REPORT

Golden Hill to West Portal
100% Detailed Design Drainage Report

Prepared for

Emil Anderson Construction Ltd.

&

BC Ministry of Transportation & Infrastructure

August 2010

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1.0 PURPOSE

The purpose of this report is to describe the design basis for the drainage plan of the Golden Hill to West Portal Project for the 100% detailed design submission. Details are provided for the hydrologic and hydraulic design of culverts, channels, catchbasins, spillways, detention ponds and other features of the overall drainage system for the proposed highway.

2.0 BASIS FOR HYDROLOGIC DESIGN

2.1 Return Periods

Section 1000 of the MOT Supplement to TAC Geometric Design Guide (MoT Supplement) defines the return periods for the drainage design as follows:

Table 1: Return Periods

Hydraulic Item	Design Return Period
Gutters	5 years
Stormwater Inlets	5 years
Bridge Surface Runoff	10 years
Storm Sewers	10 years
Highway Ditches	25 years
Culverts	100 years

These criteria have been used for the design of drainage structures, with the exception of gutters and stormwater inlets. Notwithstanding MOT's normal design standard requirements related to gutters and stormwater inlets, these drainage systems elements have been designed to accommodate runoff from the 10 year return period event as specified in Schedule A of the Design/Build agreement.

2.2 Design Flow Determination

All of the drainage areas contributing runoff to culverts crossing the highway are smaller than 10 km^2, therefore the Rational Method was used to determine the peak discharges for each culvert as specified in the MOT Supplement. The general form of the equation is:

$$Q_p = C\, i\, A/360$$

where: Q_p is the peak instantaneous discharge in m^3/s
C is a runoff coefficient
i is the rainfall intensity in mm/hour
A is the drainage area in ha

Each of these parameters is discussed in more detail in the following paragraphs.

2.3 Runoff Coefficients (C)

Section 1020.02 of the MoT Supplement refers to the *RTAC Drainage Manual, Volume 1* in order to define runoff coefficients to use in highway drainage designs. Based on this reference, runoff coefficients are expected to be in the range of 0.25 to 0.35 for the forested hillside conditions. The more conservative value of 0.35 has been used in the calculations.

For smaller catchment areas, where the effect of pavement drainage has a greater influence on the estimated peak flow rates, a runoff coefficient of 0.95 is used for the paved areas, 0.35 for forested areas, and 0.55 areas that are mixed with forested land and residential development. Each of these coefficients is proportioned to calculate a combined runoff coefficient for the area of interest.

The runoff coefficient values are comparable to those values recommended in the Town of Golden stormwater management report.

2.4 Rainfall Data (i)

Design rainfall intensities for drainage design were obtained from the Atmospheric Environment Services (AES) rainfall intensity-duration-frequency data for Golden BC. Rainfall intensities are calculated using the form of equation:

$$i = A\, t^{-B}$$

where: i is the rainfall intensity in mm/hour
t is time of the storm event in hours
A and B are parameters defined by AES

Parameters A and B are identified in Table 2, which follows, for storm events with varying durations.

Table 2: Rainfall Data

Storm Duration	2 year	5 year	10 year	25 year	50 year	100 year
A	8.5	11.3	13.1	15.5	17.2	18.9
B	0.666	0.687	0.696	0.703	0.707	0.711

2.5 Catchment Areas (A)

Catchment areas have been defined for each of the watercourses and/or drainage flow routes crossing the highway. The locations of existing culverts were identified by UMA Engineering in the Preliminary Drainage Design Report dated October 2007, and were confirmed with field visits during the bid preparation stage. TRIM 20 m contour mapping from the Surveys and Resource Mapping Branch and National Topographic Survey (NTS) maps were used to delineate drainage catchment areas. Drainage catchment areas for the proposed highway cross culverts with contributing areas greater than 10 ha are shown on Figure 1.

2.6 Determination of Average Slope

In order to determine the design rainfall intensity (i), it is necessary to first calculate the time of concentration (T_c) of the contributing basin. The average slope of each catchment was used in the determination the T_c. As per MoT Supplement Section 1020.03 for small catchments, slope was calculated by:

$$s = \frac{h_1 - h_2}{L}$$

where: s is the average catchment (or stream) slope, in m/m
h_1 is the highest elevation along the flow path, in m
h_2 is the lowest elevation along the flow path, in m
L is the flow path horizontal length, in m

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GOLDEN HILL TO WEST PORTAL

DATE: FEBRUARY 2010

MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

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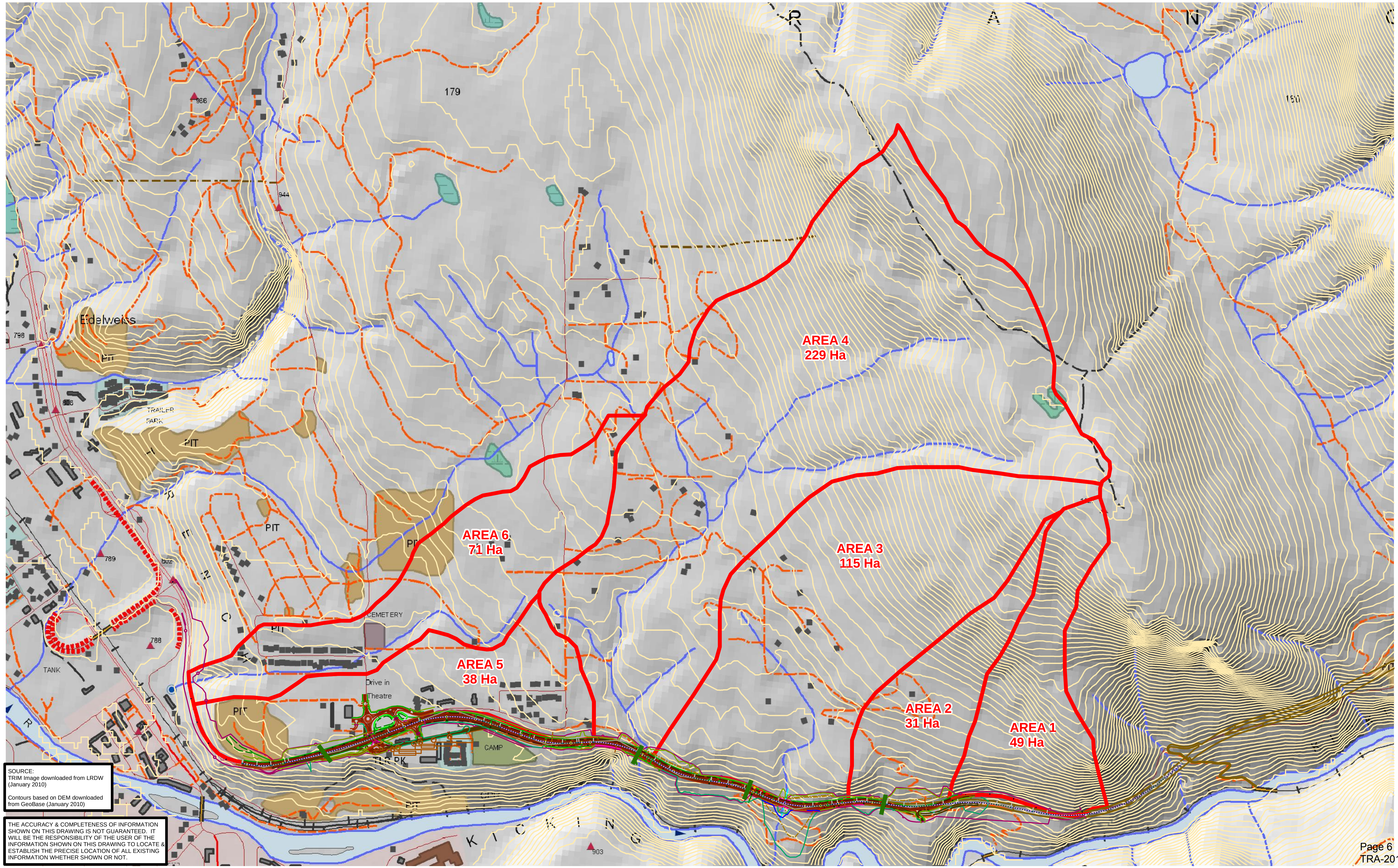
Legend

- Catchment Boundary
- Proposed Culvert
- Contours (10m)



CATCHMENTS OVERVIEW

FIGURE
1

For those catchment areas where the longest flow path was not immediately evident, multiple cases were examined and the time of concentration was calculated using the shortest flow path as it would produce the most conservative value.

2.7 Determination of Time of Concentration (t_c)

The time of concentration for each basin, t_c, was calculated using the Hathaway Formula, as described in Section 1020.04 of the MOT Supplement. The calculated values were checked against the values determined using Figure 1020.B. In all cases, and values were comparable.

3.0 BASIS FOR HYDRAULIC DESIGN

3.1 Basic Design Criteria for New Culverts

Consistent with MoT Supplement Section 1040 and 1050, the following design criteria have been applied to new culverts:

- CSP under a highway main road minimum diameter of 600mm
- CSP under frontage road minimum diameter of 500 mm
- CSP under driveways minimum diameter of 400 mm
- Headwater depth to culvert diameter ratio $HW/D \leq 1$
- Minimum profile slope of 0.5%
- Culvert slope to be set to ensure critical slope is avoided
- Culvert ends to project from fill

All culverts crossing the proposed TCH alignment east of Sta 802+300 are designed for the passage of small animals. Culvert ends extend beyond the wildlife fencing in order to allow access for the small animals.

3.2 Culvert Design

Table 3 provides data describing the culverts proposed for the upgraded highway. Data includes the catchment area, and equivalent run-off coefficient (c), t_c, and Q_{100} for each culvert. The existing culverts capacities were not assessed, since all culverts are proposed in new locations, and existing culverts will be removed and replaced with new culverts. The required culvert size was determined using CulvertMaster, the calculated design flow, criteria of $HW/D \leq 1$, and a profile slope of 1-2%. The culvert sizes were checked using the culvert design nomographs from the MoT Supplement.

3.3 Catchbasins

As per MoT Supplement Section 1050, median catchbasins have been spaced to meet the ponding width criteria for Undepressed BC Freeway Grates. A design rainfall intensity of 73.8 mm/hr has been used based on a t_c of 5 minutes (in accordance with MoT Supplement Section 1050.02) based on a 10-year return period storm.

Catchbasin spacing calculations are shown on Table 4.

