Cost
1	X004	Site Occupancy		days	$ -	$ -
2	X100	Mobilization (10%)	1	lump sum	$ 448,100.00	$ 449,000.00
3	F188	Excavation-Structural	1800	m3	$ 19.75	$ 36,000.00
4	F200	Backfill	1	lump sum	$ 141,000.00	$ 141,000.00
5	F505	Additional Heavy Rock Riprap (Class 1)	20	m3	$ 345.00	$ 7,000.00
6	F822	Pile Concrete	265	m3	$ 573.00	$ 152,000.00
7	F824	Drill Rig Set Up	20	piles	$ 7,871.00	$ 158,000.00
8	F826	Pile Installation	300	m	$ 687.00	$ 207,000.00
9	F834	Concrete - Class C	484	m3	$ 1,020.00	$ 494,000.00
10	F841	Concrete - Class HPC	536	m3	$ 2,051.00	$ 1,101,000.00
11	F018	Sealer	1	lump sum	$ 10,000.00	$ 10,000.00
12	F780	Bridgerail	1	lump sum	$ 85,000.00	$ 85,000.00
13	F853	Stainless Reinforcing Steel - Supply	57800	kg	$ 7.40	$ 428,000.00
14	F850	Plain Reinforcing Steel - Supply	72600	kg	$ 1.39	$ 101,000.00
15	F854	Reinforcing Steel - Place	130400	kg	$ 1.18	$ 154,000.00
16	F948	Supply, Delivery and Install NU Girders	393	m	$ 1,860.00	$ 731,000.00
17	F940	Delivery of Girders	393	m	$ 115.00	$ 46,000.00
18	F945	Erection of Girders	393	m	$ 145.00	$ 57,000.00
17	F905	Supply and Delivery of Bearings	1	lump sum	$ 60,000.00	$ 60,000.00
18	F910	Installation of Bearings	1	lump sum	$ 15,000.00	$ 15,000.00
19	F974	Deck Waterproofing	1222	m2	$ 43.00	$ 53,000.00
20	F980	Asphalt Concrete Pavement - Mix Type H2 (150-200A)	2298	tonne	$ 187.00	$ 430,000.00
21	F018	Approach Rail Transitions	1	lump sum	$ 10,000.00	$ 10,000.00
22	D018	Drain Troughs	1	lump sum	$ 5,000.00	$ 5,000.00

Remarks

1 Based on At Unit Price Averages Report (Provincial Average Aug 2016-Mar 2018)
2 Based on a typical semi-integral abutment with 5 piles
3 Assumes reinforced elastomeric bearings

Estimated Tender Cost:	**$4,930,000.00**
Estimated Unit Cost ($/m^2):	**$4,100.00**
Contingency: *10%*	$493,000.00
Total Estimated Project Cost:	**$5,423,000.00**

19-Oct-18
Bridge File: TBD
Estimated Length (m): 78
Estimated Width (m): 14.35
Deck Area (m2): 1119
Total Area (m2): 1230

Cost Estimate B
SR1 - Highway 22
Steel Girders - Option 2

Item No.	AT Code	Bid Item Description	Estimated Quantity	Unit	Estimated Unit Price	Estimated Cost
1	X004	Site Occupancy		days	$ -	$ -
2	X100	Mobilization (10%)	1	lump sum	$ 455,100.00	$ 456,000.00
3	F188	Excavation-Structural	1800	m3	$ 19.75	$ 36,000.00
4	F203	Backfill	1	lump sum	$ 141,000.00	$ 141,000.00
5	F505	Additional Heavy Rock Riprap (Class 1)	20	m3	$ 345.00	$ 7,000.00
6	F822	Pile Concrete	265	m3	$ 573.00	$ 152,000.00
7	F824	Drill Rig Set Up	20	piles	$ 7,871.00	$ 158,000.00
8	F826	Pile Installation	300	m	$ 687.00	$ 207,000.00
9	F834	Concrete - Class C	484	m3	$ 1,020.00	$ 494,000.00
10	F841	Concrete - Class HPC	491	m3	$ 2,051.00	$ 1,008,000.00
11	F018	Sealer	1	lump sum	$ 10,000.00	$ 10,000.00
12	F780	Bridgerail	1	lump sum	$ 85,000.00	$ 85,000.00
13	F853	Stainless Reinforcing Steel - Supply	51800	kg	$ 7.40	$ 384,000.00
14	F850	Plain Reinforcing Steel - Supply	72600	kg	$ 1.39	$ 101,000.00
15	F854	Reinforcing Steel - Place	130400	kg	$ 1.18	$ 154,000.00
16	F900	Supply of Structural Steel Girders and Associated Material	187	tonne	$ 3,864.00	$ 722,000.00
17	F925	Delivery of Girders	187	tonne	$ 300.00	$ 57,000.00
18	F930	Erection of Girders	187	tonne	$ 1,000.00	$ 187,000.00
19	F905	Supply and Delivery of Bearings	1	lump sum	$ 120,000.00	$ 120,000.00
20	F910	Installation of Bearings	1	lump sum	$ 30,000.00	$ 30,000.00
23	F974	Deck Waterproofing	1222	m2	$ 43.00	$ 53,000.00
24	F980	Asphalt Concrete Pavement - Mix Type H2 (150-200A)	2298	tonne	$ 187.00	$ 430,000.00
25	F018	Approach Rail Transitions	1	lump sum	$ 10,000.00	$ 10,000.00
26	D018	Drain Troughs	1	lump sum	$ 5,000.00	$ 5,000.00

Remarks

1 Based on At Unit Price Averages Report (Provincial Average Aug 2016-Mar 2018)
2 Based on a typical semi-integral abutment with 5 piles
3 Assumes reinforced elastomeric bearings

Estimated Tender Cost:	**$5,007,000.00**
Estimated Unit Cost ($/m^2):	**$4,100.00**
Contingency: *10%*	$501,000.00
Total Estimated Project Cost:	**$5,508,000.00**

19-Oct-18
Bridge File: TBD
Deck Area (m2): 1119
Discount Rate: 0.04

Life Cycle Cost Estimate
SR1 - Highway 22

Description:	Unit	Estimated Quantities: *Option 1 1200 mm Precast NU*	Estimated Quantities: *Option 2 1300 mm Steel Plate*	Estimated Unit Rate	Estimated Cost: *Option 1 1200 mm Precast NU*	Estimated Cost: *Option 2 1300 mm Steel Plate*
Initial Capital Cost					**$5,423,000**	**$5,508,000**
Deck Rehab - 35 years	sq.m		1 119	*$1,300.00*	$0	$368,643
Deck Rehab - 40 years	sq.m	1 119		*$1,300.00*	$302,998	$0
ACP Replacement - 15 years	sq.m	1 119	1 119	*$400.00*	$248,536	$248,536
ACP Replacement - 30 years	sq.m	1 119	1 119	*$400.00*	$138,003	$138,003
ACP Replacement - 45 years	sq.m	1 119	1 119	*$400.00*	$76,628	$76,628
Bearing Replacement - 40 years	ea.	10	20	*$10,000.00*	$20,828	$41,657
Pigmented Sealer - 15 years	sq.m	310	90	*$30.00*	$5,163	$1,499
Pigmented Sealer - 30 years	sq.m	310	90	*$30.00*	$2,867	$832
Pigmented Sealer - 45 years	sq.m	310	90	*$30.00*	$1,592	$462
				PV	$796,615	$876,260
				NPV	**$6,219,615**	**$6,384,260**

Appendix C BRIDGE CHOOSE DESIGN FORM

Bridge Choose Design

Bridge File: ____________
Region: Southern Region

Project Description: Hwy 22 over Springbank Diversion Channel Highway: 22 Road Authority: Alberta Transportation
Dept. Sponsor: ____________ Dept. Admin: ____________ TSB Liaison: N/A
Consultant: Stantec Consulting Ltd. Project Manager: ____________ CE Agreement: ____________

CLEAR ROADWAY WIDTH:	13.4	AREA (O.T.O. fills and total bridge width) :	1250 m^2

STRUCTURE ALTERNATIVES				
	Description	Selected	Cost Estimate	NPV (50 Years, 4%)
1	1200 mm deep NU Girder	Yes	$ 5.42 M	$ 6.22 M
2	1320 mm deep Steel Plate Girder		$ 5.51 M	$ 6.38 M

SPECIAL CONSIDERATIONS:	
Notes:	

SELECTED ALTERNATIVE:			
Girder Type, Size and No. of Lines:	Five 1200 mm prestressed concrete NU girders spaced at 2.9 m		
Culvert Size (span x rise x length) and Shape:	N/A		
Abutment Type:	Semi-integral	Pier Type:	Concrete T-Shape
Deck and Wearing Surface Type:	225 mm cast-in-place high performance concrete deck with 80 mm two course ACP		
Deck Joints:	C2 control joint at the end of approach slab.		
Curbs:	N/A	Bridge Rail:	TL-5 double tube bridge rail
Approach Slabs:	Cast-in-place high performance concrete	Guardrail:	Thrie-beam approach rail transition
Notes:			
DD Drawing No.'s:	N/A		

Draft Submission: ____________ Review Meeting Date: ____________ Final Submission: ____________

	Cost Estimate	Type	Date
Current:	$5,423,000	B	Oct 19, 2018
Previous:	$8,833,000	A	May 12, 2018
Includes:	Construction, Contingencies		

Milestone Schedule	Date
Project Design Brief:	
Complete detailed design:	
Tender ready for advertising:	
Tender advertize date:	

Consultant Project Manager's Signature	Dept. Administrator's Signature	Dept. Sponsor's Signature

Copies to: Consultant, TSB, Bridge File

Appendix D GEOTECHNICAL MEMO

Stantec

Memo

To:	Kristoffer Karvinen Calgary (25th Street) Office	From:	Daniel McLellan Calgary (25th Street) Office
File:	110773396	Date:	July 17, 2018

Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel

1.0 INTRODUCTION

This memorandum provides preliminary foundation recommendations for two proposed bridges that will cross over the diversion channel proposed for the Springbank Off-Stream Reservoir (SR1).

2.0 PROJECT UNDERSTANDING

The proposed bridges are located on Highway 22 and Township Road 242, west of Calgary, approximately 20 km upstream of the Glenmore Reservoir.

Our understanding of the proposed bridges comes from these previously issued reports:

- *Bridge Conceptual Design Report. Alberta Transportation BF XXX, Highway 22 over Springbank Diversion Channel* by Stantec Consulting Ltd., dated February 3, 2017
- *Bridge Conceptual Design Report. Alberta Transportation BF XXX, Township Road 242 over Springbank Diversion Channel* by Stantec Consulting Ltd., dated February 3, 2017

The location and general arrangement of the proposed bridges and figures relating to the proposed bridges are presented in **Appendix B**. We understand that both bridges will have a 3-span arrangement comprising the two abutments and two piers at each bridge. The central span will be approximately 30 m. We understand that integral abutment bridges with driven steel H-piles are the preferred bridge design type for Alberta Transportation. Cast-in-place concrete piles are also considered a foundation alternative. Exact loading conditions of the bridges and associated foundations are not currently known.

The geotechnical basis for the bridge structure foundation design is outlined in the following previously issued reports:

- *Springbank Off-Storage Project – Preliminary Geotechnical Assessment Report*, by Stantec Consulting Ltd., dated March 29, 2017
- *Springbank Off-Stream Storage Project – Geotechnical Investigation Report*, by Stantec Consulting Ltd., dated December 13, 2016
- *Seismic Hazard Assessment – Springbank Off-Stream Dam and Reservoir,* by Stantec Consulting Ltd., dated November 28, 2016

The construction sequencing for the excavation of the channel and construction of the bridges is not currently known.

Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel

3.0 GEOTECHNICAL INVESTIGATION

To characterize the subsurface conditions at the proposed bridge locations, four geotechnical boreholes were advanced at each proposed bridge using auger drilling methods. At three boreholes advanced at the Township Road 242 bridge (H10, H12, H13); rotary coring was used to advance into the bedrock following auger refusal. The as-built borehole locations, surveyed by Stantec Consulting Ltd., are shown in **Table 1**.

Table 1 Borehole Locations and Elevations

Bridge Location	Borehole ID	As-built GPS Coordinates (3TM)		Ground Elevation (m)	
		Easting	Northing	Ground Surface	Termination Depth [Elevation]
Highway 22	H01	-32713	5656427	1214.1	30.0 [1184.1]
Highway 22	H02	-32713	5656458	1214.9	30.1 [1184.8]
Highway 22	H03	-32714	5656489	1215.6	30.5 [1185.1]
Highway 22	H04	-32714	5656520	1215.9	30.0 [1185.9]
Township Road 242	H10	-33314	5655853	1217.4	30.2 [1187.2]
Township Road 242	H11	-33415	5655857	1219.5	21.4 [1198.1]
Township Road 242	H12	-33377	5655857	1217.6	34.7 [1182.9]
Township Road 242	H13	-33347	5655858	1217.1	34.8 [1182.3]

The subsurface stratigraphy encountered in the boreholes was recorded by Stantec personnel as the boreholes were advanced, and laboratory testing was completed on selected retrieved samples.

The boreholes advanced at the proposed Highway 22 bridge (H01 to H04) generally encountered topsoil, overlying glaciolacustrine deposits of clay and silt, overlying glacial clay till, overlying sedimentary bedrock comprised inferred very poor to poor quality mudstone, siltstone, and sandstone, completely to highly weathered and very weak. Auger refusal was not encountered in the sedimentary bedrock and rock core was not recovered. A cross-section for the bridge location is shown in **Appendix B**. The geological map identifies this bridge as being underlain by the Brazeau Formation[1].

[1] Hamilton, W.N., Price, M.C. and Langenberg, C.W. (compilers), 1999; Geological Map of Alberta, Alberta Geological Survey, Alberta Energy and Utilities Board, Map No. 236, scale 1:1 000 000.

**Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel**

Boreholes advanced at the proposed Township Road 242 bridge (H10 to H13) generally encountered surficial gravel fill, overlying organic clay, overlying glaciolacustrine clay, overlying clay glacial till. Bedrock comprised very poor to poor quality sandstone and claystone, completely to highly weathered and very weak. Auger refusal was encountered in the sedimentary bedrock at all boreholes. Upon encountering auger refusal in boreholes H10, H12, and H13, rotary drilling was used to advance the boreholes to target depth. A cross-section for the bridge location is shown in **Appendix B**. The geological map identifies this bridge as being underlain by the Coalspur Formation[2], however the bridge is likely underlain by the Brazeau Formation. The conglomerate boundary between the Coalspur and Brazeau Formations was observed in the Highway 22 cutting.

Measured groundwater levels at the time of borehole advancement and observed seepage in boreholes are summarized in **Table 2.** Standpipe piezometers, to permit future monitoring of groundwater levels, were not installed in any of the boreholes.

Table 2 Summary of Groundwater Levels During Drilling

Bridge Location	Borehole ID	Groundwater Level (m) after drilling, prior to backfilling	
		Below Existing Ground Surface	Elevation
Highway 22	H01	4.3	1209.8
Highway 22	H02(1)	10.0	1204.9
Highway 22	H03(1)	Dry	N/A
Highway 22	H04(2)	9.3	1206.6
Township Road 242	H10(3)(6)	N/A	N/A
Township Road 242	H11(4)	Dry	N/A
Township Road 242	H12(6)	N/A	N/A
Township Road 242	H13(5)(6)	N/A	N/A

Notes:
(1) Seepage noted at 4.6 m below existing ground surface (elev. 1210.3 m – H02; 1211.0 m – H03).
(2) Seepage noted at 3.4 m below existing ground surface (elev. 1212.5 m).
(3) Seepage noted at 14.0 m below existing ground surface (elev. 1203.4 m).
(4) Seepage noted at 6.1 m below existing ground surface (elev. 1213.4 m).
(5) Seepage noted at 15.0 m below existing ground surface (elev. 1202.1 m).
(6) Groundwater level at completion of borehole impacted by rock coring water.

[2] Hamilton, W.N., Price, M.C. and Langenberg, C.W. (compilers), 1999; Geological Map of Alberta, Alberta Geological Survey, Alberta Energy and Utilities Board, Map No. 236, scale 1:1 000 000.

**Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel**

The proposed channel alignment and hence bridge location for Township 242 bridge has changed since the site investigation. This means that there is no borehole for the western bridge abutment and one of the previous abutment holes now reflects a pier location. A borehole at the revised western bridge abutment is recommended. Alternatively, if the construction sequence allows, and depending on the bridge design flexibility, the channel excavation could be used to obtain further geotechnical information for the abutment.

The soil and bedrock conditions encountered within the boreholes are described in detail on the Borehole Records which are provided in **Appendix C**, along with an explanation of the symbols and terms used in their description. The borehole records are also superimposed on figures presented in **Appendix B**.

4.0 INTEGRAL ABUTMENT BRIDGES

Based on our current project understanding, the bridges over the diversion channel along Highway 22 and Township Road 242 are being considered for fully integral abutment bridges with a single row of driven steel H-piles at the abutments. In an integral abutment bridge, expansion joints and bearings at the ends of the bridge deck are replaced with isolation joints at the ends of the approach slabs and are integral with abutments supported on flexible foundations.

The lateral resistance of an integral abutment is directly related to the forces induced in the bridge structure due to movements; for example, from thermal expansion and contraction.

Integral abutment bridge design for the Highway 22 and Township Road 242 bridges is considered feasible if construction risks are mitigated through the following design and construction considerations.

The boreholes advanced at both bridge sites near the proposed abutments generally encountered ground conditions consisting of stiff to hard clay and clay till, and dense silt. At the proposed Highway 22 bridge location, bedrock was encountered at relatively shallow depths (approximately 6.0 m below ground surface in boreholes advanced for the abutments).

The Canadian Highway Bridge Design Code (CHBDC) recommends pre-drilling 0.6 m diameter holes to a minimum depth of 3.0 m and filling with loose sand in advance of driving piles to reduce resistance to lateral movements and provide flexibility in stiff or dense soils.

Although not observed in the boreholes, there is potential for sloughing in the soil strata encountered, especially below the groundwater table. Pre-drilled holes should be cased with a corrugated steel pipe (CSP) sleeve to prevent the hole from sloughing in and prevent migration of fines into the backfill. The loose pre-drilled backfill can densify overtime. Use of uniform loose sand will reduce potential densification; however, it will still provide some resistance to loading that will need to be accounted for in the detailed design. Alternatively, use of CSP sleeves backfilled with foam pellets may be considered as an alternative to sand to prevent load resistance over the design free-length portion of the abutment piles.

**Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel**

There is a risk of pile driving obstructions and early pile refusal when advancing steel H-piles through potential cobbles and boulders in the clay till and into bedrock at the bridge locations. At the Highway 22 bridge location, boreholes were augered into bedrock 19.7 m to 23.8 m without encountering refusal in the siltstone and mudstone, but there is potential for strong sandstone stringers in the bedrock formation. Overstressing the top of the H-pile is a risk with shallow bedrock observed in boreholes at the Highway 22 abutment locations. A large steel H-pile cross section is recommended for driving efficiency and to increase likelihood of achieving minimum design pile penetration into bedrock. Consideration should also be given to having a vibratory hammer and an auger piling rig available in the occurrence that driven pile refusal in bedrock is encountered before achieving minimum design embedment requirements. The vibratory hammer may be required to remove damaged/refused piles and the auger pile rig would allow pre-drilling through obstructions or layers that caused refusal. Further discussion and recommendations are included in **Section 5.4.1** Additional Driven Pile Considerations of this report.

Recommendations herein assume that the integral abutment design will be in accordance with the CHBDC. The top of the H-piles should be embedded into the abutment wall at least 0.6 m and should be reinforced to transfer bending forces. To reduce soil pressure, the abutment height should be limited to 6.0 m and wingwall length limited to 7.0 m. Abutments should be even in height, as a height difference may result in unbalanced lateral loading. During construction, backfill placed behind both abutments should occur simultaneously, and not until the deck has achieved at least 75% of its specified strength. Non-cohesive, free draining material sized to deliver uniform earth pressure to the back of the abutment is recommended. This material may have to be imported to site depending on availability in the common excavations and processing capabilities.

5.0 PRELIMINARY FOUNDATION ASSESSMENT

The recommended unit shaft and end bearing resistances to compressive loading at Ultimate Limit State (ULS) for cast-in-place concrete piles and driven steel piles are provided in relevant sections of this memorandum. These are based on the soil and bedrock profiles from the boreholes located at each of the proposed bridge locations. Note that there is some uncertainty regarding lateral variation of ground conditions and that the revised location of the western abutment of the Township Road 242 road bridge was not investigated by a borehole.

According to the Canadian Foundation Engineering Manual 4th Edition (CFEM) and in accordance with the Canadian Highway Bridge Design Code, the recommended geotechnical resistance factors for deep foundations are provided in **Table 3**.

Table 3 Geotechnical Resistance Factors – Deep Foundations

Description	Resistance Factor, Φ
Resistance to axial load	
• Semi-empirical analysis using laboratory and in-situ test data	0.4
• Uplift resistance by semi-empirical analysis	0.3
Horizontal load resistance	0.5

5.1 FOUNDATIONS ON ROCK

The geotechnical design of foundations in rock, particularly at the abutments where the ground slopes away, is more complex than for soils. This is due to the difference in behavior between the rock mass and the intact rock. The fracturing within the rock and the orientation of fracturing in the rock promote anisotropic behavior and contribute to the rock mass behavior, which can be substantially different to the intact rock behavior. The scale of the foundation relative to the scale of the rock discontinuities is also a factor in behavior, and within fractured rock, the in-situ stress is also particularly important, with potential to raise the bearing capacity significantly as the depth and stress increases. Given a fractured rock mass with weak layers, like the formations at these sites; the effect of these issues will be more significant due to potential for sloping ground at the abutments. The effect of the issues would be lessened if the sites were on flat ground, bearing on stronger, less fractured rock.

We cannot, therefore, finalize geotechnical recommendations for the rock foundations without knowing more about the foundations themselves. The required information for geotechnical design is:

- Bearing elevations
- Proposed loads
- Dimensions of the proposed foundations and knowledge of the grouping of foundations

**Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel**

Design of the foundations may be an iterative process, whereby the geotechnical engineers provide initial, likely conservative guidance given the uncertainties, which is used by the bridge engineers to develop concepts for the foundations, which are then re-checked by the geotechnical engineers once more information is available. The information for rock foundations provided in this memo should therefore be taken as initial guidance, that will require further work once the foundation design is clearer. Once the foundatons have been finalized, the geotechnical engineers can also check settlements, if required.

Note that the process of driving piles within rock can cause additional fracturing within the rock with an associated reduction in strength.

In addition, the rock is interbedded with weaker and stronger units. The values presented in **Table 4** and **Table 5** are based upon the weakest rock encountered; there will be beds of rock that are substantially stronger than this.

5.2 POTENTIAL FOR HEAVE

The bridge central piers have the following conditions:

- The piers are within a channel excavated up to 15 m below existing ground level; therefore, there will be active unloading.
- The foundation contains rock units that have high liquid limits and plasticity indices (including potential for bentonite layers) *(Springbank Off-Stream Storage Project – Geotechnical Investigation Report*, by Stantec Consulting Ltd., dated December 13, 2016.).
- There is potential for water to come into contact with the higher plasticity layers.
- The construction sequencing is not known but may not include for a delay between excavation and bridge construction.

This combination of circumstances means there is potential for heave within the rock foundation units. The heave could affect pile resistances and serviceability of the bridge.

Heave cannot be calculated until the bridge pier and foundation design is complete.

5.3 DRILLED CAST-IN-PLACE CONCRETE PILES

Due to the presence of saturated silt layers with varying thickness, as well as the observed groundwater seepage during borehole advancement, complications with sloughing and seepage for drilled cast-in-place concrete piles should be anticipated. At both bridge locations, the contractor should ensure casing is available on-site during installation of the bored piles.

Drilled cast-in-place concrete piles at both bridges may be designed to resist static axial compressive loads on the basis of the shaft and toe resistance parameters at ULS. ULS values are based on the understanding that the minimum pile spacing (center to center) is greater than three pile diameters. Unfactored shaft and toe resistances for cast-in-place concrete piles are shown in **Table 4** for the Highway 22 bridge and Township Road 242 bridge.

Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel

Table 4 Proposed Highway 22 and Township Road 242 Bridges – Cast-in-Place Concrete Pile Design Criteria at ULS (Unfactored)

Location	Material and Depth	Unfactored Shaft Resistance at ULS (kPa)	Unfactored Toe Resistance at ULS (kPa)
Highway 22 Abutments	Frost Zone (0.0 m to 2.0 m)	0	N/A
	Clay and silt with clay till layers (2.0 m to 6.0 m)	18	N/A
	Sedimentary bedrock (below 6.0 m)	220	1,000
Highway 22 Piers	Frost Zone (0.0 m to 2.0 m)	0	N/A
	Sedimentary bedrock (below 2.0 m)	220	1,000
Township Road 242 Abutments	Frost Zone (0.0 m to 2.0 m)	0	N/A
	Clay (2.0 m to 6.0 m)	20	N/A
	Clay till (6.0 m to 15.0 m)	55	N/A
	Sedimentary bedrock (below 15.0 m)	440	1,000
Township Road 242 Piers	Frost Zone (0.0 m to 2.0 m)	0	N/A
	Clay till (2.0 m to 7.0 m)	20	N/A
	Sedimentary bedrock (below 7.0 m)	440	1,000

Notes:

(1) Depths are relative to existing grade (at the time of borehole drilling investigations) for the abutments and relative to the proposed bottom elevation of the diversion channel for the piers (Highway 22 - elev. 1205.9 m; Township Road 242 – elev. 1206.8 m).
(2) Depth to soil layer may vary.
(3) Depth to rock may vary laterally across the site and there is potential for the rock unit type to be different over short lateral distances for the site due to dipping and bedding orientation.
(4) Resistances and recommendations for piles assume pile end bearing on a very weak mudstone bedrock layer and are based on cast-in-place concrete pile design. There is potential for end bearing on a stronger rock unit; therefore, the toe resistances should be considered 'lower bound' values.
(5) Piles should be socketed into rock a minimum of one to three times the pile diameter. The rock socket length should not be less than 1 m.

**Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel**

The toe resistance of the bedrock is dependent on pile inspection and confirmation that the pile base is clean. To achieve the shaft and toe resistance values shown in **Table 4**, the sides and base of the pile boring must be free of water and loose or remoulded (smeared) material prior to placing concrete. Inspection by qualified geotechnical personnel during piling is required to ensure that the recommended values are obtained. The inspection must also include assurance that the as-built pile installations are in accordance with pile designs as approved by the geotechnical and structural engineers and should include down-hole techniques to verify piles are not bearing on bentonitic layers, clean conditions, and if necessary, the use of roughening tools to prevent smearing in the sedimentary rocks.

Design of pile groups is governed by the Serviceability Limit State (SLS). A settlement analysis of pile groups can be completed by Stantec and reported in the future when detailed design information (number of piles, pile spacing, loading conditions) is available. For initial design assumptions, group effects should be considered when the centre to centre spacing is less than five diameters with a minimum centre to centre spacing of three pile diameters recommended.

5.4 DRIVEN STEEL PILES

Selection of pile size should consider design loads, soils resistance, material availability, and local experience. It is recommended that the contractor confirm successful nearby local driven pile experience for similar pile lengths, sizes and loads proposed.

The mechanics of driven piled foundations in weak rock is poorly understood[3,4], particularly when selecting appropriate material parameters. The driving can cause a complex combination of crushing and remolding; fracture shearing and movement; displacement of rock blocks and cement disintegration[4].

The driven pile design parameters are provided in **Table 5** for the Highway 22 bridge and Township Road 242 bridge. ULS values assume that the piles are a minimum of three pile diameters apart. If the piles are spaced closer, group effects should be considered in the detailed design.

[3] Tomlinson, M.J., 1994; Pile Design and Construction Practice.
[4] Terente, V., Irvine, J., Comrie, R., Crowley, J., 2015; Pile Driving and Pile Installation Risk in Weak Rock. Geotechnical Engineering for Infrastructure and Development.

Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel

Table 5 Proposed Highway 22 and Township Road 242 Bridges – Driven Steel Pile Design Criteria at ULS (Unfactored)

Location	Material and Depth	Unfactored Shaft Resistance at ULS (kPa)	Unfactored Toe Resistance at ULS (kPa)
Highway 22 Abutments	Frost Zone (0.0 to 2.0)	0	N/A
	Clay and silt with clay till layers (2.0 m to 6.0 m)	20	N/A
	Sedimentary bedrock (below 6.0 m)	100	1,000
Highway 22 Piers	Frost Zone (0.0 to 2.0 m)	0	N/A
	Sedimentary bedrock (below 2.0 m)	100	1,000
Township Road 242 Abutments	Frost Zone (0.0 to 2.0 m)	0	N/A
	Clay (2.0 m to 6.0 m)	20	N/A
	Clay till (6.0 m to 15.0 m)	55	N/A
	Sedimentary bedrock (below 15.0 m)	100	1,000
Township Road 242 Piers	Frost Zone (0.0 m to 2.0 m)	0	N/A
	Clay till (2.0 m to 7.0 m)	20	N/A
	Sedimentary bedrock (below 7.0 m)	100	1,000

Notes:

(1) Depths are relative to existing grade at the time of borehole drilling investigations for the abutments and proposed bottom elevation of the diversion channel for the piers (Highway 22 - elev. 1205.9 m; Township Road 242 – elev. 1206.8 m).
(2) Depth to soil layer may vary.
(3) Depth to rock may vary laterally across the site and there is potential for the rock unit type to be different over short lateral distances for the site due to dipping and bedding orientation.
(4) Resistances and recommendations for piles assume pile end bearing on a very weak mudstone bedrock layer. There is potential for end bearing on a stronger rock unit; therefore, the toe resistances should be considered 'lower bound' values. Due to rock fracturing effects from pile driving, it is recommended that an end bearing reduction factor be applied to resistances if bearing on a stronger rock unit.
(5) Piles should be socketed into rock a minimum of one to three times the pile diameter.

**Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel**

Recommended parameters provided in **Table 5** are for calculations of pile capacity versus embedment length. Actual pile capacities and pile lengths must be confirmed in the field through pile driving monitoring by qualified geotechnical personnel. Pile embedment depth into the local weathered sedimentary bedrock can be highly variable. Pile driving and refusal criteria to be used in field verification of pile capacity are directly dependent on such factors as pile size, length, and wall thickness as well as the specified design load and driving energy. If piles cannot be advanced to the design pile length, the pile capacity should be evaluated using the pile driving records. Pile load testing is recommended to determine ultimate resistance of the driven piles at the Highway 22 and Township Road 242 bridges.

The unfactored toe resistances in **Table 5** consider end bearing on the weakest rock encountered. There will be beds of rock that are substantially stronger than this, as well as potential for intermittent strong stringers of sandstone. Pile penetration depth will be affected by these factors and it is unlikely that more than 3 m to 5 m of embedment into the bedrock will be achieved before reaching refusal condition.

Final guidelines for driving criteria can be provided using a wave equation analysis program (WEAP) once the pile design and driving equipment have been finalized. Design by this method would enable an optimum match of hammer type and weight to pile type and soil conditions and allows a check to be made on driving stresses. Criteria may be developed by others; however, it is advised that Stantec be provided opportunity to review the pile design criteria prior to construction to confirm agreement with design recommendations.

In order to determine the reactions for the SLS the pile loadings, configurations and the desired settlement criteria are required. Once these data are available, the SLS reactions can be calculated, if requested.

5.4.1 Additional Driven Pile Considerations

As outlined in **Section 4.0** Integral Abutment Bridges, there is risk of encountering gravel to boulder clasts / erratics in the silty clay till and/or more resistant bedrock at both bridge locations, potentially causing pile driving obstructions. Therefore, cast steel drive shoes should be used to minimize potential for pile damage unless contractor has sufficient nearby experience to confirm they are not needed. If used, driving shoes should be fitted flush to the outside of the pipe piles so that shaft resistance is not compromised. Steel H-pile cross-sections with driving shoes are expected to have greater success in penetrating very dense silt layers and bedrock. If piles are terminated prior to reaching minimum design depth, these piles should be cut off below ground level and replacement piles installed.

All piles for a given structure should be driven into the same stratum and to similar depth, to reduce the potential for differential settlements between piles.

The elevation of the tops of driven piles should be recorded immediately after driving. This will allow checks for heave due to driving of adjacent piles. If uplift of 6 mm or greater occurs during driving of adjacent piles the displaced pile should be re-driven to at least its original embedment depth and final set. Piles should be checked during installation to ensure the vertical piles are within 2% of plumb.

Voids created near the ground surface during driving or from pre-drilling should be backfilled to maintain contact between the pile and surrounding soil to provide resistance to vertical and lateral loads. If pile installation is to occur during winter conditions, pre-drilling pilot holes through the frost may be required to avoid pile damage. Pre-drilling of driven piles may also be required for removal of an obstruction, or for ease of pile placement. Pre-drilling of driven piles will reduce shaft resistance, lateral resistance and in some cases, end bearing. Pre-drilling through the frost depth may be completed without adversely affecting pile capacities calculated using parameters identified above, provided voids are filled. Where possible, it is advised that pre-drilled holes be filled with sand prior to placing and driving piles to ensure good contact between pile and soil. If required, pre-drilled pilot holes should not exceed 90% of the pile diameter. The geotechnical engineer should be contacted for review and approval of any intended pre-drilling in excess of 90% of the pile diameter or in excess of frost depth.

Resistance to pile penetration may increase due to soil set-up or decrease due to relaxation. Pile re-striking should be carried out once equilibrium conditions in the soil have been re-established.

5.5 LATERAL CAPACITY

Vertical piles resist lateral loads and moments by deflecting until the necessary reaction in the ground is mobilized to resist the lateral loads. The design of piles subjected to lateral loads should consider such factors as the relative rigidity of the pile to the surrounding soil, the fixity conditions at the head of the pile (pile cap level), the structural capacity of the pile to withstand bending moments, the soil resistance that can be mobilized, the tolerable lateral deflection at the head of the pile, the applied vertical load, and pile group effects. For longer, more flexible piles, the maximum yield moment of the pile may be reached prior to mobilization of the lateral geotechnical resistance. For design purposes, both structural and geotechnical resistances should be evaluated to establish the governing case.

The theory of subgrade reaction assumes linear behavior of the soil and pile under static loading. CFEM 4th Edition advises this approach be limited to maximum deflections less than 1% of the pile diameter. Estimated lateral subgrade reaction modulus values for single piles were calculated based on empirical methods recommended by Terzaghi[5] and Davisson[6] and are presented as a function of pile diameter, d, and pile depth, z, in **Table 6**. For non-linear response of the soil associated with larger deflections or cyclic loading, it is recommended that p-y curves be considered for more accurate estimates of lateral pile reaction. Stantec can model lateral pile response, including generation of p-y curves, once the expected range of pile dimensions and pile head loading conditions are known, if requested.

[5] Terzaghi, K. 1955, Evaluation of Coefficients of Subgrade Reaction
[6] Davisson, M.T. 1970, Lateral Load Capacity of Piles

**Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel**

Table 6 Proposed Highway 22 and Township Road 242 Bridges – Horizontal Subgrade Reaction

Location	**Material and Depth[1]**	**Coefficient of Horizontal Subgrade Reaction[2], k_s (kPa/mm) (Static Loading)**
Highway 22 Abutments	Clay and silt with clay till layers (below 1.0 m to 6.0 m)	6/d
	Sedimentary bedrock (below 6.0 m)	30/d
Highway 22 Piers	Sedimentary bedrock (below 1.0 m)	30/d
Township Road 242 Abutments	Clay (below 1.0 m to 6.0 m)	6/d
	Clay till (6.0 m to 15.0 m)	8/d
	Sedimentary bedrock (below 15.0 m)	30/d
Township Road 242 Piers	Clay till (below 1.0 m to 7.0 m)	8/d
	Sedimentary bedrock (below 7.0 m)	30/d

NOTES:
1. Lateral and vertical extent of materials varies across the site; design should consider soil profile at nearest boring locations. Depth to soil layer may vary.
2. d = pile diameter (m)
3. Lateral resistance in the upper 1.0 m should be ignored due to disturbance from installation and seasonal effects.

If lateral resistance is expected to govern design, it is recommended that the pile response be modeled once proposed pile loading and size are confirmed. Lateral responses presented above are for single piles. When installed as a group, interaction between piles occurs such that the lateral pile deformations are increased. For designs using horizontal subgrade reaction it is advised that pile group load response be reduced as a function of center-to-center pile spacing. Recommended group reduction factors for coefficient of subgrade reaction are detailed in **Table 7** (after Davisson):

**Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel**

Table 7 Group Reduction Factors for Coefficient of Subgrade Reaction

Center-to-Center Spacing in Direction of Load	Group Reduction Factor for k_s
3d	0.25
4d	0.40
6d	0.70
8d	1.00
Note: d = pile diameter	

In each case the lead pile in the direction of the load will have a reduction factor equal to unity (e.g., for a three pile group with centre-to-centre spacing of three pile diameters the group reduction factor would be {[1+0.25+0.25] ÷ 3 = 0.5}). Note that proper analysis of pile group effects requires that soil nonlinearity be considered. Reduction factors for specific pile groups can be calculated and applied to p-y curves during detailed design, if requested.

6.0 SITE CLASS

The 2015 NBCC seismic design procedures are based on ground motion parameters (e.g., peak ground acceleration (PGA) and spectral acceleration, Sa values) having a 2% probability of exceedance in 50 years; i.e., the 2,475 year return period earthquake event.

Based on the results of the Stantec field investigation and Stantec seismic hazard assessment, it is appropriate to classify the existing ground conditions at the Highway 22 bridge as a Class C Site, and the Township Road 242 bridge as a Class D Site in accordance with the 2015 NBCC (Table 4.1.8.4.A).

Based on the observed moisture profiles and index testing, liquefaction of the native materials is unlikely. Damage to properly designed and constructed structural and non-structural components is expected to be minor during the 1 in 2,475 year design earthquake.

**Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel**

7.0 GENERAL RECOMMENDATIONS

Although there are construction risks, integral abutment bridge design with driven piles is considered feasible for the Highway 22 and Township 242 bridges. Cast-in-place concrete piles are also a viable foundation alternative for the bridges. Based on the anticipated ground conditions for bridge piers located within the bedrock (Highway 22), shallower foundation options may also be considered.

- If the proposed design changes, due to channel realignment or bridge design philosophy, future work is recommended and revision of this memorandum is required.
- Once the bridge and associated foundation design is progressed and foundations sizes, elevations, construction sequencing, and loads known, these preliminary foundation recommendations need to be reviewed as part of an iterative process. This would include an assessment of heave, bearing capacity checks, and potential effect of dipping discontinuities for foundations on sloping ground. This requires evaluation of local outcrop data to estimate the orientation of discontinuities.
- A supplementary borehole should be completed for the proposed Township Road 242 bridge during the next phase of investigation to reduce data gaps caused by the change in alignment. The borehole should extend to 30 m depth and should provide rotary core and if necessary, televiewing, through the rock. Should rock not be present within the upper 25 m, the hole depth should be revised. Ideally, the borehole should be on the south side of the existing road; this will allow evaluation of the lateral variation in ground conditions through comparison to borehole H11. Alternatively, the approach to foundation design could be flexible allowing utilization of the information obtained when excavating the channel.
- Additional boreholes at both the Highway 22 and Township Road 242 bridge locations are recommended for detailed design to determine bedrock dip and dip direction at the locations of the proposed piers and abutments for pile design considerations.
- When the channel is excavated, the conditions should be cross-referenced against anticipated foundation conditions for the bridges.

**Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel**

8.0 CLOSURE

The recommendations within this memorandum are based upon the current project understanding. This memorandum has been prepared by Daniel McLellan, P.Eng., Kyle Noble, P.Eng. (**Section 4.0** Integral Abutment Bridges), and Lucy Philip, M.Sc., P.Eng. and reviewed by Andrew Bayliss, M.Sc., P.Eng. We trust this meets your current expectations, please feel free to contact the undersigned with any questions.

STANTEC CONSULTING LTD.

PROFESSIONAL ENGINEER LUCY PHILIP ALBERTA

18 July 2018

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Appendix A
Statement of General Terms and Conditions

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec's present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

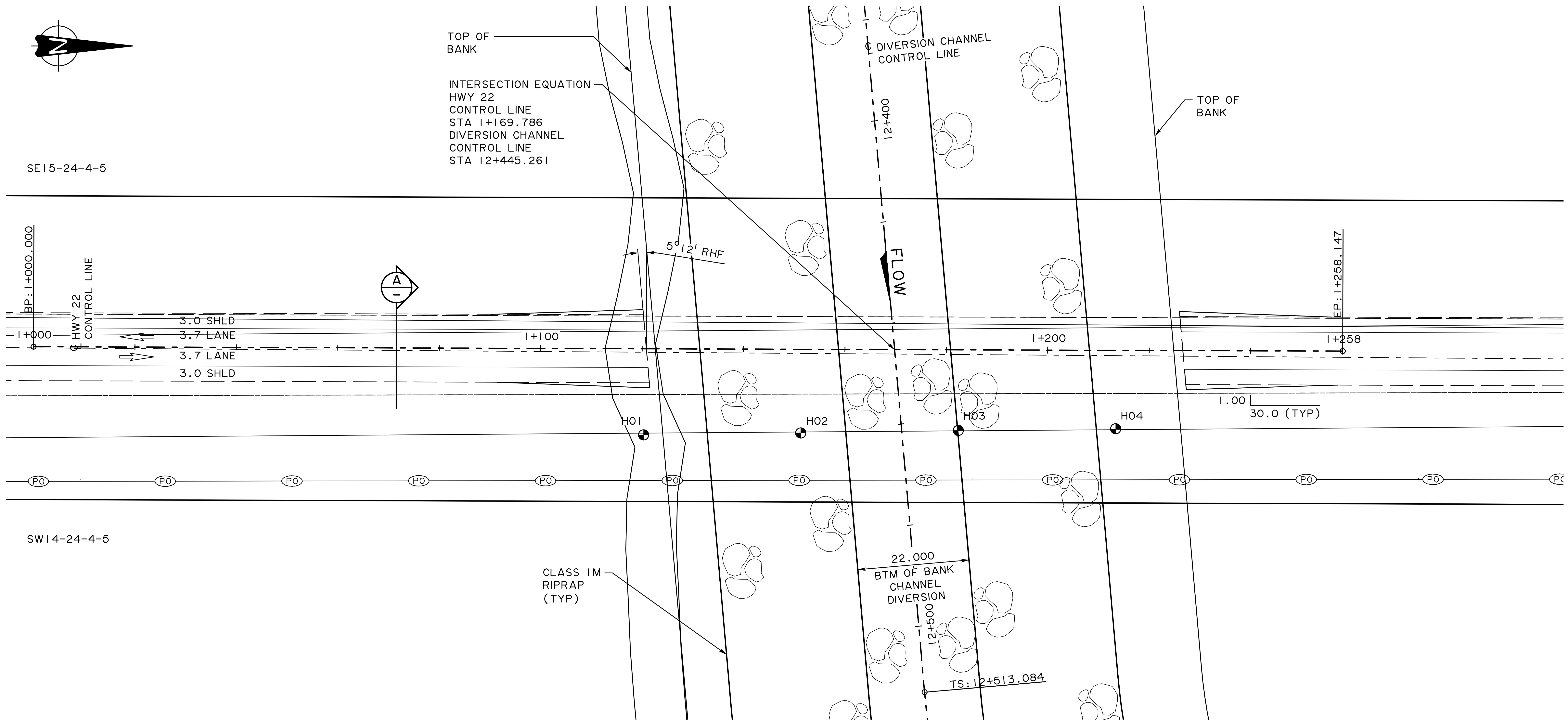
INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec will not be responsible to any party for damages incurred as a result of failing to notify Stantec that differing site or sub-surface conditions are present upon becoming aware of such conditions.

PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec, sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc.), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec cannot be responsible for site work carried out without being present.

Appendix B

Project Understanding



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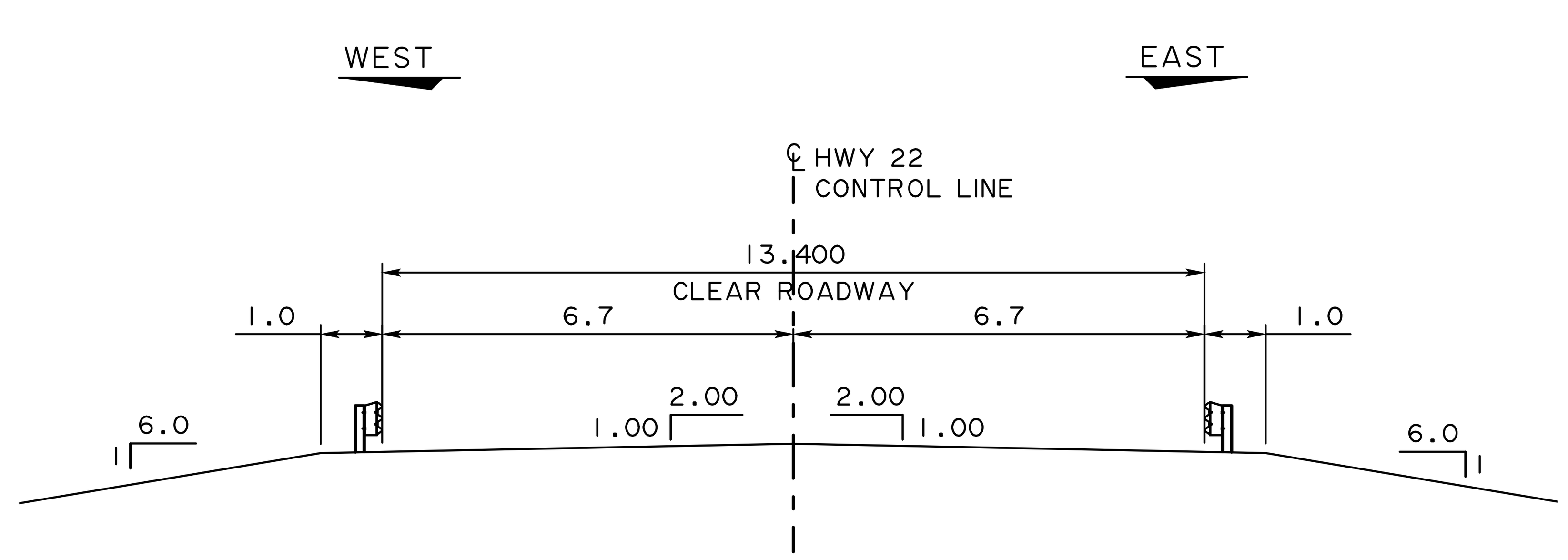

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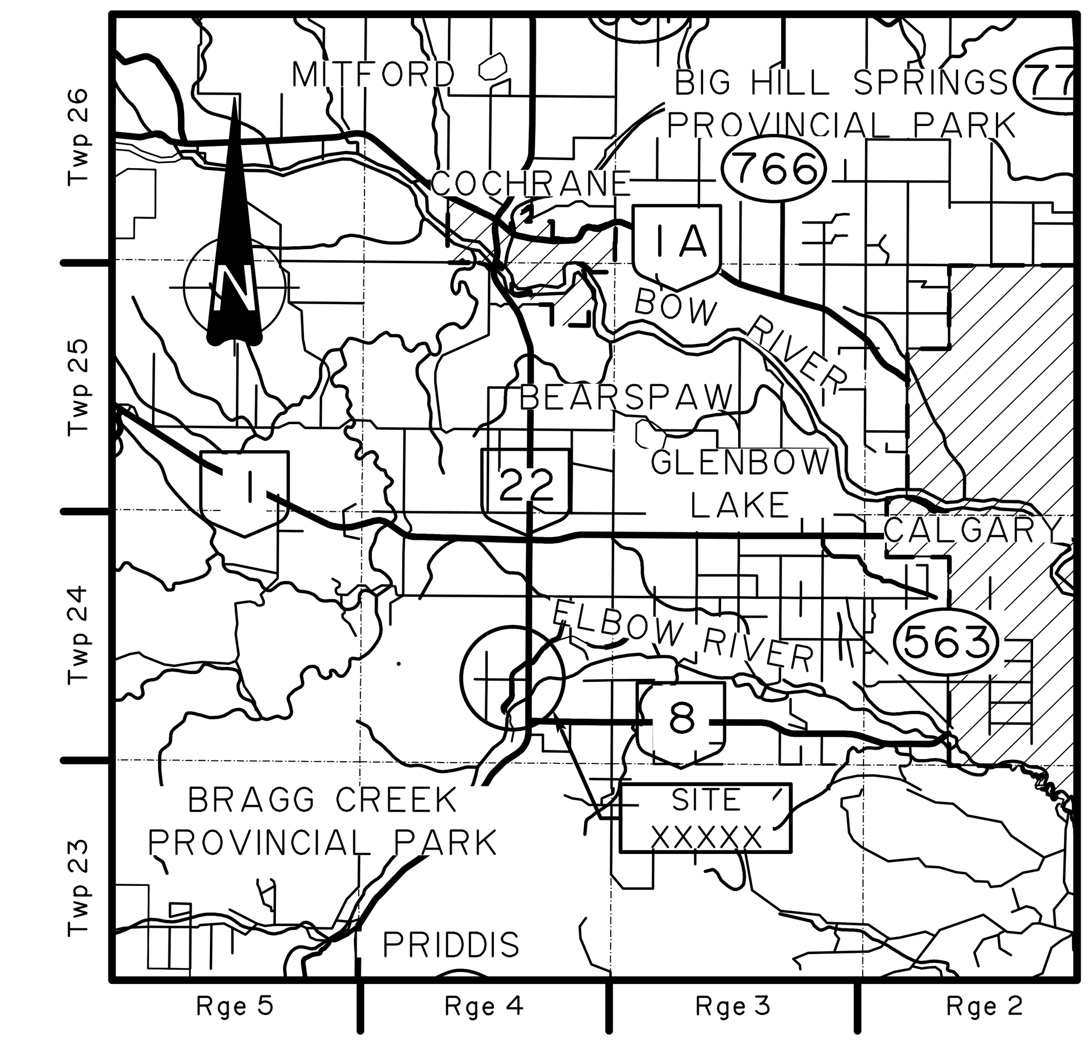

SITE PLAN
1: 250 000

- HIGHWAY 1 - 216
- HIGHWAY 500 - 986
- LOCAL ROAD

SURVEY INFORMATION

- SURVEY INFORMATION PROVIDED BY STANTEC CONSULTING LTD., COMPLETED DECEMBER 2016
- BOREHOLE
  H01 N 5656426.618 E -32712.635 EL 1214.111
  H02 N 5656457.601 E -32713.018 EL 1214.914
  H03 N 5656488.671 E -32713.511 EL 1215.550
  H04 N 5656519.691 E -32713.830 EL 1215.903
- THE COORDINATES AND STATIONING ARE BASED ON NAD '83 DATUM USING 3TM GRID PROJECTION, CENTRAL MERIDIAN 114 W

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- ROADWAY DESIGN STANDARDS:
  HWY 22 RAU-213.4-120
- ROADWAY ELEVATIONS ARE GIVEN TO TOP OF FINISHED ℄ ROADWAY

SHEET	DESCRIPTION	DRAWING
3	MOSAIC PLAN AND PROFILES	SK-3
2	ELEVATION	SK-2
1	PLAN AND GENERAL NOTES	SK-1

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DRAWING SK-1 | HIGHWAY | CONTRACT | DESCRIPTION: SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) | PHOTO | DATE | BY | SURVEYED | DEPARTMENT BAR CODE

LEGEND | KEY PLAN | CONSULTANT | JOB NO. 110773396 | DESIGNER DATE | CHECKER DATE

REV	DATE	REVISION	BY

Alberta Transportation

SPRINGBANK RESERVOIR CANAL BRIDGE ON HWY 22, 25 KM SW OF CALGARY
SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1)
PLAN AND GENERAL NOTES

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
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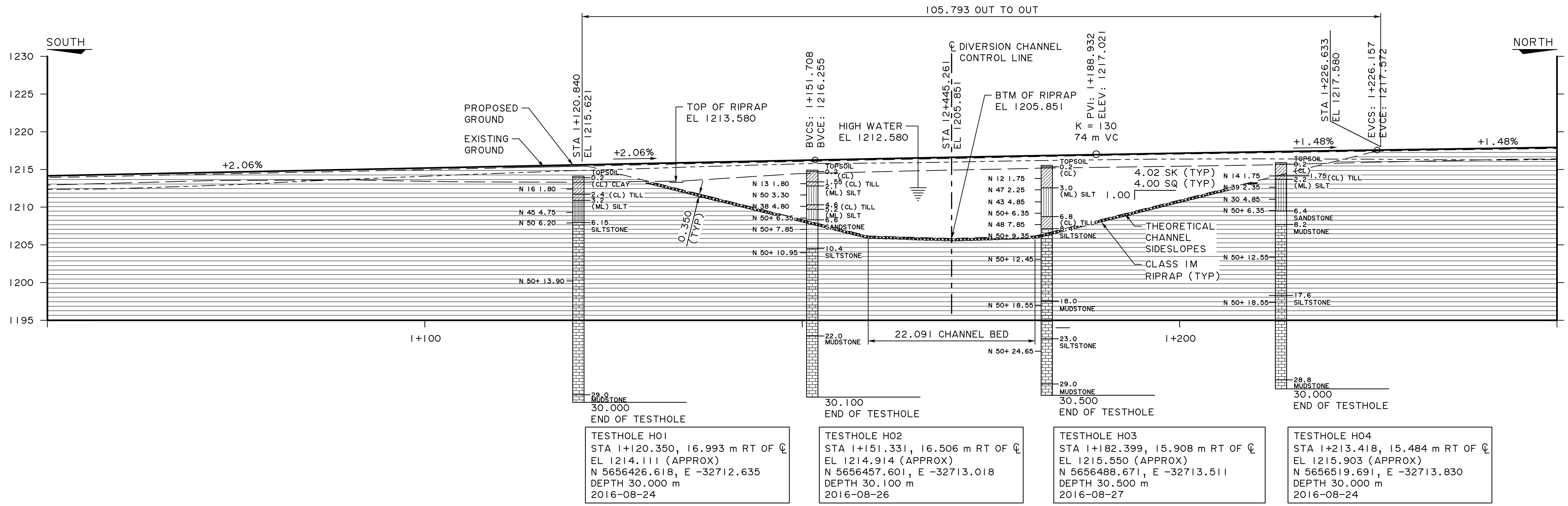

ELEVATION

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UNIFIED SOIL CLASSIFICATION SYSTEM (MODIFIED BY PFRA)

COARSE GRAINED SOILS 50%+ RETAINED ON AN 80 MICRON SIEVE			FINE GRAINED SOILS 50%+ PASSING AN 80 MICRON SIEVE		
GROUP SYM	LOG SYM	TYPICAL NAMES	GROUP SYM	LOG SYM	TYPICAL NAMES
GW		WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	CL		INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
GP		POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	CI		INORGANIC CLAYS OF MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS
GM d/u		SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CH		INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
GC		CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES	ML		INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
SW		WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	MH		INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS
SP		POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	OL		ORGANIC SILTS AND ORGANIC SILTY CLAYS OR LOW PLASTICITY
SM d/u		SILTY SANDS: SAND-SILT MIXTURES	OH		ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
SC		CLAYEY SANDS, SAND-CLAY MIXTURES	Pt		PEAT AND OTHER HIGHLY ORGANIC SOILS
OTHER SYMBOLS					
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		SANDSTONE			COAL
		SHALE			OVERBURDEN
		LIMESTONE			TOPSOIL

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LEGEND | KEY PLAN | CONSULTANT | DESIGNER | CHECKER

JOB NO. 110773396

DATE ______ DATE ______

REV	DATE	REVISION	BY

Alberta Transportation

SPRINGBANK RESERVOIR CANAL BRIDGE ON HWY 22, 25 KM SW OF CALGARY
SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1)
ELEVATION

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
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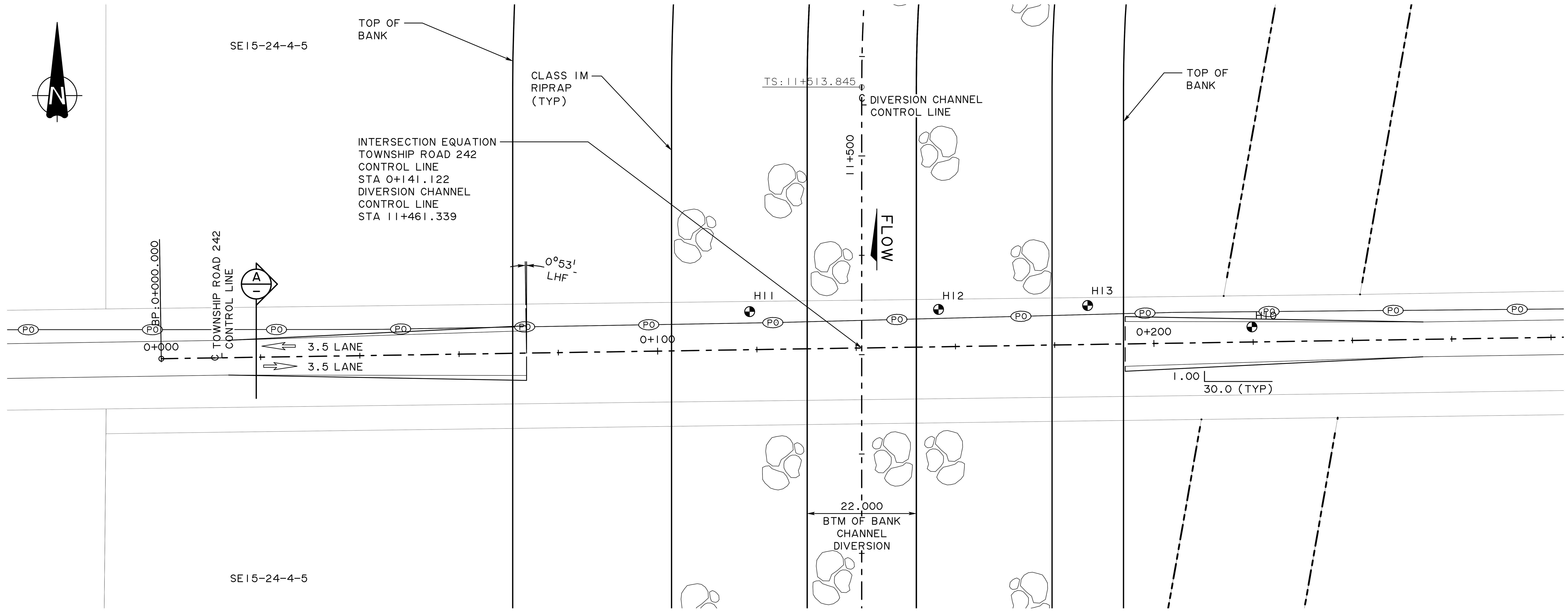
DRAWING SK-1
HIGHWAY
CONTRACT
DESCRIPTION
SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1)
PHOTO
DATE
BY
SURVEYED
DEPARTMENT BAR CODE



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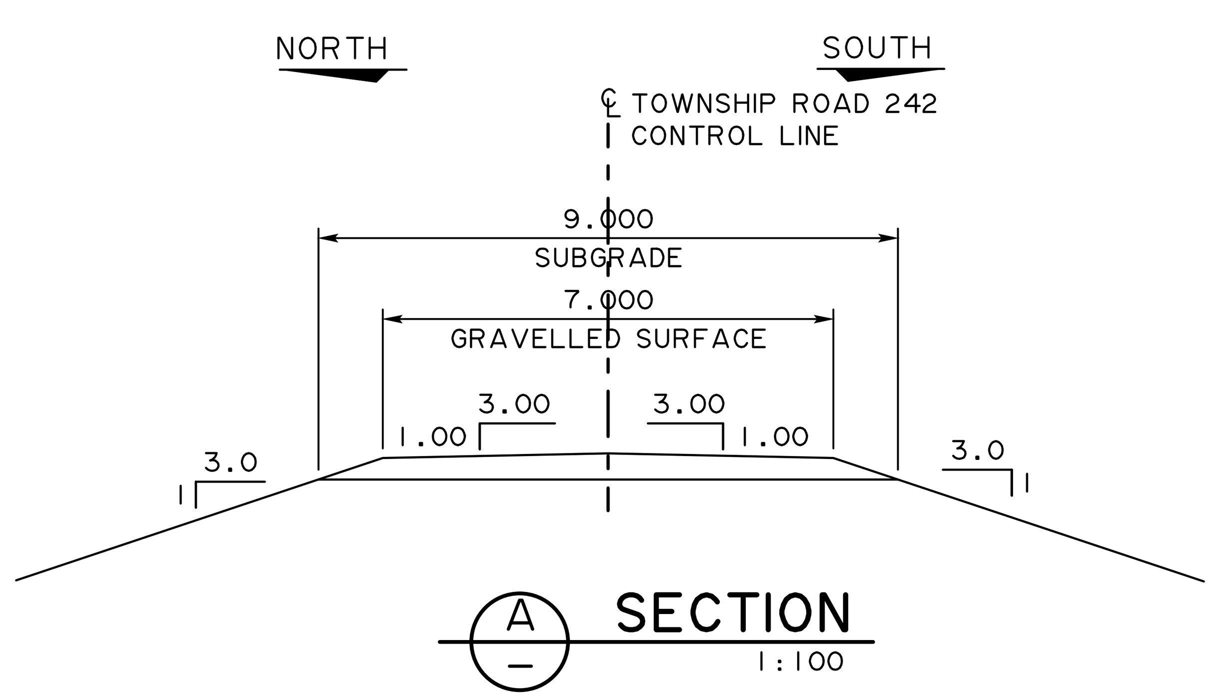

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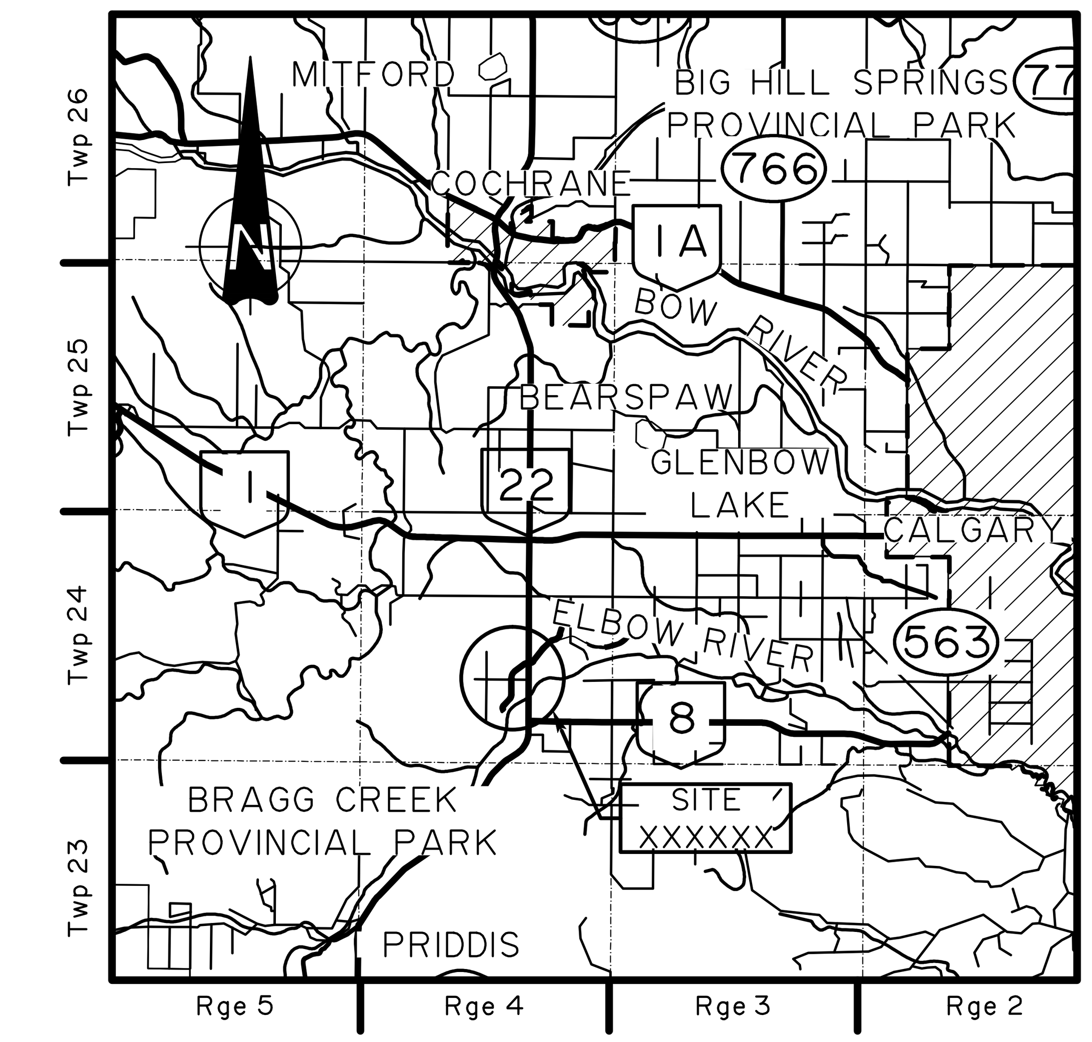

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- HIGHWAY 500 - 986
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- BOREHOLE
  - H10 N 5655853.464 E -33313.577 EL 1217.416
  - H11 N 5655856.538 E -33414.777 EL 1219.526
  - H12 N 5655856.985 E -33376.726 EL 1217.631
  - H13 N 5655857.761 E -33346.689 EL 1217.077
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  TOWNSHIP ROAD 242 RLV-207.0-070
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Alberta Transportation

SPRINGBANK RESERVOIR CANAL BRIDGE ON HWY 22, 25 KM SW OF CALGARY
SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1)
PLAN AND GENERAL NOTES

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
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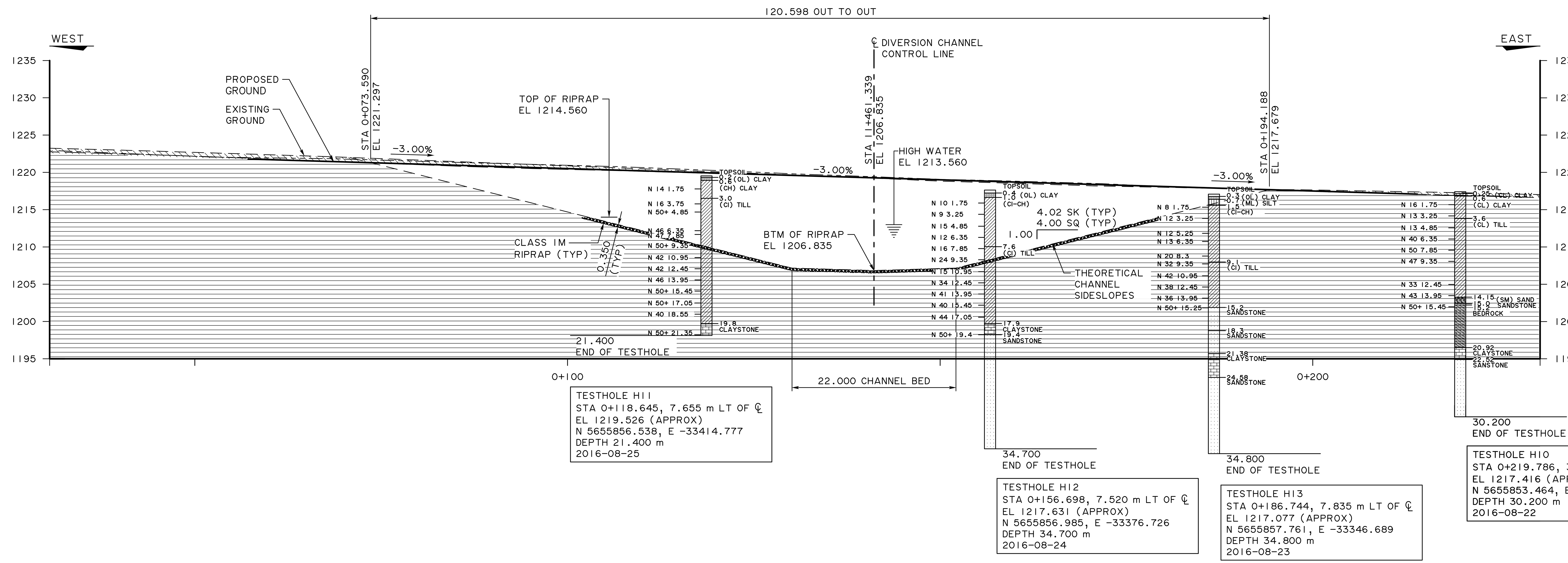

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GM d/u		SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CH		INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
GC		CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES	ML		INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
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SM d/u		SILTY SANDS: SAND-SILT MIXTURES	OH		ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
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		SHALE			OVERBURDEN
		LIMESTONE			TOPSOIL

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LEGEND | KEY PLAN | CONSULTANT | DESIGNER | CHECKER

JOB NO. 110773396

DATE____ DATE____

REV | DATE | REVISION | BY

Alberta Transportation

SPRINGBANK RESERVOIR CANAL BRIDGE ON HWY 22, 25 KM SW OF CALGARY
SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1)
ELEVATION

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
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DRAWING SK-2 | HIGHWAY | CONTRACT | DESCRIPTION SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) | PHOTO | DATE | BY | SURVEYED | DEPARTMENT BAR CODE

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2017-01-26 3:51pm By: mahansen

Appendix C

Borehole Records

Stantec

BOREHOLE RECORD

H01

CLIENT	Alberta Transportation	NORTHING	5656427	PROJECT NO.	110773396
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-32713	BH SIZE	SS:150mm
DATES BORING	2016/08/24	WATER LEVEL	(4.3 m) 2016/08/24	DATUM	Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE	ADVANCED LAB TESTS	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
0	1214.11	TOPSOIL									
0.2	1213.91	Very stiff, brown, low plasticity CLAY (CL) - trace sand, gravel, trace coal specks, damp	BS	1				1.7	14.8	51.7	31.8
			SS	2	450	16					
2.4	1211.71	Very stiff, brown, low plasticity clay (CL) TILL - silty, some sand, trace gravel, trace coal specks, damp	BS	3							
3.2	1210.91	Very dense, brown sandy SILT (ML) - damp to wet	ST	4	0						
			BS	5							
			SS	6	450	45					
			BS	7							
6.15	1207.96	Very poor to poor quality light grey (inferred) SILTSTONE - completely to highly weathered - very weak	SS	8	100	50+					
			SS	9	0	50+					
			BS	10							

UNDRAINED SHEAR STRENGTH (kPa): 40, 80, 120, 160

WATER CONTENT ATTERBERG LIMITS (%): W_P, W, W_L

STANDARD PENETRATION TEST, blows/0.30 m: 20, 40, 60, 80

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H01

CLIENT	Alberta Transportation	NORTHING	5656427	PROJECT NO.	110773396
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-32713	BH SIZE	SS:150mm
DATES BORING	2016/08/24	WATER LEVEL	(4.3 m) 2016/08/24	DATUM	Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	SAMPLES TYPE	SAMPLES NUMBER	RECOVERY (mm)	N-VALUE	ADVANCED LAB TESTS	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	UNDRAINED SHEAR STRENGTH (kPa) 40 / 80 / 120 / 160; WATER CONTENT, ATTERBERG LIMITS (%) W_P W W_L; STANDARD PENETRATION TEST, blows/0.30 m — 20 / 40 / 60 / 80
20		Very poor to poor quality light grey (inferred) SILTSTONE - completely to highly weathered - very weak										
22.5			BS	11								○
29.0	1185.11	Very poor to poor quality grey (inferred) MUDSTONE - completely to highly weathered - very weak										
29.85			BS	12								○
30.0	1184.11	End of borehole (30.0 m) - Auger refusal not encountered during drilling - Groundwater at 4.3 m and borehole open upon completion - Borehole backfilled with cuttings, bentonite seal from 0.3 m to 1.5 m										

Depth scale: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

BOREHOLE RECORD

H02

Stantec

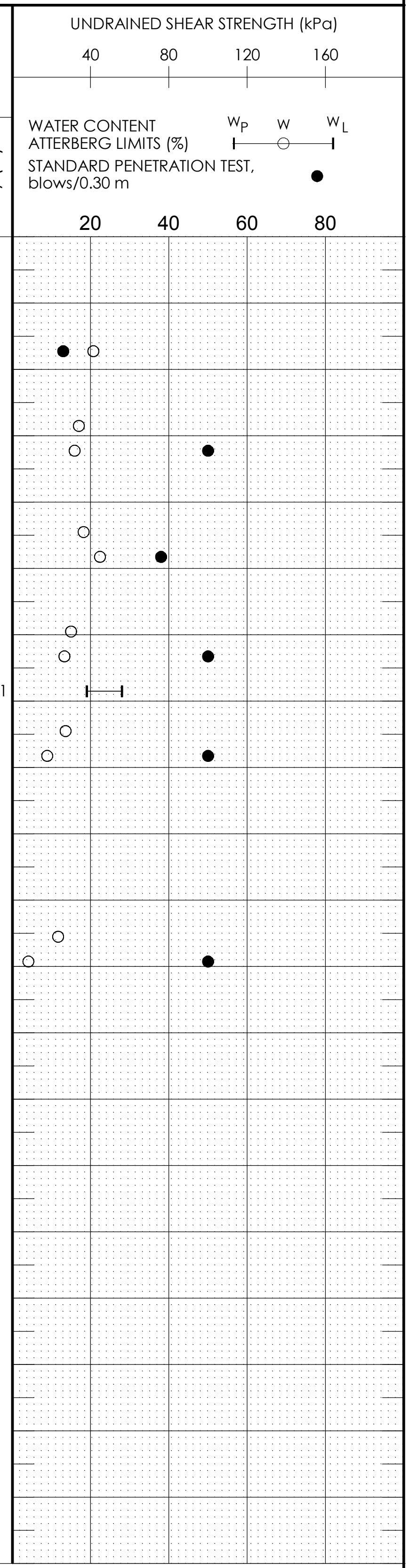
CLIENT	Alberta Transportation	NORTHING	5656458
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-32713
DATES BORING	2016/08/26	WATER LEVEL	(10.0 m) 2016/08/26
PROJECT NO.	110773396	BH SIZE	SS:150mm
DATUM	Geodetic		

Elevation (m)	Soil Description
1214.91	
1214.71	TOPSOIL
	FILL: dark brown to black, high plasticity clay (CL) - trace sand, gravel, mottled black, damp
1213.36	Stiff, brown, low plasticity clay (CL) TILL - trace sand, gravel, damp
1212.81	Very dense, brown, sandy SILT (ML) - damp
1210.31	Hard, brown, low plasticity clay (CL) TILL - sandy, trace gravel, damp - inferred seepage at 4.6 m
1209.71	Very dense, brown, sandy SILT (ML) - damp - interbedded with clay between 6.1 m and 6.5 m
1208.31	Very poor to poor quality brown (inferred) SANDSTONE - completely weathered - extremely weak - inferred highly to completely weathered, extremely weak below 7.6 m
1204.51	Very poor to poor quality grey (inferred) SILTSTONE - moderately to highly weathered - very weak to weak

Type	Number	Recovery (mm)	N-Value
BS	1		
SS	2	420	13
BS	3		
SS	4	450	50+
BS	5		
SS	6	450	38
BS	7		
SS	8	450	50+
BS	9		
SS	10	100	50+
BS	11		
SS	12	100	50+
BS	13		

Grain size analysis (at approx. 6.9 m depth):

Gravel (%)	Sand (%)	Silt (%)	Clay (%)
7.3	18.1	59.5	15.1



(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

BOREHOLE RECORD

H02

Stantec

CLIENT	Alberta Transportation	NORTHING 5656458	PROJECT NO. 110773396
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING -32713	BH SIZE SS:150mm
DATES BORING	2016/08/26	WATER LEVEL (10.0 m) 2016/08/26	DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	SAMPLE TYPE	NUMBER	RECOVERY (mm)	N-VALUE	ADVANCED LAB TESTS	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
20		Very poor to poor quality grey (inferred) SILTSTONE - moderately to highly weathered - very weak to weak									
22	1192.91	Very poor to poor quality (inferred) MUDSTONE - moderately to highly weathered - very weak									
22.7			BS	14							
25.7			BS	15							
30	1184.81		BS	16							
30.1		End of borehole (30.1 m) - Auger refusal not encountered during drilling - Groundwater at 10.0 m and borehole open upon completion - Borehole backfilled with cuttings, bentonite seal from 0.3 m to 1.5 m									

UNDRAINED SHEAR STRENGTH (kPa): 40, 80, 120, 160

WATER CONTENT ATTERBERG LIMITS (%): W_P, W, W_L

STANDARD PENETRATION TEST, blows/0.30 m: 20, 40, 60, 80

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

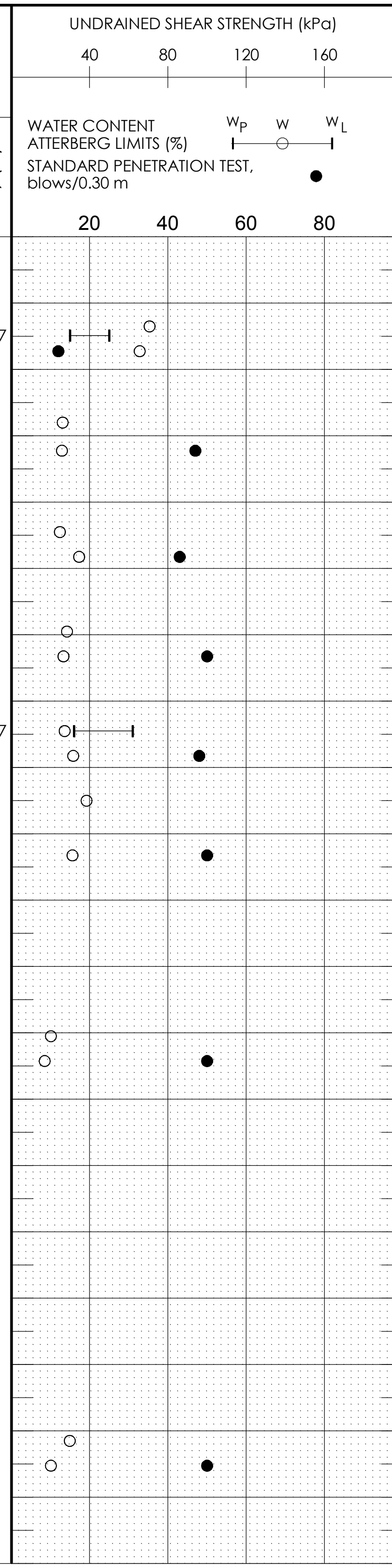
BOREHOLE RECORD H03

Stantec

CLIENT	Alberta Transportation	NORTHING	5656489
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-32714
DATES BORING	2016/08/27	WATER LEVEL	(Dry) 2016/08/27
PROJECT NO.	110773396	BH SIZE	SS:150mm
DATUM	Geodetic		

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION
0	1215.55	
	1215.35	TOPSOIL
		FILL: dark brown, low plasticity clay (CL) - silty, trace sand, gravel, frequent organics, damp - bulk sample BSA from 0.5 m to 2.5 m - trace rootlets below 1.5 m
	1212.55	Very dense, brown, sandy SILT (ML) - trace gravel, trace coal specks, damp - bulk sample BSB from 3.2 m to 5.5 m - inferred seepage at 4.6 m
	1208.75	Hard, brown, low plasticity clay (CL) TILL - silty, trace gravel, trace oxidation, damp
	1207.15	Very poor to poor quality grey (inferred) SILTSTONE - completely weathered - extremely weak - moderately weathered, very weak to weak below 11.0 m
	1197.55	Very poor to poor quality grey (inferred) MUDSTONE - completely weathered - extremely to very weak
20		

SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE	ADVANCED LAB TESTS	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
BS	1			CU, PT	1.6	45.2	34.5	18.7
SS	2	350	12					
BS	3							
SS	4	400	47					
BS	5							
SS	6	450	43					
BS	7							
SS	8	400	50+					
BS	9				7.5	35.9	36.9	19.7
SS	10	300	48					
BS	11							
SS	12	75	50+					
BS	13							
SS	14	50	50+					
BS	15							
SS	16	100	50+					



(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H03

CLIENT: Alberta Transportation
NORTHING: 5656489
PROJECT NO.: 110773396
PROJECT: SR1 - Off Stream Reservoir, Springbank, AB
EASTING: -32714
BH SIZE: SS:150mm
DATES BORING: 2016/08/27
WATER LEVEL: (Dry) 2016/08/27
DATUM: Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	TYPE	NUMBER	RECOVERY (mm)	N-VALUE
20		Very poor to poor quality grey (inferred) MUDSTONE - completely weathered - extremely to very weak				
23	1192.55	Very poor to poor quality grey (inferred) SILTSTONE - moderately to slightly weathered - very weak to weak				
~24.2			BS	17		
~24.5			SS	18	50	50+
~27.2			BS	19		
29	1186.55	Very poor to poor quality grey (inferred) MUDSTONE - completely to highly weathered - extremely to very weak				
~30.2			BS	20		
30.5	1185.05	End of borehole (30.5 m) - Auger refusal not encountered during drilling - Borehole open upon completion - borehole backfilled with cuttings, bentonite seal from 0.3 m to 1.5 m				

Column headings also printed: STRATA PLOT; WATER LEVEL; SAMPLES; ADVANCED LAB TESTS; GRAIN SIZE ANALYSIS: Gravel (%), Sand (%), Silt (%), Clay (%).

