TOWN OF COMOX

NORTH EAST COMOX NEIGHBOURHOOD STORMWATER MANAGEMENT PLAN - PHASE 3 OF 3

Prepared By:

McElhanney Consulting Services Ltd.

495 Sixth Street

Courtenay, B.C.

MCSL File: 2211-46500-2
March 1, 2018

McElhanney

McElhanney

Table of Contents

1.0 INTRODUCTION 1

2.0 MODELING UPDATE – RAW DATA REVIEW AND ADJUSTMENT 3

2.1 Rainfall File Inconsistencies 3

2.2 Changes to the Pre-Development Model Output 4

2.2.1 Hydrological Mass Balance 6

2.2.2 Unit Area Discharge Targets 6

3.0 PHASE 3 MODELING AND BMP SIZING 9

3.1 Sub-Catchments 10

3.2 Infiltration Trench Modeling 13

3.3 Dry Detention Pond Modeling 14

3.4 Hydrological Mass Balances 15

4.0 BMP DESIGN AND SELECTION 19

4.1 Standardized Best Management Practice Details 19

4.2 Standardized Best Management Practice Specifications 19

4.2.1 Storm Drainage System 19

4.2.2 Disconnected Roof Leaders (Standard Drawing SC-101) 26

4.2.3 Sediment Catch Basin (Standard Drawing SC-102) 26

4.2.4 Control Manhole (Standard Drawing SC-103) 26

4.2.5 Boulevard Infiltration Trench (Drawing SC-104) 26

4.2.6 Street Infiltration Trench (Standard Drawing SC-105) 29

4.2.7 Lot Grading (Standard Drawings SC – 108A and SC – 108B) 31

4.2.8 Dry Detention Pond (Standard Drawings Pond-101 and Pond-102) 32

4.3 Low Impact Development Infrastructure Costing 34

5.0 PUBLIC EDUCATION 36

6.0 ADAPTIVE MANAGEMENT STRATEGY 41

6.1 Stormwater Management Targets for NE Comox 42

6.2 Monitoring 43

6.2.1 Visual Inspections 43

6.2.2 Monitoring Equipment and Data Collection ... 43
6.2.3 Data Processing ... 45
6.2.4 Reporting ... 45
6.3 System Performance ... 45
6.4 System Modification to Correct Performance ... 46
7.0 SUMMARY ... 48
8.0 PUBLIC MEETING FOR PHASE 3 ... 50
9.0 STAKEHOLDER CONSULTATION ... 50

APPENDICES

Appendix A Pre- and Post- Unit Area Exceedance Curves for each Sub-Catchment
Appendix B Input and Output Files for each Sub-Catchment
Appendix C Standard Drawings
Appendix D BMP Locations
Appendix E Cost Estimates for Selected BMPs
Appendix F Typical Service Record Cards and Lot Grading Plan
Appendix G Professional Certification Statements
Appendix H GW Solutions – Hydrogeological Review
Appendix I Glossary of Terms
Appendix J Public Consultation Meeting

FIGURES

Figure 1: Flow-Duration Relationship for the Pre-Developed Study Area ... 8
Figure 2: Post-Development Modeling Routine Schematic ... 11
Figure 3: Sub-Catchment Locations ... 12

TABLES

Table 1: Original and Revised Hourly Rainfall 5

Table 2: Hydrological Mass Balance 6

Table 3: Study Area Discharge Targets 6

Table 4: Model Input Parameters 10

Table 5: Infiltration Trench Sizing 14

Table 6: Dry Detention Pond Sizing 15

Table 7A: Sub-catchment 1A Mass Balance 16

Table 7B: Sub-catchment 1B Mass Balance 16

Table 7C: Sub-catchment 2A Mass Balance 17

Table 7D: Sub-catchment 2B Mass Balance 17

Table 7E: Sub-catchment 3 Mass Balance 17

Table 7F: Sub-catchment 4A Mass Balance 18

Table 7G: Sub-catchment 4B Mass Balance 18

Table 8: Summary of BMP Costs 36

This report has been prepared based on the August 08, 2012 Terms of Reference, developed jointly with the Town of Comox. The approach developed in the Terms of Reference envisioned three distinct "phases" of work, as follows:

Phase 1 – Determination of pre-development site conditions, hydrology and hydrogeology.
Phase 2 – Determine post-development unmitigated flow rates, volumes.
Phase 3 – Develop design standards.

It is assumed herein the reader has access to, and is familiar with, the Phase 1 and Phase 2 reports and the Terms of Reference document. This Phase 3 report is a continuation of Phase 1 and Phase 2, and is not to be interpreted or read as a standalone document.

1.0 INTRODUCTION

Phase 1 of the North East Comox Neighborhood Stormwater Management Plan (NE Comox SWMP) established the physical conditions and hydrologic response of the study area based on pre-development conditions. Phase 2 of the report evaluated potential strategies and stormwater management tools or Best Management Practices (BMPs) to mitigate the effects of development on the hydrological system. Phase 2 also evaluated the impacts of climate changes, and determined the relative sizing of required BMPs.

To determine which BMPs may be appropriate, the long-term development potential of the area, and specific requirements of the Town of Comox (as the ultimate owner of any community based stormwater management infrastructure), must be clearly understood. Specific design parameters established by the Town include the following:

- Mitigation of rainfalls up to, and including a 1:100 year return event, plus allowance for climate change, is required through the use of the BMPs set out in this document.
- All Dry Detention Ponds, and other point discharges of surface runoff from stormwater infrastructure, may only be directed to that portion of the Knight Road ditch located within Town boundaries. No point discharge of surface runoff from stormwater infrastructure shall be permitted to discharge onto lands outside of the Town of Comox, regardless of topography or historic drainage patterns.
- All Infiltration Trenches must discharge through a Dry Detention Pond. That is to say, all underflow and overflow drains from Infiltration Trenches must pass through a Dry Detention Pond, prior to discharge into the eventual receiving body.
- All stormwater infrastructure, including Dry Detention Ponds, Infiltration Trenches, and Sediment Catchbasins, are to be Town owned and operated and wholly contained within lands dedicated to the Town of Comox. Land dedicated to the Town can be in fee simple, or road dedication.

- Dry Detention Ponds cannot be "bermed" (i.e., Dry Detention Ponds must be fully excavated, with water storage provided below existing grade), unless the following issues are addressed to the satisfaction of the Town: potential inspection, maintenance and replacement costs, as well as the downstream implications if there is a failure.
- Reduction in percent impervious (beyond the averages for existing developments utilized in modeling herein), will not be entertained as a BMP, as the Town is not confident public support exists to obtain compliance. In other words, all single family residential development is modeled based on 60% impervious, and all multifamily residential, industrial, commercial and institutional development is modeled based on 90% impervious. All stormwater infrastructure shall be sized and constructed based on these % impervious values.
- No temporary Dry Detention Ponds will be allowed. Ultimate (Town owned) pond construction is required prior to development of any lands. All permanent Dry Detention Ponds are to be located per Figures 3 and 4, in Appendix D. A maximum of three (3) permanent Dry Detention Ponds will be allowed. Underground storage of all or a portion of these permanent Town owned ponds is an option.
- Detention of stormwater in surface ponds or underground (rockpits, Stormceptor, or other proprietary systems) will not be considered as an alternate to the Town owned Dry Detention Ponds.
- Vegetation retention will not be considered a BMP to reduce overall percent impervious, without specifications for the location and size of areas to be retained and specifications for the maintenance and replanting of areas of retained vegetation.
- Only those BMPs identified in this document will be permitted within NE Comox.

The long-term development potential of the area is dictated by Official Community Plan designations. In addition, the Town requires a collaborative effort between Town Public Works, Planning and financial management teams. A number of potential stormwater management features, or Best Management Practices (BMPs), are considered in this phase of the study. Each such BMP is evaluated based on relative pros/cons, and tested against the seven-desirability criterion discussed herein.

The Phase 3 report provides a synopsis of changes made to the model input rainfall file and corresponding revisions to the pre-development unit area exceedance curve, mass balance and discharge targets based on discrepancies observed in the historic rainfall data. The Phase 3 report also provides an overview of detailed modeling; provides an indication of the locations of appropriate BMP types within the study area based upon the physical conditions of the site and the operating characteristics of the BMP; formalizes the design criteria and design details to be used during subdivision servicing; verifies the selection of BMP types using financial costs as part of the evaluation process; outlines Public Education requirements; and details the "Adaptive Management Plan" for ongoing refinement of the stormwater BMPs utilized.

Hydrologic modeling for this report has been completed with QualHYMO software Version 0777V1I88. Use of different QualHYMO versions or different software may result in minor differences in model output. Any future modeling must be verified to confirm that the results are consistent with the results outlined within this report.

2.0 MODELING UPDATE – RAW DATA REVIEW AND ADJUSTMENT

During hydraulic modeling for the NE Comox Stormwater Management Plan (SWMP), it was determined that the QualHYMO input rainfall file used in Phase 1 and 2 modeling, was, in some cases, inconsistent with Environment Canada's historical data. This noted inconsistency prompted further review of the QualHYMO input file, leading to a revision of the input rainfall data. Phase 1 pre-development models have since been re-run with the revised rainfall input file. The adjusted hourly data was extrapolated for climate change, to create a revised input rainfall file for use in Phase 3 (post-development) modeling. Provided below is documentation of the changes made to the QualHYMO input rainfall file and the effects those changes have on the output and design targets of the pre-development model.

2.1 Rainfall File Inconsistencies

The input rainfall file utilized in this report was specifically formatted for the QualHYMO engine, incorporating Environment Canada's historic rain and snowfall data recorded at Comox A (Station 1021830) into total precipitation, reported in tenths of a millimetre per hour. During the Phase 3, post-development analysis, it was determined there was a data inconsistency on December 21, 1986, between the QualHYMO input file and Environment Canada's historical data. It was noted that on this day the original QualHYMO data file showed a total of 210mm of rainfall, in comparison to the Environment Canada gauge of 105mm for the same day. This discrepancy is significant enough to warrant a review of the entire original data set.

The QualHYMO rainfall input file was reviewed and adjusted to match Environment Canada's historical record as follows:

- The QualHYMO input file was cross-referenced with Environment Canada's historic rainfall data on a daily basis.
- Snowfall data was converted to equivalent precipitation, and added to total daily precipitation.
- Any discrepancies between model rainfall data and Environment Canada data greater than 30mm per day (after the addition of snowfall) were revised, using Environment Canada's hourly data, to create a new QualHYMO input file.

- Days which were adjusted were then extrapolated to create a 2050 climate change input rainfall file, used to complete the Phase 3 modeling.

Overall, there was good agreement between the two sets of data, however, there were several days that required adjustment to ensure that peak discharges and volumes were not miscalculated by the model. In total, four days were adjusted. **Table 1,** overleaf, tabulates the original input, the adjusted inputs and the extrapolated (climate change) inputs on an hourly basis for each of the four days that were revised.

2.2 Changes to the Pre-Development Model Output

An updated hydrological mass balance table and exceedance curves for the study area and sub-catchments were generated, using the revised rainfall data. Discharge targets for the 2, 5, 10 and 100-year return periods were also re-calculated, using the revised annual peak discharges, and the Pearson Type III distribution, as it was found to provide the best curve fit for the new data.

Table 1: Original and Revised Hourly Rainfall

				Hourly precipitation in tenths of a mm																								Daily
Y	M	D		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total (mm)
			Original	66	77	64	88	83	77	90	114	94	110	106	103	103	88	110	99	90	92	92	85	79	77	56	59	210
1986	12	21	Revised	22	33	20	44	39	33	46	70	50	66	62	59	59	44	66	55	46	48	48	41	35	33	12	15	105
			Extrapolated	24	36	22	48	43	36	51	77	55	73	68	65	65	48	73	61	51	53	53	45	39	36	13	17	115
			Original	28	24	20	26	48	46	64	62	0	0	18	16	16	16	16	16	18	16	24	58	52	40	58	27	71
1991	11	16	Revised	12	8	40	10	32	30	48	46	0	0	0	0	0	0	0	0	0	0	8	42	36	24	42	11	39
			Extrapolated	13	9	44	11	35	33	53	51	0	0	0	0	0	0	0	0	0	0	9	46	40	26	46	12	43
			Original	22	17	17	17	17	25	35	22	32	37	40	37	40	30	20	17	17	17	17	17	17	17	17	17	56
1998	1	24	Revised	5	0	0	0	0	8	18	5	15	20	23	20	23	13	3	0	0	0	0	0	0	0	0	0	15
			Extrapolated	6	0	0	0	0	9	20	6	17	22	25	22	25	14	3	0	0	0	0	0	0	0	0	0	17
1998			Original	108	39	18	16	16	16	16	16	16	16	16	16	16	25	16	27	52	74	65	67	76	33	16	16	79
	11	24	Revised	92	23	2	0	0	0	0	0	0	0	0	0	0	9	0	11	36	58	49	51	60	17	0	0	41
			Extrapolated	101	25	2	0	0	0	0	0	0	0	0	0	0	10	0	12	40	64	54	56	66	19	0	0	45

2.2.1 Hydrological Mass Balance

The hydrologic mass balance for the study area over the period of analysis (42 years) was calculated by the QualHYMO engine, as follows.

Table 2: Hydrological Mass Balance

	Original Rainfall File (mm)	Revised Rainfall File (mm)	Change (mm)
Total Rainfall	51,180	50,964	-216
Total Surface Runoff	16,355	16,116	-239
Total Abstractions[1]	8,195	8,194	-1
Total Volume Infiltrated	26,630	26,655	25
Total Volume transferred to deep groundwater	18,380	18,393	13

2.2.2 Unit Area Discharge Targets

Study area discharge targets[2] for both the original QualHYMO rain file and the revised file are shown in **Table 3**, below.

Table 3: Study Area Discharge Targets

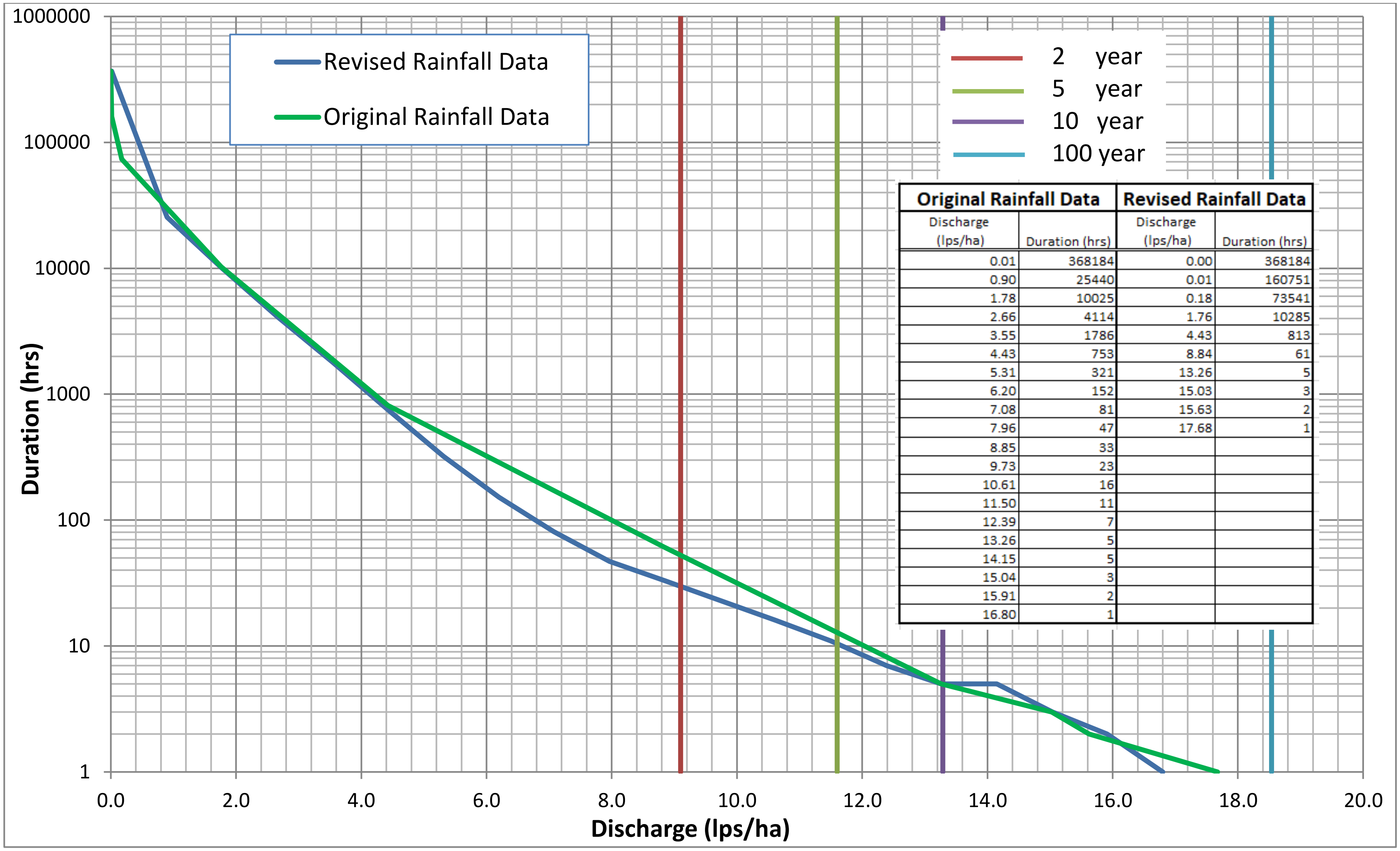
	Original File (lps/ha)	Revised File (lps/ha)
1 in 100 year	16.1	18.5
1 in 10 year	13.3	13.3
1 in 5 year	12.0	11.6
1 in 2 year	9.8	9.1

[1] Abstractions include (surface ponding, interception, and evapotranspiration)

[2] Discharge targets were calculated with the normal distribution for the original rainfall file data and with the Pearson Type III distribution for the revised rainfall file data.

Exceedance curves for the study area for both the old and new input rainfall files, as well as the updated peak discharges for the 2, 5, 10 and 100-year return periods, are shown in **Figure 1**, overleaf.

The adjusted rainfall data has a very modest effect on the overall mass balance of the site, and only a minimal effect on the flow/duration exceedance curve for the pre-developed condition. Past modeling and analysis has utilized a Normal Distribution. A Pearson Type III Distribution was used in the analysis of the revised data set, as it had the smallest standard error of distribution.



Original Rainfall Data		Revised Rainfall Data	
Discharge (lps/ha)	Duration (hrs)	Discharge (lps/ha)	Duration (hrs)
0.01	368184	0.00	368184
0.90	25440	0.01	160751
1.78	10025	0.18	73541
2.66	4114	1.76	10285
3.55	1786	4.43	813
4.43	753	8.84	61
5.31	321	13.26	5
6.20	152	15.03	3
7.08	81	15.63	2
7.96	47	17.68	1
8.85	33		
9.73	23		
10.61	16		
11.50	11		
12.39	7		
13.26	5		
14.15	5		
15.04	3		
15.91	2		
16.80	1		

Figure 1: Flow-Duration Relationship for the Pre-Developed Study Area

3.0 PHASE 3 MODELING AND BMP SIZING

To more accurately determine the size and arrangement of BMPs required within specific areas of NE Comox, a series of model simulations were run. Post-development climatic data has been adjusted based on the Pacific Climate Impacts Consortium (PCIC) at the University of Victoria Median Climate Change model, out to year 2050, to account for the predicted increase in rainfall. All post-development modeling was run with this extrapolated climate data.

QualHYMO software was used to assess post-development mitigated runoff, storage, infiltration (to interflow layer) and groundwater re-charge within the study area. (Hydrologic modeling for this report has been completed with QualHYMO software Version 0777V1I88. Use of different QualHYMO versions or different software may result in minor differences in model output. Any future modeling must be verified to confirm that the results are consistent with the results outlined within this report.) Post-development Low-Impact Design (LID) stormwater management designs will include the use of various Best Management Practices (BMPs) or mitigating strategies, including limited imperviousness, infiltration trenches, and dry detention ponds.

Although the use of amended soils and retention of native vegetation have not been modeled, their use is strongly recommended. However, use of amended soils and retention of native vegetation will not reduce percent impervious, and corresponding infrastructure requirements. Properly functioning amended soil can significantly increase the amount of initial abstractions of the pervious area of the site. Initial abstractions reflect the depth of rainfall lost to depression storage and evapotranspiration. A minimum of 300 mm of amended soil should be placed on all pervious areas of the site.

Percent impervious for typical residential and commercial/industrial development was determined in Phase 2 to be 58% and 85-90%, respectively. However, to ensure sufficient sizing of infiltration trenches and dry detention ponds, Phase 3 modeling was completed with a percent impervious of 60% for single family residential areas and 90% for multifamily residential, industrial, commercial and institutional areas. The Adaptive Management Strategy in Section 6, provides an additional factor of safety by allowing for future expansion / deletion of area / storage of infiltration trenches and dry detention ponds.

To simulate infiltration trenches, the *"SPLIT"* command was used within QualHYMO to separate infiltration from sub-catchment runoff. A primary "*POND"* command was then used to simulate infiltration trench storage, and a secondary *"POND"* command was used to simulate a sub-catchment dry detention pond.

A schematic outline of the modeling routine is shown in **Figure 2**, double overleaf.

3.1 Sub-Catchments

The study area was further divided into seven sub-catchments for use in the Post-Development Low-Impact Design modeling. The sub-catchments were designated based on zoning, topography, and geological conditions. Model input parameters, which define the characteristics of the watershed, are tabulated in **Table 4** below. See **Figure 3**, double overleaf, for sub-catchment locations.