3.4 Spillways and Curb

As per MoT Supplement Section 1050.05, integral asphalt drainage curbs and spillways will be included in the design for areas where:

- Fill height exceeds 3m high.
- Longitudinal grade is greater than 4%
- Any super-elevated pavement wider than 15m.

Spillways will also be placed where there is concrete roadside barrier (CRB) which concentrates runoff along the road edge. Spillway spacing was calculated to meet the ponding width criteria as specified in the Spreadsheet/Calculator Method detailed in MoT Supplement Section 1050. Spillways will consist of either a depressed opening in the asphalt drainage curb or combination concrete drainage barrier/spillway with either a lined rock-armoured channel or High Density Polyethylene Pipe down the fill slope. Spillways will be constructed in accordance with MOT Standard Specification Drawing SP 504-2.

Spillway spacing calculations are shown on Table 5. In cases where the calculated spillway spacing exceeds 150 meters, which is the recommended maximum spacing noted in the MOT supplement, the 150 meter value is used.

Table 3 - Catchment Areas and Culvert Sizing

Culvert Location		Catchment Hydrology											Culvert Data			Comments
Culvert No.	Station	Pervious Area	Pervious C	Pavement Area	Pavement C	Total Area	Equivalent C	Flow Length	Slope	T_c	100-Year Rainfall intensity	Q_{100}	Diameter	Length	Q @ HW/D=1	
		(ha)		(ha)				(m)	(m/m)	(hrs)	(mm/hr)	(m3/s)	(mm)	(m)	(m3/s)	
1	801+155	5.5	0.55	1.9	0.95	7.4	0.65	800	0.01	1.12	17.4	0.234	600	34.4	0.30	
2	802+510	228	0.35	0.4	0.95	228.4	0.35	2500	0.15	1.01	18.7	4.167	2000	54.0	6.0	
3	803+090	116	0.35	2.3	0.95	118.3	0.36	2200	0.27	0.83	21.5	2.558	1400	35.7	2.6	
4	803+150	10	0.35	0.5	0.95	10.5	0.38	1300	0.44	0.58	27.8	0.307	800	43.3	0.64	Animal overpass, parallel to highway
5	803+590	32	0.35	0.3	0.95	32.3	0.36	1300	0.44	0.58	27.8	0.887	900	31.7	0.90	
6	6+160	5	0.55	0.7	0.95	5.7	0.60	600	0.02	0.88	20.7	0.196	500	22.2	0.20	Driveway entrance, East side of GDUR
7	6+160	2	0.55	0.4	0.95	1.9	0.63	100	0.01	0.43	34.7	0.116	500	26.8	0.20	Driveway entrance, West side of GDUR
8	6+173	2	0.55	0.7	0.95	2.2	0.68	100	0.01	0.43	34.7	0.144	500	22.1	0.20	
9	6+290	26	0.55	3.5	0.95	29.5	0.60	600	0.02	0.83	21.5	1.052	2 x 700	15.5	1.1	Use double 700 dia. CSP
10	6+320	3	0.55	1.4	0.95	4.4	0.68	800	0.01	1.12	17.4	0.144	500	18.8	0.20	
11	6+395	1	0.55	0.7	0.95	1.7	0.71	800	0.01	1.12	17.4	0.059	500	21.9	0.20	
12	6+415 (N)	0.2	0.55	0.7	0.95	0.9	0.86	50	0.01	0.31	43.7	0.094	400	17.4	0.20	Driveway entrance, North side of Golden View
13	6+415 (S)	0.3	0.55	0.7	0.95	1.0	0.83	50	0.01	0.31	43.7	0.101	400	17.4	0.20	Driveway entrance, South side of Golden View
14	6+440 (N)	0.2	0.55	0.7	0.95	0.9	0.86	50	0.01	0.31	43.7	0.094	400	17.4	0.20	Driveway entrance, North side of Golden View
15	6+480 (S)	0.3	0.55	0.6	0.95	0.9	0.82	50	0.01	0.31	43.7	0.089	400	17.4	0.20	Driveway entrance, South side of Golden View
16	6+505 (S)	0.3	0.55	0.5	0.95	0.8	0.80	50	0.01	0.31	43.7	0.078	400	17.4	0.20	Driveway entrance, South side of Golden View
17	6+570 (S)	0.2	0.55	0.4	0.95	0.6	0.82	50	0.01	0.31	43.7	0.059	400	17.4	0.20	Driveway entrance, South side of Golden View
18	6+630 (S)	0.2	0.55	0.3	0.95	0.5	0.79	50	0.01	0.31	43.7	0.048	400	17.4	0.20	Driveway entrance, South side of Golden View
19	6+630 (N)	0.2	0.55	0.3	0.95	0.5	0.79	50	0.01	0.31	43.7	0.048	400	17.4	0.20	Driveway entrance, North side of Golden View
20	7+110	25	0.55	2.9	0.95	27.5	0.59	600	0.02	0.83	21.5	0.972	1000	27.3	1.1	
21	7+260	18	0.55	0.3	0.95	18.6	0.56	600	0.02	0.88	20.7	0.594	800	18.9	0.64	Major flow route crosses driveway entrance
22	8+030	1	0.55	1.3	0.95	2.7	0.74	800	0.02	0.95	19.5	0.109	500	33.1	0.20	
23	9+060	2	0.55	0.5	0.95	2.1	0.65	800	0.01	1.12	17.4	0.066	500	25.0	0.20	

Table 4 - Catchbasin Spacing

		Input Data								Calculation Data									Results				
Rounded Sta. for drawings	Calculated Sta.	Paved Shoulder Width	Grade	Crossfall	Manning's Roughness Coefficient	Rainfall Intensity tc=5min	Pavement Width	Runoff Coefficient	Inlet Catchment Width	Design Ponding With	Crossfall-longitudinal Grade ratio	Effective Inlet Catchment Width	Max Depth of Gutter Flow	Gutter flow	Max depth of flow outside catchment	Overflow	Intercepted Flow	Inlet Efficiency	Velocity	Initial CB	Contributing Area (m2)	Consecutive CB	Contributing Area (m2)
	802+430	SW	Sy	Sx	n	i	width	Cw	w	PW	Rs	Weff	Yo	Qo	Yover	Qover	Qint	Eff	v	CBone		CBtwo	
802+300	802+298	1.7	0.015	0.049	0.016	73.8	11.8	0.95	0.375	1.20	3.27	0.413	0.059	0.030	0.039	0.010	0.020	67.5	1.147	132.0	1558	89.1	1052
802+275	802+272	1.4	0.025	0.02	0.016	73.8	11.8	0.95	0.375	1.20	0.80	0.413	0.024	0.009	0.016	0.003	0.006	67.5	0.812	38.2	450	25.8	304
802+255	802+256	1.4	0.025	0.015	0.016	73.8	11.8	0.95	0.375	1.20	0.60	0.413	0.018	0.005	0.012	0.002	0.004	67.5	0.670	23.6	279	15.9	188
	802+250																						
802+220	802+222	1.7	0.03	0.02	0.016	73.8	11.8	0.95	0.375	1.20	0.67	0.413	0.024	0.010	0.016	0.003	0.006	67.5	0.890	41.8	493	28.2	333
802+135	802+134	1.7	0.035	0.04	0.016	73.8	13	0.95	0.375	1.20	1.14	0.413	0.048	0.033	0.032	0.011	0.022	67.5	1.529	130.4	1696	88.1	1145
802+075	802+074	1.7	0.0425	0.03	0.016	73.8	13	0.95	0.375	1.20	0.71	0.413	0.036	0.023	0.024	0.007	0.015	67.5	1.389	88.9	1156	60.0	780
802+045	802+043	1.7	0.0425	0.02	0.016	73.8	13	0.95	0.375	1.20	0.47	0.413	0.024	0.011	0.016	0.004	0.008	67.5	1.059	45.2	587	30.5	396
802+010	802+013	1.7	0.0425	0.02	0.016	73.8	13	0.95	0.375	1.20	0.47	0.413	0.024	0.011	0.016	0.004	0.008	67.5	1.059	45.2	587	30.5	396
	801+910																						
801+880	801+880	1.7	0.03	0.02	0.016	73.8	11	0.95	0.375	1.20	0.67	0.413	0.024	0.010	0.016	0.003	0.006	67.5	0.890	44.8	493	30.3	333
801+825	801+825	1.7	0.03	0.03	0.016	73.8	12	0.95	0.375	1.20	1.00	0.413	0.036	0.019	0.024	0.006	0.013	67.5	1.167	80.9	971	54.6	656
801+725	801+724	1.7	0.027	0.047	0.016	73.8	13	0.95	0.375	1.20	1.74	0.413	0.056	0.038	0.037	0.012	0.026	67.5	1.496	150.0	1950	101.3	1316
801+635	801+635	1.7	0.021	0.047	0.016	73.8	13	0.95	0.375	1.20	2.24	0.413	0.056	0.033	0.037	0.011	0.023	67.5	1.319	132.3	1719	89.3	1161
801+560	801+545	1.7	0.021	0.047	0.016	73.8	13	0.95	0.375	1.20	2.24	0.413	0.056	0.033	0.037	0.011	0.023	67.5	1.319	132.3	1719	89.3	1161
801+510	801+503	1.7	0.021	0.03	0.016	73.8	13	0.95	0.375	1.20	1.43	0.413	0.036	0.016	0.024	0.005	0.011	67.5	0.977	62.5	812	42.2	549
	801+035																						
800+985	800+992	1.0	0.06	0.02	0.016	73.8	11	0.95	0.375	1.20	0.33	0.413	0.024	0.014	0.016	0.004	0.009	67.5	1.258	63.4	698	42.8	471
800+835	800+842	1.0	0.06	0.04	0.016	73.8	11	0.95	0.375	1.20	0.67	0.413	0.048	0.043	0.032	0.014	0.028	64.3	2.002	242.2	2664	155.7	1712
	802+430																						
802+510	802+512	1.7	0.01	0.04	0.016	73.8	11	0.95	0.375	1.20	4.00	0.413	0.048	0.018	0.032	0.006	0.012	67.5	0.817	82.4	906	55.6	612
802+530	802+535	1.7	0.016	0.02	0.016	73.8	11	0.95	0.375	1.20	1.25	0.413	0.024	0.007	0.016	0.002	0.005	67.5	0.650	32.8	360	22.1	243
802+550	802+559	1.7	0.02	0.02	0.016	73.8	11	0.95	0.375	1.20	1.00	0.413	0.024	0.008	0.016	0.003	0.005	67.5	0.726	36.6	403	24.7	272
802+570	802+579	1.7	0.02	0.01	0.016	73.8	11	0.95	0.375	1.20	0.50	0.413	0.012	0.002	0.008	0.001	0.002	67.5	0.457	11.5	127	7.8	85
	802+580																						
802+605	802+602	1.7	0.0225	0.02	0.016	73.8	13	0.95	0.375	1.20	0.89	0.413	0.024	0.008	0.016	0.003	0.006	67.5	0.770	32.9	427	22.2	288
802+670	802+657	1.7	0.03	0.03	0.016	73.8	12	0.95	0.375	1.20	1.00	0.413	0.036	0.019	0.024	0.006	0.013	67.5	1.167	80.9	971	54.6	656
802+810	802+807	1.7	0.04	0.05	0.016	73.8	11	0.95	0.375	1.20	1.25	0.413	0.060	0.051	0.039	0.017	0.035	67.5	1.898	239.2	2631	161.5	1777
802+825	802+827	1.7	0.04	0.01	0.016	73.8	11	0.95	0.375	1.20	0.25	0.413	0.012	0.003	0.008	0.001	0.002	67.5	0.646	16.3	179	11.0	121
	802+830																						
802+860	802+860	1.7	0.03	0.02	0.016	73.8	11	0.95	0.375	1.20	0.67	0.413	0.024	0.010	0.016	0.003	0.006	67.5	0.890	44.8	493	30.3	333
802+910	802+909	1.7	0.02	0.03	0.016	73.8	11	0.95	0.375	1.20	1.50	0.413	0.036	0.015	0.024	0.005	0.010	67.5	0.953	72.1	793	48.7	535
802+990	802+990	1.7	0.01	0.05	0.016	73.8	11	0.95	0.375	1.20	5.00	0.413	0.060	0.026	0.039	0.008	0.017	67.5	0.949	119.6	1316	80.8	888
803+010	803+070	1.7	0.01	0.05	0.016	73.8	11	0.95	0.375	1.20	5.00	0.413	0.060	0.026	0.039	0.008	0.017	67.5	0.949	119.6	1316	80.8	888
	803+410																						
803+390	803+392	1.0	0.005	0.02	0.016	73.8	11	0.95	0.375	1.20	4.00	0.413	0.024	0.004	0.016	0.001	0.003	67.5	0.363	18.3	201	12.4	136
803+375	803+372	1.0	0.007	0.02	0.016	73.8	11	0.95	0.375	1.20	2.86	0.413	0.024	0.005	0.016	0.002	0.003	67.5	0.430	21.7	238	14.6	161
	803+350																						
803+330	803+330	1.7	0.008	0.02	0.016	73.8	13	0.95	0.375	1.20	2.50	0.413	0.024	0.005	0.016	0.002	0.003	67.5	0.459	19.6	255	13.2	172
803+300	803+304	1.7	0.008	0.03	0.016	73.8	13	0.95	0.375	1.20	3.75	0.413	0.036	0.010	0.024	0.003	0.007	67.5	0.603	38.6	501	26.0	339
803+250	803+251	1.7	0.009	0.04	0.016	73.8	11	0.95	0.375	1.20	4.44	0.413	0.048	0.017	0.032	0.005	0.011	67.5	0.775	78.2	860	52.8	581
803+130	803+130	1.7	0.011	0.06	0.016	73.8	11	0.95	0.375	1.20	5.45	0.450	0.072	0.036	0.045	0.010	0.026	71.5	1.125	170.1	1871	121.6	1338
803+090	803+099	1.7	0.008	0.03	0.016	73.8	11	0.95	0.375	1.20	3.75	0.413	0.036	0.010	0.024	0.003	0.007	67.5	0.603	45.6	501	30.8	339
803+055	803+083	1.7	0.008	0.02	0.016	73.8	11	0.95	0.375	1.20	2.50	0.413	0.024	0.005	0.016	0.002	0.003	67.5	0.459	23.2	255	15.6	172
	803+050																						
803+025	803+030	1.4	0.005	0.02	0.016	73.8	11	0.95	0.375	1.20	4.00	0.413	0.024	0.004	0.016	0.001	0.003	67.5	0.363	18.3		12.4	
	803+410																						
803+440	803+436	1.0	0.005	0.03	0.016	73.8	11	0.95	0.375	1.20	6.00	0.450	0.036	0.008	0.023	0.002	0.006	71.5	0.477	36.0		25.8	
803+515	803+543	1.0	0.008	0.05	0.016	73.8	11	0.95	0.375	1.20	6.25	0.450	0.060	0.023	0.038	0.007	0.016	71.5	0.849	107.0		76.5	