UNDRAINED SHEAR STRENGTH (kPa): 40, 80, 120, 160
WATER CONTENT ATTERBERG LIMITS (%): W_P, W, W_L
STANDARD PENETRATION TEST, blows/0.30 m
Scale: 20, 40, 60, 80

Depth scale: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

BOREHOLE RECORD

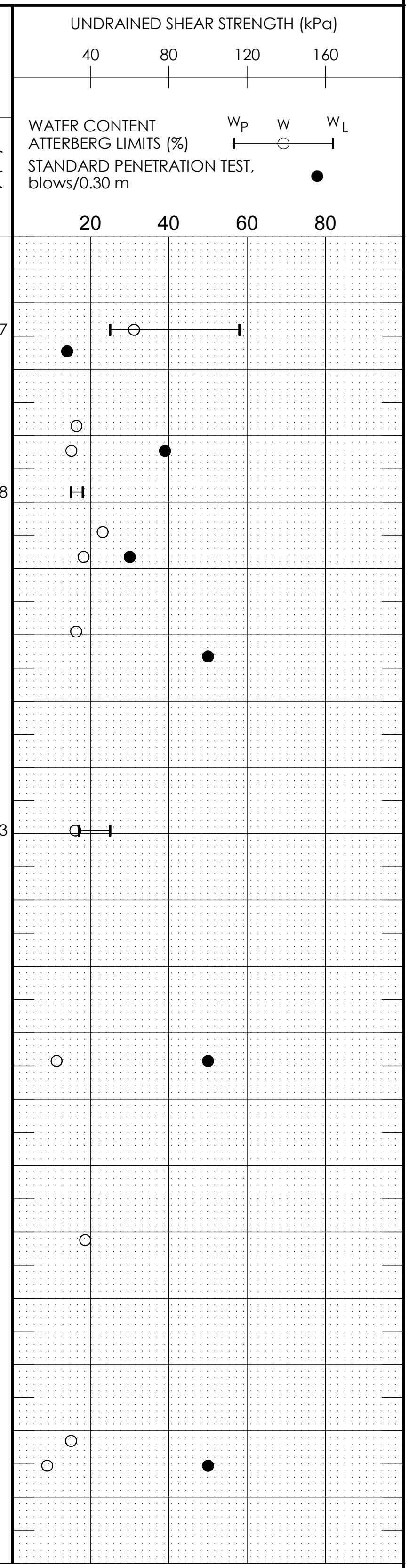
H04

CLIENT: Alberta Transportation
PROJECT: SR1 - Off Stream Reservoir, Springbank, AB
DATES BORING: 2016/08/24
NORTHING: 5656520
EASTING: -32714
WATER LEVEL: (9.3 m) 2016/08/24
PROJECT NO.: 110773396
BH SIZE: SS:150mm
DATUM: Geodetic

Depth (m)	Elevation (m)	Soil Description
0	1215.90	
0.2	1215.7	TOPSOIL
0.2–1.75	1214.15	FILL: brown, high plasticity clay (CL) - silty, trace sand, gravel, frequent rootlets and organics, damp
1.75–2.2	1213.7	Stiff, brown, low plasticity clay (CL) TILL - trace sand, gravel, damp
2.2–6.4	1209.5	Dense, brown, sandy SILT (ML) - wet - inferred seepage at 3.4 m
6.4–8.2	1207.7	Very poor to poor quality brown (inferred) SANDSTONE - completely weathered - extremely weak
8.2–17.6	1198.3	Very poor to poor quality grey (inferred) MUDSTONE - completely weathered - extremely weak
17.6–20		Very poor to poor quality grey (inferred) SILTSTONE - moderately weathered - very weak

Samples and grain size analysis:

Type	Number	Recovery (mm)	N-Value	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
BS	1			2.9	8.8	34.6	53.7
SS	2	450	14				
BS	3						
SS	4	450	39				
				0.4	39.2	43.6	16.8
BS	5						
SS	6	450	30				
BS	7						
SS	8	400	50+				
BS	9			1.6	56.9	28.1	13.3
SS	10	75	50+				
BS	11						
BS	12						
SS	13	50	50+				



(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H04

CLIENT	Alberta Transportation	NORTHING	5656520	PROJECT NO.	110773396
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-32714	BH SIZE	SS:150mm
DATES BORING	2016/08/24	WATER LEVEL	(9.3 m) 2016/08/24	DATUM	Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE	ADVANCED LAB TESTS	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	UNDRAINED SHEAR STRENGTH (kPa) 40 80 120 160 / WATER CONTENT ATTERBERG LIMITS (%) Wp W WL / STANDARD PENETRATION TEST, blows/0.30 m ● 20 40 60 80
20		Very poor to poor quality grey (inferred) SILTSTONE - moderately weathered - very weak												
28.8	1187.1	Very poor to poor quality grey (inferred) MUDSTONE - extremely weak												
30.0	1185.9				BS	14								○
		End of borehole (30.0 m) - Auger refusal not encountered during drilling - Groundwater at 9.3 m and borehole open upon completion - borehole backfilled with cuttings, bentonite seal placed from 0.3 m to 1.5 m												

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H10

CLIENT: Alberta Transportation
PROJECT: SR1 - Off Stream Reservoir, Springbank, AB
DATES BORING: 2016/08/22
WATER LEVEL:
NORTHING: 5655853
EASTING: -33314
PROJECT NO.: 110773396
BH SIZE: SS:150mm; HS:200mm
DATUM: Geodetic

Soil Description

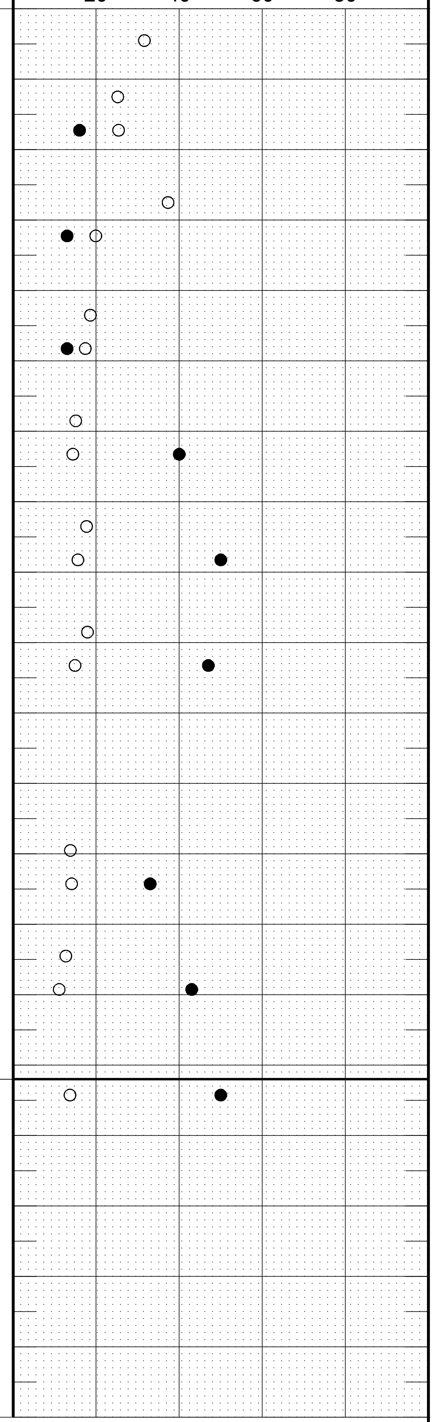
Depth (m)	Elevation (m)	Soil Description
0	1217.42	
	1217.17	FILL: 40 mm pit run
	1216.82	Stiff, brown, low plasticity CLAY (CL) - trace gravel, moist
		Stiff to very stiff, brown, medium plasticity CLAY (CI) - trace sand, moist - bulk sample BSA from 0.6 m to 1.5 m - mottled dark brown below 1.5 m - bulk sample BSB from 1.5 m to 3.0 m - trace gravel below 2.5 m - bulk sample BSC from 3.0 m to 4.6 m
	1213.82	Stiff, brown, medium plasticity clay (CL) TILL - some sand, trace coal specks, moist - bulk sample BSD from 4.6 m to 6.1 m - dry to moist below 5.5 m - hard, trace gravel below 6.1 m - bulk sample BSE from 6.1 m to 7.6 m - sandy below 7.6 m - bulk sample BSF from 7.6 m to 9.1 m - bulk sample BSG from 10.7 m to 12.2 m - bulk sample BSH from 12.2 m to 13.7 m - bulk sample BSI from 13.7 m to 15.2 m - inferred seepage at 14.0 m
	1203.27	
	1202.42	Very dense, brown silty SAND (SM) - trace gravel, moist to wet
	1202.22	Very poor to poor quality grey (inferred) SANDSTONE - completely to highly weathered - extremely to very weak
		Bedrock encountered at 15.0 m - Coring commenced at 15.2 m (see rock coring log for details) - Borehole advanced in bedrock to 30.2 m
20		

Samples

Type	Number	Recovery (mm)	N-Value
BS	1		
BS	2		
SS	3	370	16
BS	4		
SS	5	450	13
BS	6		
SS	7	430	13
BS	8		
SS	9	440	40
BS	10		
SS	11	450	50
BS	12		
SS	13	450	47
BS	14		
SS	15	450	33
BS	16		
SS	17	120	43
SS	18	25	50+

Columns: STRATA PLOT, WATER LEVEL, ADVANCED LAB TESTS, GRAIN SIZE ANALYSIS: Gravel (%), Sand (%), Silt (%), Clay (%)

UNDRAINED SHEAR STRENGTH (kPa): 40, 80, 120, 160
WATER CONTENT, ATTERBERG LIMITS (%): W_P, W, W_L
STANDARD PENETRATION TEST, blows/0.30 m: 20, 40, 60, 80



(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H10

CLIENT: Alberta Transportation
PROJECT: SR1 - Off Stream Reservoir, Springbank, AB
DRILLING DATE: 8/22/2016 to 8/22/2016
NORTHING: 5655853
EASTING: -33314
WATER LEVEL:
PROJECT No. 110773396
BH SIZE: SS:150mm, HS:200mm
DATUM: Geodetic

FX-FRACTURE, CL-CLEAVAGE, SH-SHEAR, VN-VEIN, F-FAULT, JN-JOINT, P-POLISHED, S-SLICKENSIDED, SM-SMOOTH, R-ROUGH, ST-STEPPED, PL-PLANAR, FL-FLEXURED, UE-UNEVEN, W-WAVY, C-CURVED, BC-BROKEN CORE, CONT-CONTACT, B-BEDDING, FOL-FOLIATION

DEPTH (m)	ELEVATION (m)	DESCRIPTION	SAMPLE TYPE RUN No.	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 1m	ROCK STRENGTH INDEX	WEATHERING INDEX	LABORATORY TESTING
14		Overburden - See Soil Log for overburden description								
15	1202.4	Very poor to poor quality grey (inferred) SANDSTONE - completely to highly weathered - extremely to very weak								
	1202.2	Very poor quality grey SANDSTONE - highly weathered - medium strong	RC19	31	8	0		3	W4	
16		- moderately to highly weathered below 16.4 m	RC20	93	67	0		3	W3.5	
18		- poor quality, dark grey, and moderately weathered below 17.9 m	RC21	100	83	25		3	W3	
19		- very poor quality below 19.4 m	RC22	100	83	9		3	W3	
21	1196.5	Poor quality dark grey CLAYSTONE - moderately weathered - very weak	RC23	99	96	40		R1	W3	
22	1194.9	Good quality dark grey SANDSTONE - slightly weathered - weak	RC24	100	95	79		R2	W2	
24										

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H10

CLIENT: Alberta Transportation
PROJECT: SR1 - Off Stream Reservoir, Springbank, AB
DRILLING DATE: 8/22/2016 to 8/22/2016
NORTHING: 5655853
EASTING: -33314
WATER LEVEL:
PROJECT No. 110773396
BH SIZE: SS:150mm, HS:200mm
DATUM: Geodetic

FX-FRACTURE, CL-CLEAVAGE, SH-SHEAR, VN-VEIN, F-FAULT, JN-JOINT, P-POLISHED, S-SLICKENSIDED, SM-SMOOTH, R-ROUGH, ST-STEPPED, PL-PLANAR, FL-FLEXURED, UE-UNEVEN, W-WAVY, C-CURVED, BC-BROKEN CORE, CONT-CONTACT, B-BEDDING, FOL-FOLIATION

DEPTH (m)	ELEVATION (m)	DESCRIPTION	SAMPLE TYPE RUN No.	TOTAL CORE %	SOLID CORE %	R.Q.D. %	ROCK STRENGTH INDEX	WEATHERING INDEX	LABORATORY TESTING
24		Good quality dark grey SANDSTONE - slightly weathered - weak - poor quality, and weak below 24.0 m	RC25	98	88	44	R2	W2	
25.6		- good quality below 25.6 m	RC26	98	98	83	R2	W2	
27.2		- fair quality, and weak to medium strong below 27.2 m	RC27	100	91	56	2.5	W2	
28.7		- weak below 28.7 m	RC28	100	91	56	R2	W2	
30.2	1187.2	End of borehole (30.2 m) - borehole open upon completion - seepage at 14.0 m during drilling - borehole backfilled with cuttings, and a bentonite seal placed from 1.0 m to 30.2 m							

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

TEST 6/30/17 2:54:51 PM

Stantec

BOREHOLE RECORD

H11

CLIENT: Alberta Transportation — NORTHING: 5655857 — PROJECT NO.: 110773396

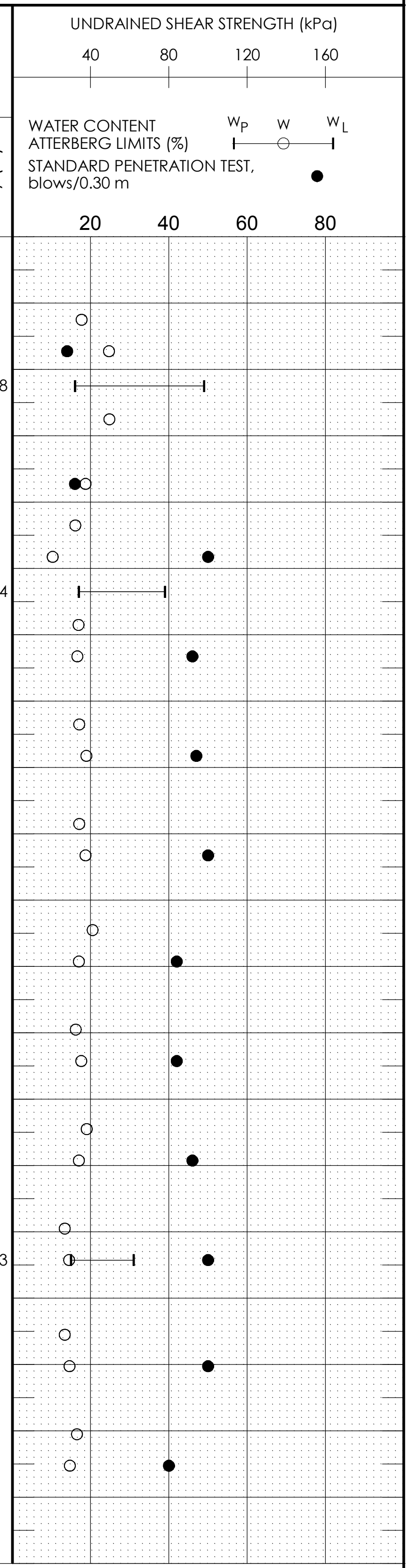
PROJECT: SR1 - Off Stream Reservoir, Springbank, AB — EASTING: -33415 — BH SIZE: SS:150mm

DATES BORING: 2016/08/25 — WATER LEVEL: (Dry) 2016/08/25 — DATUM: Geodetic

Ground elevation: 1219.53

Elevation (m)	Soil Description
1219.33	FILL: 40 mm pit run
1218.93	Black, low plasticity organic CLAY (OL) - trace sand
	Stiff, brown, high plasticity CLAY (CH) - silty, trace sand, gravel, trace coal specks, moist - bulk sample BSA from 0.6 m to 1.5 m - bulk sample BSB from 1.5 m to 3.0 m
1216.53	Very stiff, brown, medium plasticity clay (CI) TILL - silty, some sand, trace gravel, dry to moist - bulk sample BSC from 3.0 m to 4.6 m - trace coal specks below 3.5 m - brown to grey, hard below 4.6 m - bulk sample BSD from 4.6 m to 6.1 m - inferred seepage at 6.1 m - grey below 6.1 m - bulk sample BSE from 6.1 m to 7.6 m - bulk sample BSF from 7.6 m to 9.1 m - bulk sample BSG from 9.1 m to 10.7 m - bulk sample BSH from 10.7 m to 12.2 m - bulk sample BSI from 12.2 m to 13.7 m
1199.73	(end of borehole, 19.8 m)

Type	Number	Recovery (mm)	N-Value	Advanced Lab Tests	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
BS	1							
SS	2	420	14					
				CU, PT	0.2	3.1	38.9	57.8
BS	3							
ST	4	400						
SS	5	240	16					
BS	6							
SS	7	420	50+					
				CU, PT, k	3.1	18.3	39.1	39.4
BS	8							
SS	9	450	46					
BS	10							
SS	11	390	47					
BS	12							
SS	13	380	50+					
BS	14							
SS	15	450	42					
BS	16							
SS	17	440	42					
BS	18							
SS	19	450	46					
BS	20							
SS	21	400	50+		6.1	18.3	44.3	31.3
BS	22							
SS	23	450	50+					
BS	24							
SS	25	450	40					



(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H11

CLIENT: Alberta Transportation
PROJECT: SR1 - Off Stream Reservoir, Springbank, AB
DATES BORING: 2016/08/25
NORTHING: 5655857
EASTING: -33415
WATER LEVEL: (Dry) 2016/08/25
PROJECT NO.: 110773396
BH SIZE: SS:150mm
DATUM: Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	TYPE	NUMBER	RECOVERY (mm)	N-VALUE
20 – 21.4	1198.13	Very poor to poor quality brown to grey (inferred) CLAYSTONE - completely to highly weathered - extremely to very weak	BS	26		
			SS	27	25	50+
21.4		End of borehole due to auger and split spoon refusal at 21.4 m - Borehole dry and open upon completion - Borehole backfilled with cuttings, bentonite seal from 0.3 m to 21.4 m				

Column headings also printed: STRATA PLOT, WATER LEVEL, SAMPLES, ADVANCED LAB TESTS, GRAIN SIZE ANALYSIS (Gravel (%), Sand (%), Silt (%), Clay (%)), UNDRAINED SHEAR STRENGTH (kPa) 40 80 120 160; WATER CONTENT ATTERBERG LIMITS (%) W_P W W_L; STANDARD PENETRATION TEST, blows/0.30 m 20 40 60 80.

Depth scale: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

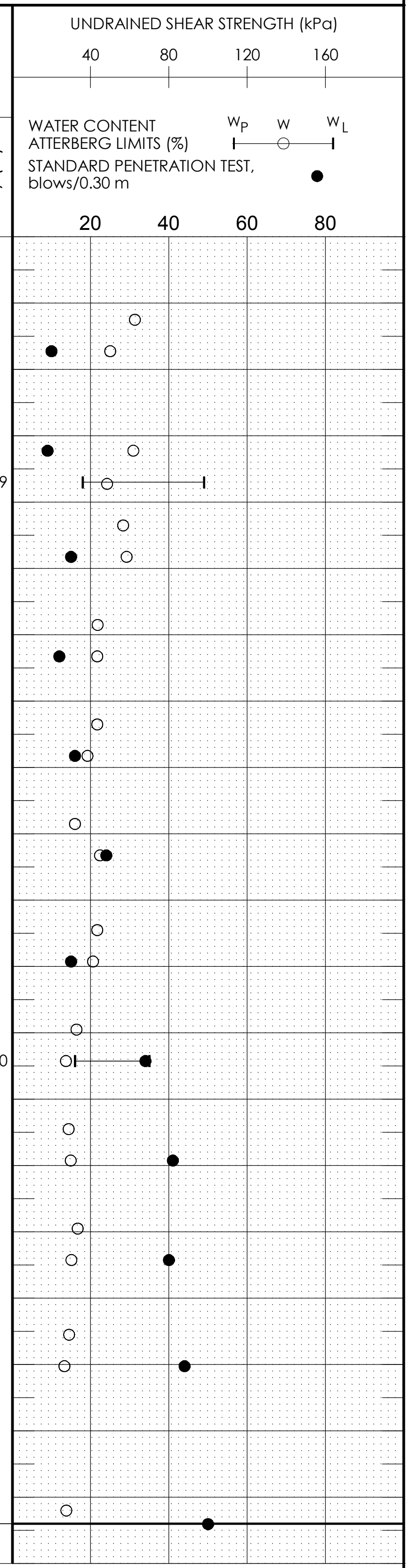
BOREHOLE RECORD

H12

CLIENT	Alberta Transportation	NORTHING	5655857
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-33377
DATES BORING	2016/08/24	WATER LEVEL	
PROJECT NO.	110773396	BH SIZE	SS:150mm; HS:200mm
DATUM	Geodetic		

ELEVATION (m)	SOIL DESCRIPTION
1217.63	
1217.23	FILL: 40 mm pit run
1216.63	Black, low plasticity organic CLAY (OL) - trace sand, moist - bulk sample BSA from 0.4 m to 1.5 m
	Stiff, brown, medium to high plasticity clay (CI-CH) - silty, trace sand, moist - bulk sample BSB from 1.5 m to 3.0 m - inferred seepage at 3.0 m - trace coal specks, mottled grey below 3.0 m - bulk sample BSC from 3.0 m to 4.6 m - trace gravel below 4.2 m - bulk sample BSD from 4.6 m to 6.1 m - bulk sample BSE from 6.1 m to 7.6 m
1210.03	Very stiff, brown medium plasticity clay (CI) TILL - silty, some sand, trace gravel, dry to moist - bulk sample BSF from 7.6 m to 9.1 m - bulk sample BSG from 9.1 m to 10.7 m - trace coal specks, moist below 9.8 m - dry to moist below 10.7 m - bulk sample BSH from 10.7 m to 12.2 m - grey below 11.3 m - bulk sample BSI from 12.2 m to 13.7 m - bulk sample BSJ from 13.7 m to 15.2 m - bulk sample BSK from 15.2 m to 16.8 m
1199.73	Very poor to poor quality grey (inferred) CLAYSTONE - completely to highly weathered - extremely to very weak
1198.23	Bedrock encountered at 17.9 m

TYPE	NUMBER	RECOVERY (mm)	N-VALUE	ADVANCED LAB TESTS	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
BS	1							
SS	2	340	10					
BS	3							
SS	4	420	9					
ST	5	450		CU, Y	0.6	4.7	41.8	52.9
BS	6							
SS	7	450	15					
BS	8							
SS	9	450	12					
BS	10							
SS	11	450	16					
BS	12							
SS	13	450	24					
BS	14							
SS	15	450	15					
BS	16							
SS	17	430	34		8.8	13.3	42.9	35.0
BS	18							
SS	19	450	41					
BS	20							
SS	21	450	40					
BS	22							
SS	23	450	44					
BS	24							
SS	25	0	50+					



(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H12

CLIENT Alberta Transportation
PROJECT SR1 - Off Stream Reservoir, Springbank, AB
DATES BORING 2016/08/24
NORTHING 5655857
EASTING -33377
WATER LEVEL
PROJECT NO. 110773396
BH SIZE SS:150mm; HS:200mm
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY (mm)	SAMPLES: N-VALUE	ADVANCED LAB TESTS	GRAIN SIZE ANALYSIS: Gravel (%)	Sand (%)	Silt (%)	Clay (%)	UNDRAINED SHEAR STRENGTH (kPa) 40 80 120 160; WATER CONTENT ATTERBERG LIMITS (%) W_P W W_L; STANDARD PENETRATION TEST, blows/0.30 m ● 20 40 60 80
20		- Coring commenced at 19.4 m (see rock coring log for details) - Borehole advanced in bedrock to 34.7 m												
21														
22														
23														
24														
25														
26														
27														
28														
29														
30														
31														
32														
33														
34														
35														
36														
37														
38														
39														
40														

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H12

CLIENT Alberta Transportation
PROJECT SR1 - Off Stream Reservoir, Springbank, AB
DRILLING DATE 8/24/2016 to 8/24/2016
NORTHING: 5655857
EASTING: -33377
WATER LEVEL
PROJECT No. 110773396
BH SIZE SS:150mm, HS:200mm
DATUM Geodetic

FX-FRACTURE, CL-CLEAVAGE, SH-SHEAR, VN-VEIN, F-FAULT, JN-JOINT, P-POLISHED, S-SLICKENSIDED, SM-SMOOTH, R-ROUGH, ST-STEPPED, PL-PLANAR, FL-FLEXURED, UE-UNEVEN, W-WAVY, C-CURVED, BC-BROKEN CORE, CONT-CONTACT, B-BEDDING, FOL-FOLIATION

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLE TYPE RUN No.	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 1m	ROCK STRENGTH INDEX	WEATHERING INDEX	LABORATORY TESTING
17		Overburden - See Soil Log for overburden description										
17.9	1199.7	Very poor to poor quality grey (inferred) CLAYSTONE - completely to highly weathered - extremely to very weak										
19.4	1198.2	Very poor quality dark grey SANDSTONE - highly weathered - very weak			RC26	100	60	0		R1	W4	
		- fair quality, weak to medium strong, and slightly weathered below 20.9 m			RC27	99	93	68		2.5	W2	
		- good quality, and medium strong below 22.5 m			RC28	100	100	79		3	W2	
		- excellent quality, and fresh below 24.0 m			RC29	99	97	94		3	W1	
		- fair quality, slightly weathered, and grey to green below 25.5 m			RC30	100	93	73		3	W2	
27												

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H12

CLIENT Alberta Transportation
PROJECT SR1 - Off Stream Reservoir, Springbank, AB
DRILLING DATE 8/24/2016 to 8/24/2016
NORTHING: 5655857
EASTING: -33377
WATER LEVEL
PROJECT No. 110773396
BH SIZE SS:150mm, HS:200mm
DATUM Geodetic

FX-FRACTURE, CL-CLEAVAGE, SH-SHEAR, VN-VEIN, F-FAULT, JN-JOINT, P-POLISHED, S-SLICKENSIDED, SM-SMOOTH, R-ROUGH, ST-STEPPED, PL-PLANAR, FL-FLEXURED, UE-UNEVEN, W-WAVY, C-CURVED, BC-BROKEN CORE, CONT-CONTACT, B-BEDDING, FOL-FOLIATION

DEPTH (m)	ELEVATION (m)	DESCRIPTION	SAMPLE TYPE RUN No.	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	ROCK STRENGTH INDEX	WEATHERING INDEX	LABORATORY TESTING
27–28.5		Very poor quality dark grey SANDSTONE - highly weathered - very weak - good quality below 27.0 m	RC31	100	95	79	3	W2	
28.5–30		- fair quality, and grey below 28.5 m	RC32	100	97	72	3	W2	
30–31.5		- good quality, and dark grey below 30.0 m	RC33	100	99	80	3	W2	
31.5–33.1		- fair quality below 31.5 m - 0.25 m thick weak, and moderately weathered layer at 32.15 m	RC34	99	88	69	3	W2	
33.1–34.7	1182.9	- excellent quality, and fresh below 33.1 m	RC35	98	98	93	3	W2	
34.7		End of borehole (34.7 m) - borehole open upon completion - borehole backfilled with cuttings, and a bentonite seal placed from 1.0 m to 34.7 m							

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

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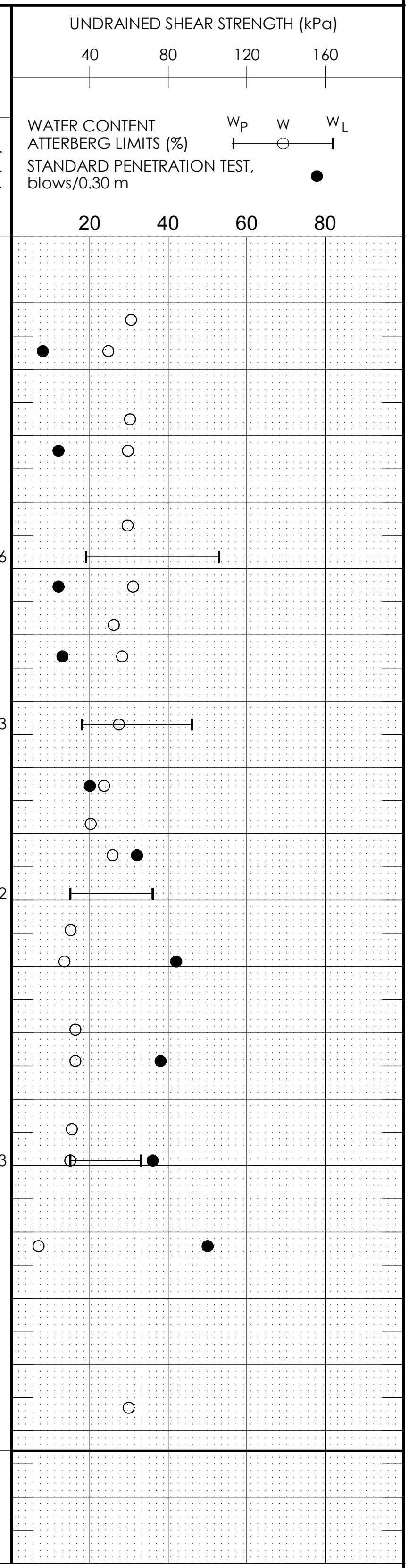
Stantec BOREHOLE RECORD H13

CLIENT	Alberta Transportation	NORTHING	5655858
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-33347
DATES BORING	2016/08/23	WATER LEVEL	
PROJECT NO.	110773396	BH SIZE	SS:150mm; HS:200mm
DATUM	Geodetic		

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION
0	1217.08	
	1216.78	FILL: 40 mm pit run
	1216.38	Black, low plasticity organic CLAY (OL)
	1215.58	Grey SILT (ML) - trace sand, wet, trace organics - bulk sample BSA from 0.7 m to 1.5 m
	1207.98	Stiff, brown, medium to high plasticity CLAY (CI-CH) - silty, trace sand, mottled grey, moist to wet - bulk sample BSB from 1.5 m to 3.0 m - moist below 3.0 m - bulk sample BSC from 3.0 m to 4.6 m - trace gravel below 4.0 m - bulk sample BSD from 4.6 m to 6.1 m - trace coal specks below 5.1 m - bulk sample BSE from 6.1 m to 7.6 m - very stiff below 7.0 m - bulk sample BSF from 7.6 m to 9.1 m
	1201.88	Hard, grey, medium plasticity clay (CI) TILL - silty, some sand, trace gravel, dry - bulk sample BSG from 9.1 m to 10.7 m - bulk sample BSH from 10.7 m to 12.2 m - bulk sample BSI from 12.2 m to 13.7 m - bulk sample BSJ from 13.7 m to 15.2 m - dry to moist below 14.0 m - inferred seepage at 15.0 m
	1198.78	Very poor to poor quality grey (inferred) SANDSTONE - highly weathered - extremely to very weak - auger refusal at 17.8 m
		Bedrock encountered at 15.2 m - Coring commenced at 18.3 m (see rock coring log for details) - Borehole advanced in bedrock
20		

TYPE	NUMBER	RECOVERY (mm)	N-VALUE	ADVANCED LAB TESTS	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
BS	1							
SS	2	320	8					
BS	3							
SS	4	450	12					
BS	5							
ST	6	290		Qu, Y	0.8	6.8	35.8	56.6
SS	7	450	12					
BS	8							
SS	9	450	13					
BS	10				2.2	8.6	40.9	48.3
ST	11	320		CU, Y				
SS	12	450	20					
BS	13							
SS	14	450	32					
				CU, k, PT	4.2	19.6	41.0	35.2
BS	15							
SS	16	450	42					
BS	17							
SS	18	280	38					
BS	19							
SS	20	450	36		2.4	18.9	44.5	34.3
SS	21	25	50+					
BS	22							



(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H13

CLIENT	Alberta Transportation	NORTHING	5655858	PROJECT NO.	110773396
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-33347	BH SIZE	SS:150mm; HS:200mm
DATES BORING	2016/08/23	WATER LEVEL		DATUM	Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE	ADVANCED LAB TESTS	GRAIN SIZE ANALYSIS Gravel (%)	Sand (%)	Silt (%)	Clay (%)	UNDRAINED SHEAR STRENGTH (kPa) 40 80 120 160; WATER CONTENT ATTERBERG LIMITS (%) W_P W W_L; STANDARD PENETRATION TEST, blows/0.30 m; 20 40 60 80
20		to 34.8 m												
21														
22														
23														
24														
25														
26														
27														
28														
29														
30														
31														
32														
33														
34														
35														
36														
37														
38														
39														
40														

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H13

CLIENT: Alberta Transportation
PROJECT: SR1 - Off Stream Reservoir, Springbank, AB
DRILLING DATE: 8/23/2016 to 8/23/2016
NORTHING: 5655858
EASTING: -33347
WATER LEVEL:
PROJECT No. 110773396
BH SIZE: SS:150mm, HS:200mm
DATUM: Geodetic

FX-FRACTURE, CL-CLEAVAGE, SH-SHEAR, VN-VEIN, F-FAULT, JN-JOINT, P-POLISHED, S-SLICKENSIDED, SM-SMOOTH, R-ROUGH, ST-STEPPED, PL-PLANAR, FL-FLEXURED, UE-UNEVEN, W-WAVY, C-CURVED, BC-BROKEN CORE, CONT-CONTACT, B-BEDDING, FOL-FOLIATION

DEPTH (m)	ELEVATION (m)	DESCRIPTION	SAMPLE TYPE RUN No.	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	ROCK STRENGTH INDEX	WEATHERING INDEX	LABORATORY TESTING
14		Overburden - See Soil Log for overburden description							
15.1	1201.9	Very poor to poor quality grey (inferred) SANDSTONE - highly weathered - extremely to very weak							
18.2	1198.8	Very poor quality grey SANDSTONE - moderately weathered - medium strong	RC23	0	0	0	R	W	
			RC24	100	91	11	R2	W3	
20.4	1196.7	Very poor quality dark grey CLAYSTONE - moderately weathered - very weak							
21.1	1196.0	Fair quality grey SANDSTONE - highly weathered - medium strong							
21.4	1195.7	Fair quality dark grey CLAYSTONE - moderately weathered - very weak	RC25	99	75	52	R2	W3	
22.6		- poor quality below 22.6 m	RC26	99	95	46	R1	W3	
24									

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H13

CLIENT: Alberta Transportation
PROJECT: SR1 - Off Stream Reservoir, Springbank, AB
DRILLING DATE: 8/23/2016 to 8/23/2016
NORTHING: 5655858
EASTING: -33347
WATER LEVEL:
PROJECT No. 110773396
BH SIZE: SS:150mm, HS:200mm
DATUM: Geodetic

FX-FRACTURE, CL-CLEAVAGE, SH-SHEAR, VN-VEIN, F-FAULT, JN-JOINT, P-POLISHED, S-SLICKENSIDED, SM-SMOOTH, R-ROUGH, ST-STEPPED, PL-PLANAR, FL-FLEXURED, UE-UNEVEN, W-WAVY, C-CURVED, BC-BROKEN CORE, CONT-CONTACT, B-BEDDING, FOL-FOLIATION

DEPTH (m)	ELEVATION (m)	DESCRIPTION	SAMPLE TYPE RUN No.	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 1m	ROCK STRENGTH INDEX	WEATHERING INDEX	LABORATORY TESTING
24		Fair quality dark grey CLAYSTONE - moderately weathered - very weak								
	1192.5	Fair poor quality dark grey SANDSTONE - slightly weathered - weak	RC27	98	80	60		R1.5	W2.5	
26		- poor quality, dark grey, moderately weathered, very weak below 25.7 m - slightly weathered, medium strong below 26.25 m - moderately weathered, very weak below 26.85 m	RC28	100	80	46		R2	W2.5	
28		- good quality, slightly weathered, medium strong below 27.2 m	RC29	100	99	86		3	W2	
29		- fair quality, weak to medium strong below 28.7 m	RC30	100	96	67		2.5	W2	
31		- medium strong below 30.2 m	RC31	100	91	73		3	W2	
32			RC32	97	94	66		3	W2	
33		- good quality below 33.3 m								
34										

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H13

CLIENT Alberta Transportation
PROJECT SR1 - Off Stream Reservoir, Springbank, AB
DRILLING DATE 8/23/2016 to 8/23/2016
NORTHING: 5655858
EASTING: -33347
WATER LEVEL
PROJECT No. 110773396
BH SIZE SS:150mm, HS:200mm
DATUM Geodetic

FX-FRACTURE, CL-CLEAVAGE, SH-SHEAR, VN-VEIN, F-FAULT, JN-JOINT, P-POLISHED, S-SLICKENSIDED, SM-SMOOTH, R-ROUGH, ST-STEPPED, PL-PLANAR, FL-FLEXURED, UE-UNEVEN, W-WAVY, C-CURVED, BC-BROKEN CORE, CONT-CONTACT, B-BEDDING, FOL-FOLIATION

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLE TYPE RUN No.	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 1m	ROCK STRENGTH INDEX	WEATHERING INDEX	LABORATORY TESTING
34		Fair poor quality dark grey SANDSTONE - slightly weathered - weak			RC33	100	98	78		3	W2	
	1182.3	End of borehole (34.8 m) - borehole open upon completion - water observed at 15.0 m during drilling - borehole backfilled with cuttings, and a bentonite seal placed from 1.0 m to 34.8 m										

Depth scale: 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Appendix E COMMENT/RESPONSE LOG

Highway 22 Structure

Revision Number	Comment Number	AT Comments (Sept 18, 2018)	Stantec Responses (Nov 11, 2018)
0	1	diaphragm? wing wall should not interfere with abutment seat.	The wingwall will extend beside the abutment seat, with a compressible material between the wingwall and abutment seat, similar to the detail provided on SK-B3 in AT's Bridge Structures Design Criteria. There will also be compressible material between the abutment seat and diaphragm, a comment about this has been added to the semi-integral section in the report.
	2	approach slab should move along wingwall and diaphragm.	The approach slab will move independently of the wingwalls. It will have a typical joint type 2 as per standard drawing S-1840 at the diaphragm, which will include a single row of reinforcing connecting the approach slab to the diaphragm.
	3	Why box girder is not considered here?	As stated in Section 9.2.1 of the AT Bridge Structures Design Criteria, NU girders are the perfered precast prestressed concrete girder shape. Since this is a major highway, box girders were not considered. Standard SLC girders were not considered as the maximum configuration available is 20m-20m-20m, which is not sufficient for this crossing
	4	40 mm max gap allowed for C2 joint. Designer need to identify that the movement is out of range for using semi integral abutment and rationalize why using semi integral will not affect serviceability. potential methodology to restrict movement need to be presented here.	Movements provided were for the total bridge length, when considering the movement due to the thermal span at each joint, it is within tolerance. This section has been updated in the report for clarity.
	5	Why NU girder option cannot have longitudinally fixed concrete diaphragm joint at both pier. this will eliminate need of bearings at pier	The piers can be fixed. Note that the pier section will require aditional reinforcing to resist the larger forces induced by the fixed connection. The cost estimate has been updated to reflect this change.
	6	semi integral abutment do not have deck joint	This has been changed to correctly state 'cycle control joint'.
	7	67 mm movement seems to be excessive when both pier is fixed longitudinally. Also 40 mm max gap allowed for C2 joint. Deck joint required in steel girder option. Semi integral abutment cannot be used.	The 67 mm was the total thermal movement based on the full span length of 69 m and assuming the piers provide no longitudinal restraint. The movement at each joint would conservatively be half of this value, 34 mm, which is within the range of the C2 joint. In addition, depending on the fixity of the piers, they will provide some longitudinal restraint, so this value will be less.