Table 4: Model Input Parameters

Sub-Catchment	Area (ha)	% Imp.	Time to peak (hr)		Initial Abstractions		S_{max}	S_{min}	Infiltration Rate (mm/hr)
			Perv.	Imp.	Perv.	Imp.			
1A	2.0	60	1.5	0.75	9.0	2.5	250	20	40
1B	5.9	90	1.5	0.75	9.0	2.5	250	20	40
2A	6.0	60	1.5	0.75	9.0	2.5	250	20	10
2B	6.4	90	1.5	0.75	9.0	2.5	250	20	50
3	25.8	90	1.5	0.75	9.0	2.5	250	20	80
4A	27.5	60	1.5	0.75	9.0	2.5	250	20	30
4B	6.4	90	1.5	0.75	9.0	2.5	250	20	10

Notes:

1) ha: Hectares
2) Imp.: Impervious
3) Perv.: Pervious
4) S_{max}: Maximum value of soil moisture storage (mm)
5) S_{min}: Minimum value of soil moisture storage (mm)

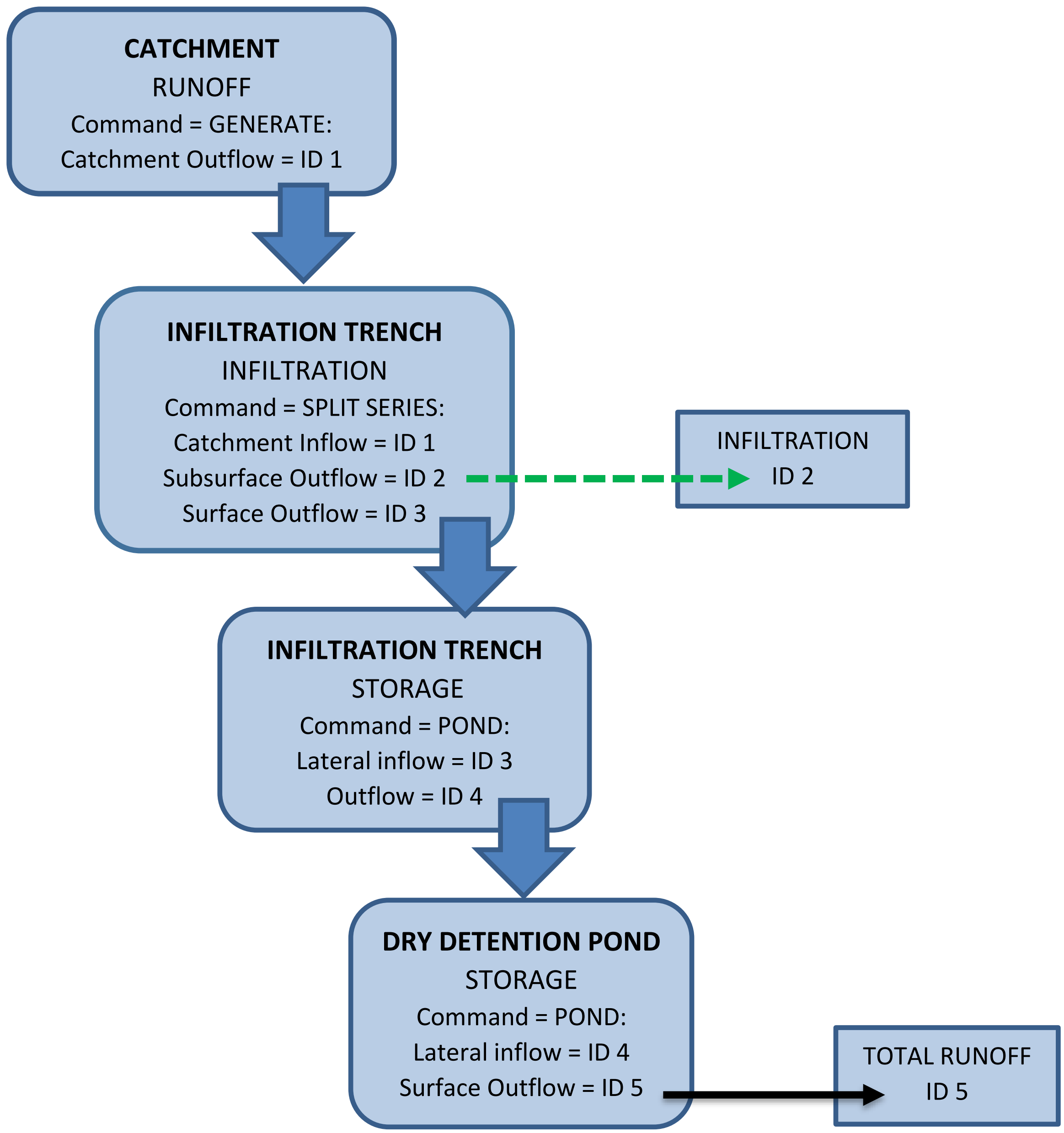


Figure 2: Post-Development Modeling Routine Schematic

FIGURE □ - SUB-CATCHMENT LOCATIONS

Soil moisture reservoir parameters (S_{min} and S_{max}) and base flow factors were set during the first phase of the study, and were verified utilizing a regional analysis based on similar watersheds, including Little River. The regional analysis included peak flood events, annual discharge volumes and hydrograph shapes.

The time to peak and initial abstractions for the post-development modeling were determined based on accepted norms for post-development hydrologic modeling. The infiltration rates of native soils are based on conservatively low values obtained from the various test pits and permeameter tests completed in each sub-catchment in Phases 1 and 2 of the study.

3.2 Infiltration Trench Modeling

Post-development mitigated scenarios were modeled with a single infiltration gallery / storage basin in each catchment. This method of modeling tests the efficacy of potential infiltrating BMPs without being specific as to their individual type, size, design, location, etc. In practice, infrastructure must be designed so that runoff is evenly distributed throughout those areas capable of receiving runoff, without worry of nuisance break out or flooding.

Infiltration potential was calculated based on the measured infiltration rate of the native soils in each catchment and the (plan view) base area of the infiltration trench. Infiltrated runoff was subtracted from the sub-catchment runoff series, simulating a diversion to ground. The remaining runoff was directed to a storage facility, simulating infiltration trench storage. The base area of each infiltration trench was then adjusted until post-developed runoff volume matched that of pre-developed.

Storage volumes for infiltration trenches are based on a 1.0 metre deep drain rock reservoir with a long-term porosity of 30%. The *"POND"* command was used (with the evaporation parameter set to zero) to simulate infiltration trench storage. Outlet rating curves for the infiltration trench "*POND*" storage are based on orifice controls sized to convey 4 lps/ha at 1 metre of head. 4 lps/ha was used as an approximation of the one year return unit area discharge target. To test the sensitivity of infiltration trench outlet controls and dry detention pond sizing, model scenarios were run based on doubling (8 lps/ha) and halving (2 lps/ha) outlet rating curves. It was determined that varying the infiltration trench outlet control had little effect on dry detention pond sizing. Increasing or decreasing the infiltration trench outlet rating curve does affect the detention time in infiltration trenches, but not the overall volume of infiltration. Note that infiltration is subtracted from the catchment discharge at a constant rate. For detailed design, infiltration trench outlet controls should target a release rate of 4 lps/ha. Overflows from infiltration trenches were modeled as oversized weirs to simulate unobstructed conveyance to downstream detention ponds.

Required infiltration trench base areas and storage volumes for each catchment are summarized in **Table 5**, overleaf.

Table 5: Infiltration Trench Sizing

Sub-Catchment				Infiltration Trench Parameters		
	Land Use	Total Area	% Imp	Total Base Area	Base Area per Hectare	Storage Volume[1] per Hectare
(#)	(Zoning)	(ha)	(%)	(m^2)	(m^2/ha)	(m^3/ha)
1A	R1.1	2.0	60	250	125	38
1B	R1.1	5.9	90	1180	200	60
2A	R1.1	6.0	60	2700	450	135
2B	I2.1 / PA1.1	6.4	90	1024	160	48
3	I2.1 / DND1.1	25.8	90	2580	100	30
4A	R1.1	27.5	60	4538	165	50
4B	I2.1	6.4	90	5120	800	240

Notes:

1) Infiltration trench storage volume is calculated as a 1 metre deep drain rock reservoir with a long-term void ratio of 30%. I.e., for every 1 square meter of base area, the total storage volume is 0.3 cubic metres.

2) Although sub-catchment 1B is zoned R1.1, the OCP has designated sub-catchment 1B for Residential: Low Rise Apartments, Townhouses and Ground Oriented Infill. As such, sub-catchment 1B was modeled at 90% impervious as a worst-case scenario.

3.3 Dry Detention Pond Modeling

Outflow from each infiltration trench storage unit was routed through a secondary *"POND"* command to estimate the sub-catchment storage requirement for larger rainfall events. All dry detention ponds were modeled as a 1.0 metre deep storage basin with the QualHYMO software. Outlet rating curves for dry detention pond storage are based on two orifice controls; one at base level and one approximately mid height of the pond. Pond volume and outlet rating curves were adjusted so that the post-development unit area exceedance curves matched the pre-development curves. The evaporation parameter was also set to zero for the dry detention ponds, as an additional factor of safety.

Appendix A contains the pre- and post- unit area exceedance curves for each of the seven sub-catchments.

The required dry detention pond volumes, summarized in **Table 6,** overleaf, are meant to provide an approximate required storage volume. The actual storage volume should be calculated at time of detailed design, through continuous simulation modeling based on the layout of each development, and the storage volume provided by the specific BMP designs within the sub-catchment. Alternative BMP designs utilizing *Storm Tech*™, *Triton*™ or similar proprietary systems which increase BMP storage capacity may be used. StormTech (or similar) chambers are particularly useful on confined commercial or industrial sites. Use of these proprietary underground storage facilities must be accepted by the Town prior to implementation, located within existing or new Town rights-of-way, and ultimately be owned, operated and maintained by the Town.

Table 6: Dry Detention Pond Sizing

Sub-Catchment				Dry Detention Pond	
	Land Use	**Total Area**	**% Impervious**	**Approximate Storage Volume**	**Storage Volume per Hectare**
(#)	**(Zoning)**	**(ha)**	**(%)**	**(m^3)**	**(m^3/ha)**
1A	R1.1	2.0	60	900	450
1B	R1.1	5.9	90	2655	450
2A	R1.1	8.0	60	2700	450
2B	I2.1 / PA1.1	4.4	90	2880	450
3	I2.1 / DND1.1	25.8	90	11610	450
4A	R1.1	27.5	60	12375	450
4B	I2.1	6.4	90	2240	350

Notes:

1) Although sub-catchment 1B is zoned R1.1, the OCP has designated sub-catchment 1B for Residential: Low Rise Apartments, Townhouses and Ground Oriented Infill. As such, sub-catchment 1B was modeled at 90% impervious as a worst-case scenario.

Prior to final sizing of dry detention ponds, detailed site-specific modeling will be required. Detailed dry detention pond modeling shall assume a percent impervious of 60% for single family residential and 90% for multi family, commercial, industrial and institutional zones, regardless of the actual percent impervious of the development. BMP sizing (including ponds) may be subject to refinement, based on actual soil conditions encountered.

3.4 Hydrological Mass Balances

Hydrological mass balances were calculated for the post-developed mitigated scenario, based on (model) generated total rainfall, initial abstractions and cumulative runoff exiting the neighbourhood pond. The cumulative runoff and initial abstractions tabulated from the model output were subtracted from the total rainfall, yielding the total infiltrated water (Catchment and BMP infiltration). Loss to deep groundwater was calculated as 69% of the total infiltrated water. This method is consistent with the model generated mass balance for each sub-catchment.

The intent of the North East Comox Storm Water Management Plan is to match both the pre-development hydrological mass balance and the unit area exceedance curves, post-development. The pre- and post-development overall (mass) water balances for each sub-catchment for the entire 42 years of rainfall are summarized in **Table 7,** below and overleaf.

Input and output files for each sub-catchment are included in **Appendix B.**

Table 7A: Sub-catchment 1A Mass Balance

Sub-Catchment 1A	**Pre-Development**	**Post-Development w/ Climate Change**	**Change in Volume**
	(mm)	**(mm)**	**(mm)**
TOTAL RAINFALL	50,964	53,348	2,384
TOTAL RUNOFF IMPRV+PERV	16,116	15,175	-941
ALL INITIAL ABSTRACTIONS	8,194	5,506	-2,688
TOTAL INFILTRATED WATER	26,655	32,668	6,013
LOSS TO DEEP GROUNDWATER	18,393	22,541	4,148
TOTAL BASE FLOW	8,264	10,127	1,863

Table 7B: Sub-catchment 1B Mass Balance

Sub-Catchment 1B	**Pre-Development**	**Post-Development w/ Climate Change**	**Change in Volume**
	(mm)	**(mm)**	**(mm)**
TOTAL RAINFALL	50,964	53348	2,384
TOTAL RUNOFF IMPRV+PERV	16,116	15457	-658
ALL INITIAL ABSTRACTIONS	8,194	4551	-3,643
TOTAL INFILTRATED WATER	26,655	33340	6,686
LOSS TO DEEP GROUNDWATER	18,393	23005	4,612
TOTAL BASE FLOW	8,264	10336	2,072

Table 7C: Sub-catchment 2A Mass Balance

Sub-Catchment 2A	Pre-Development	Post-Development w/ Climate Change	Change in Volume
	(mm)	(mm)	(mm)
TOTAL RAINFALL	50,964	53348	2,384
TOTAL RUNOFF IMPRV+PERV	16,116	16172	-658
ALL INITIAL ABSTRACTIONS	8,194	5506	-3,643
TOTAL INFILTRATED WATER	26,655	31670	6,686
LOSS TO DEEP GROUNDWATER	18,393	21853	4,612
TOTAL BASE FLOW	8,264	9818	2,072

Table 7D: Sub-catchment 2B Mass Balance

Sub-Catchment 2B	Pre-Development	Post-Development w/ Climate Change	Change in Volume
	(mm)	(mm)	(mm)
TOTAL RAINFALL	50,964	53348	2,384
TOTAL RUNOFF IMPRV+PERV	16,116	15458	-658
ALL INITIAL ABSTRACTIONS	8,194	4551	-3,643
TOTAL INFILTRATED WATER	26,655	33340	6,685
LOSS TO DEEP GROUNDWATER	18,393	23005	4,612
TOTAL BASE FLOW	8,264	10335	2,072

Table 7E: Sub-catchment 3 Mass Balance

Sub-Catchment 3	Pre-Development	Post-Development w/ Climate Change	Change in Volume
	(mm)	(mm)	(mm)
TOTAL RAINFALL	50,964	53348	2,384
TOTAL RUNOFF IMPRV+PERV	16,116	15449	-667
ALL INITIAL ABSTRACTIONS	8,194	4551	-3,643
TOTAL INFILTRATED WATER	26,655	33349	6,694
LOSS TO DEEP GROUNDWATER	18,393	23011	4,618
TOTAL BASE FLOW	8,264	10338	2,075

Table 7F: Sub-catchment 4A Mass Balance

Sub-Catchment 4A	Pre-Development	Post-Development w/ Climate Change	Change in Volume
	(mm)	(mm)	(mm)
TOTAL RAINFALL	50,964	53348	2,384
TOTAL RUNOFF IMPRV+PERV	16,116	15231	-885
ALL INITIAL ABSTRACTIONS	8,194	5506	-2,688
TOTAL INFILTRATED WATER	26,655	32612	5,957
LOSS TO DEEP GROUNDWATER	18,393	22502	4,109
TOTAL BASE FLOW	8,264	10110	1,846

Table 7G: Sub-catchment 4B Mass Balance

Sub-Catchment 4B	Pre-Development	Post-Development w/ Climate Change	Change in Volume
	(mm)	(mm)	(mm)
TOTAL RAINFALL	50,964	53348	2,384
TOTAL RUNOFF IMPRV+PERV	16,116	15457	-659
ALL INITIAL ABSTRACTIONS	8,194	4551	-3,643
TOTAL INFILTRATED WATER	26,655	33341	6,686
LOSS TO DEEP GROUNDWATER	18,393	23005	4,612
TOTAL BASE FLOW	8,264	10336	2,072

4.0 BMP DESIGN AND SELECTION

4.1 Standardized Best Management Practice Details

A series of standardized detailed drawings were developed for those BMPs selected for further consideration in Phase 2. These details have been developed with input from the Town and its consultant, and are generally based upon designs utilized by other municipalities with experience in Low Impact Development. These details will, upon review and adoption by the Town, be integrated into the Subdivision Servicing Bylaw, for use within not only NE Comox, but also other areas of the Town where traditional pipe and pond stormwater management is not practical or desired.

The following Standard Drawings can be found in **Appendix C**:

SC-101 – Service Connections with Disconnected Roof Leaders

SC-102 – Sediment Catch Basin

SC-103 – Control Manhole

SC-104 – Boulevard Infiltration Trench

SC-105 – Street Infiltration Trench

SC-106 – Clean Out

SC-107 – Curbing Options at Infiltration Trenches

SC-108A – Typical Lot Grading

SC-108B – Typical Lot Grading

SC-109 – Dry Detention Pond Sign Detail

Pond-101 – Dry Detention Pond Plan & Sections

Pond-102 – Dry Detention Pond Outlet Control Structure Sections and Details

Appendix D contains sub-catchment mapping showing suitable locations for infiltration trenches and dry detention ponds. The purpose of sub-catchment mapping in **Appendix D** is to show possible areas for each of the BMPs. Actual BMP locations may vary.

4.2 Standardized Best Management Practice Specifications

4.2.1 Storm Drainage System

The storm drainage works and services shall be designed, constructed and installed in accordance with the latest edition of the Town of Comox Subdivision and Development Servicing Bylaw unless otherwise noted herein.

4.2.1.1 General

4.2.1.1.1 Stormwater BMPs shall be incorporated into subdivision and lot development to meet the requirements of the approved stormwater management plan for the development, and the requirements herein.

4.2.1.1.2 Selection of stormwater BMPs shall be made with regard to the topography, water table, soil or rock infiltration capacity, and downstream slope stability hazards.

4.2.1.1.3 Infiltration trenches shall not be consecutive. That is, once runoff travels through a control manhole downstream of an infiltration trench, said runoff shall not be directed to additional infiltration trenches, but conveyed via the storm system to an outlet or neighbourhood dry detention pond.

4.2.1.1.4 Prior to design, infiltration rates for each site shall be confirmed. Infiltration rates to be verified using the *Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer ASTM D3385 – 09*. If field tested infiltration rates vary by more than 25% of the applicable modeled rates shown in **Table 4 – Model Input Parameters**, the required base area and storage volume of the infiltration trench shall be re-calculated.

4.2.1.1.5 Infiltration trenches must meet both the base area and storage volume for the applicable sub-catchment as specified in **Table 5**.

4.2.1.1.6 Infiltration trenches shall be sized by the design engineer based on the tributary area of developed land and the land use, and in accordance with the surface areas and volumes specified in **Table 5 – Infiltration Trench Sizing**. To calculate the required Infiltration trench base area and storage volume, multiply the tributary area (in hectares) by the per hectare base area and storage volumes, for the applicable sub-catchment, tabulated in **Table 5**.

4.2.1.1.7 Base areas for infiltration trenches shall be calculated as the total base area of the drain rock reservoir.

4.2.1.1.8 Storage volumes for infiltration trenches shall be calculated as the total volume of the drain rock reservoir multiplied by a porosity of 30%.

4.2.1.1.9 Maximum discharge rate, infiltration rate, storage volume and drawdown time (the time it takes for an infiltration trench or dry detention pond to completely drain once inflow has stopped) for each BMP, shall be calculated by the design engineer and submitted to the Town for acceptance.

4.2.1.1.10 To the extent possible, infiltration trenches shall be dispersed throughout the development.

4.2.1.1.11 All BMPs except for amended soil shall be located within municipal rights-of-way or statutory rights-of-way in favour of the Town.

4.2.1.2 Guidelines

4.2.1.2.1 All unpaved landscape areas shall have a minimum depth of 300mm of amended soil, either existing (if acceptable) or imported over scarified subgrade. The surface shall be vegetated or re-vegetated. Immediately before seeding or planting, the surface shall be cultivated to remove surface crusting. Compacted areas that do not exhibit free drainage shall be scarified. At time of subdivision:

(1) lots shall be graded as per SC-108A or SC-108B as applicable with a minimum slope of 1% and;

(2) a lot grading plan shall be submitted to the Approving Officer confirming that the grades at time of final subdivision approval are in compliance to SC-108A / SC-108B. The lot grading plan shall provide the geodetic elevation at the corners of each lot, 0.5 metre contours for any lot with a grade deferential of 1.0 metre or more and arrows showing the direction of the lot grades.

The lot grading established at time of subdivision is to be maintained at time of building permit, with the exception of allowing for the grading of building foundation backfill in conformance to BC Building Code requirements and the addition of 300mm of amended soil. The slope of the amended soil must follow the slope of the lot grades established at time of subdivision with the exception of allowing for the grading of building foundation backfill in conformance to BC Building Code requirements.

4.2.1.2.2 All paved areas, such as streets, driveways or walkways, shall either be sloped to drain onto adjacent unpaved landscape areas, boulevard infiltration trenches, or collected in catch basins and routed through subsurface infiltration trenches. Infiltration trenches and landscaped areas designed as infiltration trenches shall be designed in accordance with the guidelines below, to encourage runoff from these areas to infiltrate into the soil.