Table 5 - Spillway Spacing

		Input Data								Calculation Data								Results				
Rounded Sta. for drawings	**Calculated Sta.**	Paved Shoulder Width	Grade	Crossfall	Manning's Roughness Coefficient	Rainfall Intensity tc=5min	Pavement Width	Runoff Coefficient	Inlet Catchment Width	Design Ponding With	Crossfall-longitudinal Grade ratio	Effective Inlet Catchment Width	Max Depth of Gutter Flow	Gutter flow	Max depth of flow outside catchment	Overflow	Intercepted Flow	Velocity	Initial CB	Contributing Area (m2)	Consecutive CB	Contributing Area (m2)
		SW	**Sy**	**Sx**	**n**	**i**	**width**	**Cw**	**w**	**PW**	**Rs**	**Weff**	**Yo**	**Qo**	**Yover**	**Qover**	**Qint**	**v**	**CBone**		**CBtwo**	
	802+430																					
802+255	802+280	2.5	0.015	0.049	0.016	73.8	11.8	0.95	0.6	1.63	3.3	0.66	0.080	0.068	0.047	0.017	0.051	1.405	296.6	1770	222.8	1770
	802+250																					
802+200	802+179	2.5	0.03	0.02	0.016	73.8	11.8	0.95	0.6	1.63	0.7	0.66	0.033	0.022	0.019	0.005	0.016	1.090	93.9	1108	70.6	833
	802+003																					
801+960	801+965	1.5	0.04	0.02	0.016	73.5	13.4	0.95	0.6	1.20	0.5	0.66	0.024	0.011	0.011	0.001	0.010	1.027	42.7	572	37.6	504
801+930	801+930	1.5	0.035	0.02	0.016	73.8	13.4	0.95	0.6	1.20	0.6	0.66	0.024	0.010	0.011	0.001	0.009	0.961	39.8	533	35.0	470
801+900	801+897	1.5	0.032	0.02	0.016	73.8	13.4	0.95	0.6	1.20	0.6	0.66	0.024	0.010	0.011	0.001	0.009	0.919	38.0	509	33.5	449
801+865	801+864	1.5	0.03	0.02	0.016	73.8	13.4	0.95	0.6	1.20	0.7	0.66	0.024	0.010	0.011	0.001	0.008	0.890	36.8	493	32.4	435
801+740	801+739	1.5	0.026	0.047	0.016	73.8	13.4	0.95	0.6	1.20	1.8	0.66	0.056	0.037	0.025	0.004	0.033	1.468	142.8	1913	125.8	1686
801+625	801+625	1.5	0.021	0.047	0.016	73.8	13.4	0.95	0.6	1.20	2.2	0.66	0.056	0.033	0.025	0.004	0.030	1.319	128.3	1719	113.1	1515
801+565	801+512	1.5	0.021	0.047	0.016	73.8	13.4	0.95	0.6	1.20	2.2	0.66	0.056	0.033	0.025	0.004	0.030	1.319	128.3	1719	113.1	1515
	801+470																					
801+425	801+424	1.5	0.06	0.02	0.016	73.8	13.4	0.95	0.6	1.20	0.3	0.66	0.024	0.014	0.011	0.002	0.012	1.258	52.1	698	45.9	615
801+380	801+378	1.5	0.06	0.02	0.016	73.8	13.4	0.95	0.6	1.20	0.3	0.66	0.024	0.014	0.011	0.002	0.012	1.258	52.1	698	45.9	615
801+330	801+332	1.5	0.06	0.02	0.016	73.8	13.4	0.95	0.6	1.20	0.3	0.66	0.024	0.014	0.011	0.002	0.012	1.258	52.1	698	45.9	615
801+290	801+286	1.5	0.06	0.02	0.016	73.8	13.4	0.95	0.6	1.20	0.3	0.66	0.024	0.014	0.011	0.002	0.012	1.258	52.1	698	45.9	615
800+240	801+241	1.5	0.06	0.02	0.016	73.8	13.4	0.95	0.6	1.20	0.3	0.66	0.024	0.014	0.011	0.002	0.012	1.258	52.1	698	45.9	615
801+140	801+141	2.5	0.06	0.02	0.016	73.8	11.8	0.95	0.6	1.63	0.3	0.66	0.033	0.031	0.019	0.008	0.023	1.541	132.8	1568	99.8	1178
801+000	800+991	2.5	0.07	0.054	0.016	73.8	11.8	0.95	0.6	1.63	0.8	0.66	0.088	0.173	0.052	0.043	0.117	3.239	904.4	1770	612.0	1770
800+840	800+841	2.5	0.07	0.054	0.016	73.8	11.8	0.95	0.6	1.63	0.8	0.66	0.088	0.173	0.052	0.043	0.117	3.239	904.4	1770	612.0	1770
	801+390																					
801+350	801+344	1.5	0.06	0.02	0.016	73.8	13.4	0.95	0.6	1.20	0.3	0.66	0.024	0.014	0.011	0.002	0.012	1.258	52.1	698	45.9	615
801+300	801+194	2.5	0.06	0.02	0.016	73.8	13.4	0.95	0.6	1.63	0.3	0.66	0.033	0.031	0.019	0.008	0.023	1.541	117.0	1568	87.9	1178
	801+140																					
801+035	801+040	2.5	0.06	0.02	0.016	73.8	11.8	0.95	0.6	1.63	0.3	0.66	0.033	0.031	0.019	0.008	0.023	1.541	132.8	1568	99.8	1178
	802+580																					
802+640	802+641	2.5	0.0225	0.02	0.016	73.8	11.8	0.95	0.6	1.63	0.9	0.66	0.033	0.019	0.019	0.005	0.014	0.944	81.3	960	61.1	721
802+790	802+791	2.5	0.02	0.05	0.016	73.8	11.8	0.95	0.6	1.63	2.5	0.66	0.081	0.081	0.048	0.020	0.061	1.644	354.3	1770	266.2	1770
802+875	802+873	2.5	0.04	0.02	0.016	73.8	11.8	0.95	0.6	1.63	0.5	0.66	0.033	0.025	0.019	0.006	0.019	1.259	108.5	1280	81.5	962
802+825	802+954	2.5	0.04	0.02	0.016	73.8	11.8	0.95	0.6	1.63	0.5	0.66	0.033	0.025	0.019	0.006	0.019	1.259	108.5	1280	81.5	962
	802+830																					
802+890	802+888	2.5	0.02	0.02	0.016	73.8	11.8	0.95	0.6	1.63	1.0	0.66	0.033	0.018	0.019	0.004	0.013	0.890	76.7	905	57.6	680
803+010	803+038	2.5	0.01	0.05	0.016	73.8	11.8	0.95	0.6	1.63	5.0	0.66	0.081	0.058	0.048	0.014	0.043	1.163	250.5	1770	188.2	1770
	803+410																					
803+375	803+380	2.5	0.003	0.02	0.016	73.8	11.8	0.95	0.6	1.63	6.7	0.72	0.033	0.007	0.018	0.001	0.005	0.345	29.7	351	23.5	277
803+355	803+355	2.5	0.004	0.02	0.016	73.8	11.8	0.95	0.6	1.63	5.0	0.66	0.033	0.008	0.019	0.002	0.006	0.398	34.3	405	25.8	304
	803+370																					
803+345	803+347	2.5	0.003	0.02	0.016	73.8	11.8	0.95	0.6	1.63	6.7	0.72	0.033	0.007	0.018	0.001	0.005	0.345	29.7	351	23.5	277
803+320	803+318	2.5	0.005	0.02	0.016	73.8	11.8	0.95	0.6	1.63	4.0	0.66	0.033	0.009	0.019	0.002	0.007	0.445	38.3	452	28.8	340
803+250	803+251	2.5	0.007	0.03	0.016	73.8	11.8	0.95	0.6	1.63	4.3	0.66	0.049	0.021	0.029	0.005	0.015	0.691	89.3	1054	67.1	792
803+100	803+101	2.5	0.01	0.06	0.016	73.8	11.8	0.95	0.6	1.63	6.0	0.72	0.098	0.078	0.054	0.016	0.062	1.314	339.7	1770	268.5	1770
	803+410																					
803+470	803+468	2.5	0.003	0.03	0.016	73.8	11.8	0.95	0.6	1.63	10.0	0.72	0.049	0.013	0.027	0.003	0.011	0.452	58.5	690	46.2	545
803+570	803+618	2.5	0.004	0.05	0.016	73.8	11.8	0.95	0.6	1.63	12.5	0.78	0.081	0.036	0.042	0.006	0.030	0.735	158.4	1770	130.8	1770
	803+788																					
803+850	803+846	2.5	0.02	0.02	0.016	73.8	11.8	0.95	0.6	1.63	1.0	0.66	0.033	0.018	0.019	0.004	0.013	0.890	76.7	905	57.6	680