APPENDIX F.9.3
STRUCTURE ALTERNATIVES REPORT
TOWNSHIP ROAD 242 BRIDGE
OVER SPRINGBANK DIVERSION CHANNEL

Structure Alternatives Report
Alberta Transportation,
Township Road 242 over
Springbank Diversion Channel

Prepared for:
Alberta Transportation

Prepared by:
Stantec Consulting Ltd.

December 19, 2018

Revision	Description	Author		Quality Check		Independent Review	
0.1	Draft	C. Smit	7/18/2018	K. Karvinen	7/18/2018	K. Karvinen	7/18/2018
0.2	Draft	C. Smit	11/8/2018	K. Karvinen	11/8/2018	K. Karvinen	11/8/2018
1.0	Final	C. Smit	12/19/2018	K. Karvinen	12/19/2018	K. Karvinen	12/19/2018

Stantec

Sign-off Sheet

This document entitled Structure Alternatives Report Alberta Transportation, Township Road 242 over Springbank Diversion Channel was prepared by Stantec Consulting Ltd. ("Stantec") for the account of Alberta Transportation (AT) (the "Client"). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

PROFESSIONAL ENGINEER CARI A. SMIT ALBERTA

Prepared by ______________________ Dec 19/2018

(signature)

Cari Smit, P.Eng.

PROFESSIONAL ENGINEER KRISTOFFER G. KARVINEN ALBERTA

Reviewed by ______________________ Dec 19 2018

(signature)

Kristoffer Karvinen, M.A.Sc., PMP, P.Eng.

Table of Contents

LIST OF TABLES

LIST OF APPENDICES

1.0 INTRODUCTION

The purpose of this report is to summarize design options for a new structure that will carry Township Road 242 over a flood diversion channel near Springbank. The diversion channel is part of a larger flood mitigation project that will see flood water from the Elbow River be diverted into an off-stream storage reservoir.

2.0 BACKGROUND DESIGN INFORMATION

The proposed Springbank Off-Stream Reservoir Project (SR1), located west of Calgary approximately 20 km upstream of the Glenmore Reservoir, will capture flood flow from the Elbow River in an off-stream storage reservoir. The storage reservoir will temporarily contain flood water until the water is released back into the Elbow River. A diversion channel is required to convey water from the Elbow River to the storage reservoir. This channel will intersect both Highway 22 and Township Road 242, both locations require a new bridge crossing

2.1 ROADWAY DESIGN INFORMATION

Township Road 242 has a 3% vertical profile ascending to the west with the alignment consisting of a horizontal tangent; the other road information is presented in Table 2-1. The current road design will be maintained over the proposed bridge structure, further details on the design of Township Road 242 can be found in the report *Springbank Off-Stream Reservoir Project (SR1) – Highway 22 and Springbank Road Planning Study*.

Table 2-1: Township Road 242 Design Parameters

Design Parameter	Value
Cross Slope	2%
Number of Lanes	2
Land Width	3.5 m
Shoulder Width	1.0 m
Posted Speed	60 km/hr
Design Speed	70 km/hr
AADT (2015)	517
Commercial Vehicles (2015)	36.6%

2.2 DIVERSION CHANNEL HYDROTECHNICAL DESIGN INFORMATION

The diversion channel's proposed geometry at the Township Road 242 crossing is:

- A 0°53' LHF skew relative to the bridge,
- Design high water elevation of 1212.3m,
- A 1 m freeboard, providing a minimum bottom flange elevation of 1213.3 m, and
- 600 mm thick Class 1 heavy rock riprap to protect the channel banks.

Additional channel data is presented in Table 2-2.

Table 2-2: Channel Design Parameters

Design Parameter	Value
Side Slope	3H:1V
Long. Slope	0.1%
Peak Flow	600 m^3/s
Mean Velocity	2 m/s

The channel is intended to be used only in high water scenarios and will be dry through the winter months; therefore, ice is not considered in design.

2.2.1 Channel Debris

Stantec, using a scale model, carried out testing on the entrance of the diversion channel. A portion of the testing related to debris/inlet interaction. A debris containment measures will be installed at the beginning of the channel which will prevent debris in the channel. A 1 m freeboard provides adequate protection for the superstructure and there is minimal concern of debris impact on the piers.

2.3 GEOTECHNICAL INFORMATION

The geotechnical memo issued to the bridge design team is provided in Appendix D. The following is a summary. Four boreholes were drilled near the proposed bridge. Typical soil conditions consist of:

- Pit run, overlaying clay soil, overlaying bed rock.
- The bed rock encountered consists of sandstone and claystone.
- Bed rock encountered at an elevation around 1198.23, 15 – 16 m below existing ground and approximately 6 m below channel bed.

2.3.1 Foundation Recommendation Summary

The foundation design will present a unique challenge due to the fractured rock layers and channel side slopes. Because of this, the foundation design will be an iterative process between the bridge design team, and the geotechnical engineering team. After preliminary foundation systems are designed, they will be reviewed by the geotechnical team for a refinement of their recommendations, that may in turn revise the structural design.

Table 2-3 outlines preliminary design parameters for both cast-in-place piles and H-piles.

Table 2-3: Preliminary Pile Design Parameters

Pile Type	Location	Depth (m)	Unfactored Shaft Resistance at ULS (kPa)	Unfactored Toe Resistance at ULS (kPa)
Cast-in-Place	TWP 242 Abutments	0.0 to 2.0	0	Neglect
		2.0 to 6.0	20	Neglect
		6.0 to 15.0	55	Neglect
		>15.0	440	1000
	TWP 242 Piers	0.0 to 2.0	0	Neglect
		2.0 to 7.0	20	Neglect
		>7.0	440	1000
H-Piles	TWP 242 Abutments	0.0 to 2.0	0	Neglect
		2.0 to 6.0	20	Neglect
		6.0 to 15.0	55	Neglect
		>15.0	100	1000
	TWP 242 Piers	0.0 to 2.0	0	Neglect
		2.0 to 7.0	20	Neglect
		>7.0	100	1000

The modulus of subgrade reaction (k_s) was given as:

$$k_s = \frac{E_s}{d}$$

Where:

d = External diameter of pile (m)
E_s = Modulus of elasticity

Table 2-4: Pile Design Parameters for Lateral Loads

Location	Depth (m)	k_s (kPa/mm)[1]
TWP 242 Abutments	1.0 to 6.0	6/d
	6.0 to 15.0	8/d
	>15.0	30/d
TWP 242 Piers	1.0 to 7.0	8/d
	>7.0	30/d

2.3.2 Seismic

Township Road 242 is not classified as a major highway as per the provincial classification system, which is deemed an 'other' structure. The site is site class 'D'. Therefore, it is considered seismic performance category 2 and force-based seismic design is required.

2.4 DESIGN STANDARDS

The design will meet the following requirements:

- Canadian Highway Bridge Design Code CAN/CSA S6-14 (CHBDC)
- Alberta Transportation Bridge Structures Design Criteria (BSDC), Version 8, 2017
- Alberta Transportation Standard Specifications for Bridge Construction, Edition 16, 2017
- Alberta Transportation Roadside Design Guide, November 2007, Revision 8
- Alberta Transportation Highway Geometric Design Guide, 1999

3.0 CONSTRUCTION ISSUES

3.1 SITE ACCESS

Township Road 242 is a local road that is the only access to a gravel pit as well as several private residences and will remain open throughout construction. Since Township Road 242 will maintain its current alignment, a temporary detour is required during construction. No other site access issues are expected. The temporary detour will be specified to have the following parameters:

- 9 m road width,
- Gravel or pavement road surfacing,
- 60 km/hr detour design speed,
- 50 km/hr posted speed,
- 120 m minimum radius,
- 3:1 side slope,
- Max 5% superelevation,
- 21.5 m horizontal distance between centre line of the road to centre line of the detour, and

3.2 CONSTRUCTION METHODS

The contractor could consider a top-down construction method, since the new bridge is being constructed to match the existing grade of Township Road 242, and the diversion channel will be cut into existing grade. Abutment construction would involve installing piles from existing grade to design cut-off elevation, then casting the abutment seat. The piers could be constructed in trenches

4.0 TENDER ISSUES

No issue noted at this time.

5.0 GEOMETRY AND SPAN CONFIGURATION

The road and channel profiles restrict the superstructure depth to less than 5.0 m. As stated in the *Bridge Conceptual Design Report* a three-span allows the piers to be placed out of the center of the channel. The proposed bridge geometry is as follows:

- 3 – spans: 30 m – 30 m – 30 m,
- No skew between road and bridge,
- Maintain the current vertical and horizontal alignment of the road,
- Overall width of 10.0 m,
- 2 – 3.5 m wide lanes,
- 1.0 m shoulders,
- 0.5 m barriers on both sides,
- Longitudinal slope of 3%, and
- Crossfall of 2% away from crown.

6.0 STRUCTURE ALTERNATIVES

6.1 EXPOSURE CLASS

As per AT's *BSDC, Appendix C,* with an AADT of 517 and a deck area of 810 m^2, the bridge is exposure class 2. Therefore, corrosion resistant or stainless steel reinforcing bars will be used for:

- The deck,
- Barriers,
- Approach slabs,
- Sleeper slabs, and
- Top 300 mm of the wingwalls, backwalls and diaphragms.

6.2 FOUNDATIONS

As recommended in *Springbank Off-Stream Storage Project Bridge Structure Foundation Design Memorandum – Township Road 242 and Highway 22 over Springbank Diversion Channel,* both cast-in-place piles and H-piles are potential options. However, the mechanics of cast-in-place pile foundations in weak bedrock are better understood. There are several risks associated with driven steel piles that need to be considered.

6.2.1 Cast-in-Place Concrete Piles

Based on preliminary geometry and soil parameters listed in Table 2-3 it is estimated that four 1.2 m diameter piles spaced at 3.6 m are sufficient for the piers and four 0.9 m diameter piles spaced at 2.7 m are sufficient for the abutments.

6.2.2 H-Piles

The bedrock layers at this site vary, however the bedrock is anticipated to be approximately 10 m below the abutments and 4 m below the piers. Given the shallow depth of bedrock and the complicated mechanics of driven piles in the expected ground conditions, there is a risk that the steel piles will not sufficiently be able to penetrate the bedrock layer. If a pile is damaged in the process, the Contractor would need to remove the pile. Additional equipment may be required to remove the damaged piles and to bore through the strong bedrock layer, if necessary. If this is encountered, there will be delays to construction and additional construction cost.

Some ways to minimize the potential for damage to the piles is by using a large section size, such as HP 360x132 and by using steel driving shoes.

A summary of the soil parameters are listed in Table 2-3.

6.3 ABUTMENTS

Three abutment configurations have been considered for this structure: fully integral, conventional, and semi-integral with sliding bearings.

6.3.1 Conventional

As per AT's *Best Practice Guidelines* and AT's BSDC, *Appendix A*, conventional abutments should only be considered if integral abutments cannot be used. With proper design considerations, such as longitudinal restraints at the piers, acceptable thermal spans can be achieve making semi-integral abutments feasible. For these reasons conventional abutments were not considered further.

6.3.2 Fully Integral

A fully integral abutment would eliminate the need for sliding bearings and deck joints, reducing the life cycle costs of the structure. A single row of driven steel piles would be required at the abutments, to provide the flexibility required to accommodate movement of the structure. To reduce the risk of driven steel piles, concrete piles could be used at the piers, however this would increase the cost to mobilize a second piling rig.

Due to the risks of additional cost and potential construction delays associated with driven steel piles, discussed in the foundation section, a fully integral abutment is not the recommended option.

6.3.3 Semi-Integral

Semi-integral abutments can be constructed using cast-in-place piles, while removing the need for traditional deck joints. Differential movement between the superstructure and substructure will be accommodated by a type C2 joints located at the ends of the approach slabs and reinforced elastomeric bearings. A concrete abutment diaphragm will retain fill behind the abutment as well as provide support for the approach slabs. A compressible material is required between the moving diaphragm and the stationary abutment seat.

The overall cost of a semi-integral bridge is anticipated to be approximately $250,000 more than an integral bridge. However, the risks associated with damaged steel piles, including potential construction delays and cost, are undesirable and therefore semi-integral abutments are recommended.

6.3.4 Wingwalls

On conventional abutments, the wingwall are connected to the backwall and abutment seat. For semi-integral abutments, the wingwall are typically connected to the diaphragm and are required to move.

6.3.4.1 Stationary

The challenge with a stationary wingwall for semi-integral abutments, is that a joint is required between the barrier on the overhang and the barrier on the wingwall. One of the benefits of semi-integral abutments is the elimination of joints near the bearings. Compared to a moving wingwall, a stationary wall requires additional reinforcing steel for a long cantilever or the addition of piles to limit the cantilever. For this reason, a stationary wingwall is not recommended.

6.3.4.2 Moving

When wingwalls are connected to the diaphragm they must be designed to accommodate longitudinal movement of the superstructure. Compressible material is required between the wingwall and abutment seat. The approach slab will move independently of the wingwalls. Moving wingwalls have successfully been used on Northeast Anthony Henday and Southeast Stoney Trail. Moving wingwalls are recommended for this structure.

6.3.5 Approach Slab

The approach slabs will be cast-in-place 6.0 m long and 300 mm thick.

6.3.6 Slope Protection

At the bridge location, the channel slopes will consist of 600 mm deep, Class 1 riprap. It will extend up to the face of the abutment seat to prevent erosion. Outside the bridge footprint, it will extend up to 1 m above the design high water elevation.

6.4 PIERS

The piers are within the highwater line. It is assumed that the debris mitigation measures will prevent any large debris from the channel. Debris and ice loads on the piers will not be designed for.

As the piers are not within the splash zone, the rebar will consist of standard carbon steel and the concrete will be Class C (35 MPa). Generally, the public will not be able to see the piers, so aesthetics will be a minor consideration.

6.4.1 Multi-Shaft Pier

A two-shaft pier would reduce the amount of concrete and steel required. However, a multi-shaft pier may cause more disruption to the flow. In addition, a multi-shaft configuration is prone to the accumulation of small debris, resulting in additional loading on the piers and an increase in maintenance cost. Multi-shaft piers are not recommended for this structure.

6.4.2 T-Shaped Piers

T-shaped piers are recommended as a single solid shaft is easier to construct, will reduce the amount of concrete within the channel and will reduce the likelihood of debris accumulation. The preliminary pier size is 6 m by 1.8 m.

6.5 GIRDERS

Three girder types were considered, precast 1100 box girders, precast 1200 NU girders, and steel plate girders. The depth of all girder systems are restricted to allow the profile of Township Road 242 to be maintained while allowing a 1 m freeboard during a flood event. The maximum distance from top of deck to bottom of girder is 5.0 m. The girder options will be discussed further in the cost estimate and recommendations section.

6.5.1 Precast concrete 1100 Box Girders

The precast box girder option consists of:

- 8 girder lines,
- 1100 mm precast box girders, and
- 70 MPa high performance concrete.

Shear keys will be used to connect the girders. The use of box girders will change the width of the road to 9.65 m, which is 350 mm less than that mentioned in section 5.0. Alberta Transportations Best Practice Guideline 10 (BPG 10) *Minimum Bridge Width for SLC Girder Structures* allows for a reduction in width to eliminate the need of an extra girder line. Even though box girders are being used instead of SLC the intent of BPG 10 is still applicable and for this reason 8 girders are recommended for this option.

6.5.2 Precast Concrete 1200 NU Girders

The NU girder option consists of:

- 4 girder lines,
- 1200 mm deep precast NU girders,
- 2500 mm spacing,
- 70 MPa high performance concrete, and
- No post-tensioning.

Intermediate steel diaphragms would be required to increase lateral stability during erection. Cast-in-place concrete diaphragms would be required at the abutments and piers.

6.5.3 Steel Plate Girders

The steel option consists of:

- 4 girder lines,
- 1320 mm deep welded steel plate girders, and
- 2500 mm spacing.

The steel plates are grade 350 AT category 3 weathering steel. The approximate weight of each girder (including diaphragms) is 479 kg/m. Based on preliminary design no longitudinal or transverse stiffeners are required. It is anticipated that twelve intermediate weathering steel diaphragms are required, including at the piers and abutments. Lateral bracing is not required.

6.6 DECK

The deck will have a longitudinal slope of 3% with a 2% cross fall away from the crown. Based on preliminary calculations, deck drains are not required

Precast panels were not considered as schedule is expected to have minimal impact on the public, making precast panels unnecessary. A standard cast-in-place 45 MPa, 225 mm thick, high performance concrete deck system is recommended. The bridge is exposure class 2, therefore, either corrosion resistant reinforcing or stainless steel reinforcing can be used.

Following AT's *Bridge Best Practice Guide 3* (BPG 3) "*Protection Systems for New Concrete Bridge Decks*", waterproofing and asphalt will not be provided for this structure as it is on a local gravel road with no exposure to de-icing salts. However, the structure will be designed to accommodate ACP and waterproofing, if it is desired in the future.

6.6.1 Drain Trough

The water will be directed to both barriers via the cross fall and flow to the east due to the longitudinal grade. At the ends of the bridge the water will be directed, via a drain trough, into the diversion channel. Runoff is not expected to encroach on the travel lanes.

6.7 BARRIERS

The exposure index for this structure is 1, therefore the structure requires minimum TL-2 barriers on both sides of the structure. According to *Alberta Transportation's BSDC,* it is recommended for larger bridges that a TL-4 be considered even where a TL-2 barrier meets the minimum CAN/CSA-S6 code requirements; given the length of the structure (81 m), it is recommended the barrier be upgraded to a TL-4 double tube bridgerail. Cyclists and pedestrians will not be considered in the design of the barriers.

6.7.1 TL-2 Barrier

The standard Alberta Transportation TL-2 barrier is continuous thrie-beam, as per S-1652-17. As mentioned above this barrier type is not recommended.

6.7.2 TL-4 Barrier

The recommended barrier type is the standard Alberta Transportation TL-4 double tube barrier, as per S-1642-17 with a transition detail as per S-1643-17. The barrier will consist of a 290 mm high concrete curb, to allow for a future 90 mm ACP surface, with a double tube metal railing on top. The transition will consist of a thrie-beam approach rail.

6.7.3 Utilities

A power line and Telus line are currently running along the north edge of Township Road 242. It is proposed that the utilities be placed in ducts in the bridge barriers. Therefore, a minimum TL-4 barrier is required.

6.8 JOINTS AND BEARINGS

The proposed arrangement will consist of expansion bearings at the abutments and fixed supports at the piers. Transverse restrain will be provided via shear blocks. Based on preliminary load calculations all bearings will be steel reinforced elastomeric bearings.

According to AT's BSDC *Appendix A*, the maximum thermal span for concrete and steel girder systems is 60 m and 45 m, respectively. It is assumed that the thermal fixity of the superstructure is located at the centre of the structure.

According to CAN/CSA S6-14 the maximum and minimum mean daily temperatures, for this area, are +28°C and -38°C, respectively. The expected thermal movement is dependent on the superstructure type. Assuming the piers provided no restriction to longitudinal movement, the following thermal movement can be expected:

- For the concrete girder system, the structure is classified as a type C structure according to clause 3.9 of CAN/CSA S6-14. The estimated thermal movement, based on a maximum thermal span of 45 m, is 31 mm.
- For the steel girder system, the structure is classified as a type B structure according to clause 3.9 of CAN/CSA S6-14. The estimated thermal movement, based on a maximum thermal span of 45 m length, is 45 mm. Steel girders are not recommended.

As this is on a gravel road, a typical C2 cycle control joint is not applicable, but based on these movements a sleeper slab is recommended, as there is potential for erosion at the end of the approach slab.

7.0 COST ESTIMATE

The opinions of probable cost assembled in this report are based only on major structural components and the minimum extents of fills required to achieve stability. It does not provide for any cost of elements such as, roadway construction, detour construction, utility placement or relocation, electrical distribution, smaller secondary items, excavation, or channel riprap. The cost of the temporary detour, excavation and riprap placement are included in civil works. This methodology is consistent with providing the owner with comparative costs to identify preferable options.

For comparison purposes, an initial capital cost (Class B) cost estimate for a box girder system, NU girder system and a steel plate girder system is summarized in the table below and further details can be found in Appendix B. The costs include construction cost plus a 10% contingency. The cost does not include engineering fees. It is noted that the level of accuracy of the estimate at this stage is within ± 20%. All figures have been rounded up to the nearest $10-thousand value.

Table 7-1: Estimated Initial Capital Cost (Class B)

Option	Structure Type	Initial Capital Cost (±20%)	Cost per m^2
1	1100 mm deep Box Girder	$ 4.84 M	$ 4,800
2	1200 mm deep NU Girder	$ 4.21 M	$ 4,000
3	1320 mm deep Steel Plate Girder	$ 4.25 M	$ 4,100

The three cost estimates provided are based on the recommended alternatives stated above. It has been assumed that a semi-integral abutment with 4 cast-in-place concrete piles per abutment/pier and reinforced elastomeric bearings are used. As well, the estimates assume a cast-in-place concrete deck and TL-4 double tube railings.

The cost estimate is based on a structure with a total width of 10.0 m. The estimated unit cost values were derived from the 2018 Unit Prices Average Reports, recent experience and presumed escalation. It is noted that these values are assumed based on construction in today's market, however, if the tender is postponed, the estimates may fluctuate due to changes in the market and inflation.

7.1 LIFE CYCLE COST ESTIMATE

Table 7-2: Estimated Life Cycle Cost

Option	Structure Type	Life Cycle Cost Estimate
1	1100 mm deep Box Girder	$ 5.25 M
2	1200 mm deep NU Girder	$ 4.61 M
3	1320 mm deep Steel Plate Girder	$ 4.72 M

The life cycle cost estimate includes major rehabilitation items that present potentially expensive future cost liabilities; these include items such as deck rehabilitation, sealer and paint applications, and bearing replacements. The life cycle costs do not include the user costs associated with future maintenance work. Depending on the maintenance work required, the structure may be partially or fully closed temporarily. The user delays associated with maintenance for all options presented are assumed to be equivalent, as maintenance techniques will be similar.

To determine the dollar value of future maintenance, an assumed (long term) interest rate of 4% was used, and an estimate of when future maintenance work would be required.

8.0 DESIGN DECISIONS AND RECOMMENDATIONS

After a review of the alternatives presented in this report, a 3 span 1200 mm deep prestressed concrete NU girder structure is recommended, with:

- Semi-integral abutments,
- Moving wingwalls,
- Concrete piles,
- Concrete T-shaped pier shafts,
- TL-4 barriers,
- Sleeper slabs at ends of approach slabs, and
- Reinforced elastomeric bearings.

The structure has the lowest initial capital cost and life cycle cost. A summary of the recommended structure can be found in the Bridge Choose Design Form in Appendix C.

APPENDIX A SKETCHES

PLAN
1:500

DRAWING SK-1001
HIGHWAY
CONTRACT
DESCRIPTION SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
PHOTO
DATE
BY
SURVEYED
DEPARTMENT BAR CODE

LEGEND

KEY PLAN

CONSULTANT

JOB NO. 110773396

DESIGNER DATE

CHECKER DATE

REV	DATE	REVISION	BY

DATE	LOCATION	SITE
2017-10-18	SSE15-24-4-5	BF 84156

Alberta Transportation

SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
TWP 242 BRIDGE OVER DIVERSION CHANNEL
SITE PLAN

CONTRACT	HIGHWAY	SHEET	DRAWING
-	TWP RD 242	1 OF 7	SK-1001

DRAWING SK-1002

HIGHWAY

CONTRACT

DESCRIPTION SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)

PHOTO

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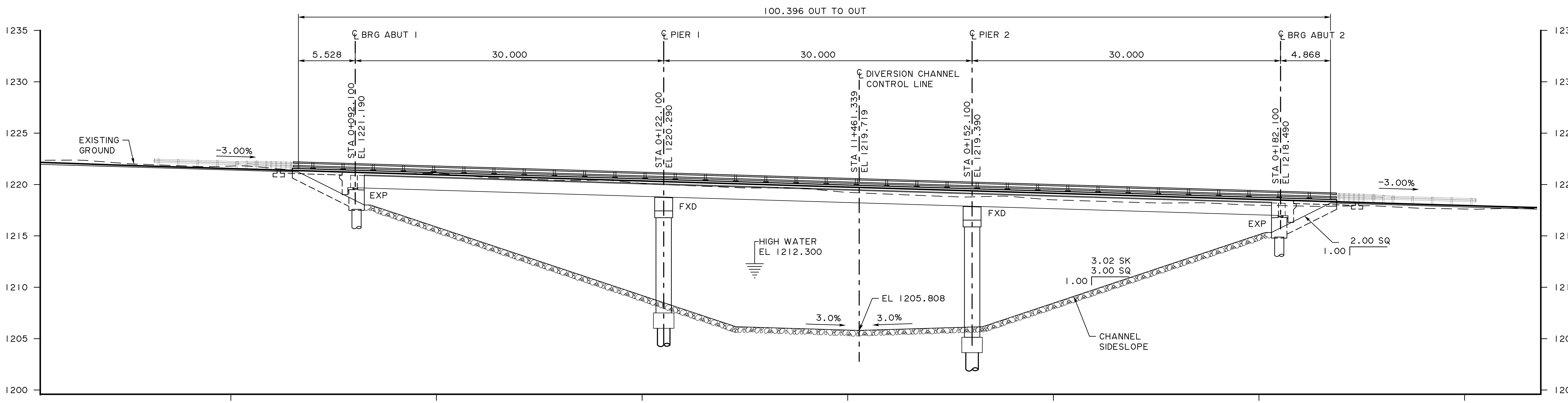

ELEVATION

1:200

LEGEND	KEY PLAN	CONSULTANT		DESIGNER	CHECKER
		JOB NO. 110773396		DATE	DATE

REV	DATE	REVISION	BY

DATE	LOCATION	SITE
2017-10-18	SSE15-24-4-5	BF 84156

Alberta Transportation

SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
TWP 242 BRIDGE OVER DIVERSION CHANNEL
ELEVATION

CONTRACT	HIGHWAY	SHEET	DRAWING
-	TWP RD 242	2 OF 7	SK-1002

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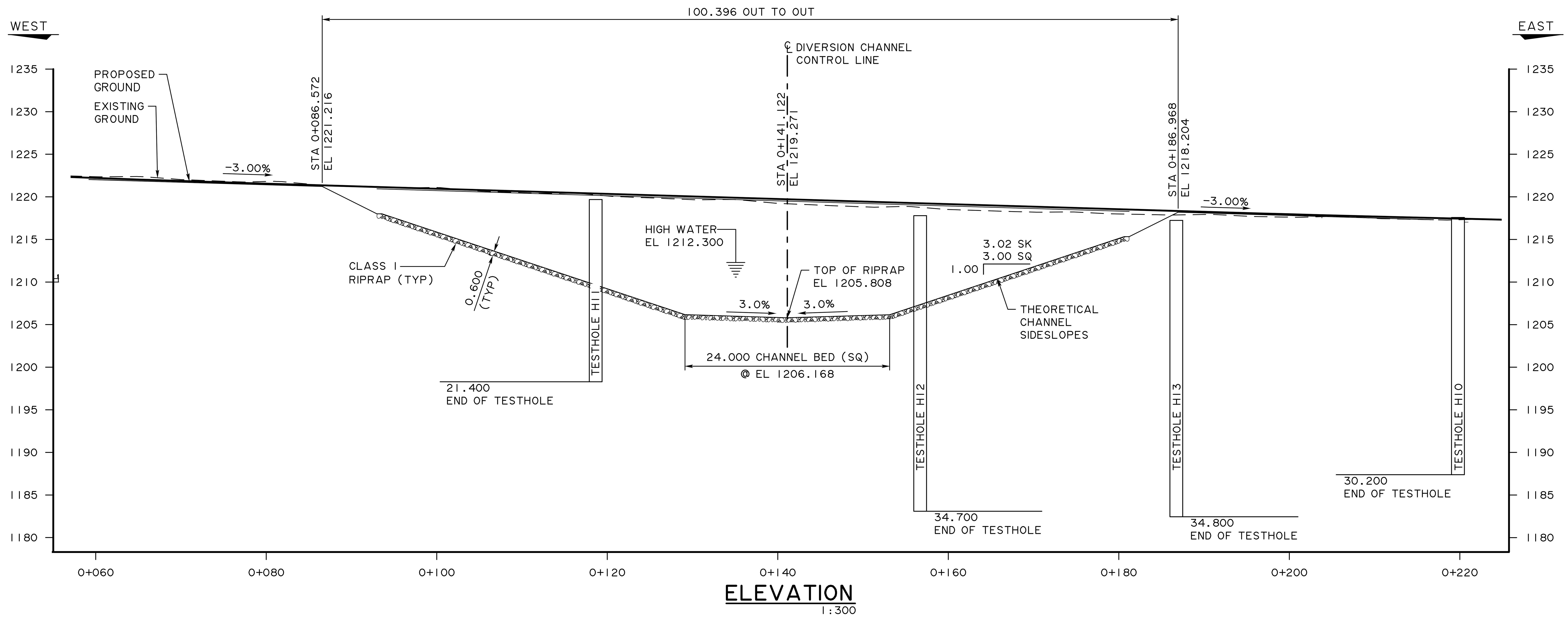
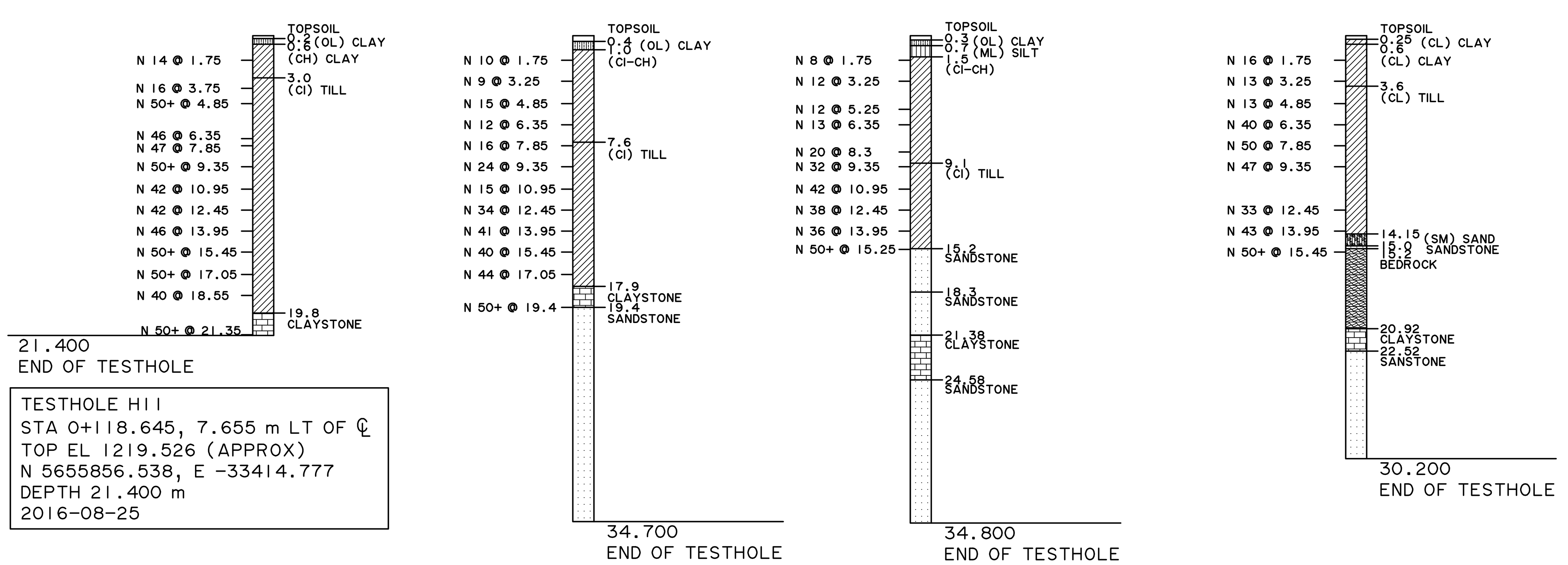


ELEVATION

1:300



TESTHOLE H11
STA 0+118.645, 7.655 m LT OF ℄
TOP EL 1219.526 (APPROX)
N 5655856.538, E -33414.777
DEPTH 21.400 m
2016-08-25

TESTHOLE H12
STA 0+156.698, 7.520 m LT OF ℄
TOP EL 1217.631 (APPROX)
N 5655856.985, E -33376.726
DEPTH 34.700 m
2016-08-24

TESTHOLE H13
STA 0+186.744, 7.835 m LT OF ℄
TOP EL 1217.077 (APPROX)
N 5655857.761, E -33346.689
DEPTH 34.800 m
2016-08-23

TESTHOLE H10
STA 0+219.786, 3.032 m LT OF ℄
TOP EL 1217.416 (APPROX)
N 5655853.464, E -33313.577
DEPTH 30.200 m
2016-08-22

GEOTECHNICAL NOTES

- ALL GEOTECHNICAL INFORMATION PROVIDED FOR THIS PROJECT HAS BEEN COMPILED FOR ALBERTA TRANSPORTATION FOR DESIGN PURPOSES ONLY. INFORMATION WAS COMPILED FROM STANTEC CONSULTING LTD. MEMORANDUM, "SPRINGBANK OFF-STREAM STORAGE PROJECT BRIDGE STRUCTURE FOUNDATION DESIGN MEMORANDUM -" JULY 2018 AND REPORT, "SPRINGBANK OFF-STREAM STORAGE PROJECT GEOTECHNICAL INVESTIGATION REPORT" DECEMBER 2016. ADDITIONAL INFORMATION IS AVAILABLE IN THE REPORT AND SHOULD BE EXAMINED AND SUPPLEMENTED AS REQUIRED. ALL DISCLAIMERS IN THIS REPORT ARE APPLICABLE AND IN CASE OF DISCREPANCY, THE GEOTECHNICAL REPORT GOVERNS.
- GEOTECHNICAL LIMITATION: WHILE THE GEOTECHNICAL INFORMATION PROVIDED FOR THIS PROJECT IS BELIEVED TO CORRECTLY REPRODUCE OR SUMMARIZE OBSERVATIONS MADE DURING TESTING, IT IS VALID ONLY FOR THE PRECISE LOCATION(S) SHOWN, AND IT IS NOT TO BE CONSTRUED AS GUARANTEEING THE ACTUAL MATERIALS AND CONDITIONS EXISTING THROUGHOUT THE SITE. THE TESTING METHODS USED MAY NOT HAVE DETERMINED THE PRESENCE, ABSENCE OR EXTENT OF BOULDERS, HARD OR SOFT FORMATIONS, WATER TABLES, ARTESIAN CONDITIONS AND OTHER VARIABLES. IT IS THE RESPONSIBILITY OF OTHERS USING THIS INFORMATION TO ENSURE THAT IT IS ADEQUATE FOR THEIR PURPOSES, OR TO SUPPLEMENT IT WITH ADDITIONAL INFORMATION.
- ALL CHANNEL ELEVATIONS AND DIMENSIONS ARE TO TOP OF ROCK RIPRAP

UNIFIED SOIL CLASSIFICATION SYSTEM (MODIFIED BY PFRA)

COARSE GRAINED SOILS 50%+ RETAINED ON AN 80 MICRON SIEVE			FINE GRAINED SOILS 50%+ PASSING AN 80 MICRON SIEVE		
GROUP SYM	LOG SYM	TYPICAL NAMES	GROUP SYM	LOG SYM	TYPICAL NAMES
GW		WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	CL		INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
GP		POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	CI		INORGANIC CLAYS OF MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS
GM d / u		SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CH		INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
GC		CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES	ML		INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
SW		WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	MH		INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS
SP		POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	OL		ORGANIC SILTS AND ORGANIC SILTY CLAYS OR LOW PLASTICITY
SM d / u		SILTY SANDS: SAND-SILT MIXTURES	OH		ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
SC		CLAYEY SANDS, SAND-CLAY MIXTURES	Pt		PEAT AND OTHER HIGHLY ORGANIC SOILS
OTHER SYMBOLS					
		BEDROCK (UNCLASSIFIED)			CONGLOMERATE
		SANDSTONE			COAL
		SHALE			OVERBURDEN
		LIMESTONE			TOPSOIL