4.2.1.2.3 Roof runoff shall not be directly connected to the storm service connection. All roof runoff shall be directed onto adjacent unpaved landscape areas. Lots shall be graded to direct overland flow onto adjacent unpaved landscape areas, or permeable infiltration trenches.

4.2.1.2.4 Maximum ponding depth of boulevard infiltration trenches shall be 150mm. All boulevard infiltration trenches shall drain away from buildings and shall have an overflow to the 100-year return period flow path.

4.2.1.2.5 The surface of unpaved landscape areas shall be designed for positive drainage away from buildings. Slopes of 1% to 4% are desirable to encourage infiltration of small rainfalls while facilitating drainage of large storms and to prevent flooding of buildings.

4.2.1.2.6 Geotechnical investigation will be required prior to implementing infiltration trenches in the following conditions:

4.2.1.2.6.1 Areas within 30m of a slope that is steeper than 3 (horizontal) to 1 (vertical) and higher than 6m, or other unstable slopes as determined by the Town.

4.2.1.2.7 Infiltration trenches are required in all developments. Required practices are:

4.2.1.2.7.1 Infiltration trenches shall be installed where appropriate and with Town acceptance, in accordance with this document.

4.2.1.2.7.2 All utility crossings of infiltration trenches shall have trench dams installed as necessary to stop infiltration water from flowing down the utility trench. Trench dams to be constructed of either non-shrink grout, a minimum of 150mm thick and keyed into trench walls a minimum of 150mm, or compacted impermeable earthen material approved by a geotechnical engineer a minimum of 450mm thick and keyed into trench walls a minimum of 300mm.

4.2.1.3 <u>Materials</u>

All materials to be in accordance with the current edition of the Town of Comox Subdivision and Development Specifications Bylaw unless specified herein.

4.2.1.3.1 Infiltration Drain Rock: clean round stone or crushed rock conforming to the following gradations:

Drain Rock

Sieve Designation	Percent Passing
25.0 mm	100
19.0mm	0 – 100
9.50mm	0 – 5
4.75mm	0

4.2.1.3.2 Geosynthetics: as specified on contract drawings.

4.2.1.3.3 Sand: Pit Run Sand, well graded, free from organic materials and conforming to following gradations:

Pit Run Sand

Sieve Designation	Percent Passing
12.5mm	100
4.75mm	35 – 100
2.36mm	20 – 100
1.18mm	13 – 70
0.600mm	8 – 50
0.300mm	5 – 35
0.150mm	2 – 25
0.075mm	0 – 6

4.2.1.4 Amended soil shall meet the requirements of Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13 in WDOE Stormwater Manual for Western Washington (see Phase 2 Report), with organic matter requirements modified as follows:

4.2.1.4.1 For lawn areas 4 – 8%

4.2.1.4.2 For planting areas 4 – 18%

4.2.1.5 <u>Installation and Testing</u>

Installation and testing to be in accordance with the current edition of the Town of Comox Subdivision and Development Specifications Bylaw.

Testing of infiltration trenches may be required upon the Town's request. The recommended procedure for testing infiltration rate, and storage volume of infiltration trenches is as follows:

- Check the weather. Testing should be completed on a dry day with no rain in the forecast.
- Prior to testing, a complete inspection of the infiltration trench is required. Check the control manhole, cleanouts, observation well, upstream catch basins and manhole inlet piping. Remove any signs of sediment or debris buildup with the use of a vactor truck or other means capable of removing sediment without flushing sediment and debris into the infiltration trench or storm sewer. Allow system to completely drain prior to testing.
- Check the observation well to ensure the infiltration trench is completely empty.
- Ensure that there is ample supply of clean water free of contaminants. It is recommended to fill the infiltration trench at a minimum rate of three times the

maximum design infiltration rate. A minimum available volume of water of one half the infiltration trench design storage volume is recommended.

- Block the downstream outlet.
- Install a water level meter at ¼ of the depth of the infiltration trench either in the observation well or the control manhole overflow piping.
- Fill infiltration trench with clean water via manhole, catch basin or cleanout until ¼ full.
- Record total input volume, and time to fill ¼ full.
- Let infiltration trench completely drain through infiltration and record the total time.
- First calculate the infiltration rate using the following formula:

$$\frac{total\ input\ volume}{total\ time} = infiltration\ rate$$

  If calculated infiltration rate is not within 15% of design infiltration rate, the Town may require the infiltration trench be reconstructed.

- Second, calculate the storage volume using the following formula:

$$4 \times [total\ input\ volume - (infiltration\ rate \times time\ to\ fill)] = storage\ volume$$

  If calculated storage volume is not within 15% of design storage volume (this could mean that sediment has filled in a portion of the available volume), the Town may require the storage volume to be rehabilitated.

- Ensure that all manhole covers, catch basin grates, clean out and observation well lids are securely in place once test is complete.

For ponded areas of boulevard infiltration trenches, the ponded area drain time should also be checked using the following recommended method:

- On a dry day with no rain in the forecast, fill surface collection area with clean water to a ponded depth of 100mm and record time to completely drain.
- Drain time should be less than 4 hours. If drain time is greater than 4 hours, the Town may require the amended soil / washed sand layer to be removed and replaced.

4.2.1.6 Maintenance

The developer shall maintain the storm drainage works and services within the public right-of-way for the duration of the Maintenance Period. "Maintenance Period" is defined as:

a) Where construction works consist of subdivision and subdivision servicing for minor development.

   Until such time as occupancy permit issuance for a minimum of 90 percent of the parcels created and certification by the designated environmental monitor has been received by the Building Inspector that all Erosion Sediment Control Plan (ESCP) requirements have been completed, including the construction of gravel access pads for each building lot, final decommissioning of ESCP facilities for each of the phases, proper disposal of any waste materials, and disturbed or exposed soil areas have been re-vegetated and stabilized pursuant to the ESCP for which a permit has been issued.

b) Where construction works consist of subdivision and subdivision servicing for development other than minor development:

   Until such time as Approving Officer approval of the subdivision, or fulfillment of the terms of a subdivision services agreement, whichever is the latter, and certification by the designated environmental monitor has been received by the Municipal Engineer that all Erosion Sediment Control Plan (ESCP) requirements have been completed, including the construction of gravel access pads for each building lot, final decommissioning of ESCP facilities for each of the phases, proper disposal of any waste materials, and disturbed or exposed soil areas have been re-vegetated and stabilized pursuant to the ESCP for which a permit has been issued. Municipal Engineer receipt of the designated environmental monitor certification of ESCP completion is required before Approving Officer approval of the subdivision, or fulfillment of the terms of a subdivision services agreement, whichever is the latter.

c) Where construction works consist of a building permit other than for minor development:

   Until such time as occupancy permit issuance and certification by the Designated Environmental Monitor has been received by the Building Inspector that all Erosion Sediment Control Plan (ESCP) requirements have been completed, including final decommissioning of ESCP facilities for each of the phases, proper disposal of any waste materials, and disturbed or exposed soil areas have been re-vegetated and stabilized pursuant to the ESCP for which a permit has been issued. Building Inspector receipt of the Designated Environmental Monitor certification of ESCP completion is required before Building Inspector issuance of an occupancy permit. At the termination of the Maintenance Period and upon the Town's satisfaction that the system is performing as intended, the maintenance responsibility for the works within the public right-of-way will be transferred to the Town.

4.2.1.7 Monitoring

See Section 6.2.

4.2.2 Disconnected Roof Leaders (Standard Drawing SC-101)

Roof leaders shall not be connected to the municipal storm service. Roof leaders shall be disconnected and directed via lot grading to an unpaved landscaped area per **Standard Drawing SC-101**. Splash pads, drain rock or other similar means to displace energy and eliminate erosion at roof leader outlets should be used. Building lots shall be graded so that each property either drains directly to a municipal / statutory right-of-way or, at most, across one (1) other lot before reaching a municipal / statutory right-of-way. Subdivision lot grading and ultimate lot grading (post-building construction) shall be per the details on **Standard Drawing SC – 108A or SC – 108B as applicable**. Grading away from buildings shall be as per the latest edition of the British Columbia Building Code with a recommended minimum grade away from buildings of 4% for 1.8 metres or 2% for 4.0 metres.

4.2.3 Sediment Catch Basin (Standard Drawing SC-102)

Sediment catch basins shall conform to the current edition of the Town of Comox Subdivision and Development Specifications Bylaw. Where appropriate, catch basins shall have an underdrain connected to an infiltration trench per **Standard Drawing SC-102**.

4.2.4 Control Manhole (Standard Drawing SC-103)

Control manholes shall conform to the current edition of the Town of Comox Subdivision and Development Specifications Bylaw with the addition of an outlet flow control and overflow per **Standard Drawing SC-103**. Flow control to consist of a PVC tee, pipe stub cut at 30 degrees to the horizontal and a 15mm thick PVC plate solvent welded to pipe stub. Orifices to be sized to discharge 4 litres per second per hectare of tributary area per the sizing table on **Standard Drawing SC-103**. Overflow shall be a PVC pipe stub securely attached to the manhole wall with an inlet elevation set at the top elevation of the upstream infiltration facility.

4.2.5 Boulevard Infiltration Trench (Drawing SC-104)

4.2.5.1 Design Guidelines

4.2.5.1.1 Smaller, distributed infiltration trenches are preferred to single large-scale facilities.

4.2.5.1.2 Locate boulevard infiltration trenches so there is at least 3m of undisturbed soil between the trench and any building. Where the trenches are within 30m of wells or unstable slopes, a geotechnical review will be required.

4.2.5.1.3 Flow to boulevard infiltration trenches shall be distributed sheet flow, travelling through a filter strip: non-erodible material for erosion and scour protection, either vegetated (grassed) or non-vegetated (drain rock) filter area or swale (500mm minimum, greater than 3000mm desirable filter length) see **Standard Drawing SC-107**.

4.2.5.1.4 Boulevard infiltration trench to have a level perforated drain pipe with either a manhole or clean out per **Standard Drawing SC-106** installed at the upstream end.

4.2.5.1.5 Outflow from boulevard infiltration trench will be regulated by a control manhole per **Standard Drawing SC-103** prior to discharge into a storm main.

4.2.5.1.6 Boulevard infiltration trench bottom to be level.

4.2.5.1.7 Boulevard infiltration trench bottom width - 600mm minimum.

4.2.5.1.8 Install boulevard infiltration trench in native ground, and avoid over-compaction of the trench sides and bottom, which reduces infiltration.

4.2.5.1.9 Provide erosion control along all sides of drainage inlets.

4.2.5.1.10 Pavement edge at the swale to be per **Standard Drawing SC-107**. Provide a 100mm drop at the edge of paving to the filter strip, to allow for positive drainage and buildup of road sanding/organic materials at this edge. Ensure positive drainage from curb into the ponded invert.

4.2.5.1.11 Ponded area side slopes of a maximum of 2H:1V, 4H:1V are recommended to aid operations and maintenance. Provide amended soil on side slopes similar to bottom. Approved plantings are provided below. Alternative native species may be used upon acceptance of the Town. See **Standard Drawing SC-104** for an overview of the three planting zones; Center, Sloped Sides and Bermed Edges.

Center:

This area floods often and requires species that tolerate frequent flooding. Approved species that may be used in this zone are as follows:

- Tall sedge (Carex appressa)
- Spike rush (Eleocharis)
- Common cottongrass (Eriophorum angustifolium)
- Land quillwort (Isoetes histrix)
- Dwarf cattail (Typha minima)
- Giant leather fern (Acrostichum danaeifolium)
- Lady fern (Athyrium fillix –femina)

- Cinnamon fern (Osmunda cinnamomea)
- Royal fern (Osmunda regalis)
- Sword fern (Polystichum munitum

Sloped Sides:

This area floods briefly and requires plant species that tolerate damp soil but require only modest amounts of water during the dry season. Deciduous native shrubs, ferns, and grasses could be considered for use in this zone. Approved species of grasses and native shrubs that may be used in this zone are as follows:

Grasses:

- Big bluestem (Andropogon gerardii)
- Meadow pinegrss, reedgrass (Calamagrostis Canadensis)
- Meadow barley (Hordeum secalinum)
- Moor grass (Molinia caerulea)
- Switchgrass (Panicum virgatum)

Shrubs:

- Dogwood (cornus)
- Oceanspray (Holodiscus discolor)
- Sumac (Rhus)
- Thimbleberry (Rubus parviflorus

Bermed Edges:

These areas are outside the flood zone. Approved species of herbaceous perennials that may be used in this zone are as follows:

- Yarrow (Achillea millefolium)
- Swamp milkweed (Asclepias incarnata)
- Purple coneflower (Echinacea purpurea)
- Tuffted bluebell (Wahlenbergia communis)

4.2.5.1.12 Provide observation well for each boulevard infiltration trench: vertical standpipe, with perforated sides (perforated in drain rock reservoir only), and locking lid, to allow monitoring of water depth and sediment loading.

4.2.5.1.13 Maximum ponded level: 150mm.

4.2.5.1.14 A non-erodible outlet or spillway must be established to discharge overflow.

4.2.5.1.15 Avoid utility or other crossings of the boulevard infiltration trench. Where utility trenches must be constructed crossing below the boulevard infiltration trench, install trench dams to avoid infiltration water following the utility trench.

4.2.5.2 Construction

4.2.5.2.1 Isolate the ponded area from sedimentation during construction, either by use of effective erosion and sediment control measures upstream, or by delaying the excavation of 300mm of material over the final subgrade of the ponded area, until all sediment-producing construction in the drainage area has been completed.

4.2.5.2.2 Prevent natural fill soils from intermixing with the infiltration drain rock. All contaminated stone aggregate must be removed and replaced.

4.2.5.2.3 Infiltration drain rock shall be installed in 300mm lifts and "compacted" to eliminate voids between the geotextile and surrounding soils.

4.2.5.3 Maintenance

4.2.5.3.1 Cleaning out leaves, debris and accumulated sediment caught in manhole sumps, trenches, inlets and outlets (quarterly or as required).

4.2.5.3.2 Periodic internal inspection (via observation well) shall be performed to ensure the facility drains within the maximum acceptable length of time (typically 72 hours or as required by specific design) at least twice annually (spring and fall), and following a major storm event (>25 mm in 24 hrs). If the time required to fully drain exceeds the allowable time, drain via pumping and flush the perforated drain pipe. If slow drainage persists, the system may need removal and replacement of granular material and/or geotextile fabric.

4.2.5.3.3 Infiltration trench design must be accompanied by a comprehensive Erosion and Sediment Control Plan (ESCP) for the development, which shall document the required mitigation practices.

4.2.6 Street Infiltration Trench (Standard Drawing SC-105)

4.2.6.1 Design Guidelines

4.2.6.1.1 Locate street infiltration trenches so there is at least 3m of undisturbed soil between the trench and any building. Where the trenches are within 30m of wells or unstable slopes a geotechnical review will be required.

4.2.6.1.2 Provide a sump manhole or catch basin upstream of all street infiltration trenches for pre-treatment grit separation to avoid sedimentation in the infiltration trench. Do not allow drainage from land uses with a high risk for water pollution (e.g. refueling stations) to enter an infiltration trench.

4.2.6.1.3 Installation of perforated drain pipe within the drain rock reservoir to be level.

4.2.6.1.4 Outflow from street infiltration trenches will be regulated by a control manhole per **Standard Drawing SC-103** prior to discharge to a storm main.

4.2.6.1.5 Street infiltration trench bottom to be level.

4.2.6.1.6 Street infiltration trench bottom width - 600mm minimum.

4.2.6.1.7 Install the street infiltration trench in native ground, and avoid over-compaction of the trench sides and bottom, which reduces infiltration.

4.2.6.1.8 Provide observation well for each street infiltration trench: vertical standpipe, with perforated sides (perforated in drain rock reservoir only), and locking lid, to allow the monitoring of water depth and sediment loading.

4.2.6.1.9 Avoid utility or other crossings of the street infiltration trench. Where utility trenches must be constructed crossing below the street infiltration trench, install trench dams to avoid infiltration water following the utility trench.

4.2.6.2 <u>Construction</u>

4.2.6.2.1 Physically isolate the street infiltration trench from flow during construction by capping all inlet and outlet pipes and directing runoff directly to the municipal storm main.

4.2.6.2.2 Prevent natural fill soils from intermixing with the infiltration drain rock. All contaminated stone aggregate must be removed and replaced.

4.2.6.2.3 Infiltration drain rock shall be installed in 300mm lifts and compacted to eliminate voids between the geotextile and surrounding soils.

4.2.6.3 <u>Maintenance</u>

4.2.6.3.1 Clean out leaves, debris and accumulated sediment caught in manhole sumps, inlets and outlets (quarterly or as required).

4.2.6.3.2 Periodic internal inspection (via observation well) shall be performed to ensure the facility drains within the maximum acceptable length of time (typically 72 hours or as required by specific design) at least twice annually (spring and fall), and following a major storm event (>25 mm in 24hrs). If the time required to fully drain exceeds the allowable time, drain via pumping and flushing the perforated drain pipe. If slow drainage persists, the system may need removal and replacement of granular material and/or geotextile fabric.

4.2.6.3.3 Street infiltration trench design must be accompanied by a comprehensive Erosion and Sediment Control Plan (ESCP) for the development, which shall document the required mitigation practices before, during and after the subdivision civil servicing construction.

4.2.7 Lot Grading (Standard Drawings SC–108A and SC–108B)

4.2.7.1 General

4.2.7.1.1 At time of subdivision:

(1) lots shall be graded as per **Standard Drawings SC-108A** or **SC-108B** as applicable, with a minimum slope of 1% and;

(2) a lot grading plan shall be submitted to the Approving Officer confirming that the grades at time of final subdivision approval are in compliance to **Standard Drawings SC-108A / SC-108B**. The lot grading plan shall provide the geodetic elevation at the corners of each lot, 0.5 metre contours for any lot with a grade deferential of 1.0 metre or more, and arrows showing the direction of the lot grades.

The lot grading established at time of subdivision is to be maintained at time of building permit, with the exception of allowing for the grading of building foundation backfill in conformance to BC Building Code requirements and the addition of 300mm of amended soil. The slope of the amended soil must follow the slope of the lot grades established at time of subdivision with the exception of allowing for the grading of building foundation backfill in conformance to BC Building Code requirements.

4.2.7.1.2 Where possible, avoid drainage across adjacent lots. When not possible, lots shall be graded so that drainage is only required to travel across one (1) adjacent lot before discharging to a municipal / statutory right-of-way. **Standard Drawings SC–108A and SC–108B** provide typical lot grading details for lots draining directly to a municipal / statutory right-of-way and for lots draining across an adjacent lot prior to reaching a municipal / statutory right-of-way.

4.2.7.1.3 Lots shall be graded to comply with the BC Building Code latest edition.

4.2.8 Dry Detention Pond (Standard Drawings Pond-101 and Pond-102)

4.2.8.1 General

4.2.8.1.1 Size dry detention ponds by continuous flow modeling to provide rainfall capture of historic rainfall adjusted for 2050 climate change. **Table 6 –Dry Detention Pond Sizing**, provides a rough estimate of required dry detention pond sizing based on the tributary area of developed land and current Official Community Plan designation.

4.2.8.1.2 A maximum of three dry detention ponds will be permitted within the study area to facilitate ease of ongoing maintenance.

4.2.8.1.3 Dry detention ponds shall be sized to service their entire upstream tributary catchment area within the NE Comox neighbourhood based on the current Official Community Plan designation. Ponds may be built in phases so that the pond volume can be expanded with additional upstream development. The pond volume can be expanded a maximum of two times. All components constructed in the first phase shall be sized to accommodate the entire buildout of the upstream tributary area, with the exception of overall pond volume. All dry detention ponds must drain to the Knight Road right-of-way.

4.2.8.1.4 Dry detention pond locations to be determined at time of detailed design, in conjunction with Town acceptance, to maximize the upstream tributary area while allowing for downstream conveyance to the Knight Road right-of-way.

4.2.8.2 Design Guidelines

4.2.8.2.1 Dry Detention Ponds and underground storage reservoirs are the preferred method of stormwater detention for the NE Comox neighborhood, as water fowl pose a risk to the nearby airport. Dry Detention Ponds shall be built in conformance with Transport Canada's document *TP 1247 - Aviation - Land Use in the Vicinity of Aerodromes.*

4.2.8.2.2 Base elevations of dry detention ponds shall be above the seasonal groundwater elevation to avoid saturation in the winter months.

4.2.8.2.3 The design maximum water level shall be at or below the existing ground elevation[3].

[3] Maximum pond water level above existing the existing ground elevation may be considered provided the following issues are addressed to the satisfaction of the Town: potential inspection, maintenance and replacement costs as well as the downstream implications if there is a failure

4.2.8.2.4 A minimum freeboard of 0.6m shall be provided above the designed maximum water level.

4.2.8.2.5 The dry detention pond berms shall be constructed with a maximum interior side slope of 5H:1V and a maximum exterior side slope of 5H:1V.

4.2.8.2.6 The top of dry detention pond berms shall be a minimum width of 3.0m.

4.2.8.2.7 Pilot channels may be piped.

4.2.8.2.8 A pre-treatment sump or sediment forebay is to be provided at the inlet to pilot channels.

4.2.8.2.9 Pond inlets and outlets shall have safety grillage and be constructed of either precast concrete or fiberglass materials as approved by the Town.