3.5 Ditches and Channels

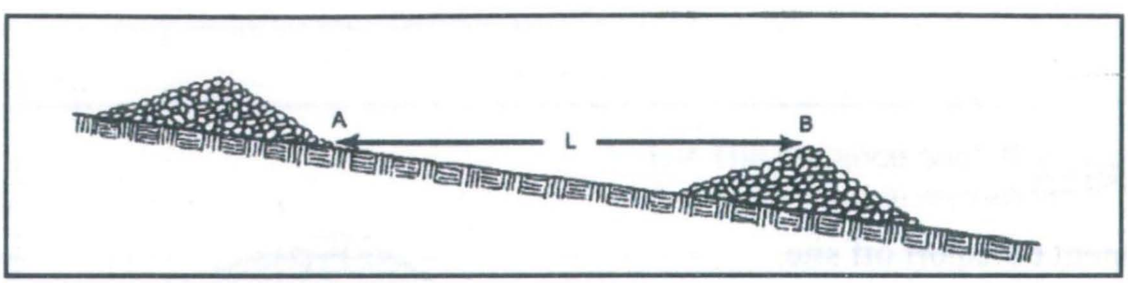
Critical segments of longitudinal highway ditches have been designed to convey the specified design flow while protecting the highway structure from saturation. Furthermore, in locations where ditch grades are relatively steep, and peak design flows are relatively large, estimated maximum velocities have been checked against the permissible velocities for unlined channels to determine whether additional measures beyond grass lining are required to prevent erosion under design conditions. The details of all critical ditches and channels are shown on Table 6.

Most of the ditches have been designed to convey runoff from the 25 year event, as specified in MOT guidelines. However, the North and South ditches between 800+810 and 801+500 are sized for Q_{100}, rather than Q_{25}, as these ditches will be required to convey the overflow from the detention ponds under emergency conditions.

All roadside ditches, except as noted in the following paragraph, were found to be adequate with coarse gravel lining, which can be achieved with the native materials on site.

The grade of the ditch on the north side of the highway between the project limit at station 800+810 and the emergency overflow of the detention pond at about 801+430 varies from 6% to 8%, and may convey design flows of as much as 1.1 m^3/s under emergency conditions. In order to check the potential for erosion for this ditch segment, rock check dams will be placed in the ditch. The check dams will be a minimum of 0.3 m and a maximum of 0.5 m in height at their center, and will be spaced such that the crest of the downstream check dam is at the same height as the toe of the upstream check dam as shown in Figure 2. This spacing will be between 4 and 5 m

Figure 2 – Rock Check Dam Spacing



Because of the larger flow rates and steeper channel grades, the channels downstream of the culverts at station 802+500 and 803+150 are to be protected with 1000 mm thick 250 kg class rip rap.

4.0 DETENTION POND

Due to concerns about the potential adverse impact to the environment within the Town of Golden, concentrated drainage from the highway within the Town will be directed to a storm water detention pond which is intended to both reduce peak flow rates and remove suspended solids from the highway runoff. This facility has been designed to control post construction discharge to the 10 year predevelopment flow rate. Following storm events, the facility will drain completely through a combination of ground infiltration and a regulated discharge control structure, and will not contain standing water under normal conditions.

The total drainage area upstream of the highway project that contributes runoff to the Town of Golden is approximately 33.5 ha. The vast majority of this area consists of development within the town itself, and not just the existing highway or the proposed improvements. In fact, of the total 33.5 ha of contributing drainage area, only about 6 ha is related to the highway.

The contributing area can be further divided into approximately 28 ha situated on the north side of the highway, and 5.5 ha situated on the south side of the highway. At present, the 28 ha to the north of the highway drains down the ditch along the north side of the highway.

Furthermore, the vast majority of the 5.5 ha of contributing area south of the highway drains over the steep bank and onto CP Rail property. At present, this causes considerable erosion of the steep slope, as well as nuisance for the CP Rail property. Following the construction of the highway improvements, the drainage system for much of this area, particularly the impervious roads, will be reconfigured so that it no longer drains to the CP Rail lands, and will be instead contained within the highway right of way.

Under pre-development conditions, which are assumed to be those conditions which currently exist, including development within the Town of Golden, the peak flow rates were estimate for both the 10 year and 100 year return period events using the rational method. The impervious coefficient was estimated to be C=0.25 for these conditions, and t_c was estimated to be 60 minutes for these conditions, which result in i_{10} =14 mm/hr and i_{100} = 19 mm/hr. The result peak pre-development flow rates are Q_{10} = 0.326 m^3/s and Q_{100} = 0.553 m^3/s.

Table 6 - Catchment Areas for Ditches and Channels

Channel Location			Catchment Hydrology											Channel						
From	To	Side of Highway	Pervious Area	Pervious C	Pavement Area	Pavement C	Total Area	Equivalent C	Flow Length	Slope	T_c	25-Year Rainfall intensity	Q_{25}	Left Side-slope	Right Side-slope	Bottom Width	Slope	Manning's "n"	Velocity	Depth of Flow
			(ha)		(ha)				(m)	(m/m)	(hrs)	(mm/hr)	(m3/s)			(m)	(m/m)		(m/s)	(m)
203+740	203+560	north	6	0.55	0.4	0.95	6.40	0.58	500	0.25	0.42	28.3	0.289	3	4	1	0.0325	0.025	1.524	0.13
203+400	203+560	north	10	0.55	0.5	0.95	10.50	0.57	500	0.25	0.42	28.3	0.470	3	4	1	0.01	0.025	1.155	0.23
803+400	803+150	north	8	0.55	0.4	0.95	8.40	0.57	500	0.25	0.42	28.3	0.376	3	4	1	0.015	0.025	1.237	0.18
802+520	803+080	north	15	0.55	1.2	0.95	16.20	0.58	800	0.25	0.53	24.3	0.633	3	4	1	0.04	0.025	2.081	0.19
802+400	801+540	north	4	0.55	0.9	0.95	4.90	0.62	150	0.05	0.35	32.3	0.274	3	4	1	0.0425	0.025	1.667	0.12
*801+500	801+160	south	5.5	0.55	1.9	0.95	7.40	0.65	500	0.02	0.77	22.8	0.306	3	4	1	0.06	0.025	1.981	0.12
*801+440	801+150	north	26	0.55	3.5	0.95	29.50	0.60	600	0.02	0.83	21.5	1.052	3	4	1	0.06	0.025	2.761	0.22
*801+150	800+620	north	32	0.55	5.4	0.95	36.90	0.61	1000	0.02	1.06	18.1	1.131	3	4	1	0.06	0.025	2.829	0.23
*Culvert at 802+500			228	0.35	0.4	0.95	228.40	0.35	2500	0.15	1.01	18.7	4.167	3	3	1	0.5	0.04	6.299	0.33
*Culvert at 803+150			116	0.35	2.3	0.95	118.30	0.36	2200	0.27	0.83	21.5	2.558	3	3	1	0.5	0.04	5.531	0.26

* These channel segments have been assessed based on 100 year event as they are the major drainage routes to detention ponds

Under post development conditions, which are assumed to be full highway development, 28 ha of the total 33.5 ha contributing area can be captured by the proposed detention pond. This pond will provide a detention volume of about 4,950 m^3 based on the configuration of the site. The detention pond volume was determined on the basis of establishing the maximum available pond volume in areas that are suitable for this purpose, and available for this purpose. While several sites were identified, some were not available, while others were deemed unsuitable because of their location adjacent to steep slopes.

Furthermore, the infiltration capacity of the site soils at the detention pond site were tested by Klohn Crippen Berger using a falling head permeability test, and the results showed that the hydraulic conductivity of the native soils is between 1.2 and 1.9 x 10^{-4} m/s. The average value was calculated to be 1.55 x 10^{-4} m/s, and a factor of safety of 2 was applied to result in a design value of 0.75 x 10^{-4} m/s.