LEGEND	KEY PLAN	CONSULTANT	DESIGNER	CHECKER
		JOB NO. 110773396	DATE	DATE

REV	DATE	REVISION	BY

Alberta Transportation

SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
TWP 242 BRIDGE OVER DIVERSION CHANNEL GEOTECHNICAL INFORMATION

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
2017-10-18	SSE15-24-4-5	BF 84156	-	TWP RD 242	3 OF 7	SK-1003

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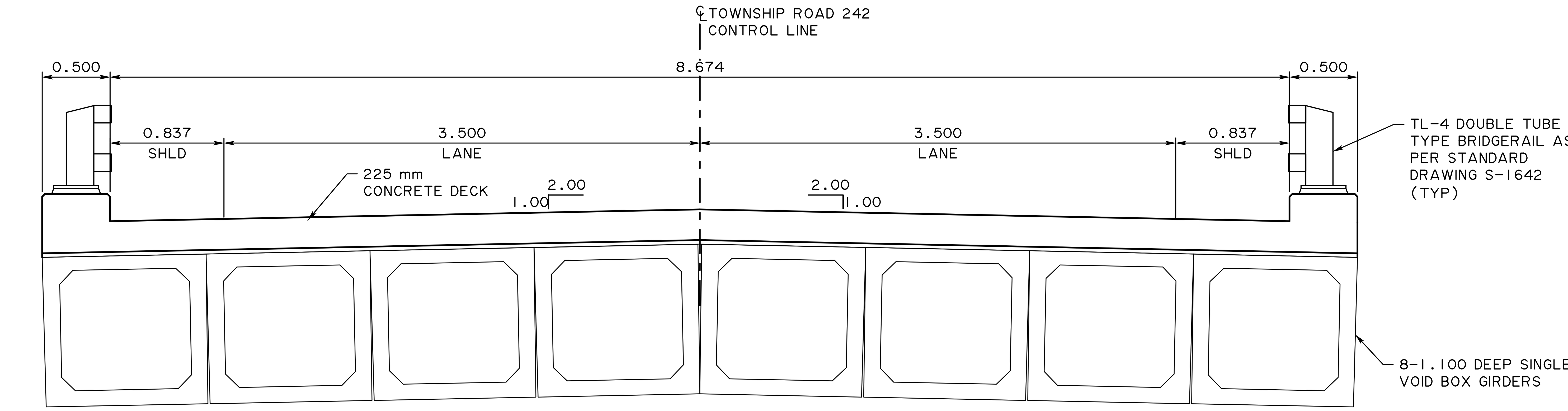

A – BOX GIRDER OPTION
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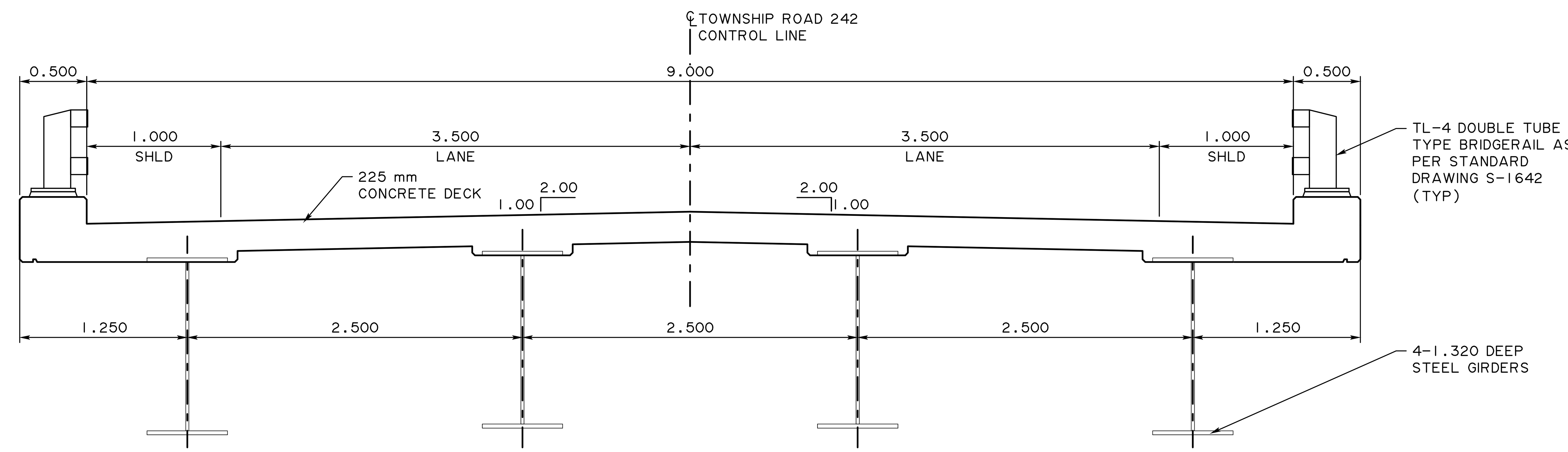

B – STEEL GIRDER OPTION
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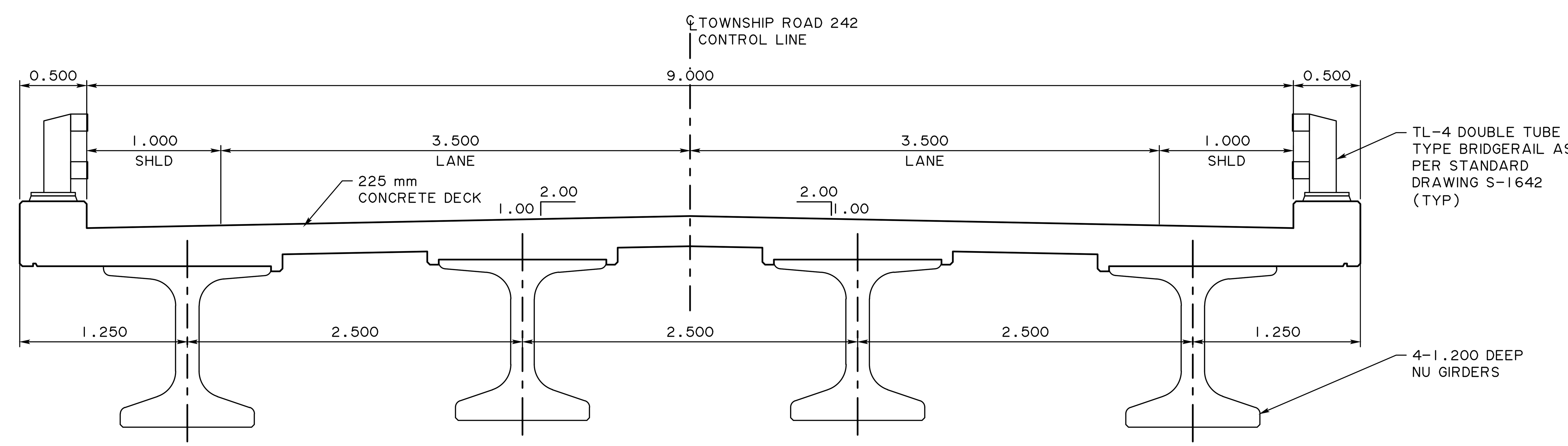

C – NU GIRDER OPTION
1:25

DRAWING SK-1004
HIGHWAY
CONTRACT
DESCRIPTION SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
PHOTO
DATE
BY
SURVEYED
DEPARTMENT BAR CODE

LEGEND

KEY PLAN

CONSULTANT

JOB NO. 110773396

DESIGNER
DATE

CHECKER
DATE

REV	DATE	REVISION	BY

Alberta Transportation

SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
TWP 242 BRIDGE OVER DIVERSION CHANNEL
GIRDER OPTIONS

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
2017-10-18	SSE15-24-4-5	BF 84156	-	TWP RD 242	4 OF 7	SK-1004

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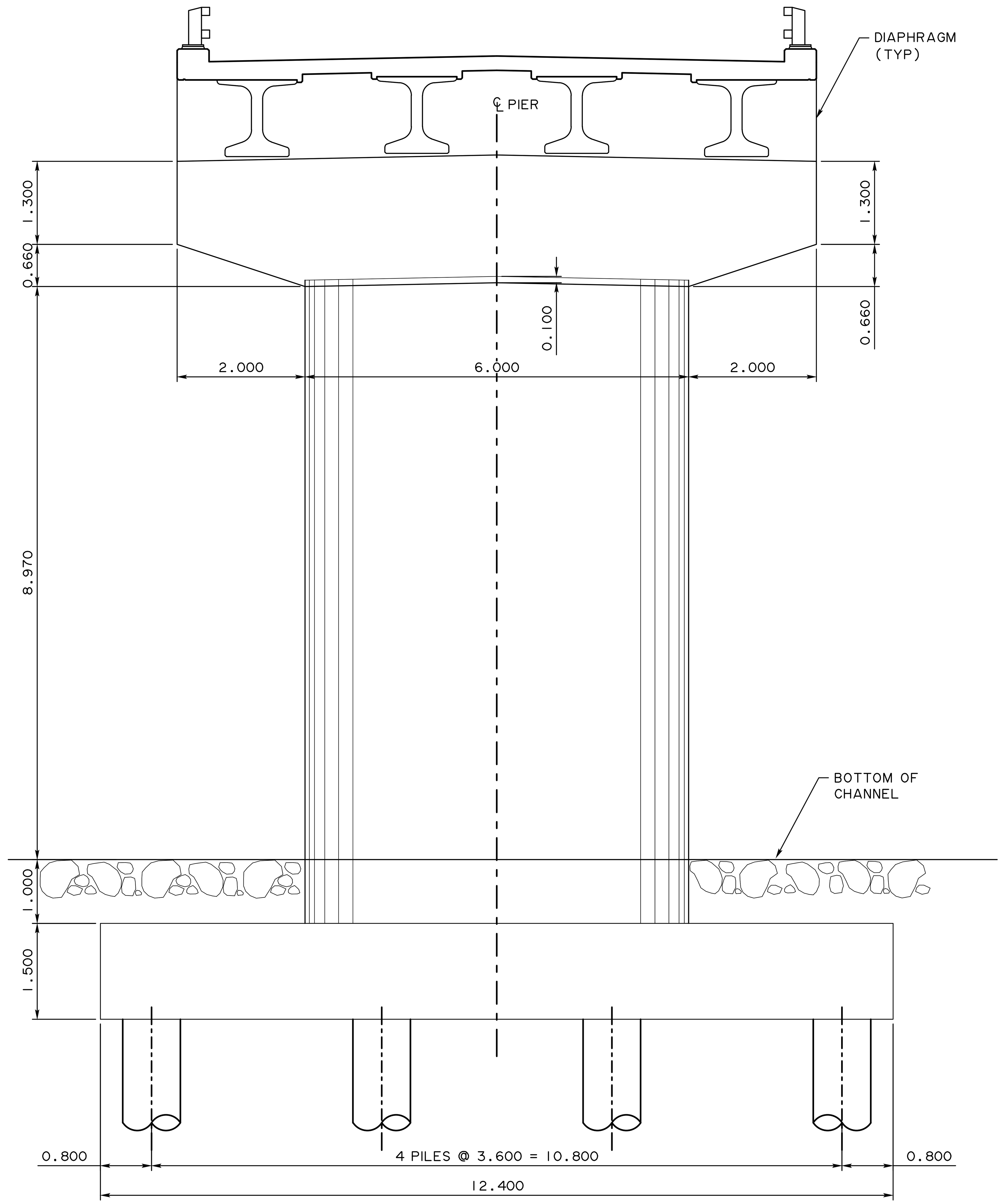
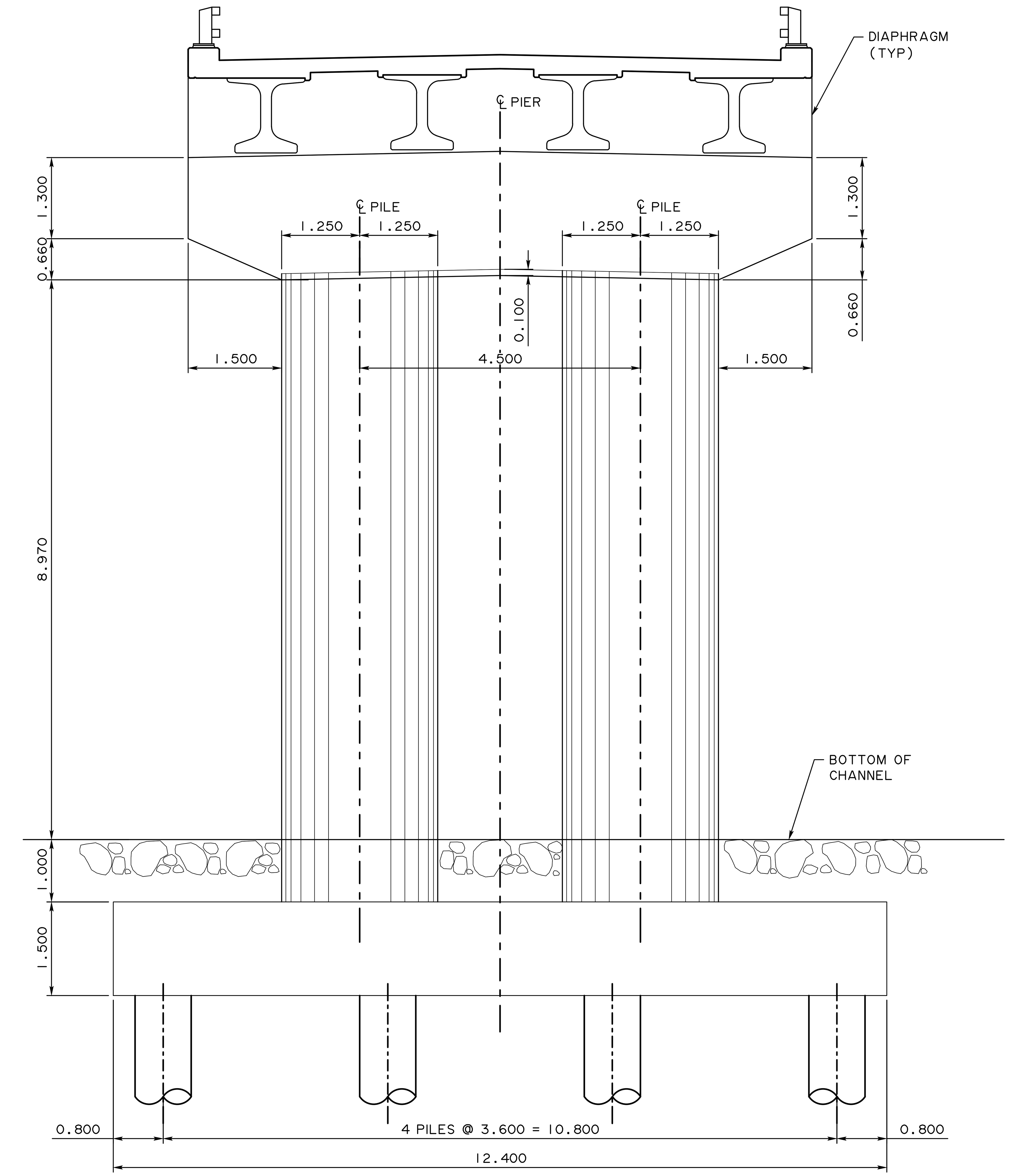


A PIER OPTION 1
(PIER 1 SHOWN) 1:50



B PIER OPTION 2
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LEGEND	KEY PLAN	CONSULTANT	DESIGNER	CHECKER
		JOB NO. 110773396	DATE	DATE

REV	DATE	REVISION	BY

DATE	LOCATION	SITE
2017-10-18	SSE15-24-4-5	BF 84156

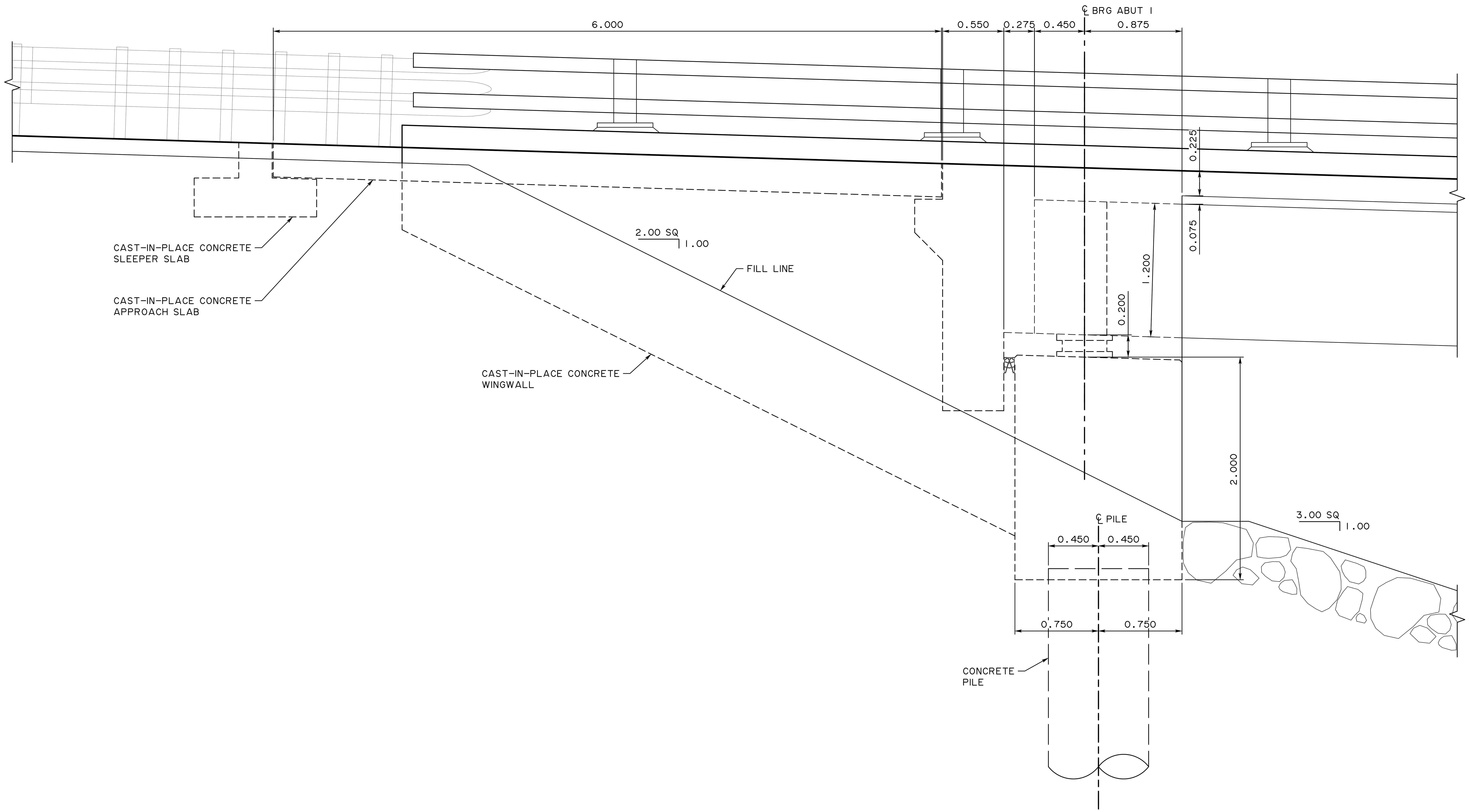
Alberta Transportation

SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
TWP 242 BRIDGE OVER DIVERSION CHANNEL
PIER OPTION

CONTRACT	HIGHWAY	SHEET	DRAWING
-	TWP RD 242	5 OF 7	SK-1005

\\Cd1002-f04\shared_projects\110773396\CAD\transportation\sheet_files\03_bridges\structural_alternatives_(choose_design)\twp_242\73396_SK-1005_pier_options.dwg
2018-10-18 10:40am By: jlo

DRAWING
SK-1006
HIGHWAY
CONTRACT
DESCRIPTION
SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
PHOTO
DATE
BY
SURVEYED
DEPARTMENT BAR CODE



A/– SEMI-INTEGRAL ABUTMENT 1
1:20

LEGEND	KEY PLAN	CONSULTANT		DESIGNER	CHECKER
		JOB NO.	110773396	DATE	DATE

REV	DATE	REVISION	BY

Alberta Transportation

SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
TWP 242 BRIDGE OVER DIVERSION CHANNEL
ABUTMENT 1 DETAIL

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
2017-10-18	SSE15-24-4-5	BF 84156	-	TWP RD 242	6 OF 7	SK-1006

DRAWING SK-1007

HIGHWAY

CONTRACT

DESCRIPTION SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)

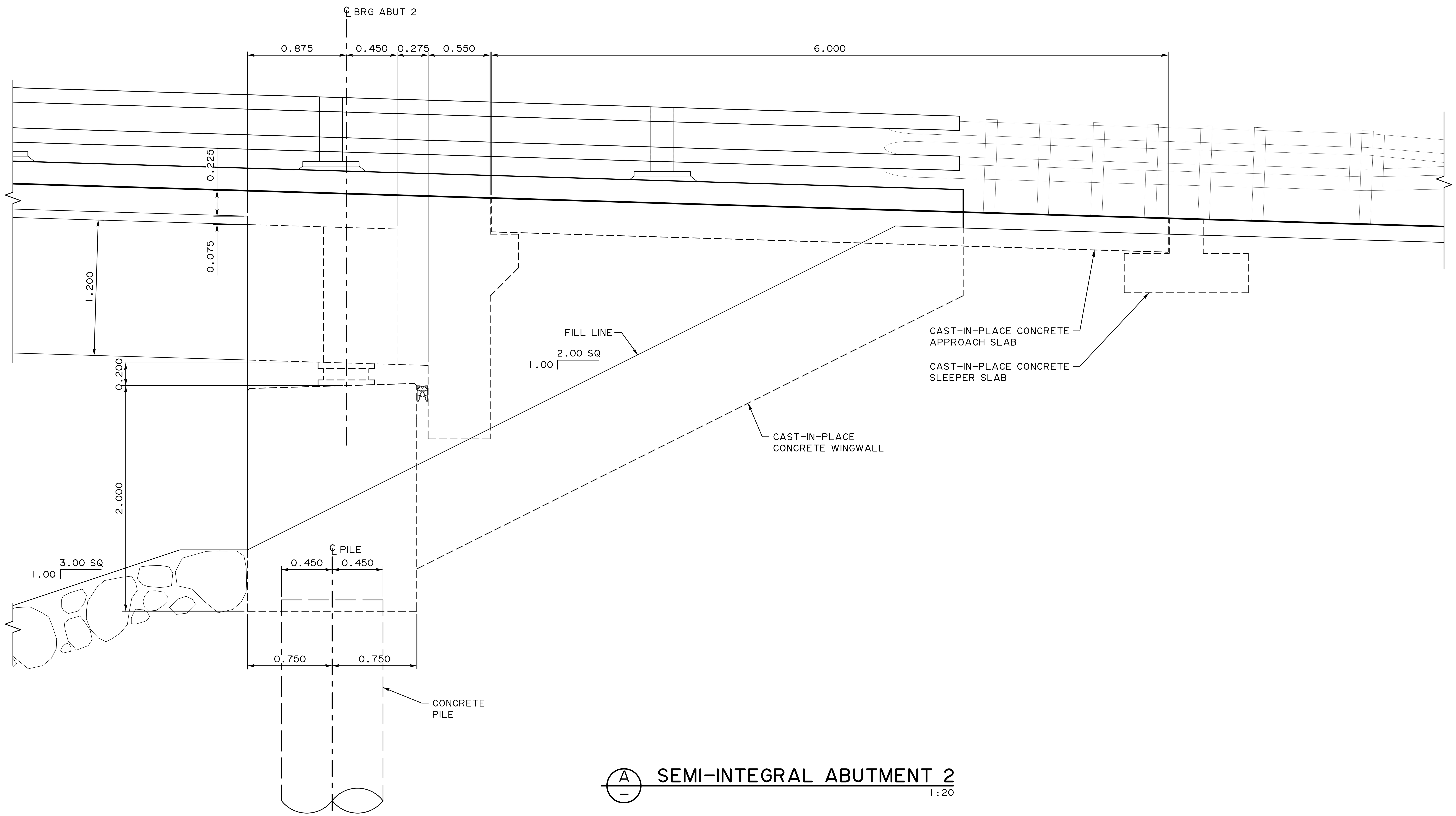
PHOTO

DATE

BY

SURVEYED

DEPARTMENT BAR CODE



A
–
SEMI-INTEGRAL ABUTMENT 2
1:20

LEGEND	KEY PLAN	CONSULTANT		DESIGNER	CHECKER
		JOB NO. 110773396		DATE______	DATE______

REV	DATE	REVISION	BY

Alberta Transportation

SPRINGBANK OFF-STREAM RESERVOIR PROJECT (SR1)
TWP 242 BRIDGE OVER DIVERSION CHANNEL
ABUTMENT 2 DETAIL

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
2017-10-18	SSE15-24-4-5	BF 84156	-	TWP RD 242	7 OF 7	SK-1007

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2018-10-19 11:45am By: jlo

APPENDIX B COST ESTIMATE (CLASS B)

19-Oct-18
Bridge File: TBD
Estimated Length (m): 90
Estimated Width (m): 9.674
Deck Area (m2): 871
Total Area (m2): 930

Cost Estimate B
SR1 - Township Road 242
1100 mm Deep Precast Box Girder - Option 1

Item No.	AT Code	Bid Item Description	Estimated Quantity	Unit	Estimated Unit Price	Estimated Cost
1	X004	Site Occupancy		days	$ -	$ -
2	X100	Mobilization (10%)	1	lump sum	$ 400,000.00	$ 400,000.00
3	F188	Excavation-Structural	1400	m3	$ 19.75	$ 28,000.00
4	F203	Backfill	1	lump sum	$ 261,000.00	$ 261,000.00
5	F505	Additional Heavy Rock Riprap (Class 1)	20	m3	$ 345.00	$ 7,000.00
6	F822	Pile Concrete	308	m3	$ 573.00	$ 177,000.00
7	F824	Drill Rig Set Up	16	piles	$ 7,871.00	$ 126,000.00
8	F826	Pile Installation	272	m	$ 687.00	$ 187,000.00
9	F834	Concrete - Class C	398	m3	$ 1,020.00	$ 407,000.00
10	F841	Concrete - Class HPC	367	m3	$ 2,051.00	$ 753,000.00
11	F018	Sealer	1	lump sum	$ 10,000.00	$ 10,000.00
12	F780	Bridgerail	1	lump sum	$ 96,000.00	$ 96,000.00
13	F851	Corrosion Resistant Reinforcing Steel - Supply	43100	kg	$ 5.06	$ 219,000.00
14	F850	Plain Reinforcing Steel - Supply	92500	kg	$ 1.39	$ 129,000.00
15	F854	Reinforcing Steel - Place	135600	kg	$ 1.18	$ 161,000.00
16	F948	Supply of Box Girders	720	m	$ 1,550.00	$ 1,116,000.00
17	F940	Delivery of Girders	720	m	$ 115.00	$ 83,000.00
18	F945	Erection of Girders	720	m	$ 145.00	$ 105,000.00
19	F905	Supply and Delivery of Bearings	1	lump sum	$ 96,000.00	$ 96,000.00
20	F910	Installation of Bearings	1	lump sum	$ 24,000.00	$ 24,000.00
21	F018	Approach Rail Transitions	1	lump sum	$ 10,000.00	$ 10,000.00
22	D018	Drain Troughs	1	lump sum	$ 5,000.00	$ 5,000.00

Remarks

1 Based on At Unit Price Averages Report (Provincial Average Aug 2016-Mar 2018)
2 Based on a typical semi-integral abutment with 4 piles
3 Assumes reinforced elastomeric bearings

Estimated Tender Cost:	**$4,400,000.00**
Estimated Unit Cost ($/m^2):	**$4,800.00**
Contingency: *10%*	$440,000.00
Total Estimated Project Cost:	**$4,840,000.00**

Stantec

19-Oct-18
Bridge File: TBD
Estimated Length (m): 90
Estimated Width (m): 10
Deck Area (m2): 900
Total Area (m2): 960

Cost Estimate B
SR1 - Township Road 242
1200 mm Deep Precast NU - Option 2

Item No.	AT Code	Bid Item Description	Estimated Quantity	Unit	Estimated Unit Price	Estimated Cost
1	X004	Site Occupancy		days	$ -	$ -
2	X100	Mobilization (10%)	1	lump sum	$ 347,600.00	$ 348,000.00
3	F188	Excavation-Structural	1400	m3	$ 19.75	$ 28,000.00
4	F203	Backfill	1	lump sum	$ 261,000.00	$ 261,000.00
5	F505	Additional Heavy Rock Riprap (Class 1)	20	m3	$ 345.00	$ 7,000.00
6	F822	Pile Concrete	308	m3	$ 573.00	$ 177,000.00
7	F824	Drill Rig Set Up	16	piles	$ 7,871.00	$ 126,000.00
8	F826	Pile Installation	272	m	$ 687.00	$ 187,000.00
9	F834	Concrete - Class C	393	m3	$ 1,020.00	$ 401,000.00
10	F841	Concrete - Class HPC	388	m3	$ 2,051.00	$ 796,000.00
11	F018	Sealer	1	lump sum	$ 10,000.00	$ 10,000.00
12	F780	Bridgerail	1	lump sum	$ 96,000.00	$ 96,000.00
13	F851	Corrosion Resistant Reinforcing Steel - Supply	49700	kg	$ 5.06	$ 252,000.00
14	F850	Plain Reinforcing Steel - Supply	91500	kg	$ 1.39	$ 128,000.00
15	F854	Reinforcing Steel - Place	141200	kg	$ 1.18	$ 167,000.00
16	F948	Supply NU girders	360	m	$ 1,860.00	$ 670,000.00
17	F940	Delivery of Girders	360	m	$ 115.00	$ 42,000.00
18	F945	Erection of Girders	360	m	$ 145.00	$ 53,000.00
19	F905	Supply and Delivery of Bearings	1	lump sum	$ 48,000.00	$ 48,000.00
20	F910	Installation of Bearings	1	lump sum	$ 12,000.00	$ 12,000.00
21	F018	Approach Rail Transitions	1	lump sum	$ 10,000.00	$ 10,000.00
22	D018	Drain Troughs	1	lump sum	$ 5,000.00	$ 5,000.00

Remarks

1 Based on At Unit Price Averages Report (Provincial Average Aug 2016-Mar 2018)
2 Based on a typical semi-integral abutment with 4 piles
3 Assumes reinforced elastomeric bearings

Estimated Tender Cost:		**$3,824,000.00**
Estimated Unit Cost ($/m^2):		**$4,000.00**
Contingency:	*10%*	$383,000.00
Total Estimated Project Cost:		**$4,207,000.00**

Stantec

19-Oct-18
Bridge File: TBD
Estimated Length (m): 90
Estimated Width (m): 90
Deck Area (m2): 900
Total Area (m2): 960

Cost Estimate B
SR1 - Township Road 242
Steel Girders - Option 3

Item No.	AT Code	Bid Item Description	Estimated Quantity	Unit	Estimated Unit Price	Estimated Cost
1	X004	Site Occupancy		days	$ -	$ -
2	X100	Mobilization (10%)	1	lump sum	$ 351,200.00	$ 352,000.00
3	F188	Excavation-Structural	1400	m3	$ 19.75	$ 28,000.00
4	F203	Backfill	1	lump sum	$ 261,000.00	$ 261,000.00
5	F505	Additional Heavy Rock Riprap (Class 1)	20	m3	$ 345.00	$ 7,000.00
6	F822	Pile Concrete	308	m3	$ 573.00	$ 177,000.00
7	F824	Drill Rig Set Up	16	piles	$ 7,871.00	$ 126,000.00
8	F826	Pile Installation	272	m	$ 687.00	$ 187,000.00
9	F834	Concrete - Class C	409	m3	$ 1,020.00	$ 418,000.00
10	F841	Concrete - Class HPC	324	m3	$ 2,051.00	$ 666,000.00
11	F018	Sealer	1	lump sum	$ 10,000.00	$ 10,000.00
12	F780	Bridgerail	1	lump sum	$ 96,000.00	$ 96,000.00
13	F851	Corrosion Resistant Reinforcing Steel - Supply	42600	kg	$ 5.06	$ 216,000.00
14	F850	Plain Reinforcing Steel - Supply	94000	kg	$ 1.39	$ 131,000.00
15	F854	Reinforcing Steel - Place	136600	kg	$ 1.18	$ 162,000.00
16	F900	Supply of Structural Steel Girders and Associated Material	172	tonne	$ 3,864.00	$ 667,000.00
17	F925	Delivery of Girders	172	tonne	$ 300.00	$ 52,000.00
18	F930	Erection of Girders	172	tonne	$ 1,000.00	$ 173,000.00
19	F905	Supply and Delivery of Bearings	1	lump sum	$ 96,000.00	$ 96,000.00
20	F910	Installation of Bearings	1	lump sum	$ 24,000.00	$ 24,000.00
21	F018	Approach Rail Transitions	1	lump sum	$ 10,000.00	$ 10,000.00
22	D018	Drain Troughs	1	lump sum	$ 5,000.00	$ 5,000.00

Remarks

1 Based on At Unit Price Averages Report (Provincial Average Aug 2016-Mar 2018)
2 Based on a typical semi-integral abutment with 4 piles
3 Assumes reinforced elastomeric bearings

Estimated Tender Cost:		**$3,864,000.00**
Estimated Unit Cost ($/m^2):		**$4,100.00**
Contingency:	*10%*	$387,000.00
Total Estimated Project Cost:		**$4,251,000.00**

19-Oct-18
Bridge File: TBD
Deck Area (m2): 900
Discount Rate: 0.04

Life Cycle Cost Estimate
SR1 - Township Road 242

Description:	Unit	Estimated Quantities *Option 1 1100 mm Precast Box*	*Option 2 1200 mm Precast NU*	*Option 3 1300 mm Steel Plate*	Estimated Unit Rate	Estimated Cost *Option 1 1100 mm Precast Box*	*Option 2 1200 mm Precast NU*	*Option 3 1300 mm Steel Plate*
Initial Capital Cost						**$4,840,000**	**$4,207,000**	**$4,251,000**
Deck Rehab - 35 years	sq.m			900	*$1,300.00*	$0	$0	$296,496
Deck Rehab - 40 years	sq.m	871	900		*$1,300.00*	$235,845	$243,698	$0
Overlay Replacement - 35 years	sq.m	871	900	900	*$600.00*	$132,434	$136,844	$136,844
Bearing Replacement - 40 years	ea.	16	8	16	*$10,000.00*	$33,326	$16,663	$33,326
Pigmented Sealer - 15 years	sq.m	290	310	90	*$30.00*	$4,830	$5,163	$1,499
Pigmented Sealer - 30 years	sq.m	290	310	90	*$30.00*	$2,682	$2,867	$832
Pigmented Sealer - 45 years	sq.m	290	310	90	*$30.00*	$1,489	$1,592	$462
					PV	$410,606	$406,827	$469,459
					NPV	**$5,250,606**	**$4,613,827**	**$4,720,459**

APPENDIX C BRIDGE CHOOSE DESIGN FORM

Bridge Choose Design

Bridge File: ____________

Region: Southern Region

Project Description: Twp 242 over Springbank Diversion Channel Highway: Twp Rd. 242 Road Authority: Alberta Transportation

Dept. Sponsor: ____________ Dept. Admin: ____________ TSB Liaison: N/A

Consultant: Stantec Consulting Ltd. Project Manager: ____________ CE Agreement: ____________

CLEAR ROADWAY WIDTH:	9.0 m	AREA (O.T.O. fills and total bridge width) :	1003 m^2

STRUCTURE ALTERNATIVES				
	Description	Selected	Cost Estimate	NPV (50 Years, 4%)
1	1100 mm deep Box Girder		$ 4.84 M	$ 5.25 M
2	1200 mm deep NU Girder	Yes	$ 4.21 M	$ 4.61 M
3	1320 mm deep Steel Plate Girder		$ 4.25 M	$ 4.72 M

SPECIAL CONSIDERATIONS:	
Notes:	

SELECTED ALTERNATIVE:			
Girder Type, Size and No. of Lines:	Four 1200 mm prestressed concrete NU girders spaced at 2.5 m		
Culvert Size (span x rise x length) and Shape:	N/A		
Abutment Type:	Semi-integral	Pier Type:	Concrete T-Shape
Deck and Wearing Surface Type:	225 mm cast-in-place high performance concrete deck with 80 mm two course ACP		
Deck Joints:	N/A		
Curbs:	N/A	Bridge Rail:	TL-4 double tube bridge rail
Approach Slabs:	Cast-in-place high performance concrete	Guardrail:	Thrie-beam approach rail transition
Notes:			
DD Drawing No.'s:	N/A		

Draft Submission: ____________ Review Meeting Date: ____________ Final Submission: ____________

	Cost Estimate	Type	Date
Current:	$4,840,000	B	Oct 19, 2018
Previous:	$5,929,000	A	May 12, 2018
Includes:	Construction, Contingencies		

Milestone Schedule	Date
Project Design Brief:	
Complete detailed design:	
Tender ready for advertising:	
Tender advertize date:	

Consultant Project Manager's Signature	Dept. Administrator's Signature	Dept. Sponsor's Signature

Copies to: Consultant, TSB, Bridge File

APPENDIX D GEOTECHNICAL MEMO

Stantec

Memo

To:	Kristoffer Karvinen	From:	Daniel McLellan
	Calgary (25th Street) Office		Calgary (25th Street) Office
File:	110773396	Date:	July 17, 2018

Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel

1.0 INTRODUCTION

This memorandum provides preliminary foundation recommendations for two proposed bridges that will cross over the diversion channel proposed for the Springbank Off-Stream Reservoir (SR1).

2.0 PROJECT UNDERSTANDING

The proposed bridges are located on Highway 22 and Township Road 242, west of Calgary, approximately 20 km upstream of the Glenmore Reservoir.

Our understanding of the proposed bridges comes from these previously issued reports:

- *Bridge Conceptual Design Report. Alberta Transportation BF XXX, Highway 22 over Springbank Diversion Channel* by Stantec Consulting Ltd., dated February 3, 2017
- *Bridge Conceptual Design Report. Alberta Transportation BF XXX, Township Road 242 over Springbank Diversion Channel* by Stantec Consulting Ltd., dated February 3, 2017

The location and general arrangement of the proposed bridges and figures relating to the proposed bridges are presented in **Appendix B**. We understand that both bridges will have a 3-span arrangement comprising the two abutments and two piers at each bridge. The central span will be approximately 30 m. We understand that integral abutment bridges with driven steel H-piles are the preferred bridge design type for Alberta Transportation. Cast-in-place concrete piles are also considered a foundation alternative. Exact loading conditions of the bridges and associated foundations are not currently known.

The geotechnical basis for the bridge structure foundation design is outlined in the following previously issued reports:

- *Springbank Off-Storage Project – Preliminary Geotechnical Assessment Report*, by Stantec Consulting Ltd., dated March 29, 2017
- *Springbank Off-Stream Storage Project – Geotechnical Investigation Report*, by Stantec Consulting Ltd., dated December 13, 2016
- *Seismic Hazard Assessment – Springbank Off-Stream Dam and Reservoir,* by Stantec Consulting Ltd., dated November 28, 2016

The construction sequencing for the excavation of the channel and construction of the bridges is not currently known.

Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel

3.0 GEOTECHNICAL INVESTIGATION

To characterize the subsurface conditions at the proposed bridge locations, four geotechnical boreholes were advanced at each proposed bridge using auger drilling methods. At three boreholes advanced at the Township Road 242 bridge (H10, H12, H13); rotary coring was used to advance into the bedrock following auger refusal. The as-built borehole locations, surveyed by Stantec Consulting Ltd., are shown in **Table 1**.

Table 1 Borehole Locations and Elevations

Bridge Location	Borehole ID	As-built GPS Coordinates (3TM)		Ground Elevation (m)	
		Easting	Northing	Ground Surface	Termination Depth [Elevation]
Highway 22	H01	-32713	5656427	1214.1	30.0 [1184.1]
Highway 22	H02	-32713	5656458	1214.9	30.1 [1184.8]
Highway 22	H03	-32714	5656489	1215.6	30.5 [1185.1]
Highway 22	H04	-32714	5656520	1215.9	30.0 [1185.9]
Township Road 242	H10	-33314	5655853	1217.4	30.2 [1187.2]
Township Road 242	H11	-33415	5655857	1219.5	21.4 [1198.1]
Township Road 242	H12	-33377	5655857	1217.6	34.7 [1182.9]
Township Road 242	H13	-33347	5655858	1217.1	34.8 [1182.3]

The subsurface stratigraphy encountered in the boreholes was recorded by Stantec personnel as the boreholes were advanced, and laboratory testing was completed on selected retrieved samples.

The boreholes advanced at the proposed Highway 22 bridge (H01 to H04) generally encountered topsoil, overlying glaciolacustrine deposits of clay and silt, overlying glacial clay till, overlying sedimentary bedrock comprised inferred very poor to poor quality mudstone, siltstone, and sandstone, completely to highly weathered and very weak. Auger refusal was not encountered in the sedimentary bedrock and rock core was not recovered. A cross-section for the bridge location is shown in **Appendix B**. The geological map identifies this bridge as being underlain by the Brazeau Formation[1].

[1] Hamilton, W.N., Price, M.C. and Langenberg, C.W. (compilers), 1999; Geological Map of Alberta, Alberta Geological Survey, Alberta Energy and Utilities Board, Map No. 236, scale 1:1 000 000.

Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel

Boreholes advanced at the proposed Township Road 242 bridge (H10 to H13) generally encountered surficial gravel fill, overlying organic clay, overlying glaciolacustrine clay, overlying clay glacial till. Bedrock comprised very poor to poor quality sandstone and claystone, completely to highly weathered and very weak. Auger refusal was encountered in the sedimentary bedrock at all boreholes. Upon encountering auger refusal in boreholes H10, H12, and H13, rotary drilling was used to advance the boreholes to target depth. A cross-section for the bridge location is shown in **Appendix B**. The geological map identifies this bridge as being underlain by the Coalspur Formation[2], however the bridge is likely underlain by the Brazeau Formation. The conglomerate boundary between the Coalspur and Brazeau Formations was observed in the Highway 22 cutting.

Measured groundwater levels at the time of borehole advancement and observed seepage in boreholes are summarized in **Table 2.** Standpipe piezometers, to permit future monitoring of groundwater levels, were not installed in any of the boreholes.

Table 2 Summary of Groundwater Levels During Drilling

Bridge Location	Borehole ID	Groundwater Level (m) after drilling, prior to backfilling	
		Below Existing Ground Surface	Elevation
Highway 22	H01	4.3	1209.8
Highway 22	H02(1)	10.0	1204.9
Highway 22	H03(1)	Dry	N/A
Highway 22	H04(2)	9.3	1206.6
Township Road 242	H10(3)(6)	N/A	N/A
Township Road 242	H11(4)	Dry	N/A
Township Road 242	H12(6)	N/A	N/A
Township Road 242	H13(5)(6)	N/A	N/A

Notes:
(1) Seepage noted at 4.6 m below existing ground surface (elev. 1210.3 m – H02; 1211.0 m – H03).
(2) Seepage noted at 3.4 m below existing ground surface (elev. 1212.5 m).
(3) Seepage noted at 14.0 m below existing ground surface (elev. 1203.4 m).
(4) Seepage noted at 6.1 m below existing ground surface (elev. 1213.4 m).
(5) Seepage noted at 15.0 m below existing ground surface (elev. 1202.1 m).
(6) Groundwater level at completion of borehole impacted by rock coring water.

[2] Hamilton, W.N., Price, M.C. and Langenberg, C.W. (compilers), 1999; Geological Map of Alberta, Alberta Geological Survey, Alberta Energy and Utilities Board, Map No. 236, scale 1:1 000 000.

**Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel**

The proposed channel alignment and hence bridge location for Township 242 bridge has changed since the site investigation. This means that there is no borehole for the western bridge abutment and one of the previous abutment holes now reflects a pier location. A borehole at the revised western bridge abutment is recommended. Alternatively, if the construction sequence allows, and depending on the bridge design flexibility, the channel excavation could be used to obtain further geotechnical information for the abutment.

The soil and bedrock conditions encountered within the boreholes are described in detail on the Borehole Records which are provided in **Appendix C**, along with an explanation of the symbols and terms used in their description. The borehole records are also superimposed on figures presented in **Appendix B**.

4.0 INTEGRAL ABUTMENT BRIDGES

Based on our current project understanding, the bridges over the diversion channel along Highway 22 and Township Road 242 are being considered for fully integral abutment bridges with a single row of driven steel H-piles at the abutments. In an integral abutment bridge, expansion joints and bearings at the ends of the bridge deck are replaced with isolation joints at the ends of the approach slabs and are integral with abutments supported on flexible foundations.

The lateral resistance of an integral abutment is directly related to the forces induced in the bridge structure due to movements; for example, from thermal expansion and contraction.

Integral abutment bridge design for the Highway 22 and Township Road 242 bridges is considered feasible if construction risks are mitigated through the following design and construction considerations.

The boreholes advanced at both bridge sites near the proposed abutments generally encountered ground conditions consisting of stiff to hard clay and clay till, and dense silt. At the proposed Highway 22 bridge location, bedrock was encountered at relatively shallow depths (approximately 6.0 m below ground surface in boreholes advanced for the abutments).

The Canadian Highway Bridge Design Code (CHBDC) recommends pre-drilling 0.6 m diameter holes to a minimum depth of 3.0 m and filling with loose sand in advance of driving piles to reduce resistance to lateral movements and provide flexibility in stiff or dense soils.

Although not observed in the boreholes, there is potential for sloughing in the soil strata encountered, especially below the groundwater table. Pre-drilled holes should be cased with a corrugated steel pipe (CSP) sleeve to prevent the hole from sloughing in and prevent migration of fines into the backfill. The loose pre-drilled backfill can densify overtime. Use of uniform loose sand will reduce potential densification; however, it will still provide some resistance to loading that will need to be accounted for in the detailed design. Alternatively, use of CSP sleeves backfilled with foam pellets may be considered as an alternative to sand to prevent load resistance over the design free-length portion of the abutment piles.

Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel

There is a risk of pile driving obstructions and early pile refusal when advancing steel H-piles through potential cobbles and boulders in the clay till and into bedrock at the bridge locations. At the Highway 22 bridge location, boreholes were augered into bedrock 19.7 m to 23.8 m without encountering refusal in the siltstone and mudstone, but there is potential for strong sandstone stringers in the bedrock formation. Overstressing the top of the H-pile is a risk with shallow bedrock observed in boreholes at the Highway 22 abutment locations. A large steel H-pile cross section is recommended for driving efficiency and to increase likelihood of achieving minimum design pile penetration into bedrock. Consideration should also be given to having a vibratory hammer and an auger piling rig available in the occurrence that driven pile refusal in bedrock is encountered before achieving minimum design embedment requirements. The vibratory hammer may be required to remove damaged/refused piles and the auger pile rig would allow pre-drilling through obstructions or layers that caused refusal. Further discussion and recommendations are included in **Section 5.4.1** Additional Driven Pile Considerations of this report.

Recommendations herein assume that the integral abutment design will be in accordance with the CHBDC. The top of the H-piles should be embedded into the abutment wall at least 0.6 m and should be reinforced to transfer bending forces. To reduce soil pressure, the abutment height should be limited to 6.0 m and wingwall length limited to 7.0 m. Abutments should be even in height, as a height difference may result in unbalanced lateral loading. During construction, backfill placed behind both abutments should occur simultaneously, and not until the deck has achieved at least 75% of its specified strength. Non-cohesive, free draining material sized to deliver uniform earth pressure to the back of the abutment is recommended. This material may have to be imported to site depending on availability in the common excavations and processing capabilities.

Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel

5.0 PRELIMINARY FOUNDATION ASSESSMENT

The recommended unit shaft and end bearing resistances to compressive loading at Ultimate Limit State (ULS) for cast-in-place concrete piles and driven steel piles are provided in relevant sections of this memorandum. These are based on the soil and bedrock profiles from the boreholes located at each of the proposed bridge locations. Note that there is some uncertainty regarding lateral variation of ground conditions and that the revised location of the western abutment of the Township Road 242 road bridge was not investigated by a borehole.

According to the Canadian Foundation Engineering Manual 4th Edition (CFEM) and in accordance with the Canadian Highway Bridge Design Code, the recommended geotechnical resistance factors for deep foundations are provided in **Table 3**.

Table 3 Geotechnical Resistance Factors – Deep Foundations

Description	Resistance Factor, Φ
Resistance to axial load	
• Semi-empirical analysis using laboratory and in-situ test data	0.4
• Uplift resistance by semi-empirical analysis	0.3
Horizontal load resistance	0.5

5.1 FOUNDATIONS ON ROCK

The geotechnical design of foundations in rock, particularly at the abutments where the ground slopes away, is more complex than for soils. This is due to the difference in behavior between the rock mass and the intact rock. The fracturing within the rock and the orientation of fracturing in the rock promote anisotropic behavior and contribute to the rock mass behavior, which can be substantially different to the intact rock behavior. The scale of the foundation relative to the scale of the rock discontinuities is also a factor in behavior, and within fractured rock, the in-situ stress is also particularly important, with potential to raise the bearing capacity significantly as the depth and stress increases. Given a fractured rock mass with weak layers, like the formations at these sites; the effect of these issues will be more significant due to potential for sloping ground at the abutments. The effect of the issues would be lessened if the sites were on flat ground, bearing on stronger, less fractured rock.

We cannot, therefore, finalize geotechnical recommendations for the rock foundations without knowing more about the foundations themselves. The required information for geotechnical design is:

- Bearing elevations
- Proposed loads
- Dimensions of the proposed foundations and knowledge of the grouping of foundations

Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel

Design of the foundations may be an iterative process, whereby the geotechnical engineers provide initial, likely conservative guidance given the uncertainties, which is used by the bridge engineers to develop concepts for the foundations, which are then re-checked by the geotechnical engineers once more information is available. The information for rock foundations provided in this memo should therefore be taken as initial guidance, that will require further work once the foundation design is clearer. Once the foundatons have been finalized, the geotechnical engineers can also check settlements, if required.

Note that the process of driving piles within rock can cause additional fracturing within the rock with an associated reduction in strength.

In addition, the rock is interbedded with weaker and stronger units. The values presented in **Table 4** and **Table 5** are based upon the weakest rock encountered; there will be beds of rock that are substantially stronger than this.

5.2 POTENTIAL FOR HEAVE

The bridge central piers have the following conditions:

- The piers are within a channel excavated up to 15 m below existing ground level; therefore, there will be active unloading.
- The foundation contains rock units that have high liquid limits and plasticity indices (including potential for bentonite layers) *(Springbank Off-Stream Storage Project – Geotechnical Investigation Report*, by Stantec Consulting Ltd., dated December 13, 2016.).
- There is potential for water to come into contact with the higher plasticity layers.
- The construction sequencing is not known but may not include for a delay between excavation and bridge construction.

This combination of circumstances means there is potential for heave within the rock foundation units. The heave could affect pile resistances and serviceability of the bridge.

Heave cannot be calculated until the bridge pier and foundation design is complete.

5.3 DRILLED CAST-IN-PLACE CONCRETE PILES

Due to the presence of saturated silt layers with varying thickness, as well as the observed groundwater seepage during borehole advancement, complications with sloughing and seepage for drilled cast-in-place concrete piles should be anticipated. At both bridge locations, the contractor should ensure casing is available on-site during installation of the bored piles.

Drilled cast-in-place concrete piles at both bridges may be designed to resist static axial compressive loads on the basis of the shaft and toe resistance parameters at ULS. ULS values are based on the understanding that the minimum pile spacing (center to center) is greater than three pile diameters. Unfactored shaft and toe resistances for cast-in-place concrete piles are shown in **Table 4** for the Highway 22 bridge and Township Road 242 bridge.

Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel

Table 4 Proposed Highway 22 and Township Road 242 Bridges – Cast-in-Place Concrete Pile Design Criteria at ULS (Unfactored)

Location	Material and Depth	Unfactored Shaft Resistance at ULS (kPa)	Unfactored Toe Resistance at ULS (kPa)
Highway 22 Abutments	Frost Zone (0.0 m to 2.0 m)	0	N/A
	Clay and silt with clay till layers (2.0 m to 6.0 m)	18	N/A
	Sedimentary bedrock (below 6.0 m)	220	1,000
Highway 22 Piers	Frost Zone (0.0 m to 2.0 m)	0	N/A
	Sedimentary bedrock (below 2.0 m)	220	1,000
Township Road 242 Abutments	Frost Zone (0.0 m to 2.0 m)	0	N/A
	Clay (2.0 m to 6.0 m)	20	N/A
	Clay till (6.0 m to 15.0 m)	55	N/A
	Sedimentary bedrock (below 15.0 m)	440	1,000
Township Road 242 Piers	Frost Zone (0.0 m to 2.0 m)	0	N/A
	Clay till (2.0 m to 7.0 m)	20	N/A
	Sedimentary bedrock (below 7.0 m)	440	1,000

Notes:

(1) Depths are relative to existing grade (at the time of borehole drilling investigations) for the abutments and relative to the proposed bottom elevation of the diversion channel for the piers (Highway 22 - elev. 1205.9 m; Township Road 242 – elev. 1206.8 m).
(2) Depth to soil layer may vary.
(3) Depth to rock may vary laterally across the site and there is potential for the rock unit type to be different over short lateral distances for the site due to dipping and bedding orientation.
(4) Resistances and recommendations for piles assume pile end bearing on a very weak mudstone bedrock layer and are based on cast-in-place concrete pile design. There is potential for end bearing on a stronger rock unit; therefore, the toe resistances should be considered 'lower bound' values.
(5) Piles should be socketed into rock a minimum of one to three times the pile diameter. The rock socket length should not be less than 1 m.

**Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel**

The toe resistance of the bedrock is dependent on pile inspection and confirmation that the pile base is clean. To achieve the shaft and toe resistance values shown in **Table 4**, the sides and base of the pile boring must be free of water and loose or remoulded (smeared) material prior to placing concrete. Inspection by qualified geotechnical personnel during piling is required to ensure that the recommended values are obtained. The inspection must also include assurance that the as-built pile installations are in accordance with pile designs as approved by the geotechnical and structural engineers and should include down-hole techniques to verify piles are not bearing on bentonitic layers, clean conditions, and if necessary, the use of roughening tools to prevent smearing in the sedimentary rocks.

Design of pile groups is governed by the Serviceability Limit State (SLS). A settlement analysis of pile groups can be completed by Stantec and reported in the future when detailed design information (number of piles, pile spacing, loading conditions) is available. For initial design assumptions, group effects should be considered when the centre to centre spacing is less than five diameters with a minimum centre to centre spacing of three pile diameters recommended.

5.4 DRIVEN STEEL PILES

Selection of pile size should consider design loads, soils resistance, material availability, and local experience. It is recommended that the contractor confirm successful nearby local driven pile experience for similar pile lengths, sizes and loads proposed.

The mechanics of driven piled foundations in weak rock is poorly understood[3,4], particularly when selecting appropriate material parameters. The driving can cause a complex combination of crushing and remolding; fracture shearing and movement; displacement of rock blocks and cement disintegration[4].

The driven pile design parameters are provided in **Table 5** for the Highway 22 bridge and Township Road 242 bridge. ULS values assume that the piles are a minimum of three pile diameters apart. If the piles are spaced closer, group effects should be considered in the detailed design.

[3] Tomlinson, M.J., 1994; Pile Design and Construction Practice.
[4] Terente, V., Irvine, J., Comrie, R., Crowley, J., 2015; Pile Driving and Pile Installation Risk in Weak Rock. Geotechnical Engineering for Infrastructure and Development.

**Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel**

Table 5 Proposed Highway 22 and Township Road 242 Bridges – Driven Steel Pile Design Criteria at ULS (Unfactored)

Location	Material and Depth	Unfactored Shaft Resistance at ULS (kPa)	Unfactored Toe Resistance at ULS (kPa)
Highway 22 Abutments	Frost Zone (0.0 to 2.0)	0	N/A
	Clay and silt with clay till layers (2.0 m to 6.0 m)	20	N/A
	Sedimentary bedrock (below 6.0 m)	100	1,000
Highway 22 Piers	Frost Zone (0.0 to 2.0 m)	0	N/A
	Sedimentary bedrock (below 2.0 m)	100	1,000
Township Road 242 Abutments	Frost Zone (0.0 to 2.0 m)	0	N/A
	Clay (2.0 m to 6.0 m)	20	N/A
	Clay till (6.0 m to 15.0 m)	55	N/A
	Sedimentary bedrock (below 15.0 m)	100	1,000
Township Road 242 Piers	Frost Zone (0.0 m to 2.0 m)	0	N/A
	Clay till (2.0 m to 7.0 m)	20	N/A
	Sedimentary bedrock (below 7.0 m)	100	1,000

Notes:
(1) Depths are relative to existing grade at the time of borehole drilling investigations for the abutments and proposed bottom elevation of the diversion channel for the piers (Highway 22 - elev. 1205.9 m; Township Road 242 – elev. 1206.8 m).
(2) Depth to soil layer may vary.
(3) Depth to rock may vary laterally across the site and there is potential for the rock unit type to be different over short lateral distances for the site due to dipping and bedding orientation.
(4) Resistances and recommendations for piles assume pile end bearing on a very weak mudstone bedrock layer. There is potential for end bearing on a stronger rock unit; therefore, the toe resistances should be considered 'lower bound' values. Due to rock fracturing effects from pile driving, it is recommended that an end bearing reduction factor be applied to resistances if bearing on a stronger rock unit.
(5) Piles should be socketed into rock a minimum of one to three times the pile diameter.

Recommended parameters provided in **Table 5** are for calculations of pile capacity versus embedment length. Actual pile capacities and pile lengths must be confirmed in the field through pile driving monitoring by qualified geotechnical personnel. Pile embedment depth into the local weathered sedimentary bedrock can be highly variable. Pile driving and refusal criteria to be used in field verification of pile capacity are directly dependent on such factors as pile size, length, and wall thickness as well as the specified design load and driving energy. If piles cannot be advanced to the design pile length, the pile capacity should be evaluated using the pile driving records. Pile load testing is recommended to determine ultimate resistance of the driven piles at the Highway 22 and Township Road 242 bridges.

The unfactored toe resistances in **Table 5** consider end bearing on the weakest rock encountered. There will be beds of rock that are substantially stronger than this, as well as potential for intermittent strong stringers of sandstone. Pile penetration depth will be affected by these factors and it is unlikely that more than 3 m to 5 m of embedment into the bedrock will be achieved before reaching refusal condition.

Final guidelines for driving criteria can be provided using a wave equation analysis program (WEAP) once the pile design and driving equipment have been finalized. Design by this method would enable an optimum match of hammer type and weight to pile type and soil conditions and allows a check to be made on driving stresses. Criteria may be developed by others; however, it is advised that Stantec be provided opportunity to review the pile design criteria prior to construction to confirm agreement with design recommendations.

In order to determine the reactions for the SLS the pile loadings, configurations and the desired settlement criteria are required. Once these data are available, the SLS reactions can be calculated, if requested.

5.4.1 Additional Driven Pile Considerations

As outlined in **Section 4.0** Integral Abutment Bridges, there is risk of encountering gravel to boulder clasts / erratics in the silty clay till and/or more resistant bedrock at both bridge locations, potentially causing pile driving obstructions. Therefore, cast steel drive shoes should be used to minimize potential for pile damage unless contractor has sufficient nearby experience to confirm they are not needed. If used, driving shoes should be fitted flush to the outside of the pipe piles so that shaft resistance is not compromised. Steel H-pile cross-sections with driving shoes are expected to have greater success in penetrating very dense silt layers and bedrock. If piles are terminated prior to reaching minimum design depth, these piles should be cut off below ground level and replacement piles installed.

All piles for a given structure should be driven into the same stratum and to similar depth, to reduce the potential for differential settlements between piles.

The elevation of the tops of driven piles should be recorded immediately after driving. This will allow checks for heave due to driving of adjacent piles. If uplift of 6 mm or greater occurs during driving of adjacent piles the displaced pile should be re-driven to at least its original embedment depth and final set. Piles should be checked during installation to ensure the vertical piles are within 2% of plumb.

Voids created near the ground surface during driving or from pre-drilling should be backfilled to maintain contact between the pile and surrounding soil to provide resistance to vertical and lateral loads. If pile installation is to occur during winter conditions, pre-drilling pilot holes through the frost may be required to avoid pile damage. Pre-drilling of driven piles may also be required for removal of an obstruction, or for ease of pile placement. Pre-drilling of driven piles will reduce shaft resistance, lateral resistance and in some cases, end bearing. Pre-drilling through the frost depth may be completed without adversely affecting pile capacities calculated using parameters identified above, provided voids are filled. Where possible, it is advised that pre-drilled holes be filled with sand prior to placing and driving piles to ensure good contact between pile and soil. If required, pre-drilled pilot holes should not exceed 90% of the pile diameter. The geotechnical engineer should be contacted for review and approval of any intended pre-drilling in excess of 90% of the pile diameter or in excess of frost depth.

Resistance to pile penetration may increase due to soil set-up or decrease due to relaxation. Pile re-striking should be carried out once equilibrium conditions in the soil have been re-established.

5.5 LATERAL CAPACITY

Vertical piles resist lateral loads and moments by deflecting until the necessary reaction in the ground is mobilized to resist the lateral loads. The design of piles subjected to lateral loads should consider such factors as the relative rigidity of the pile to the surrounding soil, the fixity conditions at the head of the pile (pile cap level), the structural capacity of the pile to withstand bending moments, the soil resistance that can be mobilized, the tolerable lateral deflection at the head of the pile, the applied vertical load, and pile group effects. For longer, more flexible piles, the maximum yield moment of the pile may be reached prior to mobilization of the lateral geotechnical resistance. For design purposes, both structural and geotechnical resistances should be evaluated to establish the governing case.

The theory of subgrade reaction assumes linear behavior of the soil and pile under static loading. CFEM 4th Edition advises this approach be limited to maximum deflections less than 1% of the pile diameter. Estimated lateral subgrade reaction modulus values for single piles were calculated based on empirical methods recommended by Terzaghi[5] and Davisson[6] and are presented as a function of pile diameter, d, and pile depth, z, in **Table 6**. For non-linear response of the soil associated with larger deflections or cyclic loading, it is recommended that p-y curves be considered for more accurate estimates of lateral pile reaction. Stantec can model lateral pile response, including generation of p-y curves, once the expected range of pile dimensions and pile head loading conditions are known, if requested.

[5] Terzaghi, K. 1955, Evaluation of Coefficients of Subgrade Reaction
[6] Davisson, M.T. 1970, Lateral Load Capacity of Piles

**Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel**

Table 6 Proposed Highway 22 and Township Road 242 Bridges – Horizontal Subgrade Reaction

Location	Material and Depth[1]	Coefficient of Horizontal Subgrade Reaction[2], k_s (kPa/mm) (Static Loading)
Highway 22 Abutments	Clay and silt with clay till layers (below 1.0 m to 6.0 m)	6/d
	Sedimentary bedrock (below 6.0 m)	30/d
Highway 22 Piers	Sedimentary bedrock (below 1.0 m)	30/d
Township Road 242 Abutments	Clay (below 1.0 m to 6.0 m)	6/d
	Clay till (6.0 m to 15.0 m)	8/d
	Sedimentary bedrock (below 15.0 m)	30/d
Township Road 242 Piers	Clay till (below 1.0 m to 7.0 m)	8/d
	Sedimentary bedrock (below 7.0 m)	30/d

NOTES:
1. Lateral and vertical extent of materials varies across the site; design should consider soil profile at nearest boring locations. Depth to soil layer may vary.
2. d = pile diameter (m)
3. Lateral resistance in the upper 1.0 m should be ignored due to disturbance from installation and seasonal effects.

If lateral resistance is expected to govern design, it is recommended that the pile response be modeled once proposed pile loading and size are confirmed. Lateral responses presented above are for single piles. When installed as a group, interaction between piles occurs such that the lateral pile deformations are increased. For designs using horizontal subgrade reaction it is advised that pile group load response be reduced as a function of center-to-center pile spacing. Recommended group reduction factors for coefficient of subgrade reaction are detailed in **Table 7** (after Davisson):

**Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel**

Table 7 Group Reduction Factors for Coefficient of Subgrade Reaction

Center-to-Center Spacing in Direction of Load	Group Reduction Factor for k_s
3d	0.25
4d	0.40
6d	0.70
8d	1.00
Note: d = pile diameter	

In each case the lead pile in the direction of the load will have a reduction factor equal to unity (e.g., for a three pile group with centre-to-centre spacing of three pile diameters the group reduction factor would be {[1+0.25+0.25] ÷ 3 = 0.5}). Note that proper analysis of pile group effects requires that soil nonlinearity be considered. Reduction factors for specific pile groups can be calculated and applied to p-y curves during detailed design, if requested.

6.0 SITE CLASS

The 2015 NBCC seismic design procedures are based on ground motion parameters (e.g., peak ground acceleration (PGA) and spectral acceleration, Sa values) having a 2% probability of exceedance in 50 years; i.e., the 2,475 year return period earthquake event.

Based on the results of the Stantec field investigation and Stantec seismic hazard assessment, it is appropriate to classify the existing ground conditions at the Highway 22 bridge as a Class C Site, and the Township Road 242 bridge as a Class D Site in accordance with the 2015 NBCC (Table 4.1.8.4.A).

Based on the observed moisture profiles and index testing, liquefaction of the native materials is unlikely. Damage to properly designed and constructed structural and non-structural components is expected to be minor during the 1 in 2,475 year design earthquake.

Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel

7.0 GENERAL RECOMMENDATIONS

Although there are construction risks, integral abutment bridge design with driven piles is considered feasible for the Highway 22 and Township 242 bridges. Cast-in-place concrete piles are also a viable foundation alternative for the bridges. Based on the anticipated ground conditions for bridge piers located within the bedrock (Highway 22), shallower foundation options may also be considered.

- If the proposed design changes, due to channel realignment or bridge design philosophy, future work is recommended and revision of this memorandum is required.
- Once the bridge and associated foundation design is progressed and foundations sizes, elevations, construction sequencing, and loads known, these preliminary foundation recommendations need to be reviewed as part of an iterative process. This would include an assessment of heave, bearing capacity checks, and potential effect of dipping discontinuities for foundations on sloping ground. This requires evaluation of local outcrop data to estimate the orientation of discontinuities.
- A supplementary borehole should be completed for the proposed Township Road 242 bridge during the next phase of investigation to reduce data gaps caused by the change in alignment. The borehole should extend to 30 m depth and should provide rotary core and if necessary, televiewing, through the rock. Should rock not be present within the upper 25 m, the hole depth should be revised. Ideally, the borehole should be on the south side of the existing road; this will allow evaluation of the lateral variation in ground conditions through comparison to borehole H11. Alternatively, the approach to foundation design could be flexible allowing utilization of the information obtained when excavating the channel.
- Additional boreholes at both the Highway 22 and Township Road 242 bridge locations are recommended for detailed design to determine bedrock dip and dip direction at the locations of the proposed piers and abutments for pile design considerations.
- When the channel is excavated, the conditions should be cross-referenced against anticipated foundation conditions for the bridges.

**Reference: Springbank Off-Stream Storage Project
Bridge Structure Foundation Design Memorandum –
Township Road 242 and Highway 22 over Springbank Diversion Channel**

8.0 CLOSURE

The recommendations within this memorandum are based upon the current project understanding. This memorandum has been prepared by Daniel McLellan, P.Eng., Kyle Noble, P.Eng. (**Section 4.0** Integral Abutment Bridges), and Lucy Philip, M.Sc., P.Eng. and reviewed by Andrew Bayliss, M.Sc., P.Eng. We trust this meets your current expectations, please feel free to contact the undersigned with any questions.

STANTEC CONSULTING LTD.

PROFESSIONAL ENGINEER LUCY PHILIP ALBERTA
18 July 2018

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Appendix A

Statement of General Terms and Conditions

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec's present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

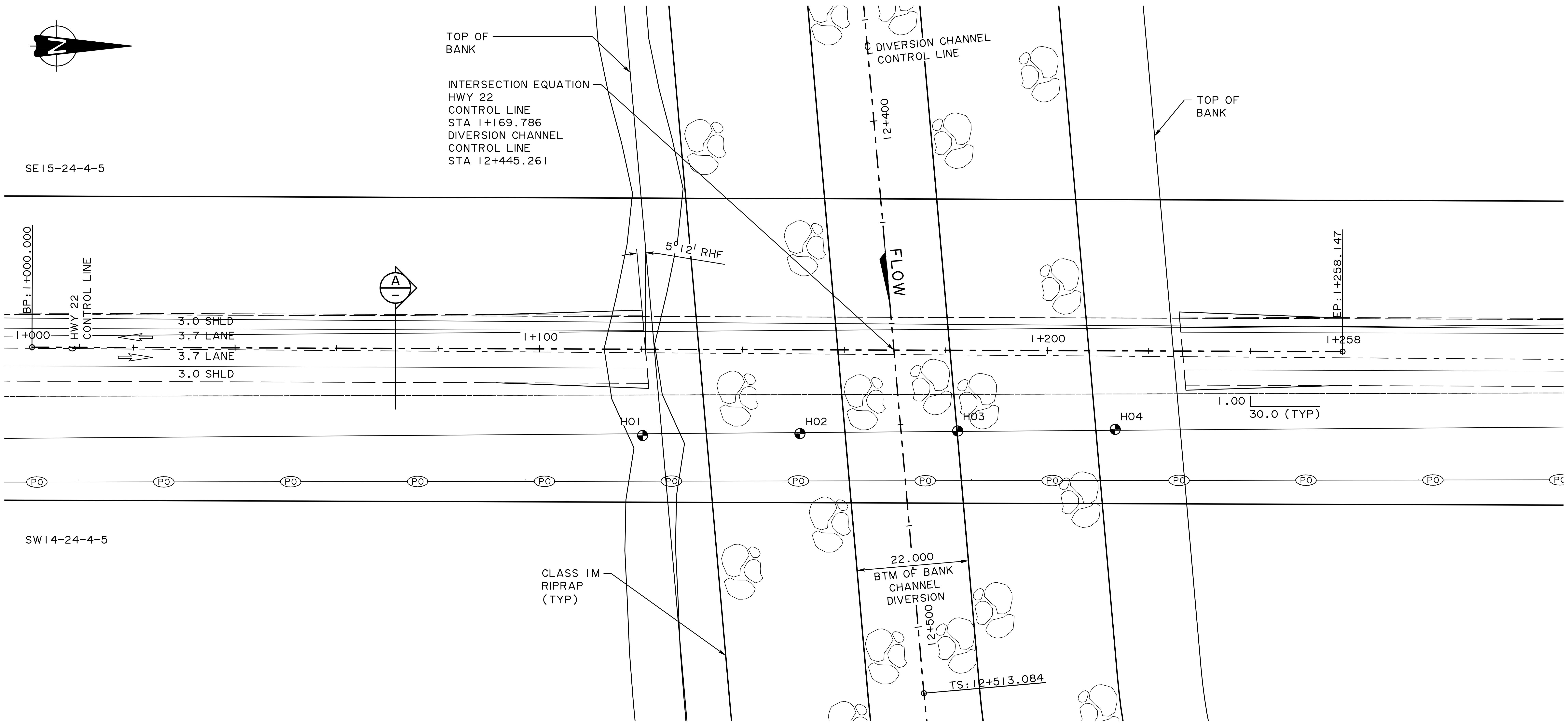
INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec will not be responsible to any party for damages incurred as a result of failing to notify Stantec that differing site or sub-surface conditions are present upon becoming aware of such conditions.

PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec, sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc.), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec cannot be responsible for site work carried out without being present.

Appendix B

Project Understanding



PLAN
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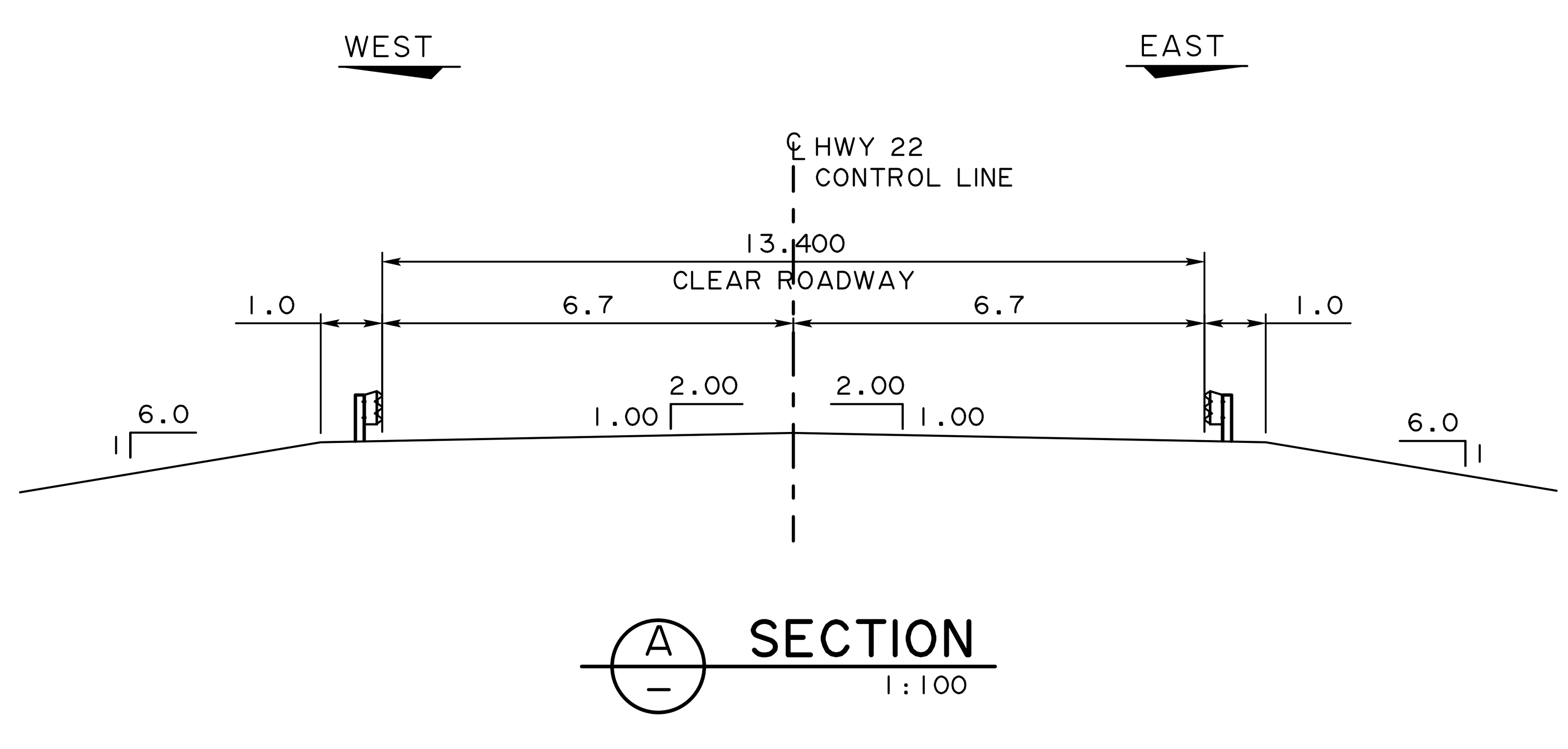

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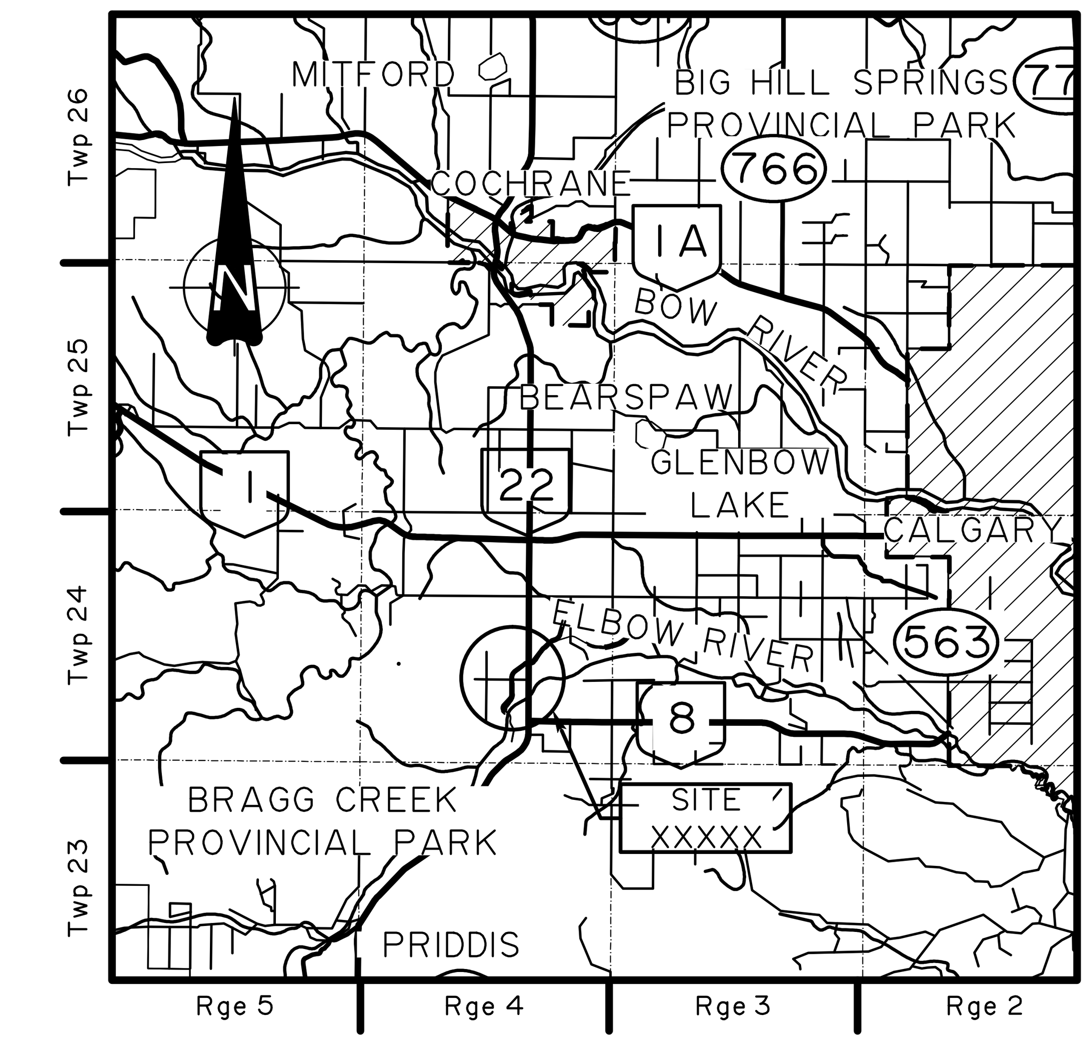