4.2.8.2.10 The dry detention pond and outlet structure shall be designed to function with the overall objective of the NE Comox Stormwater Management Plan.

4.2.8.2.11 The flow control structure is to be constructed with a removable orifice plate sized to restrict flows to the pre-development target rates and shall be located within a lockable manhole positioned within the embankment for purpose of maintenance, access, safety and aesthetics.

4.2.8.2.12 An emergency spillway shall be designed to accommodate the post-development runoff in excess of a 1:100-year storm event. The discharge path from the dry detention pond to the receiving environment shall be adequately protected from erosion.

4.2.8.2.13 The design of the emergency spillway shall be determined based on the exit velocity of stormwater runoff from the dry detention pond.

4.2.8.2.14 A minimum of 4 signs shall be installed around the perimeter of dry detention ponds. Signs to be per **Standard Drawing SC-109**.

4.2.8.2.15 An access tract or road sufficient to accommodate maintenance vehicles shall be provided from the public right-of-way to the inlet and outlet structures and to the pond bottom.

4.2.8.2.16 Pedestrian trails to Town Standards may be included where applicable and desired, subject to Town acceptance.

4.2.8.2.17 Dry detention pond and surrounding green space landscaping should be designed and installed under the direction of a landscape architect with preference given to native species.

4.2.8.3 Maintenance

4.2.8.3.1 Inspection is recommended at least twice annually in the fall prior to the rainy season and spring after the rainy season, and after significant rainfall events (>25 mm in 24hrs).

4.2.8.3.2 Cleaning out leaves, debris and accumulated sediment caught in manhole sumps, pre-treatment sumps, sediment forebays, inlets and outlets is required twice per year, or as needed.

4.2.8.3.3 Maintain pilot channel (where applicable) free and clear of debris and vegetation buildup. Base flows should not be impeded.

4.2.8.3.4 Maintain grass areas to mowed height between 50mm and 150mm, above the design highwater level. Landscape Maintenance standards shall be to the BC Landscape Standard, 6th Edition, Maintenance Level 4: Open Space / Play Area.

4.2.8.3.5 Maintain access road as required. Emergency or maintenance vehicle access must be provided at all times.

4.2.8.3.6 Inspect and maintain pond berms and overflow weir as required. Any evidence of seepage or erosion should be reported immediately.

4.2.8.3.7 As accumulation of vegetation / sedimentation will decrease the overall pond volume, vegetation / sedimentation should be maintained / removed as required to ensure no net loss in pond volume. A volume survey should be conducted every five years to confirm no decrease in capacity.

4.2.8.3.8 Periodic internal inspection of control structure shall be performed to ensure proper functionality. Inspect at least annually following a significant storm event. If the facility does not drain within the maximum acceptable length of time (typically 48 hours or as required by specific design), check and clean control structure.

4.3 Low Impact Development Infrastructure Costing

The use of Low Impact Development (LID) infrastructure is more expensive than conventional "pipe and pond" methods of managing stormwater/runoff. Historically, pipe and pond infrastructure was utilized, primarily because it was an effective means of conveying stormwater from developed lands/mitigating flooding of upland areas, and was relatively inexpensive to install.

Financial cost alone is no longer justification for selection of municipally owned infrastructure, where a number of options exist. The Town has elected to take a more holistic approach in the management of rainwater, consciously electing to place value on the environment, agricultural productivity, and the concerns of its residents, in addition to financial costs.

The Town has indicated a desire to fund the ongoing operation and maintenance, as well as potential renewal of infrastructure, through the creation of a Local Area Service (LAS). An LAS allows the Town to levy a special tax on those properties within a specified service area boundary. This levy can be used to fund an operations and maintenance budget, and to create a sinking fund for infrastructure renewal. Similar LASs have been created within the Town to fund, amongst other things, sanitary sewer lift stations.

Prior to accepting the use of LID infrastructure, the Town requires an understanding of actual construction costs, specifically the increased costs of servicing based on the use of LID infrastructure vs traditional stormwater management infrastructure. Ultimately, this infrastructure will require renewal (as would any other infrastructure). The cost of renewal could, depending on initial design and construction practices, cost more than initial construction costs. Factors that could affect replacement costs include:

- Location of LID infrastructure and the need for incidental replacement of pavement, curbs, sidewalks, etc. Increased costs required as a function of location of hard surface infrastructure can, in many cases, be mitigated through design. In those instances where infrastructure must be located under hard surfaces, these costs should be accounted for in renewal cost estimates.
- Location of other underground utilities, particularly service crossings atop of linear infiltration trenches.
- Public nuisance, including the need to disrupt service, temporarily close roads, or limit access to parks and other public spaces.

Cost estimates are provided for selected BMPs in **Appendix E.** These costs are based on typical BMP sizing that has been normalized to provide a cost “per unit area of infiltration”, and “per cubic metre of storage”. A summary of costs is provided in **Table 8** overleaf.

Table 8: Summary of BMP Costs

		BMP		
		Boulevard Infiltration Trench w/ Surface Collection	**Street Infiltration Trench w/ Impervious Cover**	**Dry Detention Pond**
Initial Construction Costs	Per m^3 of storage:	$625	$414	$103
	Per m^2 of infiltration:	$281	$124	n/a
Replacement Costs	Per m^3 of storage:	$778	$755	$26
	Per m^2 of infiltration:	$350	$227	n/a
Annual O&M Costs	Per m^3 of storage:	$29	$8	$1
	Per m^2 of infiltration:	$13	$2	n/a

Notes:

1) Class C cost estimate in 2015 dollars (+/- 25%).

2) Costs are exclusive of land value, landscaping or other improvements surrounding the BMPs.

3) Infiltration and evaporation have not been modeled for dry detention ponds, to be conservative.

5.0 PUBLIC EDUCATION

Developers will be required to engage in public education to inform builders, visitors and potential property buyers of the specific stormwater BMPs in the neighbourhood, the required maintenance and care of the stormwater BMPs and the requirement for specific taxes in the Local Area Service (LAS). Public education will come in three forms: Neighbourhood Street Signs; Identifier Signs for Boulevard Infiltration Trenches; and Information Brochures.

Neighbourhood street signs will be placed at the entrances to new subdivisions to educate all visitors about the specific neighbourhood BMPs and their required care. Neighbourhood street signs shall conform to the Town of Comox sign specifications and contain the information outlined below:

> *Welcome to the NE Comox Local Service Area. This neighbourhood has been specially designed to reduce rainwater runoff from roofs, driveways, and roads that wash pollutants into our streams and rivers, and to prevent an increase in the risks of downstream flooding. The following Low Impact Development features are at work in this neighbourhood.*

BOULEVARD INFILTRATION TRENCH

Boulevard infiltration trenches are vegetated or rock covered depressions located within roadside boulevards. They use vegetation, mulch, and permeable soils to filter pollutants, reduce runoff volume, and protect our watercourses. To maintain proper function, ***keep vehicle and foot traffic out of boulevard infiltration trenches.***

DRY DETENTION POND

Stormwater dry detention ponds prevent the erosion of downstream rivers by collecting and detaining stormwater, then slowly releasing it into the municipal system. The slow release of water reduces scouring of the natural channels downstream and prevents an increase in the risks of downstream flooding. Be advised that ***dry detention ponds are subject to flooding during rainy periods.***

Identifier signs for boulevard infiltration trenches will be installed in front of all boulevard infiltration trenches. Identifier signs for boulevard infiltration trenches will also conform to the Town of Comox sign specifications and contain the information outlined below:

BOULEVARD INFILTRATION TRENCH

Boulevard infiltration trenches are vegetated areas constructed of well-draining soil, low-maintenance plants, and landscape rock. Boulevard infiltration trenches help keep our streams and rivers clean by filtering, storing, and infiltrating rainfall that runs off roads and sidewalks. You can do your part to keep these tools functioning effectively by keeping vehicle and foot traffic out of the boulevard infiltration trenches.

The Town will choose the location and number of neighbourhood street signs and identifier signs for boulevard infiltration trenches depending on the size and location of the subdivision / development and quantity of infiltration trenches. The developer will be responsible to install street and identifier signs prior to subdivision approval or occupancy permit.

Brochures will be used to educate general contractors, sub-trades, potential and existing property owners. Brochures will be distributed by the Town, the developer and builders. The Town will distribute brochures with the issuance of building permits and tax notices. The developer will be responsible for distributing brochures to all potential buyers and real estate agents. Builders will also be responsible for distributing brochures to potential buyers and real estate agents. A laminated brochure shall be secured adjacent to the electrical panel along with the service record card and lot grading plan prior to issuance of occupancy permit. **Appendix F** provides a sample service record card and lot grading plan.

The information brochure shall contain the following:

THIS LAMINATED BROCHURE MUST BE POSTED IN A READILY VISIBLE LOCATION BESIDE THE HOT WATER TANK

Stormwater is rainfall that runs off roofs, driveways, and roads into our storm pipes, washing pollutants into our streams and rivers. The Town of Comox has many systems that help reduce the amount of runoff and pollution that reaches our rivers, some of which are installed in your neighborhood! These systems will work best if they are well maintained and cared for. With your help, we can keep these systems operating effectively, and keep our rivers and ocean clean!

DAMAGE OR UNAUTHORIZED MODIFICATION OF THESE SYSTEMS INCLUDING LOT GRADES MAY RESULT IN FLOODING AND PERSONAL LIABILITY FOR RESULTING DAMAGES.

On Your Property

Lot Coverage

Maximum impervious area of residential lots is 60%. For example, 40% of the lot must be lawn, garden or other vegetated areas. Violation may be subject to enforcement action including fines.

Amended Soil

Amended soil has been installed over all permeable areas of your property. The soil is "amended" because it has been formulated to maximize its infiltration and storage potential. Amended soil *helps reduce pollutants in the following ways:*

- *Stores water and encourages infiltration.*

- *Traps contaminants and filters out sediment.*
- *Slows the surface runoff that reaches the storm system, which helps to moderate peak stream flows.*

Your top soil requires minimal maintenance. However, to ensure its long-term effectiveness, avoid compaction of the soil by vehicles or heavy equipment, and consider aerating your lawn annually.

Roof Leaders (Down Spouts)

Rainfall captured by your gutters and down spouts is a major contributor to the stormwater leaving your property. To reduce the impact of this runoff, your house has been designed with ***Disconnected Roof Leaders.*** *This means your roof leader is not directly connected to the piped stormwater system, instead, runoff from your roof is connected to a splash pad to encourage it to infiltrate into the soil beneath your property. Disconnected Roof Leaders benefit our rivers in the following ways:*

- *Reduce the volume of stormwater entering the storm system.*
- *Reduce the potential of downstream flooding.*
- *Reduce the speed at which runoff enters the storm system.*
- *Increase infiltration and evapotranspiration of rainwater.*
- *Promote re-use with the use of a rain barrel.*

Disconnected roof leaders are widely used in many municipalities, and are a simple way to reduce the impact that development has on our watercourses. To ensure they function safely and effectively, consider the following and avoid these possible areas of concern:

- ***Basement Seepage:*** *Ensure that runoff from roof leaders does not pond directly against your foundation wall. Maintain the designed (finished) lot grading shown on your lot grading plan below and direct downspout discharge away from your foundation in the direction of your designed lot grading.*

The design grades and the approximate location and direction of flow of roof leader splash pads have been engineered to ensure proper functioning of the stormwater management system and are not to be altered with the exception of providing a positive slope away from the building foundation in accordance with BC Building Code requirements. The BC Building Code requires that "backfill shall be graded to prevent drainage towards the foundation after settling." National Research

Council Canada, 2014 Illustrated User's Guide – NBC 2010 Part 9 Housing and Small Buildings states, "The ground surface around a building should have a sufficient initial slope away from the building so that future settlement will not cause drainage towards the foundation. The amount of added slope required depends on the degree of consolidation achieved during backfilling, but on average, a settlement of 50 to 100mm (2 to 4 in.) can be expected near the foundation wall."

- *It is considered good practice that the positive slope away from the foundation is such that after settlement a minimum slope of 2% for 4.0m or 4% for 1.8m results.*

- ***Surface Ponding:*** *Surface ponding can be avoided by directing runoff into a stabilized, vegetated area, complete with well-draining soil, such as grass or a rain garden (see definition below). Consider installing a rain garden to enhance the effectiveness of this system.*

- ***Channeling:*** *Avoid water-eroded channels by encouraging shallow sheet flow over a stabilized vegetated area, such as grass or a rain garden.*

Rain Garden

A rain garden is a vegetated area with high infiltration potential. Rain gardens consist of well-draining soil (amended soil) and low-maintenance, native plants. Consider installing a rain garden on your property to enhance the effectiveness of your disconnected roof leaders.

In Your Neighborhood

Boulevard Infiltration Trenches

Boulevard infiltration trenches are vegetated or rock covered depressions located within roadside boulevards: e.g. along curbs, along sidewalks or within rock or vegetated islands within the road. They filter, store, and infiltrate runoff from roads and sidewalks to help reduce peak flows, and clean the water entering the storm system. Boulevard infiltration trenches are maintained by the Town of Comox. However, there are things you can do to keep them functioning as designed:

- *Avoid compaction of the soils within the boulevard infiltration trenches by ensuring vehicles, equipment, and pedestrians stay out of the trench depression area.*

- *Do not remove, cut, or otherwise impact any of the landscaping within the boulevard infiltration trenches.*

- *Keep leaves, grass clippings etc. out of the boulevard infiltration trenches.*

Dry Detention Pond

Dry detention ponds are large, vegetated areas that are designed to collect and hold rainwater runoff during a storm until it can be slowly and safely released. It is the last line of defense before stormwater from your neighborhood enters the municipal system, and ultimately the river, streams and ocean. The dry detention pond serves to:

- *Detain stormwater collected on site, and release it slowly into the municipal system at a rate that mimics pre-development flow rate.*

- *Provide a final opportunity for infiltration, and removal of sediment.*

As with the boulevard infiltration trenches, dry detention ponds are maintained by the Town of Comox. However, it is important to be aware that the pond areas are subject to flooding during rainy periods.

Note that the language for signs and brochures is subject to minor revisions as determined or required by the Town.

6.0 ADAPTIVE MANAGEMENT STRATEGY

To ensure that stormwater management Best Management Practices installed in NE Comox function as intended over time, an Adaptive Management Strategy (AMS) must be implemented. Very briefly, an AMS is a set of procedures and guidelines that:

1. Identifies stormwater management performance targets. These targets are the pre-developed calibrated model flow/duration relationship and water mass balance based on recorded climate data inputs.
2. Identifies specific indicators or metrics that can be used to verify performance at explicit times during a rainfall/runoff event. It can be difficult to gauge system performance at any given time without an in-depth understanding of recent weather (temperature, rainfall, humidity, etc). To allow for public works staff to gain insight into system performance "at a glance", a series of guidelines must be developed.

3. Identifies a means of evaluating system performance globally. Long term monitoring and hydraulic modeling will be required to ensure that extended duration performance is as expected, and required, or adjusted accordingly.
4. Provides recommendations and/or allowance for reasonable, cost effective physical modification of systems to refine operation, if needed. If performance shortfalls are noted, or if specific mitigating infrastructure overperforms (i.e., infiltration volumes are higher than required, thus base flows released to aquatic environments are not maintained), there must be a practical means of adjusting performance.

6.1 Stormwater Management Targets for NE Comox

Specific Best Management Practices described herein have been sized so that post-development hydrology mimics pre-development hydrology over the continuum of rainfall events (as opposed to specific synthetic design rainfall events). Post-development climatic data has been adjusted based on the Pacific Climate Impacts Consortium (PCIC) at the University of Victoria Median Climate Change model, out to year 2050, to account for the predicted increase in rainfall.

The Mass Balance Tables (**Tables 7A** through **7G** above) and Exceedance Distribution Curves (**Appendix A)** provide performance targets that can only be compared to the recorded historic and adjusted climate change data over the full 42 years of record. Mass Balance Tables and Exceedance Distribution Curves are suitable for designing and sizing BMPs. However, to verify actual system performance over time, monitoring of climate data and stormwater discharge rates will be required. These actual runoff rates will be compared to modelled output rates utilizing logged climate data.

To develop ongoing annual performance targets, continuous climate data collected within the NE Comox area is required. Climate input parameters required for model verification of system performance include:

- Hourly rainfall.
- Hourly temperature.
- Daily evaporation.

As Environment Canada no longer provides hourly rainfall, temperature, or daily evaporation data, we recommend the Town monitors and records this data. The Town's Public Works yard is in close proximity to the NE Comox Neighbourhood, making it an ideal location for the monitoring station.

Using recorded climate data, annual performance targets can be generated for each developed sub-catchment, with a pre-development model. It is our expectation that the Town will generate pre-development models for each phase of development at the developer's expense.

6.2 Monitoring

Monitoring of system performance will consist of visual inspections and data collection. The developer will be responsible for the installation and calibration of all monitoring equipment as well as the collection, processing and reporting of data for the duration of the Maintenance Period. All monitoring equipment will become the property of the Town upon registration of subdivision or issuance of an occupancy permit. Once the Maintenance Period is complete and the system is performing to the satisfaction of the Town, data collection, processing and reporting will become the responsibility of the Town.

All data collection, processing and reporting should be done in accordance with *Wastewater Planning Users Group: Guide to the Quality Modeling of Sewer Systems*, and the references therein.

6.2.1 Visual Inspections

The system should be visually inspected at least twice annually (spring and fall), and following significant rainfall events (>25mm in 24hrs). Visual inspections should, at a minimum, consist of:

1. Visual inspection of all sumps, sediment deposition forebays, observation wells, inlet curbs, inlet and outlet controls, etc., to ensure they are clear of debris and sediment buildup. Observed debris and sediment build up should be recorded and cleaned/maintained accordingly.
2. Monitoring and recording infiltration trench water levels through observation wells during significant rainfall events (>25mm in 24hrs), both during rainfall and immediately after rainfall stops. Continue monitoring until the facilities are empty. Note any overflows from the infiltration trenches either at the control manhole or inlet catch basin. Infiltration trenches should be drained within the drawdown time calculated by the design engineer.
3. Monitoring ponded areas of surface collecting boulevard infiltration trenches during significant rainfall events, both during rainfall and immediately after rainfall stops. Continue monitoring until the facilities are empty. Surface collection systems should be significantly drained within the drawdown time calculated by the design engineer and have a maximum ponded depth of 150mm.
4. Visual inspection of all monitoring equipment before and after significant rainfall events to ensure proper installation and good working order.

6.2.2 Monitoring Equipment and Data Collection

Developers will be required to install data collectors at the downstream end of each phase of development (to monitor infiltration trench performance) and downstream of dry detention ponds (to monitor pond performance). If requested by the Town, developers may also be required to monitor storm outflows from an adjacent similar subdivision, for reference.

An area velocity flow meter shall be installed at the downstream end of each phase of development and downstream of all dry detention ponds. Flow meters shall be installed in pipe and be easily accessible by manhole. Data collection shall include depth, velocity and temperature at 15 minute intervals.

A level logger shall be installed on the upstream side of the pond outlet control to measure the pond water level at 15 minute intervals.

If monitoring of an adjacent similar subdivision is required, area velocity flow meters shall be installed in a storm sewer. The Town will provide the specific manhole location and corresponding catchment area. Data collection shall include depth, velocity and temperature at 15 minute intervals.

All monitoring equipment shall be:

- Capable of monitoring reverse flow (flow meters only).
- Hard wired to a power source.
- Equipped with backup power capable of continued operation for 48 hours which will charge when hard wired.
- Connected to the internet and/or capable of remote data collection.
- Capable of storing a minimum of 6 months of data at 5 minute intervals.
- Capable of field data collection.
- Weatherproof or installed in a weatherproof enclosure.
- Equipped with alarm capabilities in the form of either a dial out or text message to notify of pond water levels approaching overflow (level meters only).

Ultimately, the Town will take over monitoring and hydraulic model verification as part of its ongoing operation and maintenance of its stormwater management system. As such, data collection should be consistent throughout the NE Comox catchment, in terms of the installation, data collector type, format of data, power connection, remote and field data collection and alarm capability. It is our understanding that the details of the monitoring equipment will be established during the first development, which will set the standard for all subsequent NE Comox developments.

6.2.3 Data Processing

Raw data is to be collected and processed monthly for the duration of the Maintenance Period. For flow meters, discharge rates in litres per second (lps) and total monthly volumes in cubic metres (m^3) are to be calculated. For level meters, pond depths in metres and percent full are to be calculated. Data shall be presented both in tabular form for each 15 minute interval and graphed. Calculations shall also be undertaken to convert the flow and volume into unit area measurements (L/s/ha, and m^3/ha) with these results provided as part of the reporting requirements.

6.2.4 Reporting

Reporting is required monthly for the duration of the Maintenance Period. Reports shall be submitted to the Town at the end of each month for the preceding month i.e., January's report is due at the end of February. Reports shall be in PDF format with all data submitted in an excel file. Reports shall include the following:

- Reporting period.
- Data collection location including the catchment area (hectares), zoning, percent developed.
- Visual inspection field notes including location, date, time, weather, conditions noted.
- Raw and processed data including tables and graphs.
- A summary of the reporting period including peak discharge rates, total discharge volumes, maximum pond depths, and an overview of visual inspections including any concerns noted.
- If the developer is also monitoring a similar adjacent neighbourhood, all monitoring data for that neighbourhood shall also be presented monthly along with a comparison of peak rates and total volumes to that of the NE Comox neighbourhood.