The pond bottom area, which is available for infiltration, has been calculated to be about 3,500 m^2. When the infiltration rate is applied over this area, it produces an estimated infiltration rate of about 0.27 m^3/s, which takes into consideration the factor of safety. Therefore, under normal conditions, the infiltration to ground from this pond will be about 0.27 m^3/s.

The modified rational method was then used to determine the required storage volume during the 100 year return period event for the 28 ha contributing area with an available storage volume of 4,950 m^3, and a release rate of 0.27 m^3/s. It was found that only 3,520 m^3 of storage would be required, and this also included a separate factor of safety of 1.5 which was applied to the pond volume. Therefore, during the 100 year return period design event, with 4,950 m^3 of storage available, and an infiltration to ground rate of 0.27 m^3/s, no runoff from the 28 ha area upstream of the detention pond will pass the pond. The modified rational method analysis is shown on Table 7.

By: CG
Date: 7-Jun-2010

Golden Hill, north side of highway

Area =	28	ha	
Avg C =	0.55		
Tc =	30	minutes	
Freq =	100	yr	
IDF a =	18.9		Rainfall intensity eq'n: I = a*t^b
IDF b =	-0.711		
Max release rate =	0.270	m3/s	pond infiltration rate
Safety Factor =	1.5		
Time step	10	minutes	
Pond Volume	3520	(including FS)	

Duration of Storm (D) (minutes)	Rainfall Intensity (I) (mm/hr)	Peak Flow (Qin) (m3/s)	Volume of Runoff (Vro) (m3)	Volume of Release (Qrel) (m3)	Required Storage Volume (Vstor) (m3)	
10	68	2.890	1734	324	1410	
20	41	1.766	2119	405	1714	
30	31	1.323	2381	486	1895	
40	25	1.079	2590	567	2023	
50	22	0.920	2760	648	2112	
60	19	0.809	2912	729	2183	
70	17	0.725	3045	810	2235	
80	15	0.659	3163	891	2272	
90	14	0.606	3272	972	2300	
100	13	0.562	3372	1053	2319	
110	12	0.525	3465	1134	2331	
120	12	0.494	3557	1215	2342	
130	11	0.467	3643	1296	2347	Maximum Storage Volume Req'd
140	10	0.443	3721	1377	2344	
150	10	0.421	3789	1458	2331	
160	9	0.403	3869	1539	2330	
170	9	0.386	3937	1620	2317	
180	9	0.370	3996	1701	2295	
190	8	0.356	4058	1782	2276	
200	8	0.343	4116	1863	2253	
210	8	0.332	4183	1944	2239	
220	8	0.321	4237	2025	2212	
230	7	0.311	4292	2106	2186	
240	7	0.302	4349	2187	2162	
250	7	0.293	4395	2268	2127	
260	7	0.285	4446	2349	2097	
270	6	0.277	4487	2430	2057	
280	6	0.270	4536	2511	2025	
290	6	0.264	4594	2592	2002	
300	6	0.257	4626	2673	1953	
310	6	0.252	4687	2754	1933	
320	6	0.246	4723	2835	1888	
330	6	0.241	4772	2916	1856	
340	6	0.236	4814	2997	1817	
350	5	0.231	4851	3078	1773	
360	5	0.226	4882	3159	1723	
370	5	0.222	4928	3240	1688	
380	5	0.218	4970	3321	1649	
390	5	0.214	5008	3402	1606	
400	5	0.210	5040	3483	1557	
410	5	0.206	5068	3564	1504	
420	5	0.203	5116	3645	1471	
430	5	0.199	5134	3726	1408	
440	5	0.196	5174	3807	1367	
450	5	0.193	5211	3888	1323	
460	4	0.190	5244	3969	1275	
470	4	0.187	5273	4050	1223	
480	4	0.184	5299	4131	1168	
490	4	0.182	5351	4212	1139	
500	4	0.179	5370	4293	1077	
510	4	0.177	5416	4374	1042	
520	4	0.174	5429	4455	974	
530	4	0.172	5470	4536	934	
540	4	0.170	5508	4617	891	
550	4	0.167	5511	4698	813	
560	4	0.165	5544	4779	765	
570	4	0.163	5575	4860	715	
580	4	0.161	5603	4941	662	
590	4	0.159	5629	5022	607	
600	4	0.157	5652	5103	549	

As noted, due to the relatively steep terrain in the project area, and restrictions on the use of several suitable detention pond locations, the detention ponds can be located only around the Golden Donald Upper Road bridge structure. Also, although the pond is divided into two parts so that it can fit within the space available, the two parts are hydraulically connected so that the two cells will operate as a single pond with only one outlet control structure. Furthermore, this detention pond is capable of capturing and controlling runoff from only 28 ha of the existing 33.5 ha contributing area. The remaining 5.5 ha area on the south side of the highway cannot be conveyed to a detention pond, however, because of the over control condition provided by the pond on the north side of the highway, the total runoff from the entire 33.5 ha area is controlled to approximately pre-development conditions during both the 10 year and 100 year return period events.

Also as noted, the 10 and 100 year return period event peak runoff rates during pre-development conditions were estimated to be $Q_{10} = 0.326\ m^3/s$ and $Q_{100} = 0.553\ m^3/s$. Furthermore, as already shown, during post development conditions, no runoff is expected to pass the detention pond during events up to and including the 100 year event for the 28 ha north of the highway. For the remaining 5.5 ha south of the highway, post development peak flow rates were calculated based on a time of concentration for the contributing area of only 15 minutes, which result in $i_{10} = 35$ mm/hr and $i_{100} = 51$ mm/hr. Furthermore, the coefficient of impermeability was estimated to be C=0.6 for this area under post development conditions. The estimated peak flow rates were calculated using the rational method as $Q_{10} = 0.321\ m^3/s$ and $Q_{100} = 0.584\ m^3/s$. Both of these values are comparable to the estimated pre-development peak flow rates for both the 10 and 100 year events. Therefore, the requirement to control discharges to the pre-development flow rate is met by over-controlling runoff from the north side of the highway, and not controlling runoff from the south side of the highway.

The detention pond has been designed to have a maximum ponding depth under design conditions of 1.5 meters. Pond side slopes will be a maximum of 3:1. These conditions are considered to be a normal safe condition for a detention pond which does not permanently retain water, and is dry under normal conditions.

In addition to controlling the quantity of runoff through storage, this pond will also provide benefits to storm water quality control, specifically the removal of sediment and suspended solids. The pond will need to be maintained on a regular basis, and accumulated sediment removed. The pond should be checked following significant storm events, and in the spring when most of the sand from road sanding operations will have made its way to the pond.

This pond can also be used as a sediment control pond during the construction period, and will be maintained by the contractor during that period. The final pond configuration, which is intended primarily for quantity control, will be one of the last steps in the construction process.

Other erosion and sediment control measures to be employed during construction, such as silt fencing and check dams, but the specific application of these will be determined as the phasing of construction is developed.

5.0 POTENTIAL FOR IMPACT ON CP RAIL DRAINAGE SYSTEMS

For some portions of the project, the CP Rail right-of-way is located downstream of the highway, and CP Rail has asked that an analysis be undertaken to examine whether there will be any effect on the drainage crossings of their rail lines as a result of the widening the highway. In order to address this concern, two analyses have been carried out to assess the effect of the existing drainage and the impact of the highway improvements.

The first analysis was a relatively simple one carried out using the rational method. The overall catchment areas contributing runoff to the highway will remain the same, but the paved area will increase by about 1.5 ha while the undeveloped area will decrease by this amount. The total catchment area above the highway is 379 ha, therefore the additional paved area only represents 0.5% of the total catchment area. This is expected to increase the runoff by about 20 L/s during the 100 year return period design storm event.

Also, because of the difference in timing of rainfall responses from impervious and pervious surfaces, it can be expected that the impervious surfaces, such as the highway pavement, will respond much more quickly than pervious surfaces, such as the forested woodland that makes up the majority of the overall drainage basin. As a result, during actual storm events, the peak discharge from the paved surfaces will have already been conveyed downstream before the peak discharge from the overall basin arrives at the railway crossings, and this will reduce the significance of the impact of the additional road surface further.

The simplified analysis of the existing and post construction conditions is provided in Appendix A to this report.

At the request of CP Rail, a second more detailed analysis that makes use of computer hydrologic modeling has been carried out. This analysis was carried out using the modeling software PC-SWMM, which uses the EPA SWMM engine, and details of the analysis are provided in this section.

The analysis examined three distinct areas within the project limits. The first area is the 1200 meter segment between station 801+000 and 802+200 as shown on Figure 3. Under existing conditions, runoff from much of this area on the south side of the highway makes its way to the railway right of way through numerous channels of various sizes, some which are causing erosion on the relatively steep embankment. Some of the locations which exhibit more significant erosion are noted on Figure 3, and an example of the existing condition at approximately station 801+100 is shown on Figure 4.

Figure 4 – Existing Highway Culvert at 801+100

For this segment, the post-construction condition will be such that a great deal of the areas that currently drain to the CP Rail right of way, including the widened highway, will be contained within the highway right of way and will no longer reach the railway. For this area, no further analysis has been done as the re-routing of the drainage system in this area will reduce the quantity of runoff reaching the railway compared to the current condition.

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Client/Project

GOLDEN HILL

EXISTING DRAINAGE PATH & EROSION

Scale	Date	Figure
nts	10-08-10	3

2276.0009.02

Title

SEGMENT 1

STA. 801+000 TO STA. 802+200

A small portion of this area does currently drain to a 600 mm diameter CSP culvert within the CP Rail right of way at the location shown on Figure 3, and will continue to do so in the future. However, since the total area draining to this culvert will be less following the construction of the highway than under current conditions, the capacity of this culvert was not assessed. It should be noted that during an inspection of the existing culverts along the railway right of way, this existing culvert was found to be in poor condition and in need of maintenance. This culvert is shown in Figure 5.