SITE PLAN

1: 250 000

- HIGHWAY 1 - 216
- HIGHWAY 500 - 986
- LOCAL ROAD

SURVEY INFORMATION

- SURVEY INFORMATION PROVIDED BY STANTEC CONSULTING LTD., COMPLETED DECEMBER 2016
- BOREHOLE
  - H01 N 5656426.618 E -32712.635 EL 1214.111
  - H02 N 5656457.601 E -32713.018 EL 1214.914
  - H03 N 5656488.671 E -32713.511 EL 1215.550
  - H04 N 5656519.691 E -32713.830 EL 1215.903
- THE COORDINATES AND STATIONING ARE BASED ON NAD '83 DATUM USING 3TM GRID PROJECTION, CENTRAL MERIDIAN 114 W

GENERAL NOTES

- ALL DIMENSIONS SHOWN ON THE GENERAL LAYOUT AND INFORMATION SHEETS ARE GIVEN IN METRES. ALL OTHER DRAWINGS ARE DIMENSIONED IN MILLIMETRES EXCEPT FOR STATIONS, CONTROL POINT COORDINATES AND ELEVATIONS WHICH ARE EXPRESSED IN METRES
- ROADWAY DESIGN STANDARDS:
  HWY 22 RAU-213.4-120
- ROADWAY ELEVATIONS ARE GIVEN TO TOP OF FINISHED ℄ ROADWAY

SHEET	DESCRIPTION	DRAWING
3	MOSAIC PLAN AND PROFILES	SK-3
2	ELEVATION	SK-2
1	PLAN AND GENERAL NOTES	SK-1

INDEX

DRAWING SK-1 | HIGHWAY | CONTRACT | DESCRIPTION: SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) | PHOTO | DATE | BY | SURVEYED | DEPARTMENT BAR CODE

LEGEND | KEY PLAN | CONSULTANT | JOB NO. 110773396 | DESIGNER DATE | CHECKER DATE

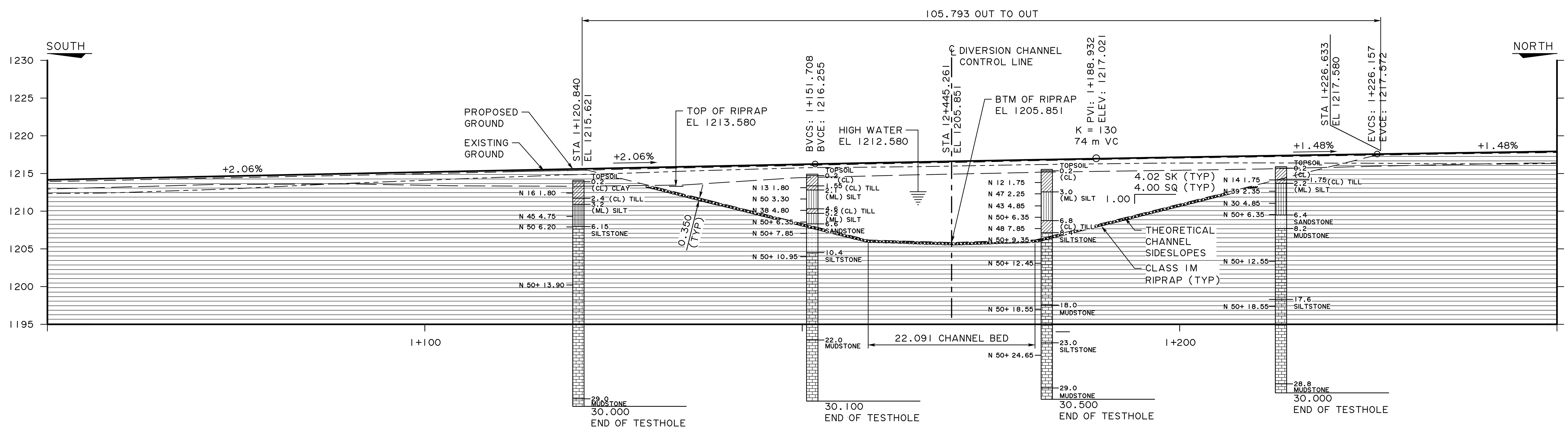
REV	DATE	REVISION	BY

Alberta Transportation

SPRINGBANK RESERVOIR CANAL BRIDGE ON HWY 22, 25 KM SW OF CALGARY
SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1)
PLAN AND GENERAL NOTES

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
2016-12-23	SE15-24-4-5	XXXX	-	22	1 OF 3	SK-1

\\Cd1002-f04\shared_projects\110773396\CAD\transportation\sheet_files\03_bridges\concept_sketches_only\hwy_22\73396_SK-1_plan.dwg
2017-01-26 3:10pm By: mohansen



TESTHOLE H01	TESTHOLE H02	TESTHOLE H03	TESTHOLE H04
STA 1+120.350, 16.993 m RT OF ℄	STA 1+151.331, 16.506 m RT OF ℄	STA 1+182.399, 15.908 m RT OF ℄	STA 1+213.418, 15.484 m RT OF ℄
EL 1214.111 (APPROX)	EL 1214.914 (APPROX)	EL 1215.550 (APPROX)	EL 1215.903 (APPROX)
N 5656426.618, E -32712.635	N 5656457.601, E -32713.018	N 5656488.671, E -32713.511	N 5656519.691, E -32713.830
DEPTH 30.000 m	DEPTH 30.100 m	DEPTH 30.500 m	DEPTH 30.000 m
2016-08-24	2016-08-26	2016-08-27	2016-08-24

ELEVATION

1:300

UNIFIED SOIL CLASSIFICATION SYSTEM (MODIFIED BY PFRA)

COARSE GRAINED SOILS 50%+ RETAINED ON AN 80 MICRON SIEVE			FINE GRAINED SOILS 50%+ PASSING AN 80 MICRON SIEVE		
GROUP SYM	LOG SYM	TYPICAL NAMES	GROUP SYM	LOG SYM	TYPICAL NAMES
GW		WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	CL		INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
GP		POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	CI		INORGANIC CLAYS OF MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS
GM d/u		SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CH		INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
GC		CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES	ML		INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
SW		WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	MH		INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS
SP		POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	OL		ORGANIC SILTS AND ORGANIC SILTY CLAYS OR LOW PLASTICITY
SM d/u		SILTY SANDS: SAND-SILT MIXTURES	OH		ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
SC		CLAYEY SANDS, SAND-CLAY MIXTURES	Pt		PEAT AND OTHER HIGHLY ORGANIC SOILS
OTHER SYMBOLS					
		BEDROCK (UNCLASSIFIED)			CONGLOMERATE
		SANDSTONE			COAL
		SHALE			OVERBURDEN
		LIMESTONE			TOPSOIL

GEOTECHNICAL NOTES

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LEGEND | KEY PLAN | CONSULTANT | DESIGNER | CHECKER

JOB NO. 110773396

DATE____ DATE____

REV	DATE	REVISION	BY

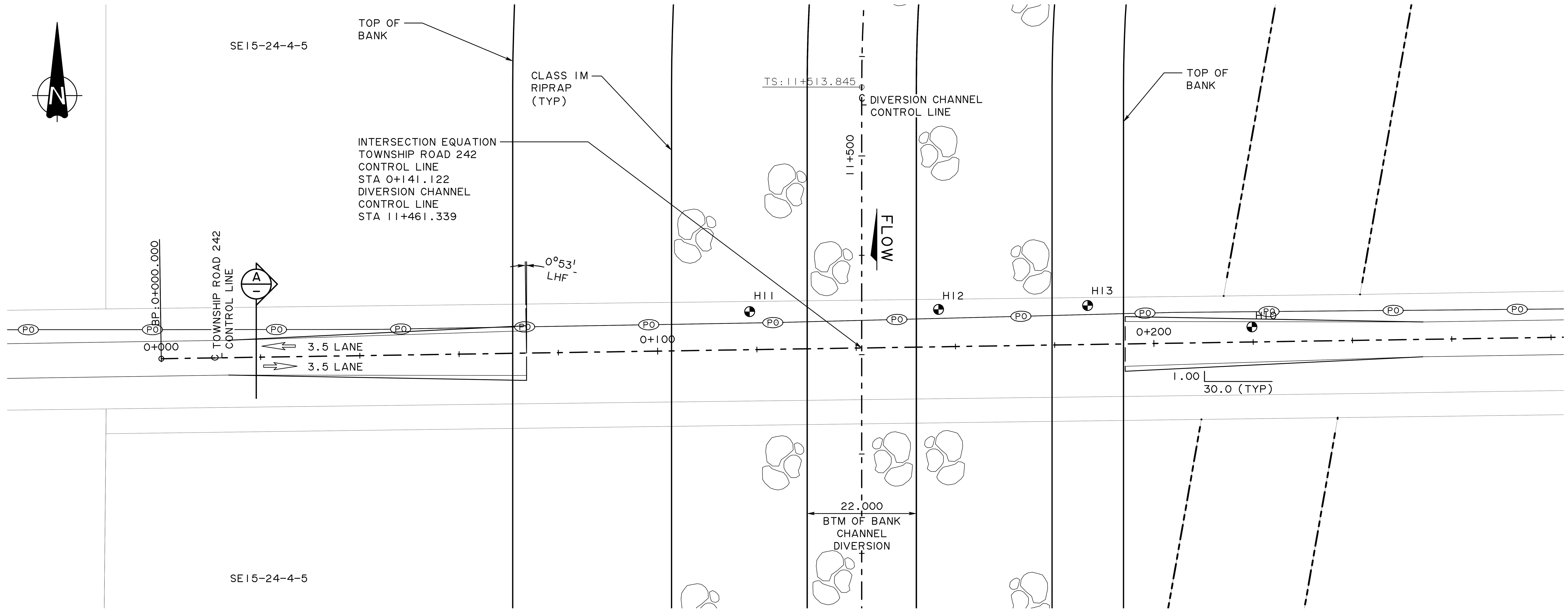
Alberta Transportation

SPRINGBANK RESERVOIR CANAL BRIDGE ON HWY 22, 25 KM SW OF CALGARY
SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1)
ELEVATION

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
2016-12-23	SE15-24-4-5	XXXX	-	22	2 OF 3	SK-2

DRAWING SK-2 | HIGHWAY | CONTRACT | DESCRIPTION SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) | PHOTO | DATE | BY | SURVEYED | DEPARTMENT BAR CODE

SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1)



PLAN
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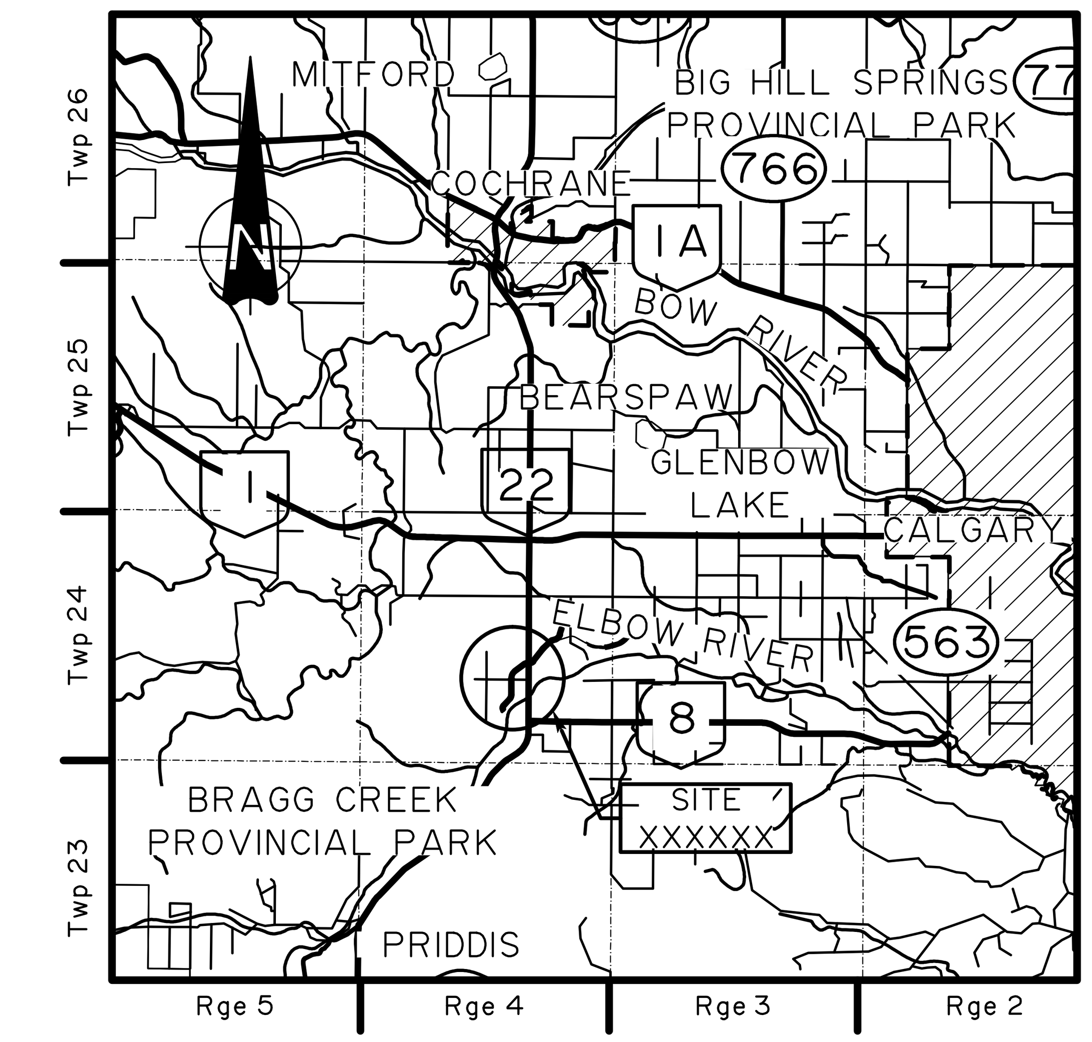


SITE PLAN

1: 250 000

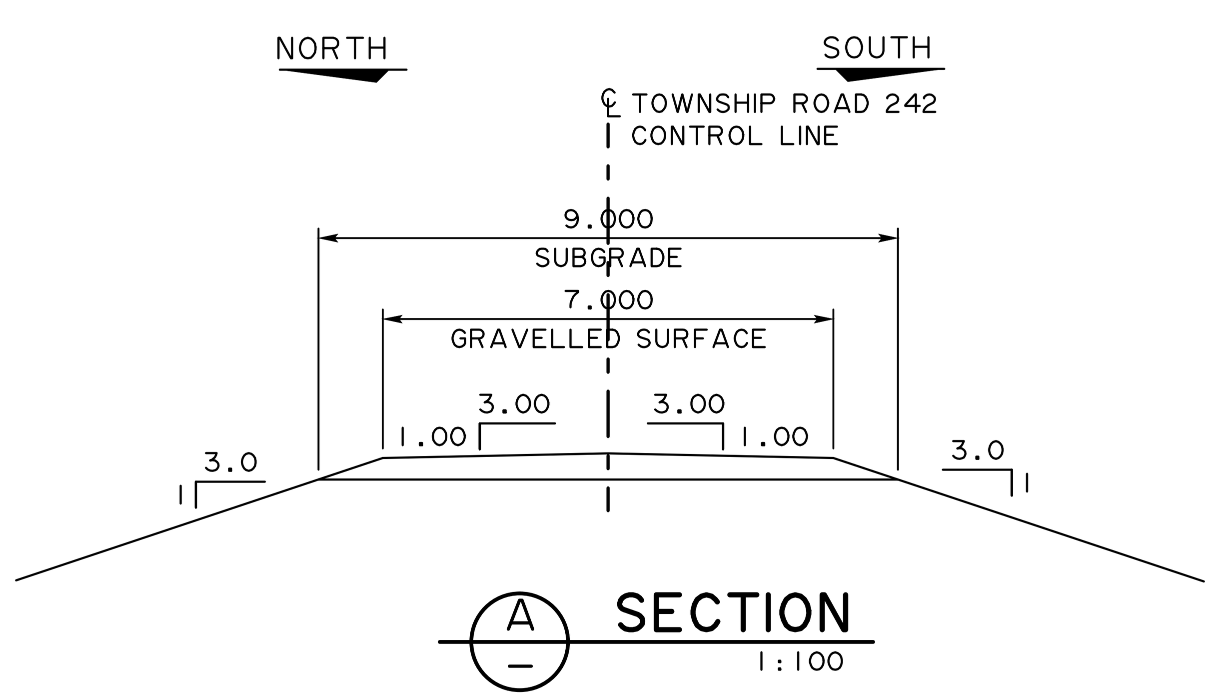
- HIGHWAY 1 - 216
- HIGHWAY 500 - 986
- LOCAL ROAD

SURVEY INFORMATION

- SURVEY INFORMATION PROVIDED BY STANTEC CONSULTING LTD., COMPLETED DECEMBER 2016
- BOREHOLE
  - H10 N 5655853.464 E -33313.577 EL 1217.416
  - H11 N 5655856.538 E -33414.777 EL 1219.526
  - H12 N 5655856.985 E -33376.726 EL 1217.631
  - H13 N 5655857.761 E -33346.689 EL 1217.077
- THE COORDINATES AND STATIONING ARE BASED ON NAD '83 DATUM USING 3TM GRID PROJECTION, CENTRAL MERIDIAN 114 W

GENERAL NOTES

- ALL DIMENSIONS SHOWN ON THE GENERAL LAYOUT AND INFORMATION SHEETS ARE GIVEN IN METRES. ALL OTHER DRAWINGS ARE DIMENSIONED IN MILLIMETRES EXCEPT FOR STATIONS, CONTROL POINT COORDINATES AND ELEVATIONS WHICH ARE EXPRESSED IN METRES.
- ROADWAY DESIGN STANDARDS:
  TOWNSHIP ROAD 242 RLV-207.0-070
- ROADWAY ELEVATIONS ARE GIVEN TO TOP OF FINISHED ℄ ROADWAY



A SECTION
1:100

SHEET	DESCRIPTION	DRAWING
3	MOSAIC PLAN AND PROFILES	SK-3
2	ELEVATION	SK-2
1	PLAN AND GENERAL NOTES	SK-1

INDEX

LEGEND | KEY PLAN | CONSULTANT | DESIGNER | CHECKER

JOB NO. 110773396

DATE______ DATE______

REV	DATE	REVISION	BY

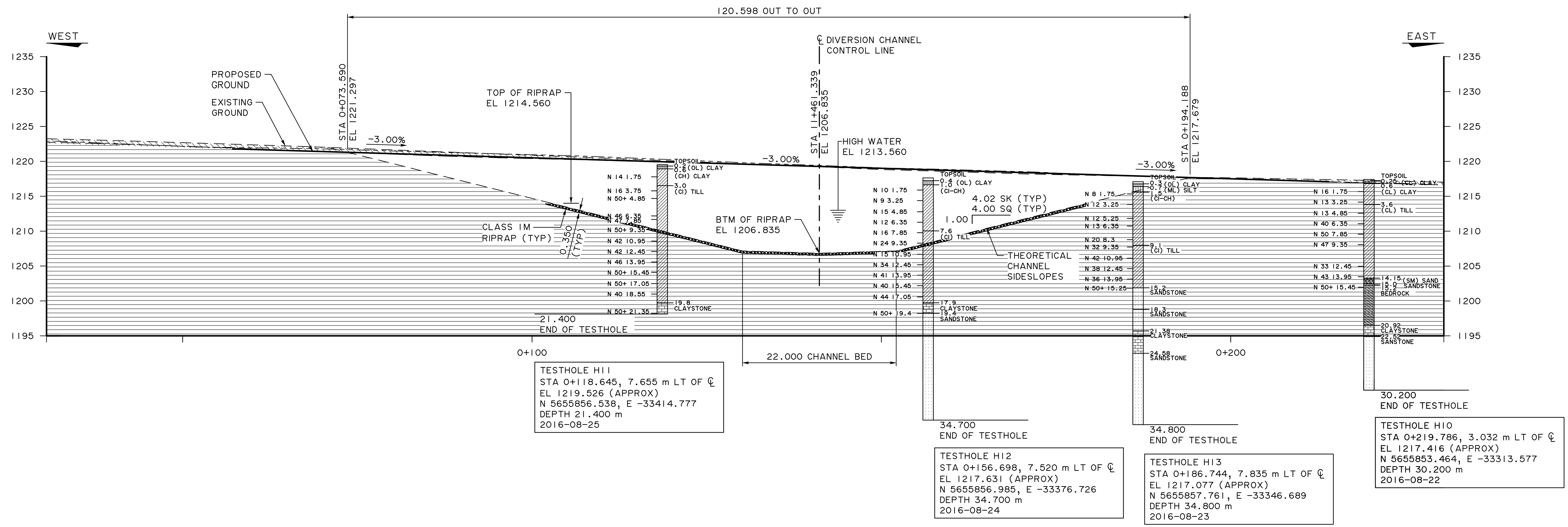
Alberta Transportation

SPRINGBANK RESERVOIR CANAL BRIDGE ON HWY 22, 25 KM SW OF CALGARY
SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1)
PLAN AND GENERAL NOTES

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
2016-12-21	SE15-24-4-5	XXXX	-	TWP RD 242	1 OF 3	SK-1

DRAWING SK-1 | HIGHWAY | CONTRACT | DESCRIPTION | PHOTO | DATE | BY | SURVEYED | DEPARTMENT BAR CODE

\\Cd1002-f04\shared_projects\110773396\CAD\transportation\sheet_files\03_bridges\concept_sketches_only\twp_rd_242\73396_SK-1_plan.dwg
2017-01-26 3:51pm By: mshansen



ELEVATION

1:300

UNIFIED SOIL CLASSIFICATION SYSTEM (MODIFIED BY PFRA)

COARSE GRAINED SOILS 50%+ RETAINED ON AN 80 MICRON SIEVE			FINE GRAINED SOILS 50%+ PASSING AN 80 MICRON SIEVE		
GROUP SYM	LOG SYM	TYPICAL NAMES	GROUP SYM	LOG SYM	TYPICAL NAMES
GW		WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	CL		INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
GP		POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	CI		INORGANIC CLAYS OF MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS
GM d/u		SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CH		INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
GC		CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES	ML		INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
SW		WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	MH		INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS
SP		POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	OL		ORGANIC SILTS AND ORGANIC SILTY CLAYS OR LOW PLASTICITY
SM d/u		SILTY SANDS: SAND-SILT MIXTURES	OH		ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
SC		CLAYEY SANDS, SAND-CLAY MIXTURES	Pt		PEAT AND OTHER HIGHLY ORGANIC SOILS
OTHER SYMBOLS					
		BEDROCK (UNCLASSIFIED)			CONGLOMERATE
		SANDSTONE			COAL
		SHALE			OVERBURDEN
		LIMESTONE			TOPSOIL

GEOTECHNICAL NOTES

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LEGEND | KEY PLAN | CONSULTANT | JOB NO. 110773396 | DESIGNER DATE | CHECKER DATE

REV	DATE	REVISION	BY

Alberta Transportation

SPRINGBANK RESERVOIR CANAL BRIDGE ON HWY 22, 25 KM SW OF CALGARY
SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1)
ELEVATION

DATE	LOCATION	SITE	CONTRACT	HIGHWAY	SHEET	DRAWING
2016-12-21	SE15-24-4-5	XXXX	-	TWP RD 242	2 OF 3	SK-2

DRAWING SK-2 | HIGHWAY | CONTRACT | DESCRIPTION SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) | PHOTO | DATE | BY | SURVEYED | DEPARTMENT BAR CODE

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2017-01-26 3:51pm By: mshansen

Stantec

Memo

Appendix C

Borehole Records

Stantec

BOREHOLE RECORD

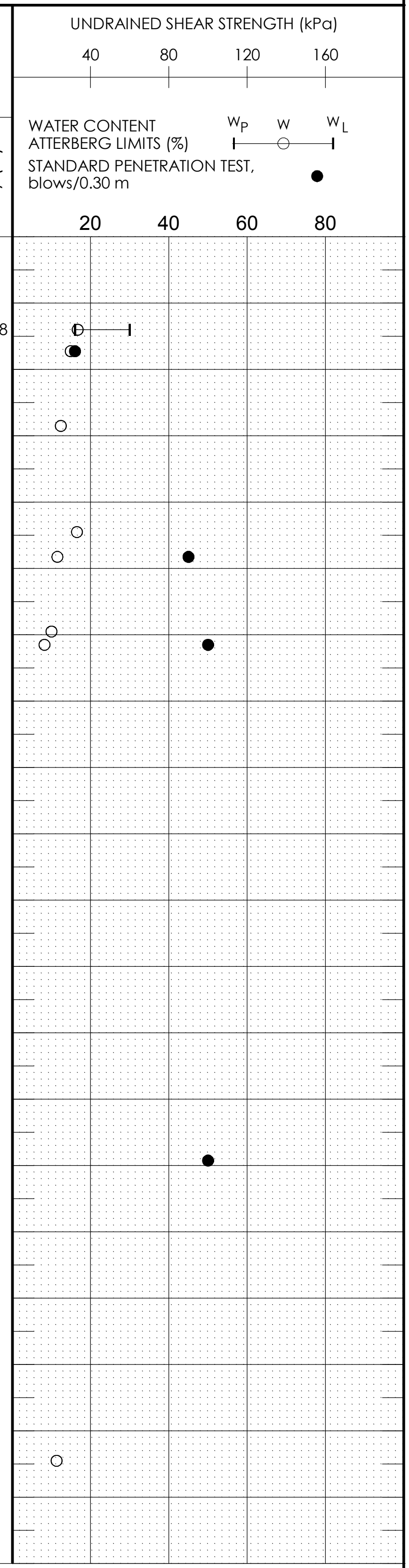
H01

CLIENT	Alberta Transportation	NORTHING	5656427	PROJECT NO.	110773396
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-32713	BH SIZE	SS:150mm
DATES BORING	2016/08/24	WATER LEVEL	(4.3 m) 2016/08/24	DATUM	Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION
0	1214.11	TOPSOIL
0.2	1213.91	Very stiff, brown, low plasticity CLAY (CL) - trace sand, gravel, trace coal specks, damp
2.4	1211.71	Very stiff, brown, low plasticity clay (CL) TILL - silty, some sand, trace gravel, trace coal specks, damp
3.2	1210.91	Very dense, brown sandy SILT (ML) - damp to wet
6.15	1207.96	Very poor to poor quality light grey (inferred) SILTSTONE - completely to highly weathered - very weak

Water level ▼ at approx. 4.3 m.

SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE	ADVANCED LAB TESTS	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
BS	1				1.7	14.8	51.7	31.8
SS	2	450	16					
BS	3							
ST	4	0						
BS	5							
SS	6	450	45					
BS	7							
SS	8	100	50+					
SS	9	0	50+					
BS	10							



(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H01

CLIENT	Alberta Transportation	NORTHING	5656427	PROJECT NO.	110773396
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-32713	BH SIZE	SS:150mm
DATES BORING	2016/08/24	WATER LEVEL	(4.3 m) 2016/08/24	DATUM	Geodetic

UNDRAINED SHEAR STRENGTH (kPa): 40, 80, 120, 160

WATER CONTENT / ATTERBERG LIMITS (%): W_P, W, W_L

STANDARD PENETRATION TEST, blows/0.30 m: 20, 40, 60, 80

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE	ADVANCED LAB TESTS	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
20		Very poor to poor quality light grey (inferred) SILTSTONE - completely to highly weathered - very weak											
22.5					BS	11							
29	1185.11	Very poor to poor quality grey (inferred) MUDSTONE - completely to highly weathered - very weak											
29.8					BS	12							
30	1184.11	End of borehole (30.0 m) - Auger refusal not encountered during drilling - Groundwater at 4.3 m and borehole open upon completion - Borehole backfilled with cuttings, bentonite seal from 0.3 m to 1.5 m											

Depth scale: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H02

CLIENT	Alberta Transportation	NORTHING 5656458	PROJECT NO. 110773396
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING -32713	BH SIZE SS:150mm
DATES BORING	2016/08/26	WATER LEVEL (10.0 m) 2016/08/26	DATUM Geodetic

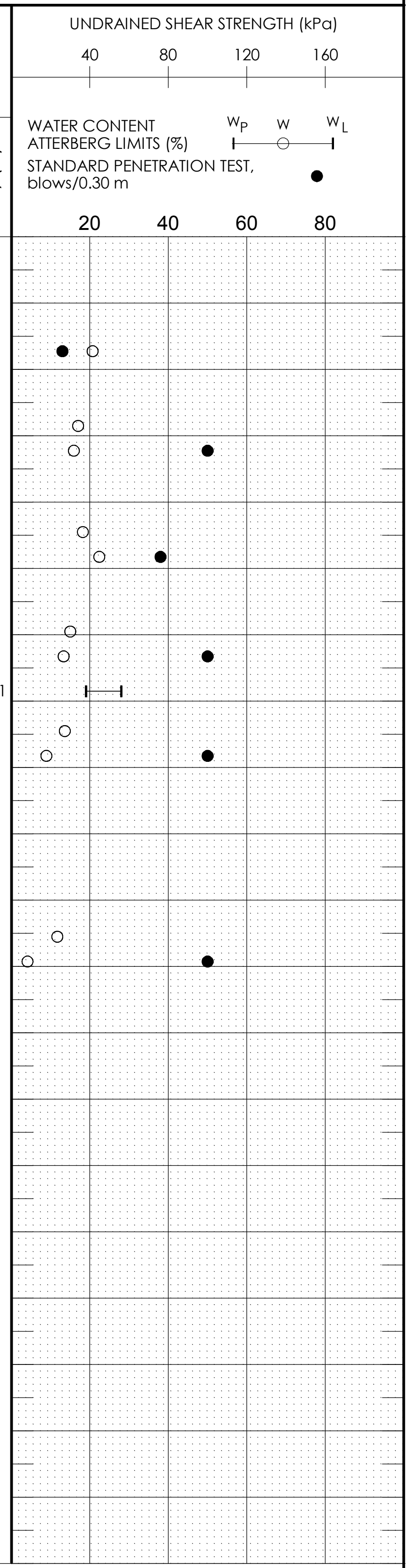
ELEVATION (m)	SOIL DESCRIPTION
1214.91	
1214.71	TOPSOIL
1213.36	FILL: dark brown to black, high plasticity clay (CL) - trace sand, gravel, mottled black, damp
1212.81	Stiff, brown, low plasticity clay (CL) TILL - trace sand, gravel, damp
1210.31	Very dense, brown, sandy SILT (ML) - damp
1209.71	Hard, brown, low plasticity clay (CL) TILL - sandy, trace gravel, damp - inferred seepage at 4.6 m
1208.31	Very dense, brown, sandy SILT (ML) - damp - interbedded with clay between 6.1 m and 6.5 m
1204.51	Very poor to poor quality brown (inferred) SANDSTONE - completely weathered - extremely weak - inferred highly to completely weathered, extremely weak below 7.6 m
	Very poor to poor quality grey (inferred) SILTSTONE - moderately to highly weathered - very weak to weak

SAMPLES

TYPE	NUMBER	RECOVERY (mm)	N-VALUE
BS	1		
SS	2	420	13
BS	3		
SS	4	450	50+
BS	5		
SS	6	450	38
BS	7		
SS	8	450	50+
BS	9		
SS	10	100	50+
BS	11		
SS	12	100	50+
BS	13		

GRAIN SIZE ANALYSIS

Gravel (%)	Sand (%)	Silt (%)	Clay (%)
7.3	18.1	59.5	15.1



(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec BOREHOLE RECORD H02

CLIENT	Alberta Transportation	NORTHING	5656458	PROJECT NO.	110773396
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-32713	BH SIZE	SS:150mm
DATES BORING	2016/08/26	WATER LEVEL	(10.0 m) 2016/08/26	DATUM	Geodetic

UNDRAINED SHEAR STRENGTH (kPa): 40, 80, 120, 160

WATER CONTENT, ATTERBERG LIMITS (%): W_P, W, W_L

STANDARD PENETRATION TEST, blows/0.30 m: 20, 40, 60, 80

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	SAMPLE TYPE	NUMBER	RECOVERY (mm)	N-VALUE	ADVANCED LAB TESTS	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
20		Very poor to poor quality grey (inferred) SILTSTONE - moderately to highly weathered - very weak to weak									
22	1192.91	Very poor to poor quality (inferred) MUDSTONE - moderately to highly weathered - very weak									
22.5			BS	14							
25.5			BS	15							
30	1184.81		BS	16							
30.1		End of borehole (30.1 m) - Auger refusal not encountered during drilling - Groundwater at 10.0 m and borehole open upon completion - Borehole backfilled with cuttings, bentonite seal from 0.3 m to 1.5 m									

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

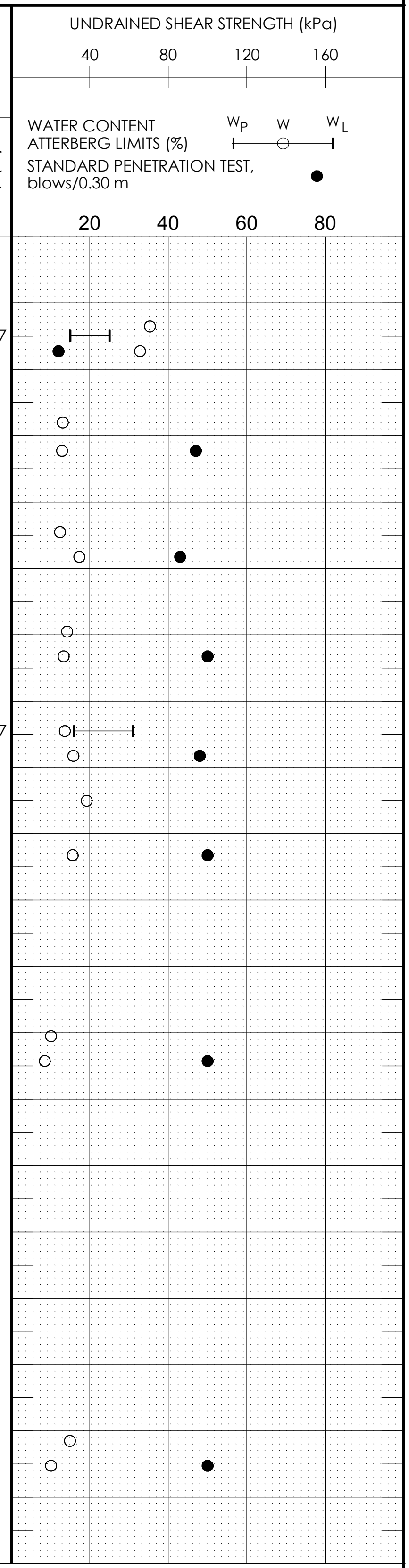
Stantec

BOREHOLE RECORD

H03

CLIENT	Alberta Transportation	NORTHING	5656489
PROJECT NO.	110773396		
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-32714
BH SIZE	SS:150mm		
DATES BORING	2016/08/27	WATER LEVEL	(Dry) 2016/08/27
DATUM	Geodetic		

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	SAMPLE TYPE	NUMBER	RECOVERY (mm)	N-VALUE	ADVANCED LAB TESTS	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
0	1215.55										
	1215.35	TOPSOIL									
		FILL: dark brown, low plasticity clay (CL) - silty, trace sand, gravel, frequent organics, damp - bulk sample BSA from 0.5 m to 2.5 m - trace rootlets below 1.5 m	BS	1			CU, PT	1.6	45.2	34.5	18.7
			SS	2	350	12					
	1212.55		BS	3							
		Very dense, brown, sandy SILT (ML) - trace gravel, trace coal specks, damp - bulk sample BSB from 3.2 m to 5.5 m - inferred seepage at 4.6 m	SS	4	400	47					
			BS	5							
			SS	6	450	43					
			BS	7							
			SS	8	400	50+					
	1208.75	Hard, brown, low plasticity clay (CL) TILL - silty, trace gravel, trace oxidation, damp	BS	9				7.5	35.9	36.9	19.7
			SS	10	300	48					
	1207.15	Very poor to poor quality grey (inferred) SILTSTONE - completely weathered - extremely weak - moderately weathered, very weak to weak below 11.0 m	BS	11							
			SS	12	75	50+					
			BS	13							
			SS	14	50	50+					
	1197.55	Very poor to poor quality grey (inferred) MUDSTONE - completely weathered - extremely to very weak	BS	15							
			SS	16	100	50+					
20											



(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec BOREHOLE RECORD H03

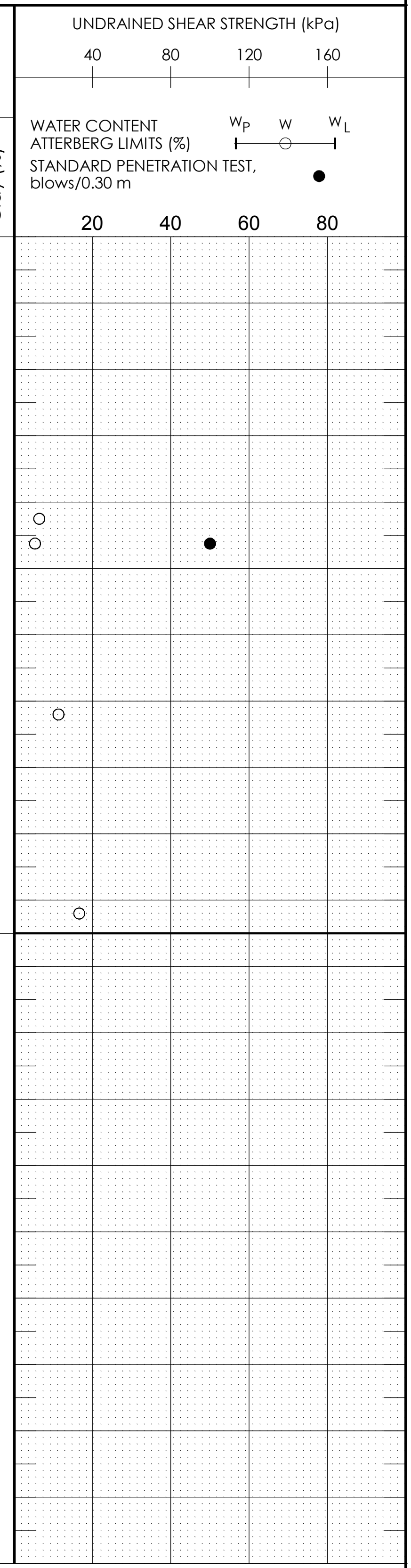
CLIENT	Alberta Transportation	NORTHING	5656489
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-32714
DATES BORING	2016/08/27	WATER LEVEL	(Dry) 2016/08/27
PROJECT NO.	110773396	BH SIZE	SS:150mm
DATUM	Geodetic		

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION
20 – 23	1192.55	Very poor to poor quality grey (inferred) MUDSTONE - completely weathered - extremely to very weak
23 – 29	1186.55	Very poor to poor quality grey (inferred) SILTSTONE - moderately to slightly weathered - very weak to weak
29 – 30.5	1185.05	Very poor to poor quality grey (inferred) MUDSTONE - completely to highly weathered - extremely to very weak
30.5		End of borehole (30.5 m) - Auger refusal not encountered during drilling - Borehole open upon completion - borehole backfilled with cuttings, bentonite seal from 0.3 m to 1.5 m