6.3 System Performance

System performance can be separated into short, medium and long-term. The developer will be responsible for collecting monitoring data and reporting to the Town on a monthly basis as outlined in Section 6.2, for the duration of the Maintenance Period. Once the Maintenance Period has ended, both monitoring and reporting will be completed by the Town.

Short-term system performance will require visual inspections and evaluations of infiltration trenches and dry detention ponds. Failure to drain within the specified time frame, excessive sediment buildup and/or ponding depths greater than 150mm are indicators that the system is underperforming. If visual inspections identify underperformance of any system components, those components should undergo a detailed review, which may include camera inspections, and testing as outlined in Section 4.2.1.5. Overflow of a dry detention pond indicates either an undersized storage volume and/or outflow control which is blocked or improperly sized, requiring review of outflow control and required storage volume and remediation of the system as required.

Medium-term system performance will be evaluated by comparing measured system rates and volumes to measured rates and volumes of a similar adjacent subdivision (selected by the Town) over the same time period. Normalizing flow rates to litres per second per hectare and runoff volumes to cubic metres per hectare will allow for direct comparison of different sized developments. Rates and volumes for the NE Comox Neighbourhood should be less than that of similar adjacent developments that do not have LID stormwater management facilities in them. Medium-term system performance evaluation will allow for a quick "health check" to establish whether or not the system is working.

Long-term system performance should be evaluated by comparing modeled system performance (based on actual recorded climate data), to actual measured system performance. Specifically, recorded climate data should be run through a pre-development model annually for each developed sub-catchment to estimate discharge rates and total volumes at each major outlet/point of discharge to the receiving environment. System performance can then be assessed by comparing actual recorded discharges to theoretical modeled results.

It is expected that actual recorded discharges rates and volumes will vary slightly from theoretical modeled results as there are inherent inaccuracies associated with modeling. Generally, if recorded system discharge rates vary by less than +/- 15% from theoretical modeled results and recorded system discharge volumes vary by less than +/- 20% from theoretical modeled results, the system is performing as intended. However, these tolerances should only be used as guidelines. If discharge rates or total discharge volumes are within the above noted tolerances, but repeatedly over or under modeled results, then system modifications may need to be made. Annual assessments of actual recorded discharges and theoretical modeled results will be required to determine the need for system modifications.

6.4 System Modification to Correct Performance

If the Town determines that stormwater management performance is not satisfactory, a number of options are available to the Town to refine the system. Adjustments to peak discharge rates can be made by adjusting dry detention pond storage volumes and/or outlet controls. By adjusting infiltration trench areas, storage volumes and outlet controls, discharge volumes can be modified.

Based on the specific BMPs recommended in this study, there are effectively five different "modifications" that can be used to adjust system performance:

- Adjust detention pond storage volume to increase or decrease system discharge rates.
- Adjust detention pond outlet controls to increase or decrease system discharge rates.
- Adjust infiltration trench areas to increase or decrease system discharge volume.
- Adjust infiltration trench volumes to increase or decrease system discharge rates and volumes.
- Modify infiltration trench outlet controls to increase or decrease system discharge rates and volumes.

Reasonable methods for correcting existing system performance should be incorporated into stormwater management design, including:

- Increased/decreased storage capacity – this will require that land be allocated for the expansion of dry detention ponds. Design drawings must clearly demonstrate an allowance for pond volume to be increased by a minimum of 10%.
- Increased infiltration area – this will require that land be allocated for the expansion of infiltration trenches and plumbing be “roughed in” to connect to the collection system. Design drawings must include an allowance for an additional 20% of the design infiltration trench area. Additional infiltration trench areas should be located outside of paved roadways and sidewalks. Plumbing under paved roadways or sidewalks for additional infiltration trenches should be built as part of initial construction to avoid trench cuts in new asphalt. Suitable locations for additional infiltration trenches could include park areas, boulevards, walkways or other public spaces.
- Decrease infiltration trench areas – allow some runoff to bypass infiltration trenches or take some infiltration trenches offline. To accommodate this modification, inlets and underflows from infiltration trenches must be adjustable. Typically, a pipe cap with an orifice drilled in it will suffice. These controls are very simple and inexpensive to modify.
- Increase or decrease base flow by adjusting the size or elevation of control orifices in ponds.
- Modify the stormwater designs of other developments within the NE Comox area to ensure that the overall catchment mass balance is maintained. That is, if additional infiltration is needed due to a shortfall in a previously constructed development, additional capacity can be provided within the current development.

7.0 SUMMARY

The Town of Comox has elected to become a leader within the Comox Valley, actively choosing to pursue a more rigorous and holistic approach to stormwater management. The design principles outlined in the NE Comox Neighborhood Stormwater Management Plan represent the most current theory and practice in responsible stormwater management. The plan has been designed to limit estimated post-development discharges from the study area to estimated pre-development discharges so that statistically there is no significant increase in discharge, both in terms of flood frequency and flow duration, while maintaining existing ground water flows to Hilton Springs and Lazo Marsh. Infiltration trenches have been utilized to manage smaller, frequent precipitation events, and dry detention ponds have been employed to manage larger, infrequent events. The design and sizing of the BMPs also includes allowances for climate change and provisions for ongoing maintenance to promote continued system functionality.

Continual monitoring and refinement of the stormwater management plan will be essential in ensuring success. An Adaptive Management Strategy (AMS) has been presented to the Town which outlines required monitoring and evaluating of system performance, as well as cost effective physical modification to refine operation if required.

A review of the hydrogeological, agricultural and environmental characteristics has also been completed by designated professionals in their fields. Reviews indicate that the NE Comox Stormwater Management Plan, if implemented as outlined herein, will not adversely impact the existing agricultural potential of down-slope lands within the Agricultural Land Reserve; will not adversely impact the existing downstream fish habitat or the environmental integrity of Lazo Marsh; and will not adversely impact existing ground water flows to Hilton Springs and Lazo Marsh.

Agricultural, environmental and hydrogeological reviews are contained in **Appendix G.**

A hydrogeological review of the NE Comox Stormwater Management Plan, prepared by GW Solutions, is contained in **Appendix H.**

The use of the proposed Best Management Practices in NE Comox will require a shift in stormwater management philosophy, and functionally, a change in operational procedures. This shift is not dramatic, but does represent change from the status quo. The implementation of BMPs requires the Town adopt a new series of procedures, policies and guidelines. These changes do come at a modest increase in administrative and operational cost. However, the level of service provided to ratepayers is increased over that of traditional stormwater management systems.

To successfully implement, monitor and refine the NE Comox Stormwater Management Plan, the following is recommended:

- The Town should adopt the NE Comox Stormwater Management Plan, and immediately implement the design standards therein.
- The Town should revise its existing subdivision servicing specifications to include the findings of this document.
- The Town should develop and implement a Sediment and Erosion Control Bylaw to ensure the operation, maintenance, and longevity of stormwater infrastructure is not compromised.
- The Town should develop and implement a bylaw or covenant requirement that all landscape areas have a minimum depth of 300mm of amended soil and all roof leaders be disconnected as outlined herein.
- The Town should work with land owners and the development community to continually refine stormwater management policies and procedures over time to minimize staff time required to administer the use of this new stormwater infrastructure, and decrease the initial construction and long-term operation and maintenance costs.
- The Town will need to train staff in the operation and maintenance of Low Impact Development infrastructure. A number of resources are readily available through the US Environmental Protection Agency.
- The Town should create a framework for a Local Area Service (LAS) to allow for the implementation of a cost recovery program to offset the increased costs of operating and maintaining stormwater management infrastructure in NE Comox.
- The Town should implement a climate monitoring station to record and log climate data in NE Comox. This climate data will be essential in developing performance targets and evaluating recorded system performance.
- The Town should retain a qualified consulting firm experienced in stormwater management and continuous simulation modeling with the QualHYMO engine. The consulting firm will be required to process raw climate data; generate pre-development performance targets based on logged rainfall data; evaluate the monitored system performance against the generated performance targets; and recommend adjustments to existing and/or future stormwater infrastructure sizing if required.

8.0 PUBLIC MEETING FOR PHASE 3 – SUMMARY

A meeting was held on April 26, 2018

One comment sheet and three sign in sheets were returned; copies are included in Appendix J.

Feedback received via NE Comox SWMP Website

None. Website for comments set up April, 2012. Email address: necismp@mcelhanney.com.

9.0 STAKEHOLDER CONSULTATION

A Stakeholder information release letter was distributed to the Department of National Defence, the Agricultural Land Commission, K'omox First Nation, the Comox Valley Regional District, the Ministry of Environment, the Ministry of Agriculture, the Ministry of Transportation and Infrastructure, and Department of Fisheries and Oceans, on April 12, 2018.

The meeting was conducted on April 26, 2018; no comments were received.

Yours truly,

MCELHANNEY CONSULTING SERVICES LTD.

Reviewed by:

Bob Hudson, P.Eng.

Mark DeGagné, P.Eng.

CD/njg

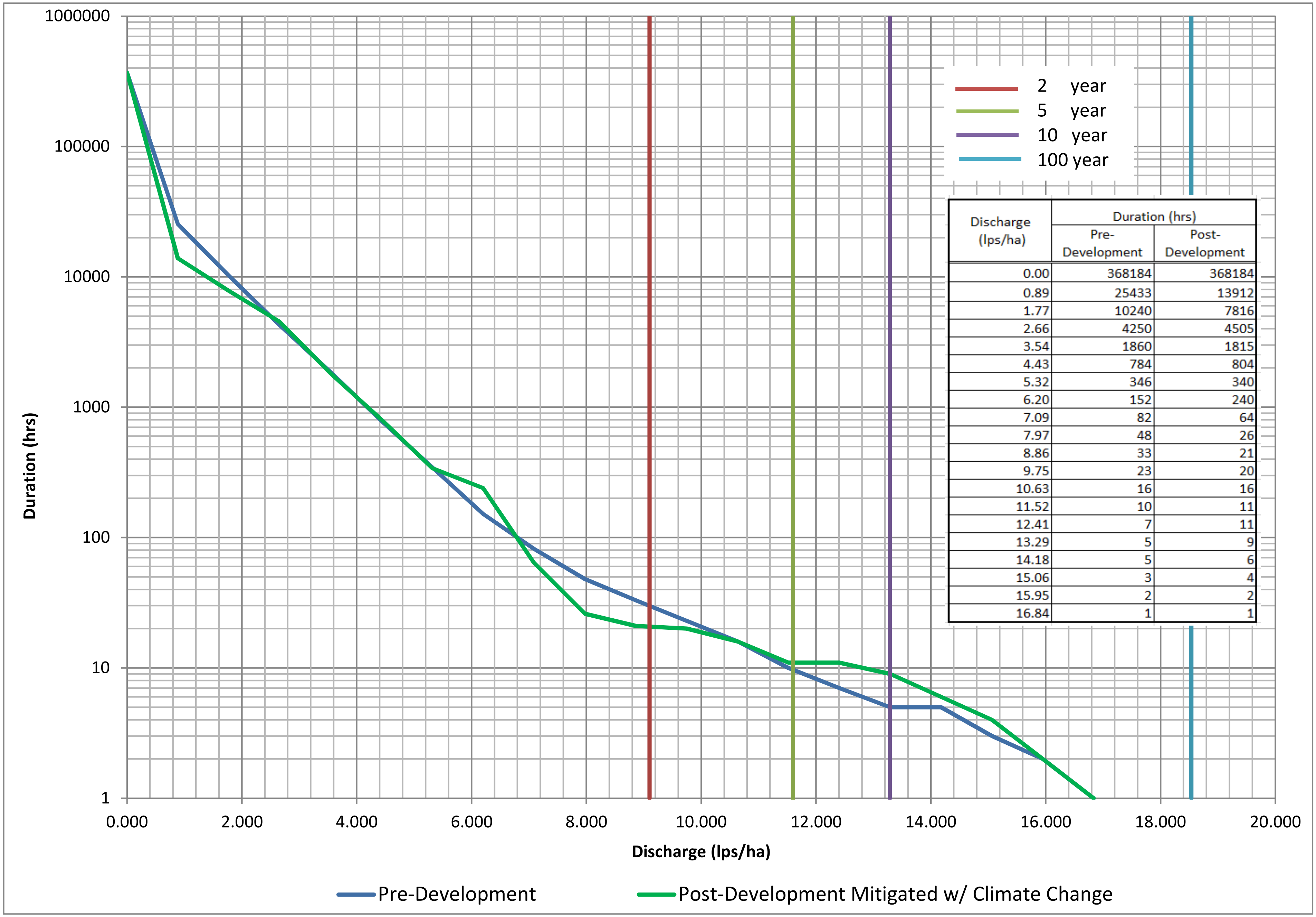
REVISION HISTORY

Date	Status	Revision	Author
March 1, 2018	Final	Rev.4 (issued September 2018)	B. Hudson, P.Eng.
March 1, 2018	Final	Rev. 3 (issued March 2018)	B. Hudson, P.Eng.
November 10, 2017	Final	Rev. 2	B. Hudson, P.Eng.
October 20, 2015	Final	Rev. 1	B. Hudson, P.Eng.
July 15, 2015	Final	Rev. 0	B. Hudson, P.Eng.

LIMITATION

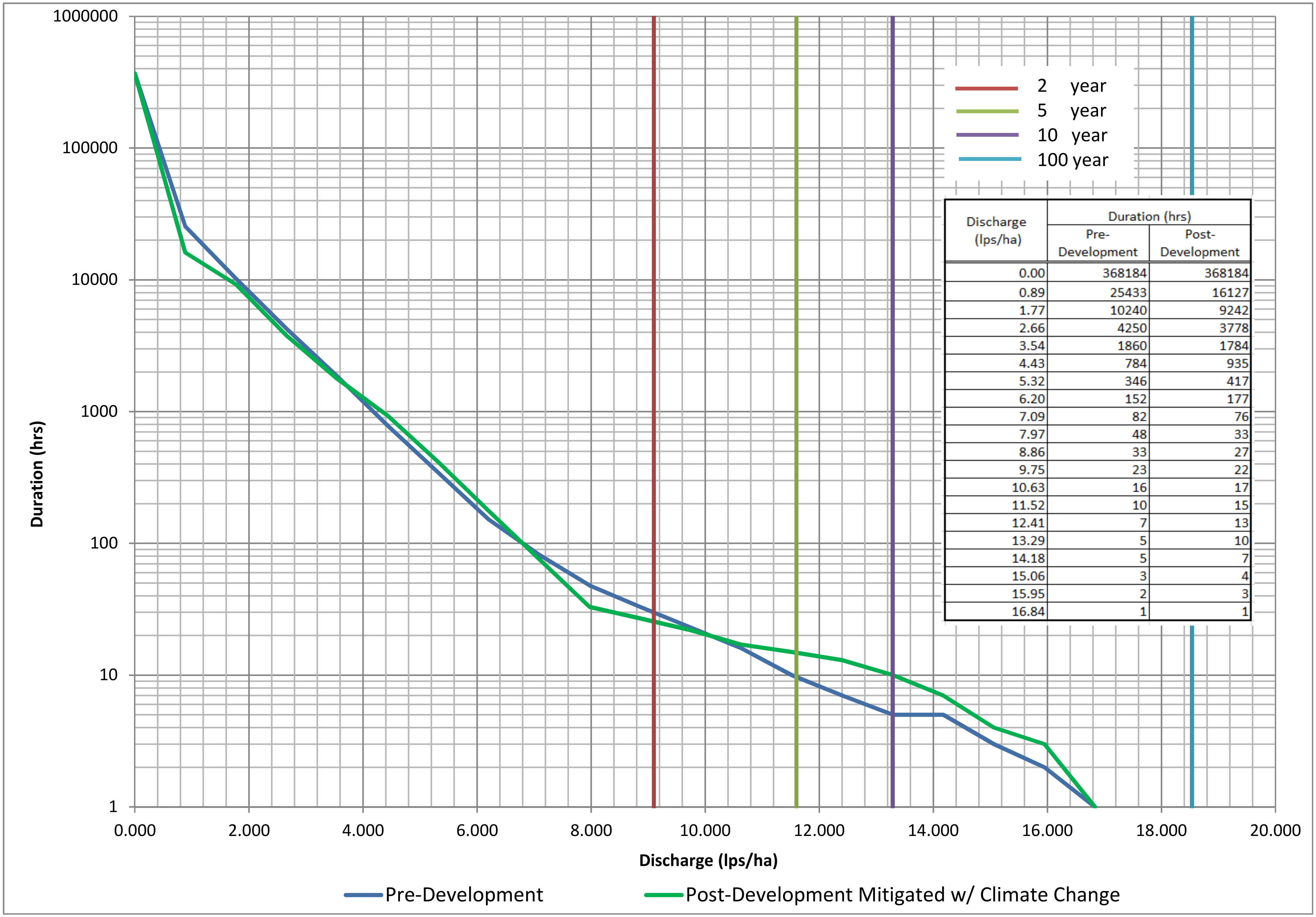
This report has been prepared for the exclusive use of the Town of Comox. The material in it reflects the best judgement of the Consultant in light of the information available to the Consultant at the time of preparation. As such, McElhanney, its employees, sub-consultants and agents will not be liable for any losses or other consequences resulting from the use or reliance on the report by any third party.

APPENDIX A – Pre- and Post- Unit Area Exceedance Curves for each Sub-Catchment



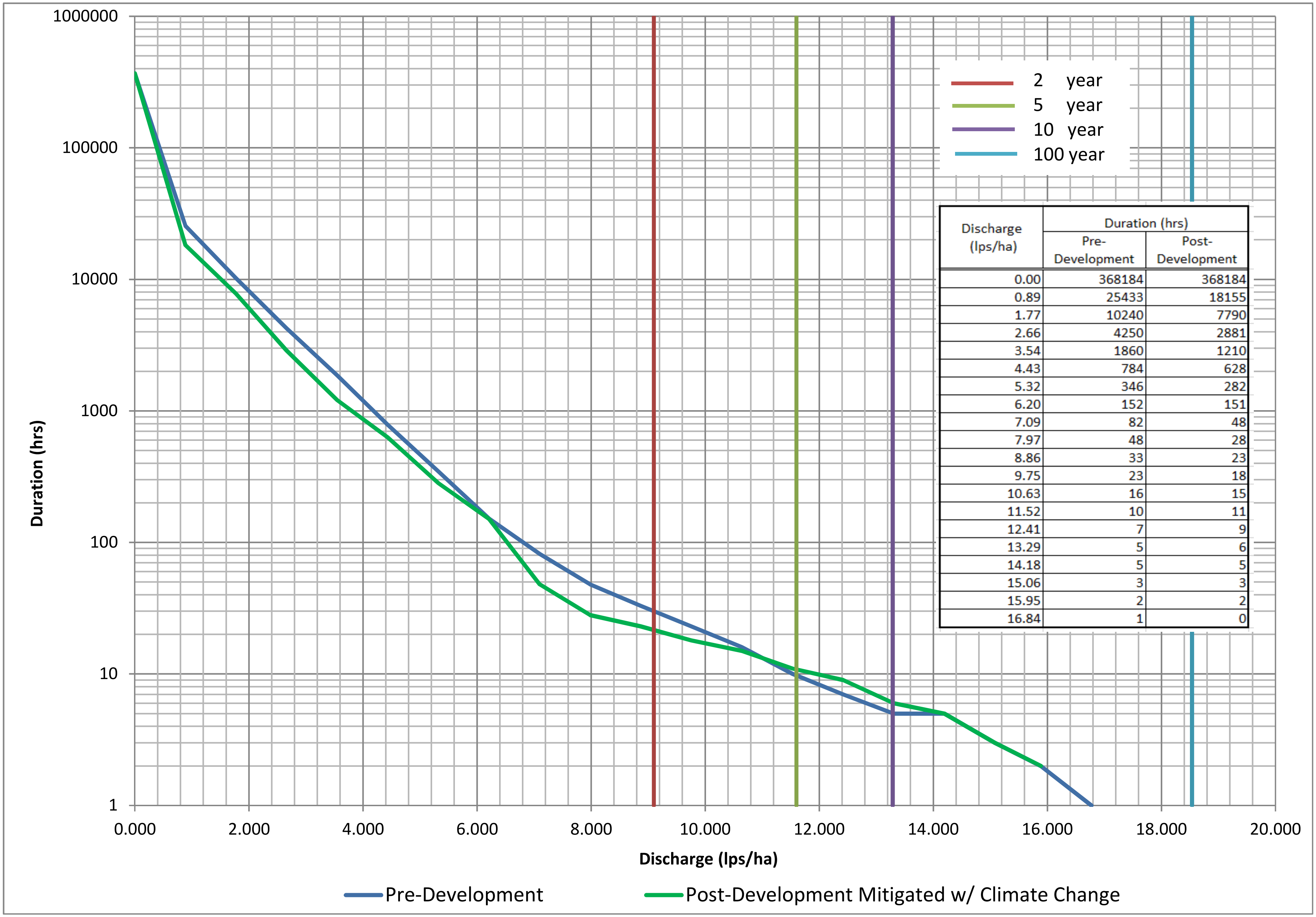
Discharge (lps/ha)	Duration (hrs)	
	Pre-Development	Post-Development
0.00	368184	368184
0.89	25433	13912
1.77	10240	7816
2.66	4250	4505
3.54	1860	1815
4.43	784	804
5.32	346	340
6.20	152	240
7.09	82	64
7.97	48	26
8.86	33	21
9.75	23	20
10.63	16	16
11.52	10	11
12.41	7	11
13.29	5	9
14.18	5	6
15.06	3	4
15.95	2	2
16.84	1	1