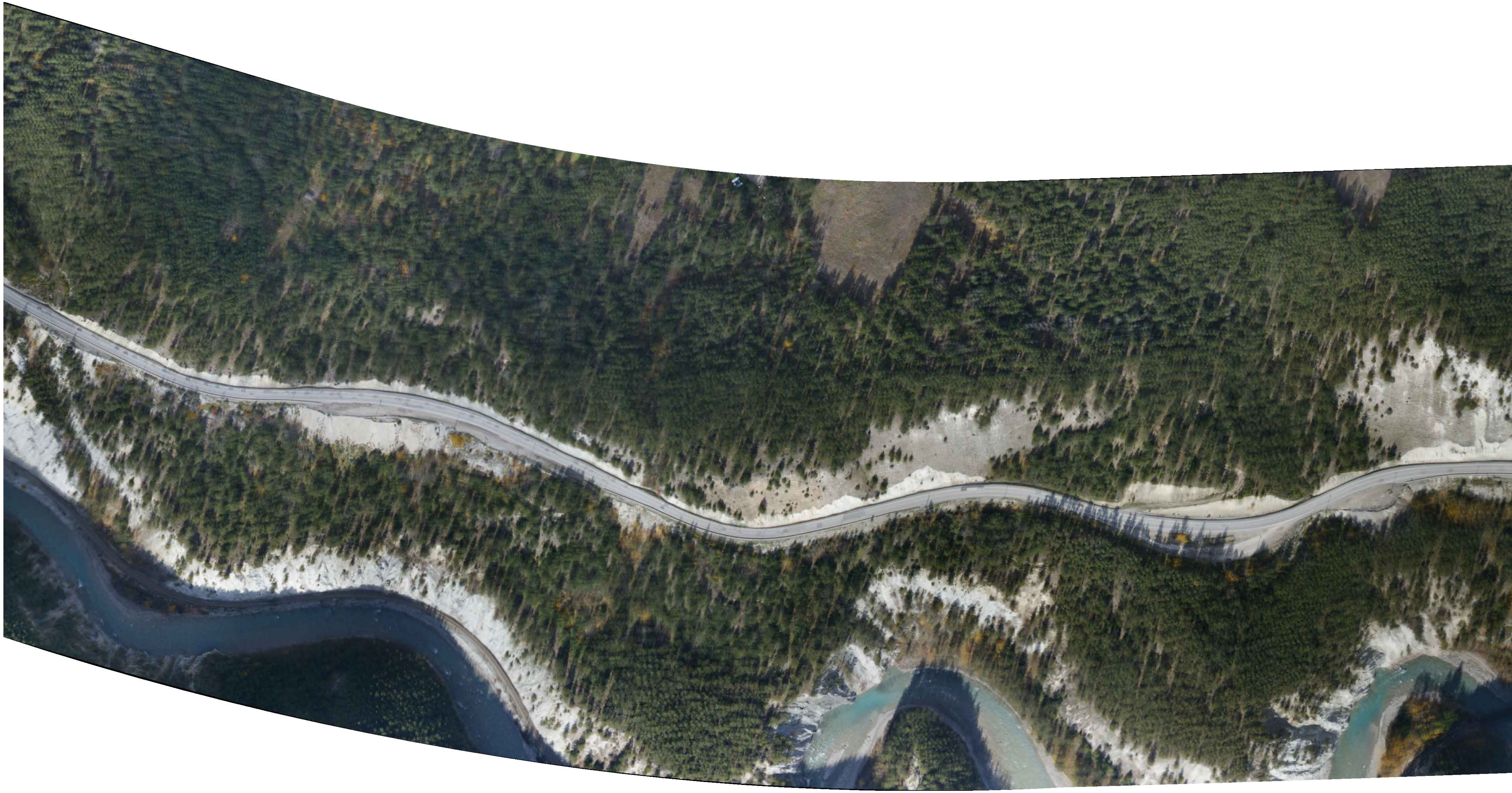
Figure 5 – Existing CP Rail Culvert at Downstream of Highway at Station 802+300

The second area that has been examined is between stations 802+400 and 802+600, and is shown on Figure 6. Although this is a relatively short segment of highway, it does include a relatively large upstream drainage area, which is labeled as Area 4 on Figure 1. This area is about 229 ha, and consists largely of forested hillside, and a small amount of rural development. Drainage from this upland area crosses the existing highway through a culvert at about station 802+510. This culvert will be replaced at the same location when the highway is improved.

Under existing conditions, drainage from this catchment continues down the hill to the CP Rail right of way and crosses through an existing 600 mm diameter culvert as shown on Figure 6. This culvert is in relatively good condition, and is shown in Figure 7, although the CSP culvert appears to have been re-lined with a steel pipe. The estimated capacity of this 600 mm diameter culvert, based on a HW/D ratio equal to 1, is 0.35 m^3/s.

This area has been analyzed using the hydrologic computer model, and it has been simulated under both a short duration 1 hour storm event and a longer duration 24 hour storm event for both existing and post-development conditions. In both cases, AES (Atmospheric Environment Services) rainfall distributions have been used with rainfall depths established using AES rainfall data for the Golden Airport rainfall station. The principal difference between existing and post-development conditions is the amount of impervious area representing the change in the highway.

Figure 7 – Existing CP Rail Culvert Downstream of Highway Culvert at Station 802+510



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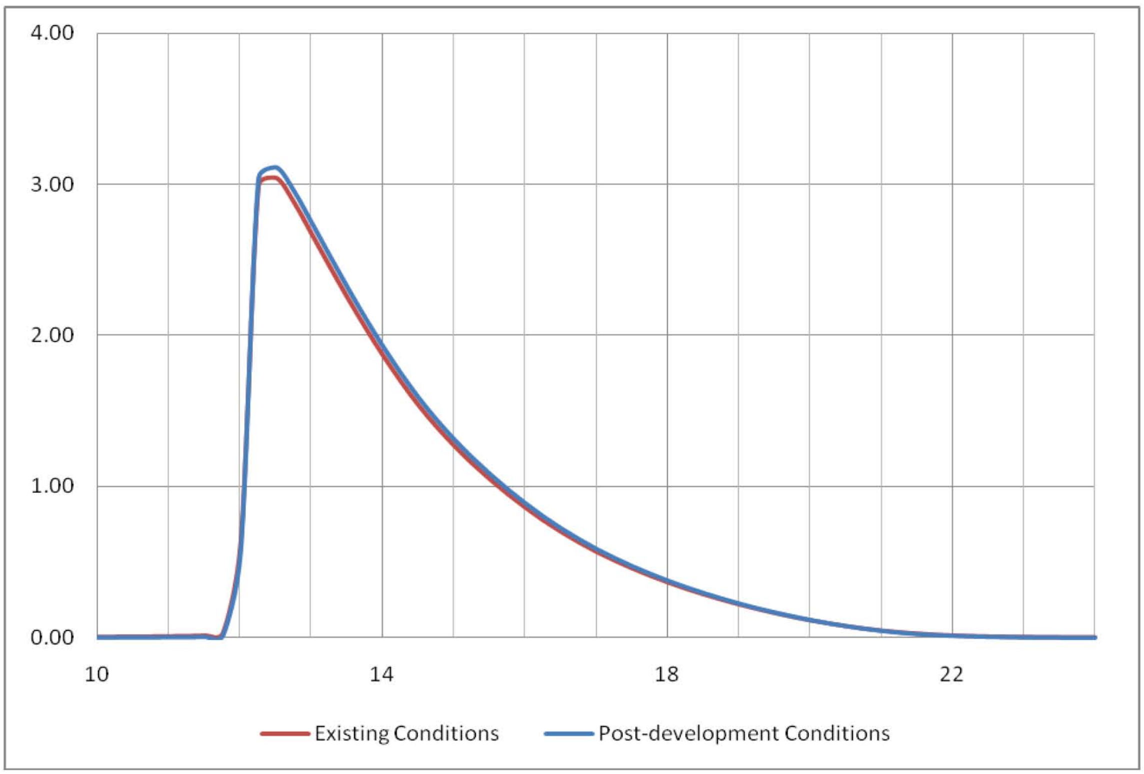
GOLDEN HILL
EXISTING DRAINAGE PATH & EROSION

Scale	Date	Figure
nts	10-08-10	6
2276.0009.02		Title

Runoff hydrographs for both storm conditions were produced, and the longer duration storm event was found to produce a greater peak flow, which is expected because of the size of the contributing area. The runoff hydrographs are shown on Figure 8, and they demonstrate only a very small difference between existing and post-development conditions. The peak flow rate under existing conditions is about 3.05 m^3/s while the post development peak flow rate is about 3.11 m^3/s for the 24 hour duration 100 year return period storm event. The slight difference, about 60 l/s, can be attributed to the increase in impervious area associated with the widened highway, but represents an increase of less than 2% of the existing estimated peak flow rate. It should be noted, however, that the existing CP Rail culvert is inadequate to convey the estimated 100 year return period design flow under even existing conditions.

Figure 8 – Existing and Post-development Runoff Hydrographs for Area 4



The third area that has been examined is between stations 802+600 and 803+400. This segment is also shown on Figure 6, and represents a smaller but still significant upland drainage area which is identified as Area 3 on Figure 1. This area encompasses about 115 ha, and drains through an existing culvert at station 803+150.

A hydrologic model analysis was undertaken for this area under the same conditions as the previous area, and the peak flow rates were estimated to be approximately 2.05 m^3/s under existing conditions, and 2.19 m^3/s under post-development conditions. This estimated increase of about 140 l/s represents an increase of less than 7%. In this case, the increase is larger than that estimated for Area 4 because there is a greater length of highway in comparison to the total drainage basin.

During the site visit in which the railway culverts were inspected it was found that there is no culvert across the railway downstream of this highway culvert. This resulted in consideration of two options: the first would be to install a culvert across the CP Rail tracks at this location, and the second would be to divert the drainage channel away from the railway and directly into the Kicking Horse River at another location. It was decided to undertake the diversion option since the area between the highway and the railway at this location will be filled with surplus material which will result from excavations associated with highway construction. A drainage channel will be constructed at the toe of the fill slope to convey drainage to the Kicking Horse River at the new location. This work will require a submission to the Provincial Ministry of Environment for work in and about a stream under the *Water Act*. This submission will be made separate from this drainage design report.

6.0 REPORT SUBMITTAL

This report has been prepared and submitted by Urban Systems Ltd.