SAMPLES

TYPE	NUMBER	RECOVERY (mm)	N-VALUE
BS	17		
SS	18	50	50+
BS	19		
BS	20		

ADVANCED LAB TESTS — GRAIN SIZE ANALYSIS: Gravel (%), Sand (%), Silt (%), Clay (%)



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(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

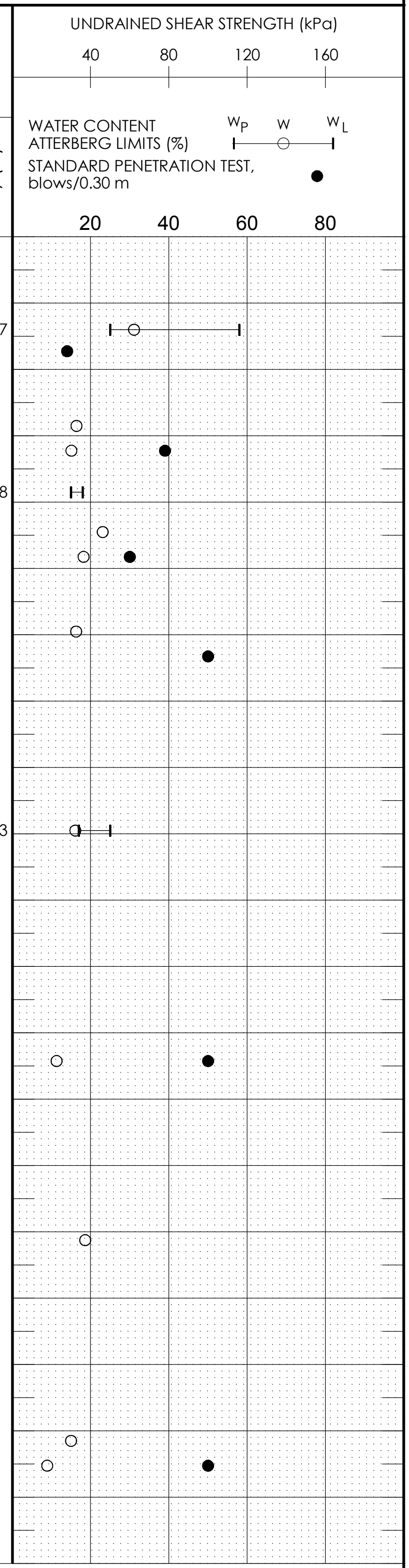
BOREHOLE RECORD

H04

CLIENT: Alberta Transportation
PROJECT: SR1 - Off Stream Reservoir, Springbank, AB
DATES BORING: 2016/08/24
NORTHING: 5656520
EASTING: -32714
WATER LEVEL: (9.3 m) 2016/08/24
PROJECT NO.: 110773396
BH SIZE: SS:150mm
DATUM: Geodetic

ELEVATION (m)	SOIL DESCRIPTION
1215.90	
1215.7	TOPSOIL
	FILL: brown, high plasticity clay (CL) - silty, trace sand, gravel, frequent rootlets and organics, damp
1214.15	Stiff, brown, low plasticity clay (CL)
1213.7	TILL - trace sand, gravel, damp
	Dense, brown, sandy SILT (ML) - wet - inferred seepage at 3.4 m
1209.5	Very poor to poor quality brown (inferred) SANDSTONE - completely weathered - extremely weak
1207.7	Very poor to poor quality grey (inferred) MUDSTONE - completely weathered - extremely weak
1198.3	Very poor to poor quality grey (inferred) SILTSTONE - moderately weathered - very weak

SAMPLES TYPE	NUMBER	RECOVERY (mm)	N-VALUE	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
BS	1			2.9	8.8	34.6	53.7
SS	2	450	14				
BS	3						
SS	4	450	39				
				0.4	39.2	43.6	16.8
BS	5						
SS	6	450	30				
BS	7						
SS	8	400	50+				
BS	9			1.6	56.9	28.1	13.3
SS	10	75	50+				
BS	11						
BS	12						
SS	13	50	50+				



(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H04

CLIENT	Alberta Transportation	NORTHING	5656520	PROJECT NO.	110773396
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-32714	BH SIZE	SS:150mm
DATES BORING	2016/08/24	WATER LEVEL	(9.3 m) 2016/08/24	DATUM	Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY (mm)	SAMPLES: N-VALUE	ADVANCED LAB TESTS	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	UNDRAINED SHEAR STRENGTH (kPa) 40 80 120 160; WATER CONTENT ATTERBERG LIMITS (%) W_P W W_L; STANDARD PENETRATION TEST, blows/0.30 m; 20 40 60 80
20		Very poor to poor quality grey (inferred) SILTSTONE - moderately weathered - very weak												
29	1187.1	Very poor to poor quality grey (inferred) MUDSTONE - extremely weak			BS	14								○
30	1185.9	End of borehole (30.0 m) - Auger refusal not encountered during drilling - Groundwater at 9.3 m and borehole open upon completion - borehole backfilled with cuttings, bentonite seal placed from 0.3 m to 1.5 m												

Depth scale: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H10

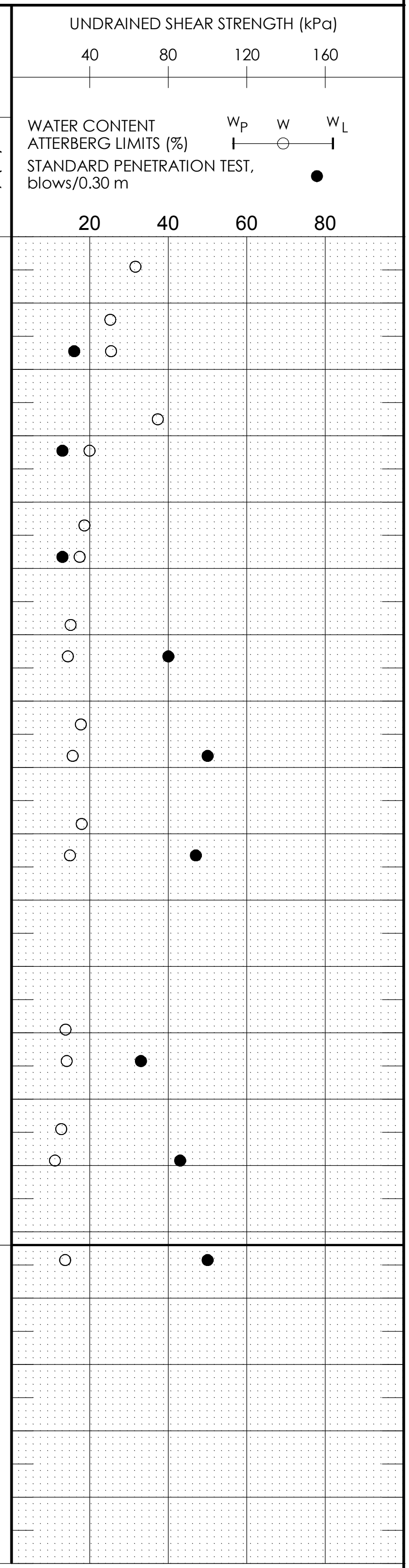
CLIENT	Alberta Transportation	NORTHING	5655853
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-33314
DATES BORING	2016/08/22	WATER LEVEL	
PROJECT NO.	110773396	BH SIZE	SS:150mm; HS:200mm
DATUM	Geodetic		

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION
0	1217.42	
	1217.17	FILL: 40 mm pit run
	1216.82	Stiff, brown, low plasticity CLAY (CL) - trace gravel, moist
		Stiff to very stiff, brown, medium plasticity CLAY (CI) - trace sand, moist - bulk sample BSA from 0.6 m to 1.5 m - mottled dark brown below 1.5 m - bulk sample BSB from 1.5 m to 3.0 m - trace gravel below 2.5 m - bulk sample BSC from 3.0 m to 4.6 m
	1213.82	Stiff, brown, medium plasticity clay (CL) TILL - some sand, trace coal specks, moist - bulk sample BSD from 4.6 m to 6.1 m - dry to moist below 5.5 m - hard, trace gravel below 6.1 m - bulk sample BSE from 6.1 m to 7.6 m - sandy below 7.6 m - bulk sample BSF from 7.6 m to 9.1 m - bulk sample BSG from 10.7 m to 12.2 m - bulk sample BSH from 12.2 m to 13.7 m - bulk sample BSI from 13.7 m to 15.2 m - inferred seepage at 14.0 m
	1203.27	
	1202.42	Very dense, brown silty SAND (SM) - trace gravel, moist to wet
	1202.22	Very poor to poor quality grey (inferred) SANDSTONE - completely to highly weathered - extremely to very weak
		Bedrock encountered at 15.0 m - Coring commenced at 15.2 m (see rock coring log for details) - Borehole advanced in bedrock to 30.2 m
20		

SAMPLES

TYPE	NUMBER	RECOVERY (mm)	N-VALUE
BS	1		
BS	2		
SS	3	370	16
BS	4		
SS	5	450	13
BS	6		
SS	7	430	13
BS	8		
SS	9	440	40
BS	10		
SS	11	450	50
BS	12		
SS	13	450	47
BS	14		
SS	15	450	33
BS	16		
SS	17	120	43
SS	18	25	50+

ADVANCED LAB TESTS | GRAIN SIZE ANALYSIS: Gravel (%), Sand (%), Silt (%), Clay (%)



(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H10

CLIENT	Alberta Transportation	NORTHING: 5655853	PROJECT No. 110773396
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING: -33314	BH SIZE SS:150mm, HS:200mm
DRILLING DATE	8/22/2016 to 8/22/2016	WATER LEVEL	DATUM Geodetic

FX-FRACTURE, CL-CLEAVAGE, SH-SHEAR, VN-VEIN, F-FAULT, JN-JOINT, P-POLISHED, S-SLICKENSIDED, SM-SMOOTH, R-ROUGH, ST-STEPPED, PL-PLANAR, FL-FLEXURED, UE-UNEVEN, W-WAVY, C-CURVED, BC-BROKEN CORE, CONT-CONTACT, B-BEDDING, FOL-FOLIATION

DEPTH (m)	ELEVATION (m)	DESCRIPTION	SAMPLE TYPE RUN No.	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 1m	ROCK STRENGTH INDEX	WEATHERING INDEX	LABORATORY TESTING
14		Overburden - See Soil Log for overburden description								
15	1202.4 / 1202.2	Very poor to poor quality grey (inferred) SANDSTONE - completely to highly weathered - extremely to very weak								
		Very poor quality grey SANDSTONE - highly weathered - medium strong	RC19	31	8	0		3	W4	
16		- moderately to highly weathered below 16.4 m	RC20	93	67	0		3	W3.5	
18		- poor quality, dark grey, and moderately weathered below 17.9 m	RC21	100	83	25		3	W3	
19		- very poor quality below 19.4 m	RC22	100	83	9		3	W3	
21	1196.5	Poor quality dark grey CLAYSTONE - moderately weathered - very weak	RC23	99	96	40		R1	W3	
22	1194.9	Good quality dark grey SANDSTONE - slightly weathered - weak	RC24	100	95	79		R2	W2	
24										

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H10

CLIENT Alberta Transportation
PROJECT SR1 - Off Stream Reservoir, Springbank, AB
DRILLING DATE 8/22/2016 to 8/22/2016
NORTHING: 5655853
EASTING: -33314
WATER LEVEL
PROJECT No. 110773396
BH SIZE SS:150mm, HS:200mm
DATUM Geodetic

FX-FRACTURE, CL-CLEAVAGE, SH-SHEAR, VN-VEIN, F-FAULT, JN-JOINT, P-POLISHED, S-SLICKENSIDED, SM-SMOOTH, R-ROUGH, ST-STEPPED, PL-PLANAR, FL-FLEXURED, UE-UNEVEN, W-WAVY, C-CURVED, BC-BROKEN CORE, CONT-CONTACT, B-BEDDING, FOL-FOLIATION

DEPTH (m)	ELEVATION (m)	DESCRIPTION	SAMPLE TYPE RUN No.	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 1m	ROCK STRENGTH INDEX	WEATHERING INDEX	LABORATORY TESTING
24		Good quality dark grey SANDSTONE - slightly weathered - weak - poor quality, and weak below 24.0 m	RC25	98	88	44		R2	W2	
25		- good quality below 25.6 m	RC26	98	98	83		R2	W2	
27		- fair quality, and weak to medium strong below 27.2 m	RC27	100	91	56		2.5	W2	
28		- weak below 28.7 m	RC28	100	91	56		R2	W2	
30.2	1187.2	End of borehole (30.2 m) - borehole open upon completion - seepage at 14.0 m during drilling - borehole backfilled with cuttings, and a bentonite seal placed from 1.0 m to 30.2 m								

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

TEST 6/30/17 2:54:51 PM

BOREHOLE RECORD

H11

Stantec

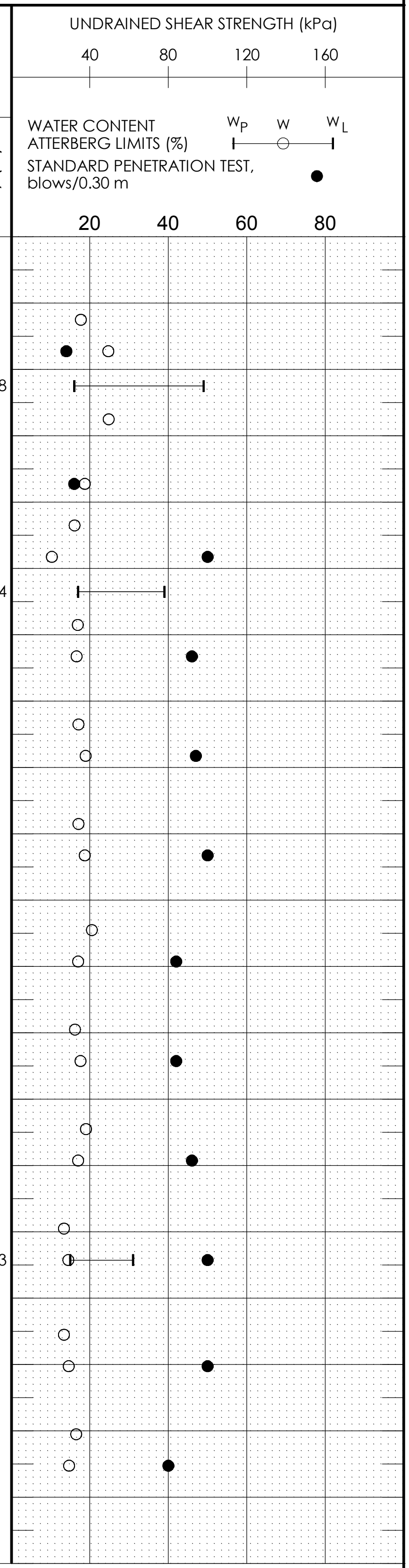
CLIENT	Alberta Transportation	NORTHING	5655857
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-33415
DATES BORING	2016/08/25	WATER LEVEL	(Dry) 2016/08/25
PROJECT NO.	110773396	BH SIZE	SS:150mm
DATUM	Geodetic		

SOIL DESCRIPTION

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION
0	1219.53	
0.2	1219.33	FILL: 40 mm pit run
0.6	1218.93	Black, low plasticity organic CLAY (OL) - trace sand Stiff, brown, high plasticity CLAY (CH) - silty, trace sand, gravel, trace coal specks, moist - bulk sample BSA from 0.6 m to 1.5 m - bulk sample BSB from 1.5 m to 3.0 m
3.0	1216.53	Very stiff, brown, medium plasticity clay (CI) TILL - silty, some sand, trace gravel, dry to moist - bulk sample BSC from 3.0 m to 4.6 m - trace coal specks below 3.5 m - brown to grey, hard below 4.6 m - bulk sample BSD from 4.6 m to 6.1 m - inferred seepage at 6.1 m - grey below 6.1 m - bulk sample BSE from 6.1 m to 7.6 m - bulk sample BSF from 7.6 m to 9.1 m - bulk sample BSG from 9.1 m to 10.7 m - bulk sample BSH from 10.7 m to 12.2 m - bulk sample BSI from 12.2 m to 13.7 m
19.8	1199.73	

SAMPLES

TYPE	NUMBER	RECOVERY (mm)	N-VALUE	ADVANCED LAB TESTS	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
BS	1							
SS	2	420	14					
				CU, PT	0.2	3.1	38.9	57.8
BS	3							
ST	4	400						
SS	5	240	16					
BS	6							
SS	7	420	50+					
				CU, PT, k	3.1	18.3	39.1	39.4
BS	8							
SS	9	450	46					
BS	10							
SS	11	390	47					
BS	12							
SS	13	380	50+					
BS	14							
SS	15	450	42					
BS	16							
SS	17	440	42					
BS	18							
SS	19	450	46					
BS	20							
SS	21	400	50+		6.1	18.3	44.3	31.3
BS	22							
SS	23	450	50+					
BS	24							
SS	25	450	40					



(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H11

CLIENT	Alberta Transportation	NORTHING	5655857	PROJECT NO.	110773396
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-33415	BH SIZE	SS:150mm
DATES BORING	2016/08/25	WATER LEVEL	(Dry) 2016/08/25	DATUM	Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE	ADVANCED LAB TESTS	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
20		Very poor to poor quality brown to grey (inferred) CLAYSTONE - completely to highly weathered - extremely to very weak											
21					BS	26							
	1198.13				SS	27	25	50+					
22		End of borehole due to auger and split spoon refusal at 21.4 m - Borehole dry and open upon completion - Borehole backfilled with cuttings, bentonite seal from 0.3 m to 21.4 m											

Chart legend: UNDRAINED SHEAR STRENGTH (kPa) 40 80 120 160; WATER CONTENT ATTERBERG LIMITS (%) W_P W W_L; STANDARD PENETRATION TEST, blows/0.30 m; 20 40 60 80

Depth scale: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

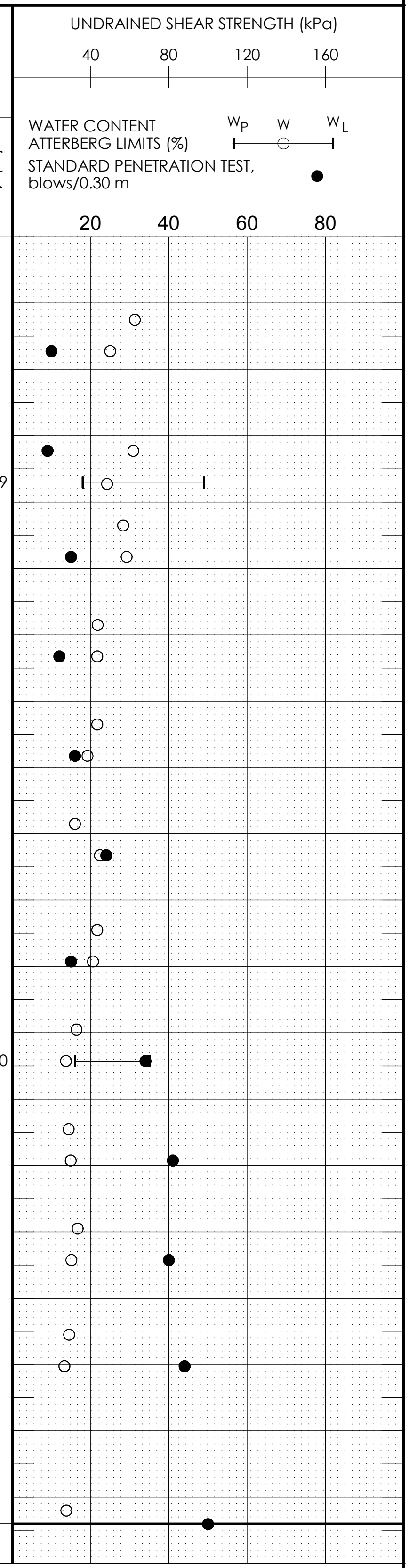
BOREHOLE RECORD — H12

Stantec

CLIENT: Alberta Transportation
PROJECT: SR1 - Off Stream Reservoir, Springbank, AB
DATES BORING: 2016/08/24
WATER LEVEL:
NORTHING: 5655857
EASTING: -33377
PROJECT NO.: 110773396
BH SIZE: SS:150mm; HS:200mm
DATUM: Geodetic

Elevation (m)	Soil Description
1217.63 (surface, depth 0)	
1217.23	FILL: 40 mm pit run
1216.63	Black, low plasticity organic CLAY (OL) - trace sand, moist - bulk sample BSA from 0.4 m to 1.5 m
	Stiff, brown, medium to high plasticity clay (CI-CH) - silty, trace sand, moist - bulk sample BSB from 1.5 m to 3.0 m - inferred seepage at 3.0 m - trace coal specks, mottled grey below 3.0 m - bulk sample BSC from 3.0 m to 4.6 m - trace gravel below 4.2 m - bulk sample BSD from 4.6 m to 6.1 m - bulk sample BSE from 6.1 m to 7.6 m
1210.03	Very stiff, brown medium plasticity clay (CI) TILL - silty, some sand, trace gravel, dry to moist - bulk sample BSF from 7.6 m to 9.1 m - bulk sample BSG from 9.1 m to 10.7 m - trace coal specks, moist below 9.8 m - dry to moist below 10.7 m - bulk sample BSH from 10.7 m to 12.2 m - grey below 11.3 m - bulk sample BSI from 12.2 m to 13.7 m - bulk sample BSJ from 13.7 m to 15.2 m - bulk sample BSK from 15.2 m to 16.8 m
1199.73	Very poor to poor quality grey (inferred) CLAYSTONE - completely to highly weathered - extremely to very weak
1198.23	Bedrock encountered at 17.9 m

Type	Number	Recovery (mm)	N-Value	Advanced Lab Tests	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
BS	1							
SS	2	340	10					
BS	3							
SS	4	420	9					
ST	5	450		CU, Y	0.6	4.7	41.8	52.9
BS	6							
SS	7	450	15					
BS	8							
SS	9	450	12					
BS	10							
SS	11	450	16					
BS	12							
SS	13	450	24					
BS	14							
SS	15	450	15					
BS	16							
SS	17	430	34		8.8	13.3	42.9	35.0
BS	18							
SS	19	450	41					
BS	20							
SS	21	450	40					
BS	22							
SS	23	450	44					
BS	24							
SS	25	0	50+					



(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H12

CLIENT Alberta Transportation
PROJECT SR1 - Off Stream Reservoir, Springbank, AB
DATES BORING 2016/08/24
WATER LEVEL
NORTHING 5655857
EASTING -33377
PROJECT NO. 110773396
BH SIZE SS:150mm; HS:200mm
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY (mm)	SAMPLES: N-VALUE	ADVANCED LAB TESTS	GRAIN SIZE ANALYSIS: Gravel (%)	Sand (%)	Silt (%)	Clay (%)	UNDRAINED SHEAR STRENGTH (kPa) 40 80 120 160; WATER CONTENT W_P W W_L ATTERBERG LIMITS (%); STANDARD PENETRATION TEST, blows/0.30 m ● 20 40 60 80
20		- Coring commenced at 19.4 m (see rock coring log for details) - Borehole advanced in bedrock to 34.7 m												

Depth scale: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H12

CLIENT: Alberta Transportation
PROJECT: SR1 - Off Stream Reservoir, Springbank, AB
DRILLING DATE: 8/24/2016 to 8/24/2016
NORTHING: 5655857
EASTING: -33377
WATER LEVEL:
PROJECT No.: 110773396
BH SIZE: SS:150mm, HS:200mm
DATUM: Geodetic

FX-FRACTURE, CL-CLEAVAGE, SH-SHEAR, VN-VEIN, F-FAULT, JN-JOINT, P-POLISHED, S-SLICKENSIDED, SM-SMOOTH, R-ROUGH, ST-STEPPED, PL-PLANAR, FL-FLEXURED, UE-UNEVEN, W-WAVY, C-CURVED, BC-BROKEN CORE, CONT-CONTACT, B-BEDDING, FOL-FOLIATION

DEPTH (m)	ELEVATION (m)	DESCRIPTION	SAMPLE TYPE RUN No.	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 1m	ROCK STRENGTH INDEX	WEATHERING INDEX	LABORATORY TESTING
17.0		Overburden - See Soil Log for overburden description								
17.9	1199.7	Very poor to poor quality grey (inferred) CLAYSTONE - completely to highly weathered - extremely to very weak								
19.4	1198.2	Very poor quality dark grey SANDSTONE - highly weathered - very weak	RC26	100	60	0		R1	W4	
		- fair quality, weak to medium strong, and slightly weathered below 20.9 m	RC27	99	93	68		2.5	W2	
		- good quality, and medium strong below 22.5 m	RC28	100	100	79		3	W2	
		- excellent quality, and fresh below 24.0 m	RC29	99	97	94		3	W1	
		- fair quality, slightly weathered, and grey to green below 25.5 m	RC30	100	93	73		3	W2	
27										

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H12

CLIENT: Alberta Transportation
PROJECT: SR1 - Off Stream Reservoir, Springbank, AB
DRILLING DATE: 8/24/2016 to 8/24/2016
NORTHING: 5655857
EASTING: -33377
WATER LEVEL:
PROJECT No.: 110773396
BH SIZE: SS:150mm, HS:200mm
DATUM: Geodetic

FX-FRACTURE, CL-CLEAVAGE, SH-SHEAR, VN-VEIN, F-FAULT, JN-JOINT, P-POLISHED, S-SLICKENSIDED, SM-SMOOTH, R-ROUGH, ST-STEPPED, PL-PLANAR, FL-FLEXURED, UE-UNEVEN, W-WAVY, C-CURVED, BC-BROKEN CORE, CONT-CONTACT, B-BEDDING, FOL-FOLIATION

DEPTH (m)	ELEVATION (m)	DESCRIPTION	SAMPLE TYPE RUN No.	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	ROCK STRENGTH INDEX	WEATHERING INDEX	LABORATORY TESTING
27		Very poor quality dark grey SANDSTONE - highly weathered - very weak - good quality below 27.0 m	RC31	100	95	79	3	W2	
28.5		- fair quality, and grey below 28.5 m	RC32	100	97	72	3	W2	
30		- good quality, and dark grey below 30.0 m	RC33	100	99	80	3	W2	
31.5		- fair quality below 31.5 m - 0.25 m thick weak, and moderately weathered layer at 32.15 m	RC34	99	88	69	3	W2	
33.1		- excellent quality, and fresh below 33.1 m	RC35	98	98	93	3	W2	
34.7	1182.9	End of borehole (34.7 m) - borehole open upon completion - borehole backfilled with cuttings, and a bentonite seal placed from 1.0 m to 34.7 m							

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

TEST 6/30/17 2:54:53 PM

Stantec

BOREHOLE RECORD

H13

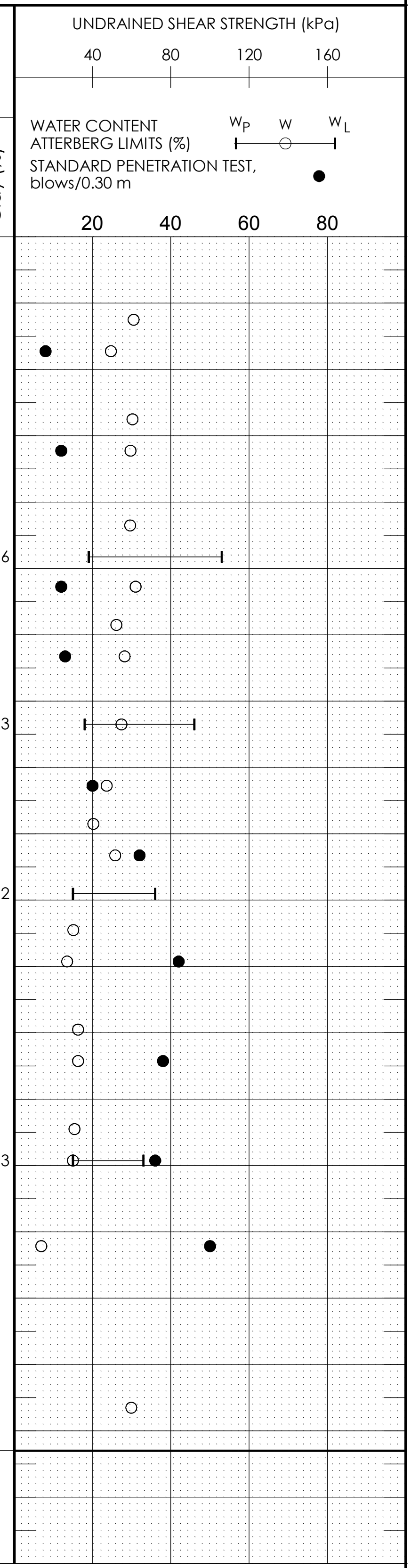
CLIENT	Alberta Transportation	NORTHING	5655858
PROJECT	SR1 - Off Stream Reservoir, Springbank, AB	EASTING	-33347
DATES BORING	2016/08/23	WATER LEVEL	
PROJECT NO.	110773396	BH SIZE	SS:150mm; HS:200mm
DATUM	Geodetic		

Soil Description

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION
0	1217.08	
	1216.78	FILL: 40 mm pit run
	1216.38	Black, low plasticity organic CLAY (OL)
	1215.58	Grey SILT (ML) - trace sand, wet, trace organics - bulk sample BSA from 0.7 m to 1.5 m
	1207.98	Stiff, brown, medium to high plasticity CLAY (CI-CH) - silty, trace sand, mottled grey, moist to wet - bulk sample BSB from 1.5 m to 3.0 m - moist below 3.0 m - bulk sample BSC from 3.0 m to 4.6 m - trace gravel below 4.0 m - bulk sample BSD from 4.6 m to 6.1 m - trace coal specks below 5.1 m - bulk sample BSE from 6.1 m to 7.6 m - very stiff below 7.0 m - bulk sample BSF from 7.6 m to 9.1 m
	1201.88	Hard, grey, medium plasticity clay (CI) TILL - silty, some sand, trace gravel, dry - bulk sample BSG from 9.1 m to 10.7 m - bulk sample BSH from 10.7 m to 12.2 m - bulk sample BSI from 12.2 m to 13.7 m - bulk sample BSJ from 13.7 m to 15.2 m - dry to moist below 14.0 m - inferred seepage at 15.0 m
	1198.78	Very poor to poor quality grey (inferred) SANDSTONE - highly weathered - extremely to very weak - auger refusal at 17.8 m
		Bedrock encountered at 15.2 m - Coring commenced at 18.3 m (see rock coring log for details) - Borehole advanced in bedrock

Samples and Laboratory Tests

TYPE	NUMBER	RECOVERY (mm)	N-VALUE	ADVANCED LAB TESTS	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
BS	1							
SS	2	320	8					
BS	3							
SS	4	450	12					
BS	5							
ST	6	290		Qu, Y	0.8	6.8	35.8	56.6
SS	7	450	12					
BS	8							
SS	9	450	13					
BS	10				2.2	8.6	40.9	48.3
ST	11	320		CU, Y				
SS	12	450	20					
BS	13							
SS	14	450	32					
				CU, k, PT	4.2	19.6	41.0	35.2
BS	15							
SS	16	450	42					
BS	17							
SS	18	280	38					
BS	19							
SS	20	450	36		2.4	18.9	44.5	34.3
SS	21	25	50+					
BS	22							



(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H13

CLIENT Alberta Transportation
PROJECT SR1 - Off Stream Reservoir, Springbank, AB
DATES BORING 2016/08/23
NORTHING 5655858
EASTING -33347
WATER LEVEL
PROJECT NO. 110773396
BH SIZE SS:150mm; HS:200mm
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE	ADVANCED LAB TESTS	GRAIN SIZE ANALYSIS Gravel (%)	Sand (%)	Silt (%)	Clay (%)	UNDRAINED SHEAR STRENGTH (kPa) 40 80 120 160; WATER CONTENT ATTERBERG LIMITS (%) W_P W W_L; STANDARD PENETRATION TEST, blows/0.30 m 20 40 60 80
20		to 34.8 m												
21														
22														
23														
24														
25														
26														
27														
28														
29														
30														
31														
32														
33														
34														
35														
36														
37														
38														
39														
40														

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

Stantec

BOREHOLE RECORD

H13

CLIENT: Alberta Transportation
PROJECT: SR1 - Off Stream Reservoir, Springbank, AB
DRILLING DATE: 8/23/2016 to 8/23/2016
NORTHING: 5655858
EASTING: -33347
WATER LEVEL:
PROJECT No.: 110773396
BH SIZE: SS:150mm, HS:200mm
DATUM: Geodetic

FX-FRACTURE, CL-CLEAVAGE, SH-SHEAR, VN-VEIN; F-FAULT, JN-JOINT, P-POLISHED, S-SLICKENSIDED; SM-SMOOTH, R-ROUGH, ST-STEPPED, PL-PLANAR; FL-FLEXURED, UE-UNEVEN, W-WAVY, C-CURVED; BC-BROKEN CORE, CONT-CONTACT, B-BEDDING, FOL-FOLIATION

DEPTH (m)	ELEVATION (m)	DESCRIPTION	SAMPLE TYPE RUN No.	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 1m	ROCK STRENGTH INDEX	WEATHERING INDEX	LABORATORY TESTING
14		Overburden - See Soil Log for overburden description								
15.2	1201.9	Very poor to poor quality grey (inferred) SANDSTONE - highly weathered - extremely to very weak								
18.3	1198.8	Very poor quality grey SANDSTONE - moderately weathered - medium strong	RC23	0	0	0		R	W	
			RC24	100	91	11		R2	W3	
20.4	1196.7	Very poor quality dark grey CLAYSTONE - moderately weathered - very weak								
21.1	1196.0	Fair quality grey SANDSTONE - highly weathered - medium strong								
21.4	1195.7	Fair quality dark grey CLAYSTONE - moderately weathered - very weak	RC25	99	75	52		R2	W3	
		- poor quality below 22.6 m	RC26	99	95	46		R1	W3	
24										

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

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Stantec

BOREHOLE RECORD

H13

CLIENT: Alberta Transportation
PROJECT: SR1 - Off Stream Reservoir, Springbank, AB
DRILLING DATE: 8/23/2016 to 8/23/2016
NORTHING: 5655858
EASTING: -33347
WATER LEVEL:
PROJECT No. 110773396
BH SIZE: SS:150mm, HS:200mm
DATUM: Geodetic

FX-FRACTURE, CL-CLEAVAGE, SH-SHEAR, VN-VEIN, F-FAULT, JN-JOINT, P-POLISHED, S-SLICKENSIDED, SM-SMOOTH, R-ROUGH, ST-STEPPED, PL-PLANAR, FL-FLEXURED, UE-UNEVEN, W-WAVY, C-CURVED, BC-BROKEN CORE, CONT-CONTACT, B-BEDDING, FOL-FOLIATION

DEPTH (m)	ELEVATION (m)	DESCRIPTION	SAMPLE TYPE RUN No.	TOTAL CORE %	SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 1m	ROCK STRENGTH INDEX	WEATHERING INDEX	LABORATORY TESTING
24		Fair quality dark grey CLAYSTONE - moderately weathered - very weak								
	1192.5	Fair poor quality dark grey SANDSTONE - slightly weathered - weak	RC27	98	80	60		R1.5	W2.5	
25–26		- poor quality, dark grey, moderately weathered, very weak below 25.7 m - slightly weathered, medium strong below 26.25 m - moderately weathered, very weak below 26.85 m	RC28	100	80	46		R2	W2.5	
27–28		- good quality, slightly weathered, medium strong below 27.2 m	RC29	100	99	86		3	W2	
29		- fair quality, weak to medium strong below 28.7 m	RC30	100	96	67		2.5	W2	
30–31		- medium strong below 30.2 m	RC31	100	91	73		3	W2	
32–33			RC32	97	94	66		3	W2	
33–34		- good quality below 33.3 m								

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
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App'd by:

Stantec

BOREHOLE RECORD

H13

CLIENT Alberta Transportation
PROJECT SR1 - Off Stream Reservoir, Springbank, AB
DRILLING DATE 8/23/2016 to 8/23/2016
NORTHING: 5655858
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WATER LEVEL
PROJECT No. 110773396
BH SIZE SS:150mm, HS:200mm
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FX-FRACTURE, CL-CLEAVAGE, SH-SHEAR, VN-VEIN, F-FAULT, JN-JOINT, P-POLISHED, S-SLICKENSIDED, SM-SMOOTH, R-ROUGH, ST-STEPPED, PL-PLANAR, FL-FLEXURED, UE-UNEVEN, W-WAVY, C-CURVED, BC-BROKEN CORE, CONT-CONTACT, B-BEDDING, FOL-FOLIATION

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLE TYPE RUN No.	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 1m	ROCK STRENGTH INDEX	WEATHERING INDEX	LABORATORY TESTING
34		Fair poor quality dark grey SANDSTONE - slightly weathered - weak			RC33	100	98	78		3	W2	
	1182.3	End of borehole (34.8 m) - borehole open upon completion - water observed at 15.0 m during drilling - borehole backfilled with cuttings, and a bentonite seal placed from 1.0 m to 34.8 m										
35												
36												
37												
38												
39												
40												
41												
42												
43												
44												

(1) Approximate borehole locations surveyed by Stantec Consulting Ltd.
(2) Water may be influenced by drilling fluids/techniques; piezometer install shown, if applicable.

App'd by:

APPENDIX E COMMENT/RESPONSE LOG

Township Road 242 Structure

Revision Number	Comment Number	AT Comments (Sept 18, 2018)	Stantec Responses (Nov 8, 2018)
0	1	why 1100 box? can we have savings using smaller box girders?	Box girders were considered as an option to optimize the structure, as it is a local road with a low AADT. Based on preliminary analysis, 1100 mm is the minimum depth required for a precast, prestressed concrete girder. Standard SLC girders were not considered as the maximum configuration available is 20m-20m-20m, which is not sufficient for this crossing.
	2	Why do we need 225 mm deck in box girder option. Potential saving compared to NU girders using less thick deck. It is possible to go deck less for box girder option?	A 225 mm deck on side-by-side precast concrete girder bridges is a requirement in the AT Bridge Structures Design Criteria V 8.0 as per section 9.2.3.
	3	To improve serviceability and minimize damage to the deck, it is recommended that the girder is designed for future ACP and waterproofing. The barriers should also have sufficient depth to accommodate ACP and waterproofing.	The structure will be designed to accomodated future ACP and waterproofing. A comment has been added to the report.
	4	Why concrete option cannot use longitudinally fixed support at both pier? this can eliminate bearings at piers.	The piers can be fixed. Note that the pier section will require aditional reinforcing to resist the larger forces induced by the fixed connection. The cost estimate has been updated to reflect this change.
	5	Thermal movement seems too much when fixing longitudinal movement at both pier. also with 79 mm movement semi integral abutment cannot be used for steel option.	As stated, the 79 mm is the total thermal movement based on the full span length of 81 m and assuming the piers provide no longitudinal restraint. The movement at each joint would conservatively be half of this value, 40 mm, which is within the range of the C2 joint. In addition, depending on the fixity of the piers, they will provide some longitudinal restraint, so this value will be less.
	6	Does the cost estimate reflect potential savings of using box girder by not requiring form work, potential use of less deck thickness, limiting number of bearing by using fix concrete diaphragm at both piers	The cost estimate has been updated to reflect the reduced number of bearings. As per comment 2, the deck thickenss cannot be reduced, however the cost estimate does include less reinforcement for the deck on the box girders.