Subcatchment 1A Exceedence Curve



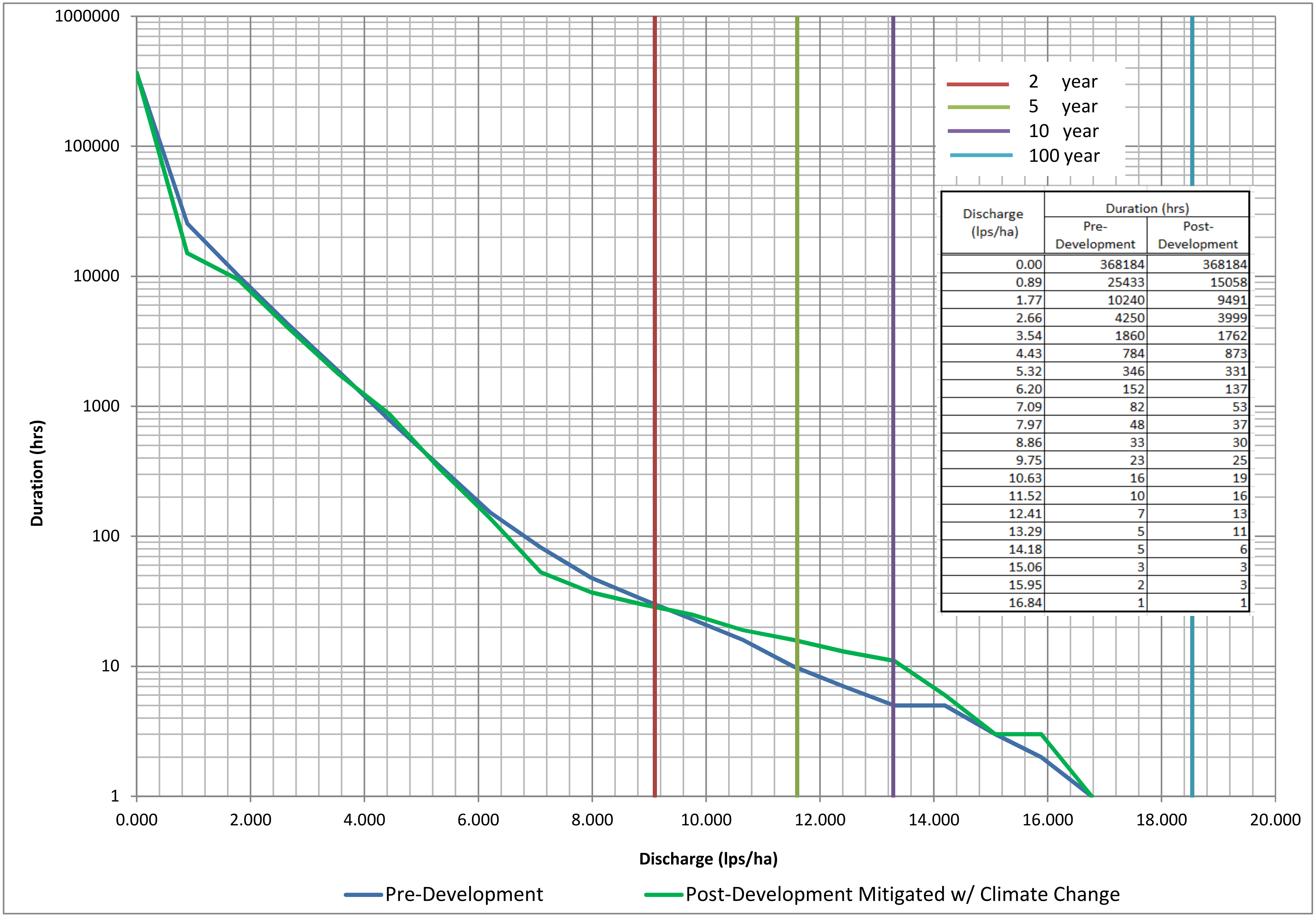
Discharge (lps/ha)	Duration (hrs)	
	Pre-Development	Post-Development
0.00	368184	368184
0.89	25433	16127
1.77	10240	9242
2.66	4250	3778
3.54	1860	1784
4.43	784	935
5.32	346	417
6.20	152	177
7.09	82	76
7.97	48	33
8.86	33	27
9.75	23	22
10.63	16	17
11.52	10	15
12.41	7	13
13.29	5	10
14.18	5	7
15.06	3	4
15.95	2	3
16.84	1	1

Subcatchment 1B Exceedence Curve



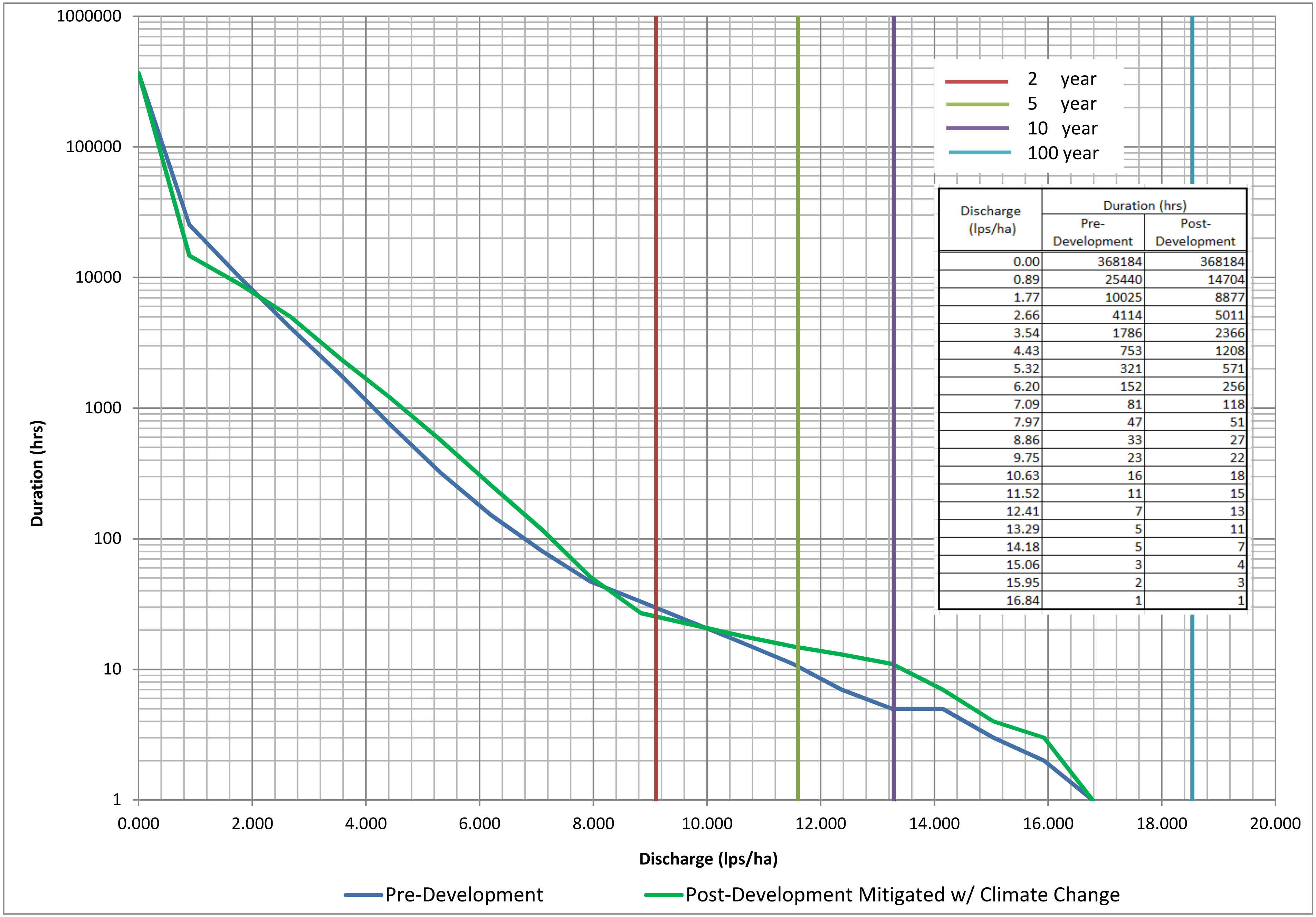
Discharge (lps/ha)	Duration (hrs)	
	Pre-Development	Post-Development
0.00	368184	368184
0.89	25433	18155
1.77	10240	7790
2.66	4250	2881
3.54	1860	1210
4.43	784	628
5.32	346	282
6.20	152	151
7.09	82	48
7.97	48	28
8.86	33	23
9.75	23	18
10.63	16	15
11.52	10	11
12.41	7	9
13.29	5	6
14.18	5	5
15.06	3	3
15.95	2	2
16.84	1	0

Subcatchment 2A Exceedence Curve



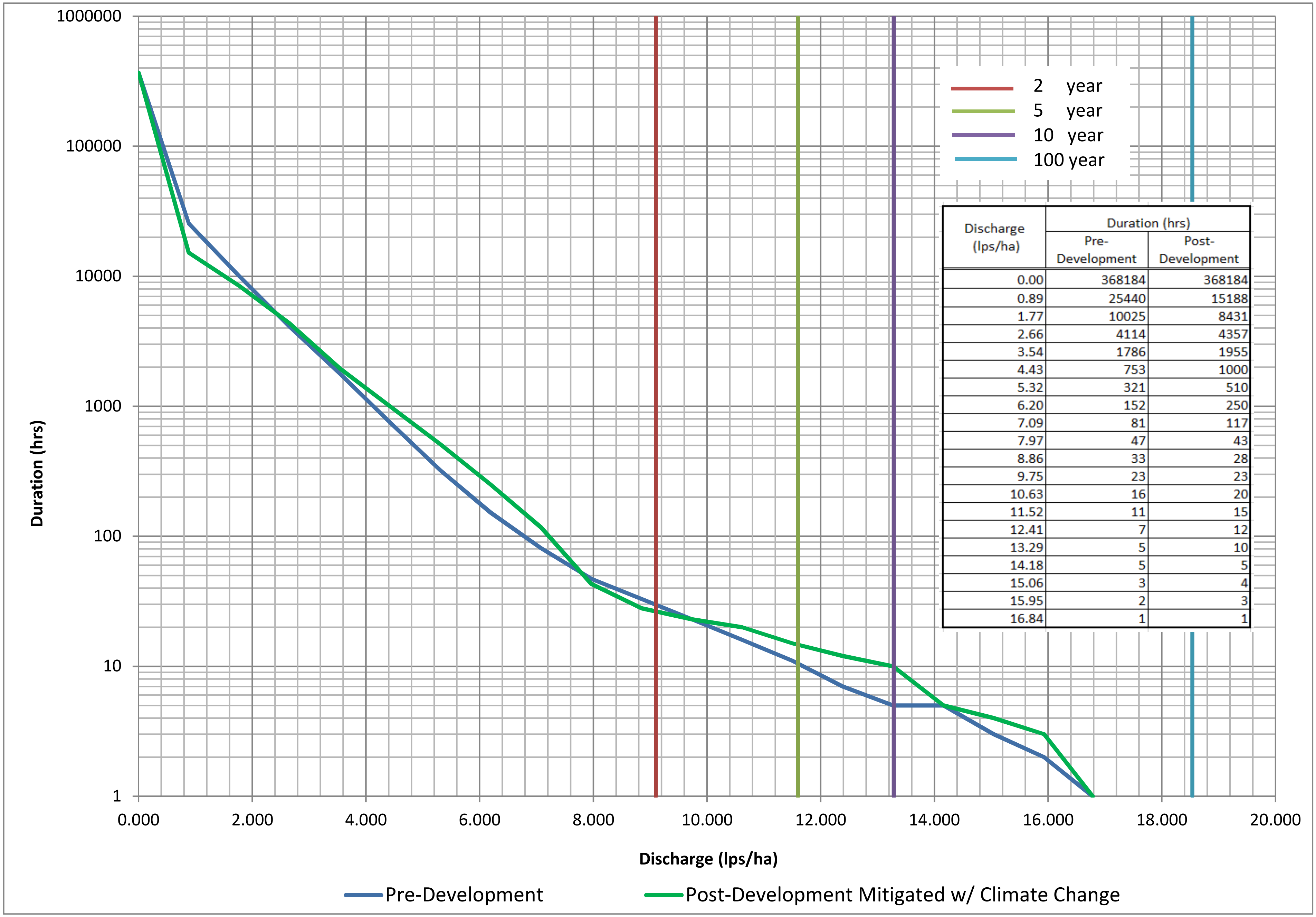
Discharge (lps/ha)	Duration (hrs)	
	Pre-Development	Post-Development
0.00	368184	368184
0.89	25433	15058
1.77	10240	9491
2.66	4250	3999
3.54	1860	1762
4.43	784	873
5.32	346	331
6.20	152	137
7.09	82	53
7.97	48	37
8.86	33	30
9.75	23	25
10.63	16	19
11.52	10	16
12.41	7	13
13.29	5	11
14.18	5	6
15.06	3	3
15.95	2	3
16.84	1	1

Subcatchment 2B Exceedence Curve



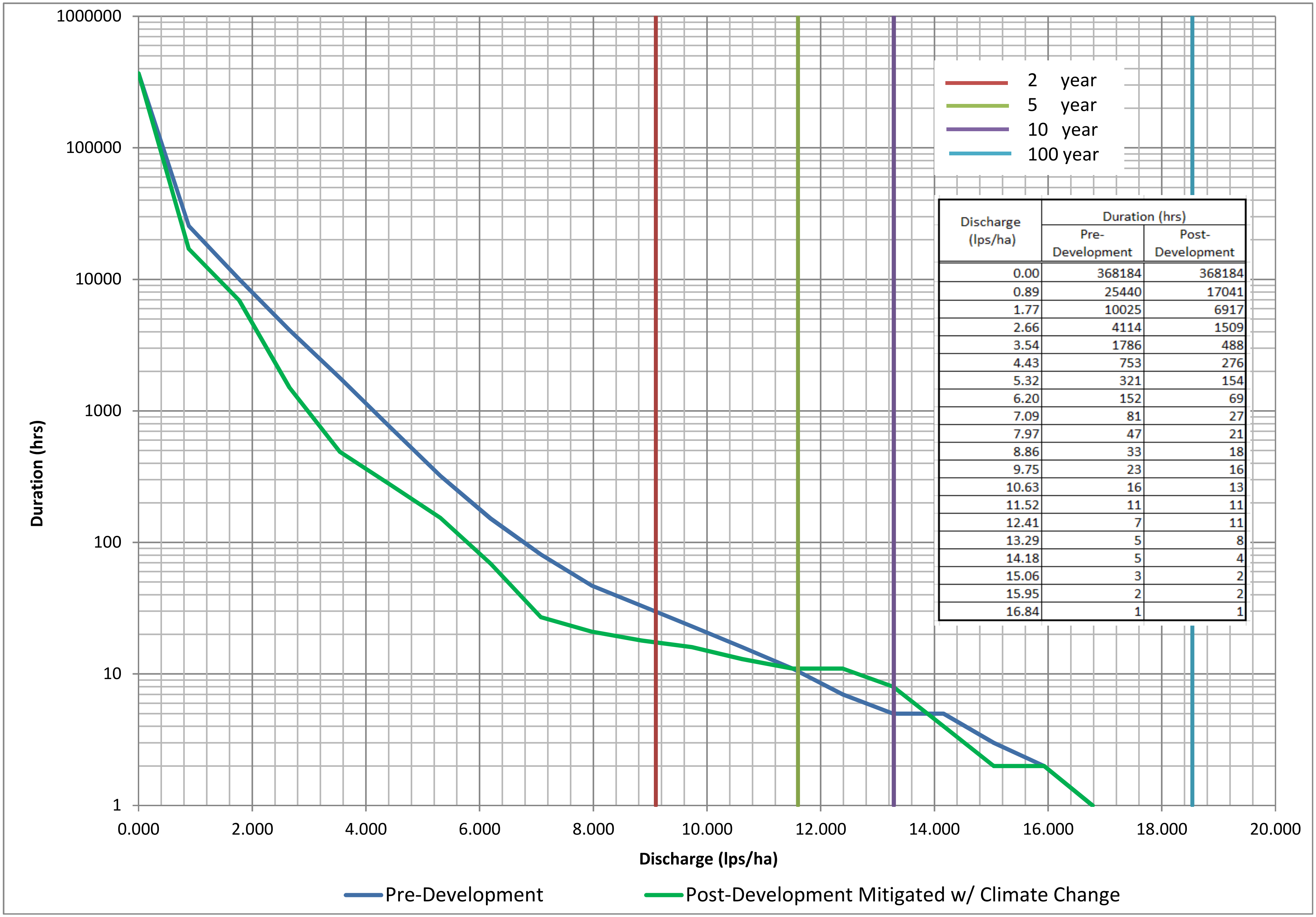
Discharge (lps/ha)	Duration (hrs)	
	Pre-Development	Post-Development
0.00	368184	368184
0.89	25440	14704
1.77	10025	8877
2.66	4114	5011
3.54	1786	2366
4.43	753	1208
5.32	321	571
6.20	152	256
7.09	81	118
7.97	47	51
8.86	33	27
9.75	23	22
10.63	16	18
11.52	11	15
12.41	7	13
13.29	5	11
14.18	5	7
15.06	3	4
15.95	2	3
16.84	1	1

Subcatchment 3 Exceedence Curve



Discharge (lps/ha)	Duration (hrs)	
	Pre-Development	Post-Development
0.00	368184	368184
0.89	25440	15188
1.77	10025	8431
2.66	4114	4357
3.54	1786	1955
4.43	753	1000
5.32	321	510
6.20	152	250
7.09	81	117
7.97	47	43
8.86	33	28
9.75	23	23
10.63	16	20
11.52	11	15
12.41	7	12
13.29	5	10
14.18	5	5
15.06	3	4
15.95	2	3
16.84	1	1

Subcatchment 4A Exceedence Curve

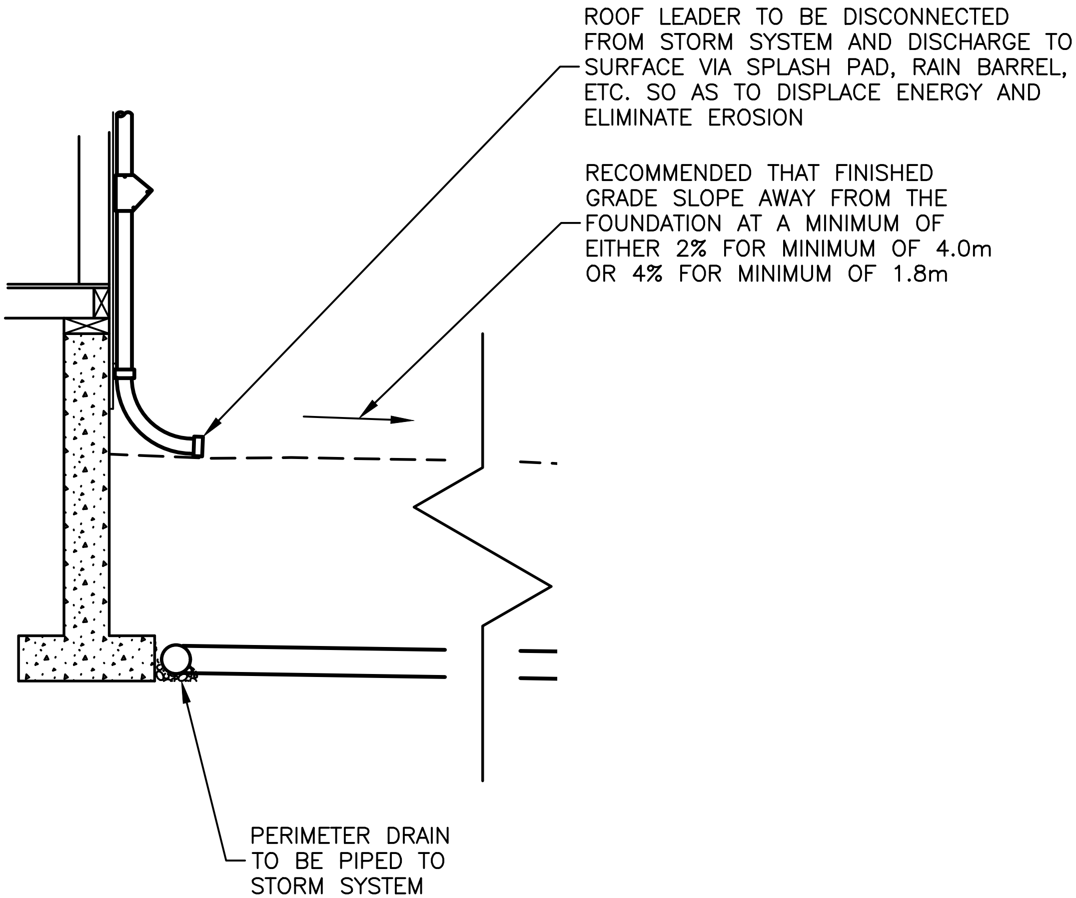


Discharge (lps/ha)	Duration (hrs)	
	Pre-Development	Post-Development
0.00	368184	368184
0.89	25440	17041
1.77	10025	6917
2.66	4114	1509
3.54	1786	488
4.43	753	276
5.32	321	154
6.20	152	69
7.09	81	27
7.97	47	21
8.86	33	18
9.75	23	16
10.63	16	13
11.52	11	11
12.41	7	11
13.29	5	8
14.18	5	4
15.06	3	2
15.95	2	2
16.84	1	1