Cameron Gatey, P.Eng.
Senior Engineer

APPENDIX A
SIMPLIFIED ANALYSIS

Comparison of Existing and Proposed Conditions

Culvert Location		Catchment Hydrology											Culvert Data			
Culvert No.	Station	Catchment Area (underveloped)	C	Pavement Area	C	Total Area	Equivalent C	Flow Length	Slope	T_c	100-Year Rainfall intensity	Q_{100}	Existing Diameter	Proposed Diameter	Length	Q at HW/D=1
		(ha)		(ha)				(m)	(m/m)	(hrs)	(mm/hr)	(m3/s)	(mm)	(mm)	(m)	(m3/s)
Existing Culverts																
1	803+942	51	0.35	0.380	0.95	50.880	0.35	1800	0.30	0.74	23.4	1.173	600			
2	803+670	20	0.35	0.162	0.95	20.660	0.35	1100	0.27	0.60	27.1	0.552	600			
3	803+305	79	0.35	0.523	0.95	79.023	0.35	2100	0.27	0.81	21.9	1.698	600			
4	802+643	228	0.35	0.333	0.95	228.358	0.35	2500	0.15	1.01	18.7	4.164	600			
	TOTAL	378		1.398		378.921					Total	7.587				
Proposed Culverts																
1	803+610	32	0.35	0.281	0.95	32.281	0.36	1300	0.44	0.58	27.8	0.886		1050		
2	803+000	116	0.35	2.280	0.95	118.280	0.36	2200	0.27	0.83	21.5	2.557		1600		
3	802+510	228	0.35	0.360	0.95	228.360	0.35	2500	0.15	1.01	18.7	4.165		1800		
	TOTAL	376		2.921		378.921					Total	7.607				

ENGINEERING PAD

URBANSYSTEMS.

Project No. 2276.0009.02 Date FEB 23, 2010

Project GOLDEN HILL Subject: EX/FUT. DRAINAGE Page 1 of 2

Designed by: CC. Checked by: Rev. No.

Under existing conditions, there are about 279 ha of land that drains to the CP Rail right of way above & including the highway. This currently drains across at four locations through existing culverts 1, 2, 3, and 4.

Under future conditions, based on the highway alignment proposed, this area will drain across at three locations

The total area will remain the same, but the amount of area of highway will increase

Based on the current design, over the portion of the highway that contributes drainage to the CP Rail right of way, about 1.523 ha of land will be converted from its current use to highway

This represents a change in the area of

$$1.523/279 \times 100 = 0.4\%$$

F041 2005-09-16

ENGINEERING PAD

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Project No. ______ Date ______

Project ______ Subject: ______ Page 2 of 2

Designed by: ______ Checked by: ______ Rev. No. ______

The attached table provides rational method calculated peak flow rates for each of the areas for the 100 year return period event.

The difference in peak flow rates from existing to proposed conditions, for the total contributing area, is:

$$7.607 - 7.587 = 0.020 \ m^3/s$$

or 20 l/s.

The principle reason for the small difference is that the peak flow for each basin is dominated by the natural area above the highway during the design event. The change in land to highway for each segment represents a relatively small change.

APPENDIX B
COMPUTER MODELING ANALYSIS OUTPUT FILE

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.013)
--------------------------------------------------------------


****************
Analysis Options
****************
Flow Units ............... CMS
Infiltration Method ...... HORTON
Flow Routing Method ...... DYNWAVE
Starting Date ............ JAN-01-2000 00:00:00
Ending Date .............. JAN-03-2000 00:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:15:00
Wet Time Step ............ 00:15:00
Dry Time Step ............ 01:00:00
Routing Time Step ........ 30.00 sec


**************************        Volume         Depth
Runoff Quantity Continuity     hectare-m            mm
**************************     ---------       -------
Total Precipitation ......        17.470        47.300
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........        12.154        32.907
Surface Runoff ...........         5.320        14.403
Final Surface Storage ....         0.002         0.006
Continuity Error (%) .....        -0.034


**************************        Volume        Volume
Flow Routing Continuity        hectare-m       Mliters
**************************     ---------     ---------
Dry Weather Inflow .......         0.000         0.000
Wet Weather Inflow .......         5.320        53.204
Groundwater Inflow .......         0.000         0.000
RDII Inflow ..............         0.000         0.000
External Inflow ..........         0.000         0.000
External Outflow .........         5.324        53.239
Internal Outflow .........         0.000         0.000
Evaporation Loss .........         0.000         0.000
Initial Stored Volume ....         0.000         0.000
Final Stored Volume ......         0.000         0.000
Continuity Error (%) .....        -0.066


***************************
Time-Step Critical Elements
***************************
Link L_6 (26.28%)
Link L_4 (10.72%)


********************************
Highest Flow Instability Indexes
********************************
Link L_11 (4)
Link L_10 (3)


*************************
Routing Time Step Summary
*************************
Minimum Time Step           :     2.08 sec
Average Time Step           :    19.83 sec
Maximum Time Step           :    30.00 sec
Percent in Steady State     :     0.00
Average Iterations per Step :     2.00
```

****
Subcatchment Runoff Summary
****

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Total Runoff mm	Total Runoff Mltrs	Peak Runoff CMS	Runoff Coeff
Ex_7	47.300	0.000	0.000	32.846	14.468	4.342	0.420	0.306
Ex_6	47.300	0.000	0.000	31.766	15.555	1.219	0.155	0.329
Ex_5	47.300	0.000	0.000	33.081	14.233	4.719	0.435	0.301
Ex_4	47.300	0.000	0.000	33.140	14.173	4.811	0.439	0.300
Ex_3	47.300	0.000	0.000	32.897	14.417	9.133	0.875	0.305
Ex_2	47.300	0.000	0.000	33.625	13.686	13.774	1.146	0.289
Catch_2	47.300	0.000	0.000	0.000	45.897	0.170	0.056	0.970
Ex_16	47.300	0.000	0.000	0.000	45.869	0.175	0.049	0.970
Ex_8	47.300	0.000	0.000	34.075	13.235	4.403	0.339	0.280
Ex_9	47.300	0.000	0.000	32.730	14.585	4.269	0.424	0.308
Ex_10	47.300	0.000	0.000	31.867	15.453	3.614	0.446	0.327
Ex_11	47.300	0.000	0.000	0.000	45.889	0.163	0.051	0.970
Ex_12	47.300	0.000	0.000	29.144	18.319	0.339	0.204	0.387
Ex_13	47.300	0.000	0.000	29.432	17.969	0.359	0.161	0.380
Ex_14	47.300	2.599	0.000	30.703	19.257	0.987	0.277	0.386
Ex_15	47.300	0.000	0.000	29.806	17.561	0.718	0.235	0.371
Catch_1	47.300	0.000	0.000	0.000	45.906	0.133	0.048	0.971
System	47.300	0.036	0.000	32.907	14.439	53.329	5.464	0.305

****
Node Depth Summary
****

Node	Type	Average Depth Meters	Maximum Depth Meters	Maximum HGL Meters	Time of Max Occurrence days hr:min
J_1	JUNCTION	0.14	0.38	1030.38	0 12:25
J_2	JUNCTION	0.16	0.43	1005.43	0 12:27
J_3	JUNCTION	0.27	0.71	935.71	0 12:29
J_4	JUNCTION	0.18	0.48	915.48	0 12:29
J_5	JUNCTION	0.12	0.33	912.33	0 12:29
J_6	JUNCTION	0.23	0.62	800.62	0 12:23
J_8	JUNCTION	0.17	0.47	990.47	0 12:21
J_9	JUNCTION	0.11	0.30	980.30	0 12:22
J_10	JUNCTION	0.09	0.26	950.26	0 12:23
J_11	JUNCTION	0.17	0.49	905.49	0 12:20
J_12	JUNCTION	0.09	0.27	904.27	0 12:20
J_14	JUNCTION	0.21	0.57	930.57	0 12:29
J_13	OUTFALL	0.09	0.27	800.27	0 12:20
J_7	OUTFALL	0.23	0.62	799.62	0 12:23

****
Node InFlow Summary
****

Node	Type	Maximum Lateral Inflow CMS	Maximum Total Inflow CMS	Time of Max Occurrence days hr:min	Lateral Inflow Volume Mltrs	Total Inflow Volume Mltrs
J_1	JUNCTION	1.585	1.585	0 12:25	18.595	18.588
J_2	JUNCTION	0.435	2.019	0 12:25	4.722	23.310
J_3	JUNCTION	0.487	2.502	0 12:26	5.626	28.936
J_4	JUNCTION	0.049	2.926	0 12:29	0.175	33.437
J_5	JUNCTION	0.051	2.934	0 12:28	0.163	33.600
J_6	JUNCTION	0.396	3.128	0 12:23	1.083	34.683

J_8	JUNCTION	1.299	1.299	0	12:20	13.412	13.404
J_9	JUNCTION	0.000	1.298	0	12:21	0.000	13.404
J_10	JUNCTION	0.000	1.298	0	12:22	0.000	13.403
J_11	JUNCTION	0.492	1.745	0	12:19	3.789	17.189
J_12	JUNCTION	0.000	1.745	0	12:20	0.000	17.187
J_14	JUNCTION	0.420	2.915	0	12:28	4.346	33.265
J_13	OUTFALL	0.482	2.094	0	12:09	1.334	18.561
J_7	OUTFALL	0.000	3.128	0	12:23	0.000	34.678

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CMS	Max. Flow CMS	Total Volume Mltrs
J_13	57.02	1.011	2.094	18.561
J_7	75.06	1.325	3.128	34.678
System	66.04	2.336	5.132	53.239

****
Link Flow Summary
****

Link	Type	Maximum Flow CMS	Time of Max Occurrence days hr:min		Maximum Velocity m/sec	Max/ Full Flow	Max/ Full Depth
L_1	CONDUIT	1.584	0	12:25	2.88	0.04	0.20
L_2	CONDUIT	2.499	0	12:29	2.37	0.11	0.32
L_3	CONDUIT	2.017	0	12:27	2.45	0.05	0.28
L_4	CONDUIT	2.926	0	12:29	5.13	0.05	0.20
L_5	CONDUIT	2.934	0	12:29	4.18	0.03	0.24
L_6	CONDUIT	3.128	0	12:23	3.09	0.09	0.31
L_7	CONDUIT	1.298	0	12:21	2.42	0.05	0.19
L_8	CONDUIT	1.298	0	12:22	3.61	0.02	0.14
L_9	CONDUIT	1.298	0	12:23	2.54	0.02	0.19
L_10	CONDUIT	1.745	0	12:20	3.35	0.05	0.19
L_11	CONDUIT	1.745	0	12:20	5.06	0.02	0.14
L_12	CONDUIT	2.915	0	12:29	3.63	0.07	0.26

****
Flow Classification Summary
****

Conduit	Adjusted /Actual Length	--- Fraction of Time in Flow Class ---- Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Avg. Froude Number	Avg. Flow Change

L_1	1.00	0.16	0.24	0.00	0.14	0.46	0.00	0.00	0.73	0.0000
L_2	1.00	0.16	0.00	0.00	0.40	0.43	0.00	0.00	0.53	0.0000
L_3	1.00	0.16	0.00	0.00	0.43	0.41	0.00	0.00	0.51	0.0000
L_4	1.00	0.04	0.00	0.00	0.48	0.48	0.00	0.00	1.40	0.0000
L_5	1.00	0.04	0.00	0.00	0.49	0.47	0.00	0.00	1.08	0.0000
L_6	1.00	0.04	0.00	0.00	0.50	0.46	0.00	0.00	0.74	0.0000
L_7	1.00	0.30	0.03	0.00	0.23	0.44	0.00	0.00	0.62	0.0000
L_8	1.00	0.28	0.02	0.00	0.24	0.45	0.00	0.00	1.06	0.0000
L_9	1.00	0.11	0.17	0.00	0.27	0.44	0.00	0.00	0.67	0.0000
L_10	1.00	0.10	0.01	0.00	0.44	0.45	0.00	0.00	0.89	0.0000
L_11	1.00	0.12	0.09	0.00	0.33	0.46	0.00	0.00	1.52	0.0000
L_12	1.00	0.04	0.12	0.00	0.37	0.47	0.00	0.00	0.87	0.0000

```
*************************
Conduit Surcharge Summary
*************************

No conduits were surcharged.


Analysis begun on:  Fri Jul 16 09:28:41 2010
Analysis ended on:  Fri Jul 16 09:28:44 2010
Total elapsed time: 00:00:03
```

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.013)
--------------------------------------------------------------


****************
Analysis Options
****************
Flow Units ............... CMS
Infiltration Method ...... HORTON
Flow Routing Method ...... DYNWAVE
Starting Date ............ JAN-01-2000 00:00:00
Ending Date .............. JAN-03-2000 00:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:15:00
Wet Time Step ............ 00:15:00
Dry Time Step ............ 01:00:00
Routing Time Step ........ 30.00 sec


**************************        Volume         Depth
Runoff Quantity Continuity     hectare-m            mm
**************************     ---------       -------
Total Precipitation ......        17.478        47.300
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........        12.102        32.750
Surface Runoff ...........         5.379        14.556
Final Surface Storage ....         0.004         0.011
Continuity Error (%) .....        -0.034


**************************        Volume        Volume
Flow Routing Continuity        hectare-m       Mliters
**************************     ---------     ---------
Dry Weather Inflow .......         0.000         0.000
Wet Weather Inflow .......         5.380        53.796
Groundwater Inflow .......         0.000         0.000
RDII Inflow ..............         0.000         0.000
External Inflow ..........         0.000         0.000
External Outflow .........         5.380        53.801
Internal Outflow .........         0.000         0.000
Evaporation Loss .........         0.000         0.000
Initial Stored Volume ....         0.000         0.000
Final Stored Volume ......         0.000         0.000
Continuity Error (%) .....        -0.011


***************************
Time-Step Critical Elements
***************************
Link L_6 (27.35%)
Link L_4 (8.54%)


********************************
Highest Flow Instability Indexes
********************************
Link L_10 (7)
Link L_11 (2)


*************************
Routing Time Step Summary
*************************
Minimum Time Step           :     2.09 sec
Average Time Step           :    20.11 sec
Maximum Time Step           :    30.00 sec
Percent in Steady State     :     0.00
Average Iterations per Step :     2.04
```

****
Subcatchment Runoff Summary
****

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Total Runoff mm	Total Runoff Mltrs	Peak Runoff CMS	Runoff Coeff
Prop_10	47.300	0.000	0.000	29.144	18.319	0.321	0.193	0.387
Prop_11	47.300	0.000	0.000	0.000	45.875	0.253	0.074	0.970
Prop_12	47.300	0.000	0.000	30.037	17.318	0.783	0.219	0.366
Prop_14	47.300	0.000	0.000	29.432	17.969	0.381	0.170	0.380
Prop_15	47.300	0.000	0.000	0.000	45.871	0.360	0.102	0.970
Prop_16	47.300	0.000	0.000	0.000	45.879	0.342	0.102	0.970
Prop_17	47.300	0.000	0.000	0.000	45.887	0.268	0.084	0.970
Prop_1	47.300	0.000	0.000	33.625	13.686	13.774	1.146	0.289
Prop_9	47.300	0.000	0.000	31.867	15.453	4.793	0.591	0.327
Prop_8	47.300	0.000	0.000	32.730	14.585	4.269	0.424	0.308
Prop_7	47.300	0.000	0.000	34.075	13.235	4.403	0.339	0.280
Prop_6	47.300	0.000	0.000	32.479	14.837	3.284	0.345	0.314
Prop_5	47.300	0.000	0.000	31.766	15.555	1.219	0.155	0.329
Prop_4	47.300	0.000	0.000	33.081	14.232	4.719	0.435	0.301
Prop_3	47.300	0.000	0.000	33.140	14.173	4.811	0.439	0.300
Prop_2	47.300	0.000	0.000	32.897	14.417	9.133	0.875	0.305
Prop_18	47.300	0.000	0.000	29.811	17.556	0.674	0.220	0.371
System	47.300	0.000	0.000	32.750	14.556	53.787	5.631	0.308

****
Node Depth Summary
****

Node	Type	Average Depth Meters	Maximum Depth Meters	Maximum HGL Meters	Time of Max Occurrence days hr:min
J_1	JUNCTION	0.14	0.38	1030.38	0 12:25
J_2	JUNCTION	0.15	0.43	1005.43	0 12:27
J_3	JUNCTION	0.26	0.71	935.71	0 12:29
J_4	JUNCTION	0.17	0.48	915.48	0 12:28
J_5	JUNCTION	0.12	0.33	912.33	0 12:28
J_6	JUNCTION	0.22	0.62	800.62	0 12:22
J_8	JUNCTION	0.17	0.47	990.47	0 12:21
J_9	JUNCTION	0.10	0.30	980.30	0 12:22
J_10	JUNCTION	0.09	0.26	950.26	0 12:23
J_11	JUNCTION	0.18	0.51	905.51	0 12:11
J_12	JUNCTION	0.10	0.29	904.29	0 12:12
J_14	JUNCTION	0.20	0.56	930.56	0 12:29
J_13	OUTFALL	0.10	0.29	800.29	0 12:12
J_7	OUTFALL	0.22	0.62	799.62	0 12:22

****
Node InFlow Summary
****

Node	Type	Maximum Lateral Inflow CMS	Maximum Total Inflow CMS	Time of Max Occurrence days hr:min	Lateral Inflow Volume Mltrs	Total Inflow Volume Mltrs
J_1	JUNCTION	1.585	1.585	0 12:25	18.594	18.588
J_2	JUNCTION	0.435	2.019	0 12:25	4.721	23.310
J_3	JUNCTION	0.487	2.502	0 12:26	5.625	28.936
J_4	JUNCTION	0.186	2.873	0 12:27	0.630	32.831
J_5	JUNCTION	0.000	2.873	0 12:28	0.000	32.832
J_6	JUNCTION	0.390	3.069	0 12:22	1.061	33.893

J_8	JUNCTION	1.299	1.299	0	12:20	13.411	13.404
J_9	JUNCTION	0.000	1.298	0	12:21	0.000	13.404
J_10	JUNCTION	0.000	1.298	0	12:22	0.000	13.402
J_11	JUNCTION	0.755	1.940	0	12:09	5.395	18.792
J_12	JUNCTION	0.000	1.940	0	12:11	0.000	18.878
J_14	JUNCTION	0.345	2.837	0	12:28	3.287	32.206
J_13	OUTFALL	0.412	2.264	0	12:08	1.111	19.912
J_7	OUTFALL	0.000	3.069	0	12:22	0.000	33.889

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CMS	Max. Flow CMS	Total Volume Mltrs
J_13	59.48	1.023	2.264	19.912
J_7	74.99	1.274	3.069	33.889
System	67.23	2.297	5.219	53.801

****
Link Flow Summary
****

Link	Type	Maximum Flow CMS	Time of Max Occurrence days hr:min	Maximum Velocity m/sec	Max/ Full Flow	Max/ Full Depth
L_1	CONDUIT	1.584	0 12:25	2.87	0.04	0.20
L_2	CONDUIT	2.499	0 12:29	2.39	0.11	0.32
L_3	CONDUIT	2.017	0 12:27	2.44	0.05	0.29
L_4	CONDUIT	2.873	0 12:28	5.11	0.05	0.20
L_5	CONDUIT	2.872	0 12:28	4.15	0.03	0.24
L_6	CONDUIT	3.069	0 12:22	3.07	0.09	0.31
L_7	CONDUIT	1.298	0 12:21	2.42	0.05	0.19
L_8	CONDUIT	1.298	0 12:22	3.61	0.02	0.14
L_9	CONDUIT	1.298	0 12:23	2.44	0.02	0.19
L_10	CONDUIT	1.940	0 12:11	3.46	0.06	0.20
L_11	CONDUIT	1.940	0 12:12	5.22	0.02	0.14
L_12	CONDUIT	2.837	0 12:29	3.59	0.07	0.26

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Flow Classification Summary
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Conduit	Adjusted /Actual Length	Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Avg. Froude Number	Avg. Flow Change

(--- Fraction of Time in Flow Class ----)

L_1	1.00	0.16	0.24	0.00	0.14	0.45	0.00	0.00	0.72	0.0000
L_2	1.00	0.16	0.00	0.00	0.40	0.43	0.00	0.00	0.53	0.0000
L_3	1.00	0.16	0.00	0.00	0.43	0.40	0.00	0.00	0.50	0.0000
L_4	1.00	0.04	0.00	0.00	0.49	0.47	0.00	0.00	1.41	0.0000
L_5	1.00	0.04	0.00	0.00	0.49	0.47	0.00	0.00	1.08	0.0000
L_6	1.00	0.05	0.00	0.00	0.50	0.46	0.00	0.00	0.74	0.0000
L_7	1.00	0.31	0.03	0.00	0.23	0.43	0.00	0.00	0.61	0.0000
L_8	1.00	0.29	0.02	0.00	0.25	0.45	0.00	0.00	1.04	0.0000
L_9	1.00	0.13	0.16	0.00	0.28	0.43	0.00	0.00	0.63	0.0000
L_10	1.00	0.11	0.02	0.00	0.41	0.46	0.00	0.00	1.18	0.0000
L_11	1.00	0.11	0.10	0.00	0.33	0.46	0.00	0.00	1.54	0.0000
L_12	1.00	0.04	0.12	0.00	0.38	0.46	0.00	0.00	0.85	0.0000

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Conduit Surcharge Summary
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No conduits were surcharged.


Analysis begun on:  Fri Jul 16 09:28:46 2010
Analysis ended on:  Fri Jul 16 09:28:49 2010
Total elapsed time: 00:00:03
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