Subcatchment 4B Exceedence Curve

APPENDIX B – Input and Output Files for each Sub-Catchment (available upon request)

APPENDIX C – Standard Drawings



McElhanney
McElhanney Consulting Services Ltd.
495 SIXTH STREET
COURTENAY BC V9N 6V4
PH (250) 338-5495

NORTHEAST COMOX

SERVICE CONNECTION WITH DISCONNECTED ROOF LEADERS

Dr[illegible] N[illegible]

SC-101

DATE [illegible] [illegible]UNE[illegible]

R[illegible]

Destroy all prints bearing previous number ▲

Plotted: December 20, 2017 , 15:22:35 Filename: G:\2211 ENGINEERING\46000 - 46999\46500-2\REPORTS - MCSL\PHASE 3 REPORT\PHASE 3 REPORT SUPPORTING DOCS\STANDARD DETAILS\NE - SC101-107 17-12-18.DWG

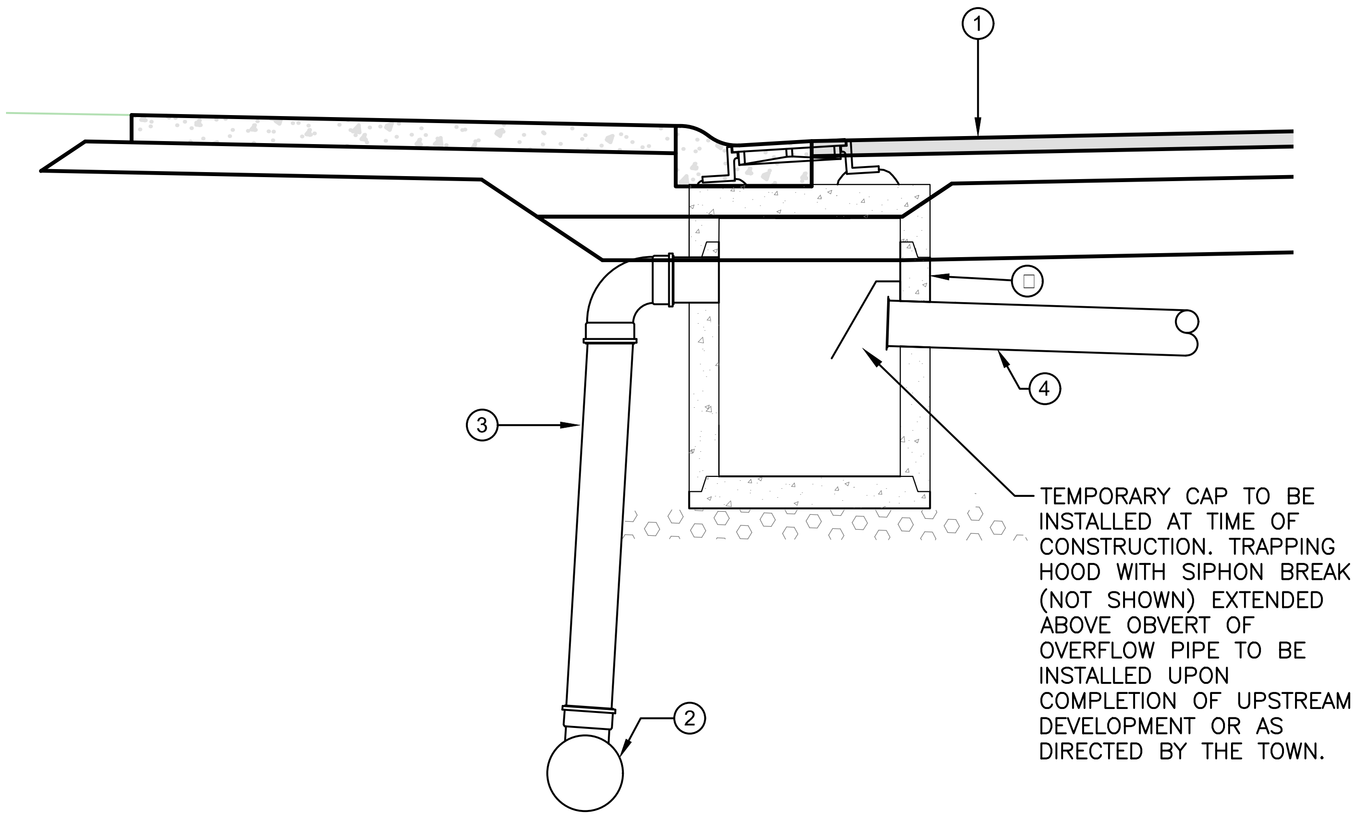
□□ ROAD SURFACE□BASE□AND SUBBASE

□□ MUNICIPAL STORM MAIN

□□ 150mm Ø (MIN.) OVERFLOW TO STORM MAIN

4□ 150mm Ø (MIN.) UNDERFLOW TO INFILTRATION TRENCH

□□ CATCHBASIN - TO CONFORM TO THE CURRENT EDITION OF THE TO□ N OF COMO□ SUBDI□ISION AND DE□ELOPMENT SPECIFICATIONS B□LA□



Plotted: December 18, 2017 , 11:46:23 Filename:

McElhanney

McElhanney Consulting Services Ltd.

495 SIXTH STREET
COURTENAY BC V9N 6V4

PH (250) 338-5495

NORTHEAST COMOX

SEDIMENT CATCHBASIN

Dr□□ □□ N□□

SC-102

DATE □ □UNE□□□□□

R□□□□□ □

1. CONTROL MANHOLE - MANHOLE TO CONFORM TO THE CURRENT EDITION OF THE TOWN OF COMOX SUBDIVISION AND DEVELOPMENT BYLAW

2. FLOW RESTRICTOR ASSEMBLY WITH ORIFICE PLATE AND OVERFLOW SET AT TOP ELEVATION OF DRAIN ROCK RESERVOIR

3. TRENCH DAMS AT END OF DRAIN ROCK RESERVOIR

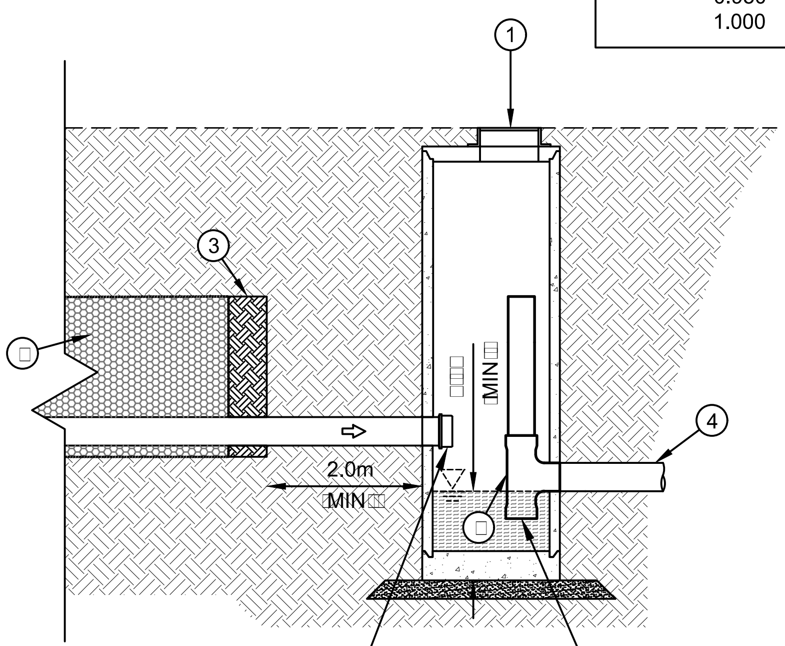
4. OUTFLOW PIPE TO STORM DRAIN OR SWALE SYSTEM

5. DRAIN ROCK RESERVOIR (DEPTH 1.0m)

6. MINIMUM PIPE DIAMETER IS 150mm

ORIFICE SI□ING TABLE

TRIBUTARY AREA (ha)	ORIFICE SIZE (mm)
0.050	10
0.075	12
0.100	13
0.125	14
0.150	16
0.175	18
0.200	19
0.225	20
0.250	21
0.275	22
0.300	23
0.325	24
0.350	25
0.375	26
0.400	27
0.450	28
0.500	30
0.550	31
0.600	33
0.650	34
0.700	35
0.750	37
0.800	38
0.850	39
0.900	40
0.950	41
1.000	42



Plotted: December 18, 2017, 11:46:45 Filename: G:\2211 ENGINEERING\46000 - 46999\46500-2\REPORTS - MCSL\PHASE 3 REPORT\PHASE 3 REPORT SUPPORTING DOCS\STANDARD DETAILS\NE - SC101-107 17-12-18.DWG

McElhanney
McElhanney Consulting Services Ltd.
495 SIXTH STREET
COURTENAY BC V9N 6V4
PH (250) 338-5495

NORTHEAST COMOX

CONTROL MANHOLE

Dr□□ □□ N□

SC-103

DATE □ □UNE □□□□

R□□□□ □

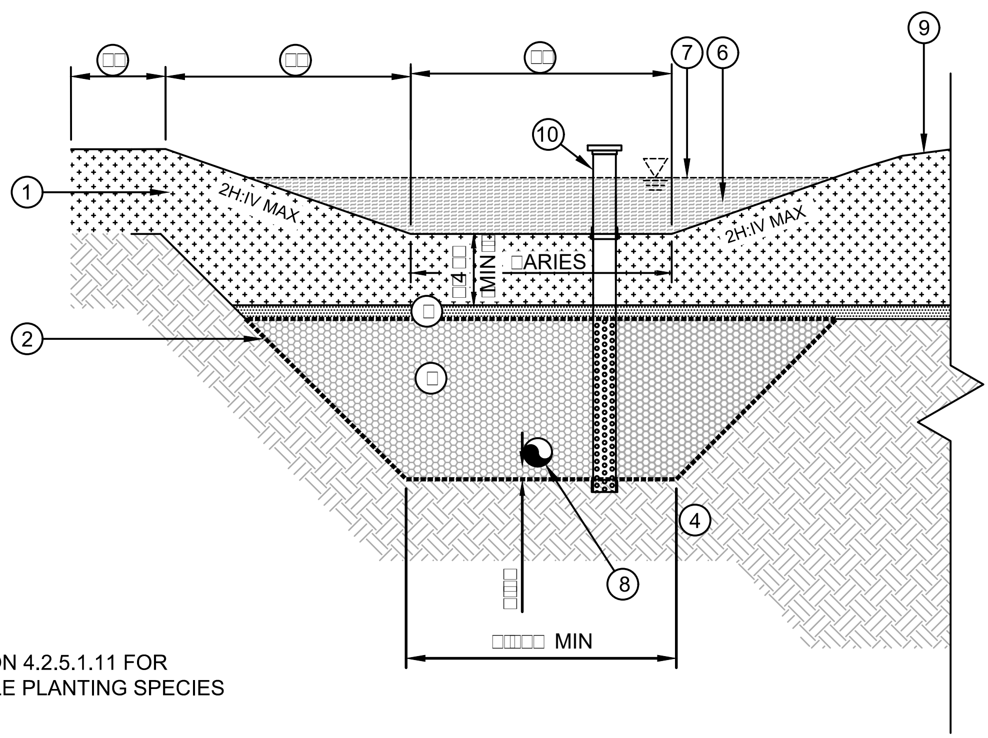
Destroy all prints bearing previous number

1. AMENDED SOIL (RAIN GARDENS) OR WASHED SAND (ROCK GARDENS) MIN 0.45m DEPTH
2. GEOTEXTILE ALONG ALL SIDES OF RESERVOIR
3. DRAIN ROCK RESERVOIR
4. FLAT, SCARIFIED SUBSOIL
5. 100mm WASHED SAND (RAIN GARDENS ONLY)
6. PONDING AREA - MAX 150mm DEPTH
7. MAX WATER LEVEL
8. PERFORATED DRAIN PIPE (150mm Ø MIN.) WITH FILTER CLOTH SOCK (OPTIONAL)
9. FILTER STRIP (SEE SC-107)
10. OBSERVATION WELL - 150mm Ø (MIN.) PIPE (PERFORATED INSIDE DRAIN ROCK RESERVOIR ONLY)
11. CENTER
12. SLOPED SIDES (4H:IV SIDE SLOPE REQUIRED FOR GRASS PLANTINGS)
13. BERMED EDGES

Table 5: Infiltration Trench Sizing

Sub-Catchment				Infiltration Trench Parameters		
	Land Use	Total Area	% Imp	Total Base Area	Base Area per Hectare	Storage Volume[1] per Hectare
(#)	(Zoning)	(ha)	(%)	(m^2)	(m^2/ha)	(m^3/ha)
1A	R1.1	2.0	60	250	125	38
1B	R1.1	5.9	90	1180	200	60
2A	R1.1	6.0	60	2700	450	135
2B	I2.1 / PA1.1	6.4	90	1024	160	48
3	I2.1 / DND1.1	25.8	90	2580	100	30
4A	R1.1	27.5	60	4538	165	50
4B	I2.1	6.4	90	5120	800	240

[illegible]SEE SECTION [illegible] FOR A COMPLETE E[illegible]PLANATION OF TABLE [illegible] SECTION 4[illegible] PRO[illegible]IDES STEP B[illegible] STEP INFILTRATION TRENCH SI[illegible]ING USING TABLE [illegible]



NOTE:

SEE SECTION 4.2.5.1.11 FOR ACCEPTABLE PLANTING SPECIES

Plotted: December 20, 2017, 15:23:31

Filename: G:\2211 ENGINEERING\46000 - 46999\46500-2\REPORTS - MCSL\PHASE 3 REPORT\PHASE 3 REPORT SUPPORTING DOCS\STANDARD DETAILS\NE - SC101-107 17-12-18.DWG

McElhanney

McElhanney Consulting Services Ltd.
495 SIXTH STREET
COURTENAY BC V9N 6V4
PH (250) 338-5495

NORTHEAST COMOX

BOULEVARD INFILTRATION TRENCH

Dr[illegible] N[illegible]

SC-104

DATE [illegible] [illegible]UNE[illegible]

R[illegible]

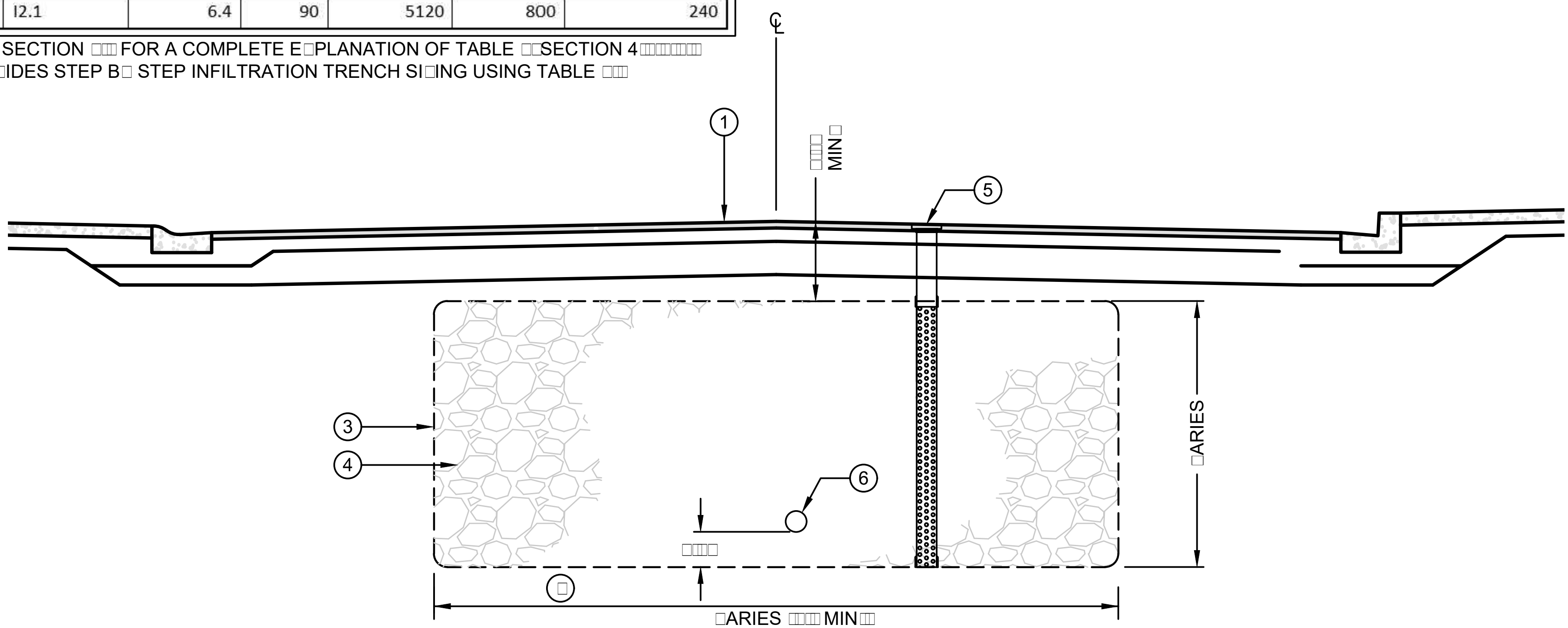
Destroy all prints bearing previous number

Table 5: Infiltration Trench Sizing

Sub-Catchment				Infiltration Trench Parameters		
	Land Use	Total Area	% Imp	Total Base Area	Base Area per Hectare	Storage Volume[1] per Hectare
(#)	(Zoning)	(ha)	(%)	(m^2)	(m^2/ha)	(m^3/ha)
1A	R1.1	2.0	60	250	125	38
1B	R1.1	5.9	90	1180	200	60
2A	R1.1	6.0	60	2700	450	135
2B	I2.1 / PA1.1	6.4	90	1024	160	48
3	I2.1 / DND1.1	25.8	90	2580	100	30
4A	R1.1	27.5	60	4538	165	50
4B	I2.1	6.4	90	5120	800	240

□SEE SECTION □□ FOR A COMPLETE E□PLANATION OF TABLE □□SECTION 4□□□□□□
PRO□IDES STEP B□ STEP INFILTRATION TRENCH SI□ING USING TABLE □□

1. ROAD SURFACE, BASE, AND SUBBASE
2. FLAT, SCARIFIED SUB SOIL
3. GEOTEXTILE ALONG ALL SIDES OF RESERVOIR
4. DRAIN ROCK RESERVOIR
5. OBSERVATION WELL - 150Ø (MIN.) PIPE (PERFORATED INSIDE DRAIN ROCK RESERVOIR ONLY) C/W "ROBAR TYPE" CAST IRON VALVE BOX MARKED "STORM"
6. 150mm Ø MIN. PERFORATED DRAIN PIPE (PERFORATED INSIDE ROCK TRENCH ONLY). CONNECT TO CONTROL MANHOLE SC-103



McElhanney

McElhanney Consulting Services Ltd.

495 SIXTH STREET
COURTENAY BC V9N 6V4
PH (250) 338-5495

NORTHEAST COMOX

STREET INFILTRATION TRENCH

Dr□□□□ N□□ SC-105

DATE □ □UNE□ □□□□

R□□□□□ □

Destroy all prints bearing previous number

□□ 150mm Ø (MIN.) PVC CAP. FOR BOULE□ARD INSTALLATIONS USE CONCRETE BO□ MAR□ED "STORM" □LANGLE□ □□□ OR E□UI□ALENT□□FOR ROAD□ A□ INSTALLATIONS USE "ROBAR T□PE" CAST IRON □AL□E BO□ MAR□ED "STORM"

□□ CONCRETE BO□ TO BE INSTALLED ON CONCRETE BLOC□ SUPPORTS □ALL SIDES□

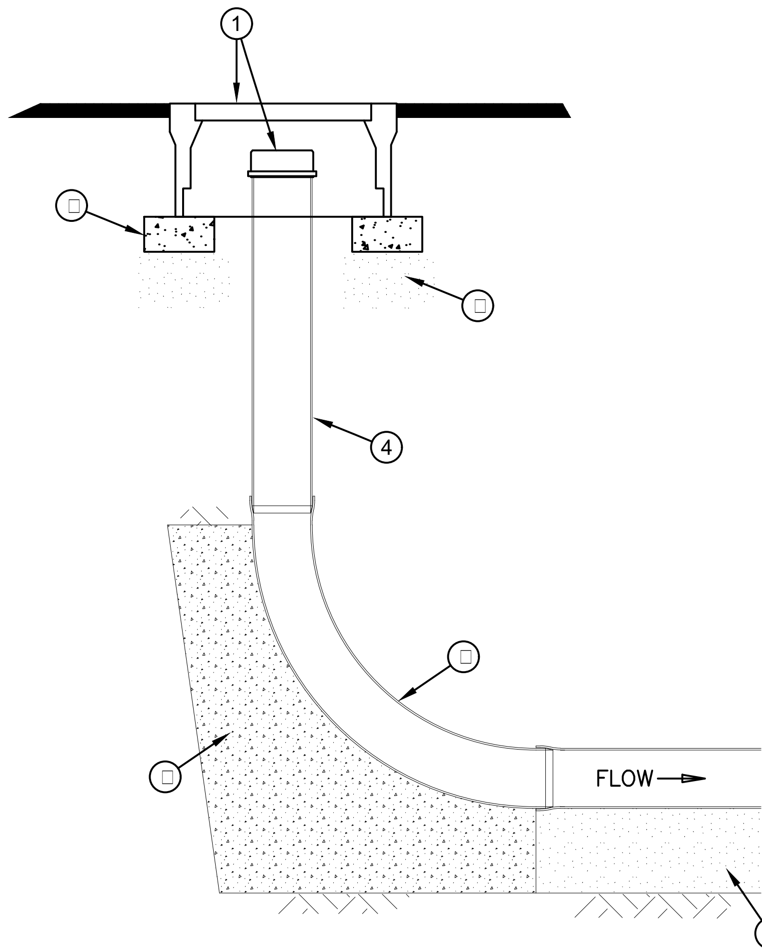
□□ GRANULAR BASE MATERIAL

4□ 150mm Ø (MIN.) DRAIN PIPE

□□ 90° LONG RADIUS BEND (OR 2 x 45° LONG RADIUS BENDS)

□□ CONCRETE ENCASEMENT MIN□ □□□□ □ THIC□ ALL AROUND

□□ GRANULAR PIPE BEDDING AND BAC□FILL



Plotted: December 18, 2017 , 11:48:44 Filename: G:\2211 ENGINEERING\46000 - 46999\46500-2\REPORTS - MCSL\PHASE 3 REPORT\PHASE 3 REPORT SUPPORTING DOCS\STANDARD DETAILS\NE - SC101-107 17-12-18.DWG

McElhanney
McElhanney Consulting Services Ltd.
495 SIXTH STREET
COURTENAY BC V9N 6V4
PH (250) 338-5495

NORTHEAST COMOX

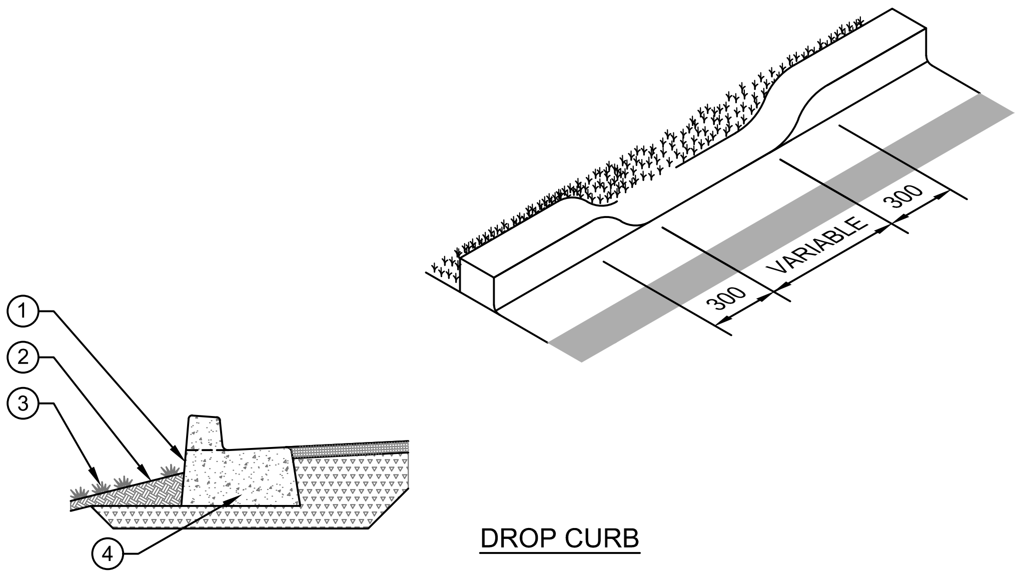
CLEAN OUT

Dr□□ □□ N□□ SC-106

DATE □ □UNE □□□□□

R□□□□□ □

Destroy all prints bearing previous number ▲



DROP CURB

1. □□□□□ □ERTICAL DROP FROM GUTTERLINE TO FILTER STRIP □T□PICAL□
2. 4 □□ MA□□□□□ □□ MIN□SLOPE FOR FIRST □□□□ □T□PICAL□
3. FILTER STRIP□EROSION RESISTANT TREATMENT □EG□ GRASS OR EROSION CONTROL FABRIC AND DRAIN ROC□□T□PICAL
4. CURB PROFILE PER TO□ N OF COMO□ SUBDI□ISION AND DE□ELOPMENT SPECIFICATIONS B□LA□

McElhanney

McElhanney Consulting Services Ltd.
495 SIXTH STREET
COURTENAY BC V9N 6V4
PH (250) 338-5495

NORTHEAST COMOX

CURBING OPTIONS AT BOULAVARD INFILTRATION TRENCHES

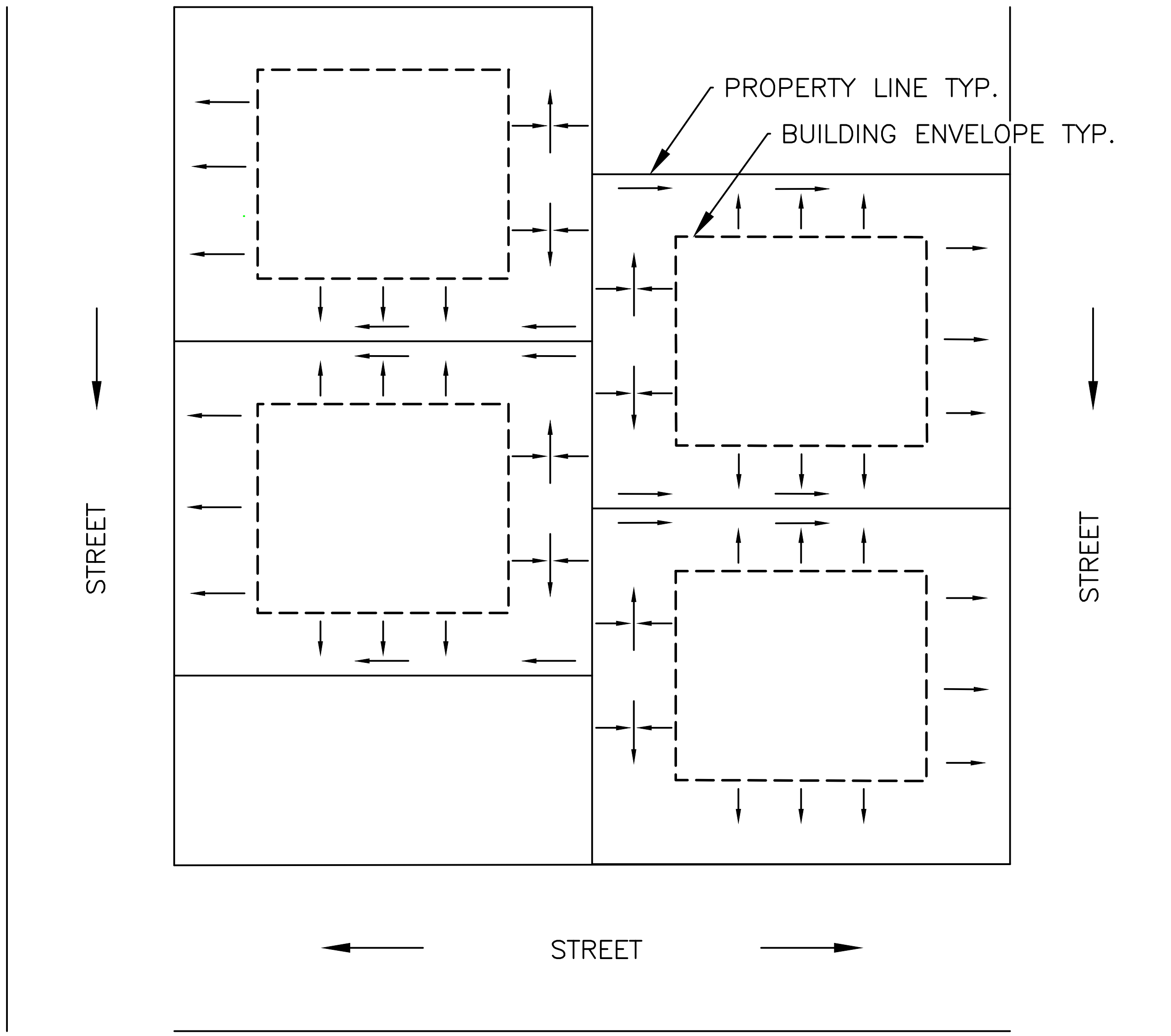
Dr□□ □□□ N□□ SC-107

DATE □ □UNE□□□□□

R□□□□□□ □

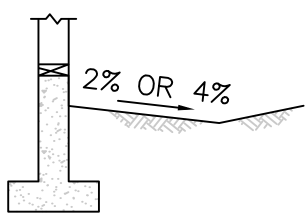
Filename: G:\2211 ENGINEERING\46000 - 46999\46500-2\REPORTS - MCSL\PHASE 3 REPORT\PHASE 3 REPORT SUPPORTING DOCS\STANDARD DETAILS\NE - SC101-107 17-12-18.DWG

Plotted: December 18, 2017 , 11:49:04



REAR TO FRONT LOT DRAINAGE

RECOMMENDED FINISHED GRADE TO SLOPE AWAY FROM HOUSE AT A MINIMUM OF EITHER 2% FOR MIN. OF 4.0m OR 4% FOR MIN. OF 1.8m



LOT GRADING AWAY FROM HOUSE DETAIL

NOTES:

1) ALL SURFACE DRAINAGE AROUND BUILDING TO BE PER BC BUILDING CODE LATEST EDITION

2) ALL BUILDING PENETRATIONS I.E. DOORS, WINDOWS, VENTS ETC. SHALL BE A MINIMUM OF 150mm ABOVE FINISHED GRADE UNLESS DRAINED PER BC BUILDING CODE LATEST EDITION.

LEGEND:

LOT GRADING AT TIME OF FINAL SUBDIVISION APPROVAL →

McElhanney
McElhanney Consulting Services Ltd.
495 SIXTH AVENUE
COURTENAY, B.C. V9N 6V4
PH (250) 338-5495

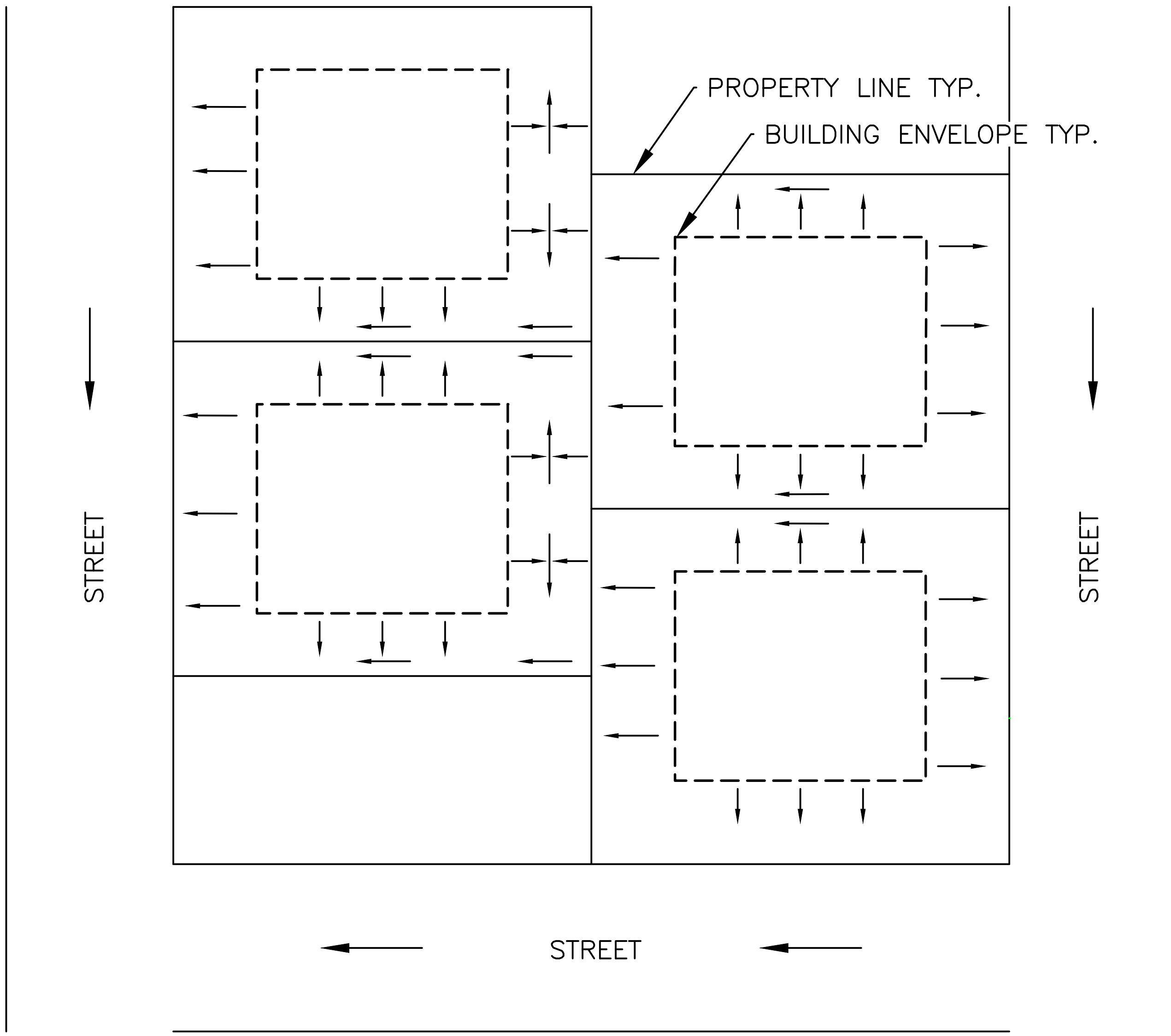
NORTHEAST COMOX

TYPICAL LOT GRADING

Drawing No.: SC-108A

DATE

Filename: G:\2211 Engineering\46000 - 46999\46500-2\Reports - MCSL\Phase 3 report\PHASE 3 REPORT supporting docs\Standard Details\SC108.dwg
Plotted: December 18, 2017 , 11:55:11



FRONT TO REAR LOT DRAINAGE

NOTES:

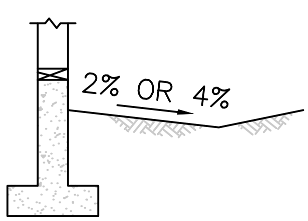
1) ALL SURFACE DRAINAGE AROUND BUILDING TO BE PER BC BUILDING CODE LATEST EDITION

2) ALL BUILDING PENETRATIONS I.E. DOORS, WINDOWS, VENTS ETC. SHALL BE A MINIMUM OF 150mm ABOVE FINISHED GRADE UNLESS DRAINED PER BC BUILDING CODE LATEST EDITION.

LEGEND:

LOT GRADING AT TIME OF FINAL SUBDIVISION APPROVAL →

RECOMMENDED FINISHED GRADE TO SLOPE AWAY FROM HOUSE AT A MINIMUM EITHER 2% FOR MIN. OF 4.0m OR 4% FOR MIN. OF 1.8m



LOT GRADING AWAY FROM HOUSE DETAIL

McElhanney
McElhanney Consulting Services Ltd.
495 SIXTH AVENUE
COURTENAY, B.C. V9N 6V4
PH (250) 338-5495

NORTHEAST COMOX

TYPICAL LOT GRADING

SC-108B

DATE

Filename: G:\2211 Engineering\46000 - 46999\46500-2\Reports - MCSL\Phase 3 report\PHASE 3 REPORT supporting docs\Standard Details\SC108.dwg
Plotted: December 18, 2017 , 11:55:48

McElhanney
McElhanney Consulting Services Ltd.
495 SIXTH STREET
COURTENAY BC V9N 6V4
PH (250) 338-5495

NORTHEAST COMOX

DRY DETENTION POND SIGN DETAIL

Dr□□ □□ N□

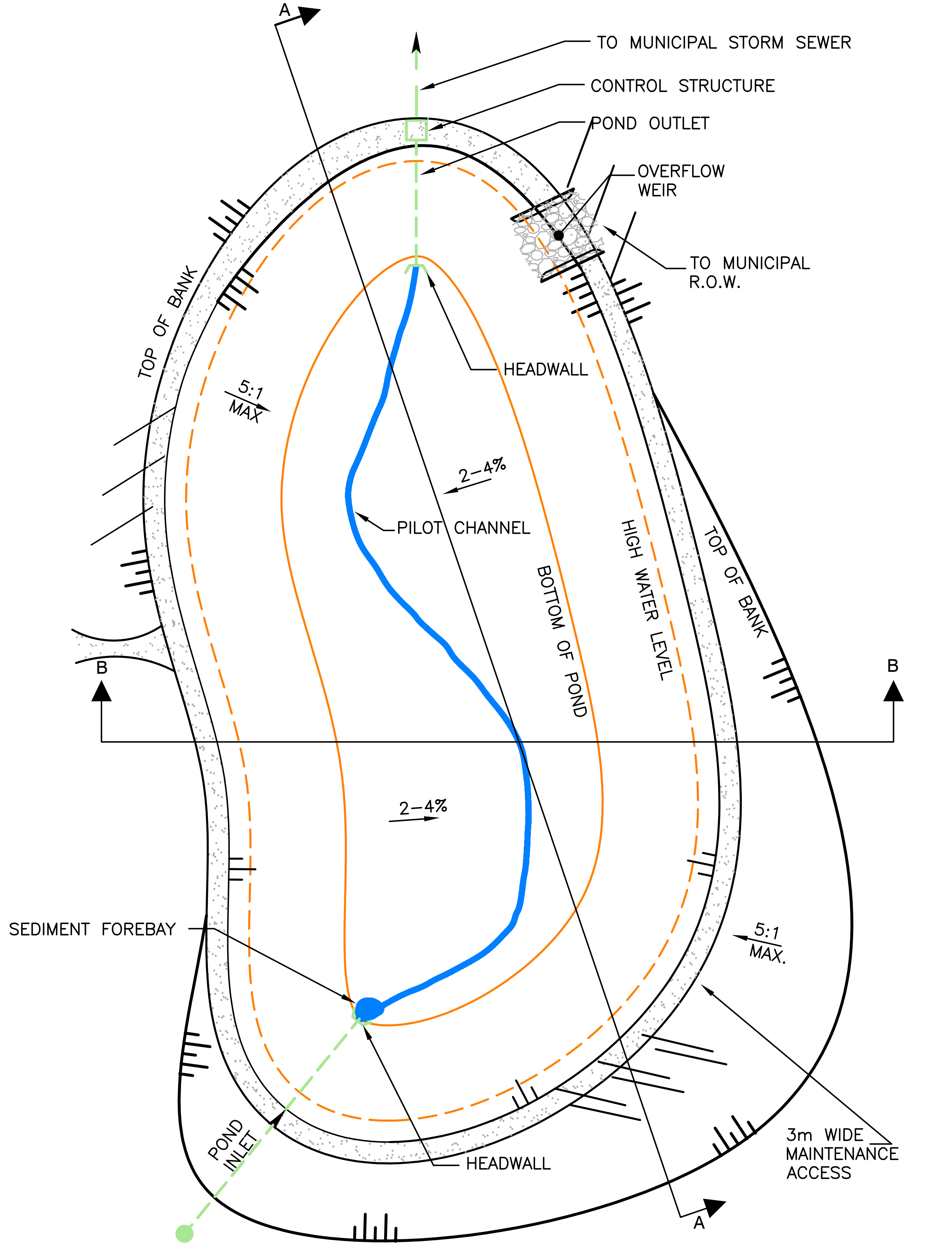
SC-109

DATE □ □ANUAR□ □□□□□

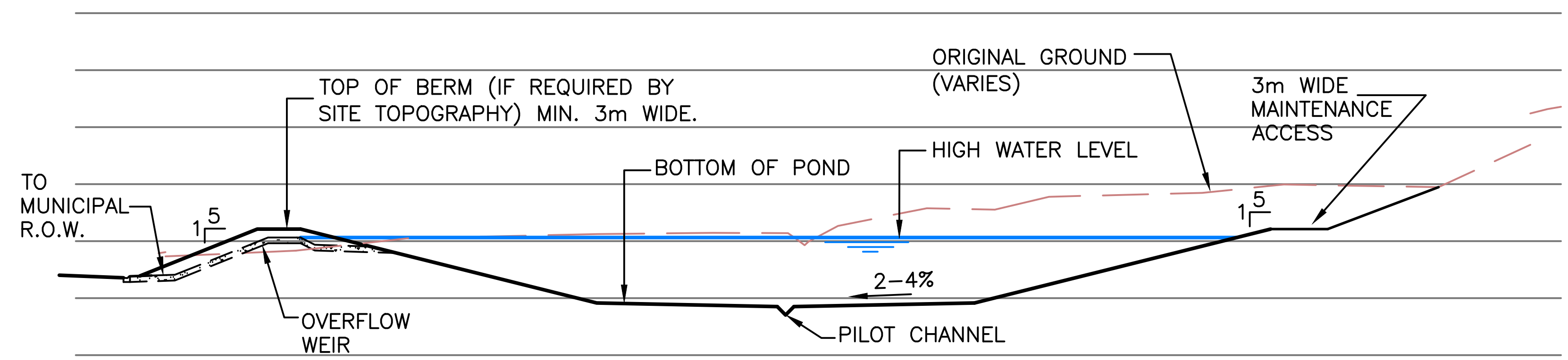
R□□□□□ □

Filename: G:\2211 Engineering\46000 - 46999\46500-2\Reports - MCSL\Phase 3 report\PHASE 3 REPORT supporting docs\Standard Details\SC109.dwg

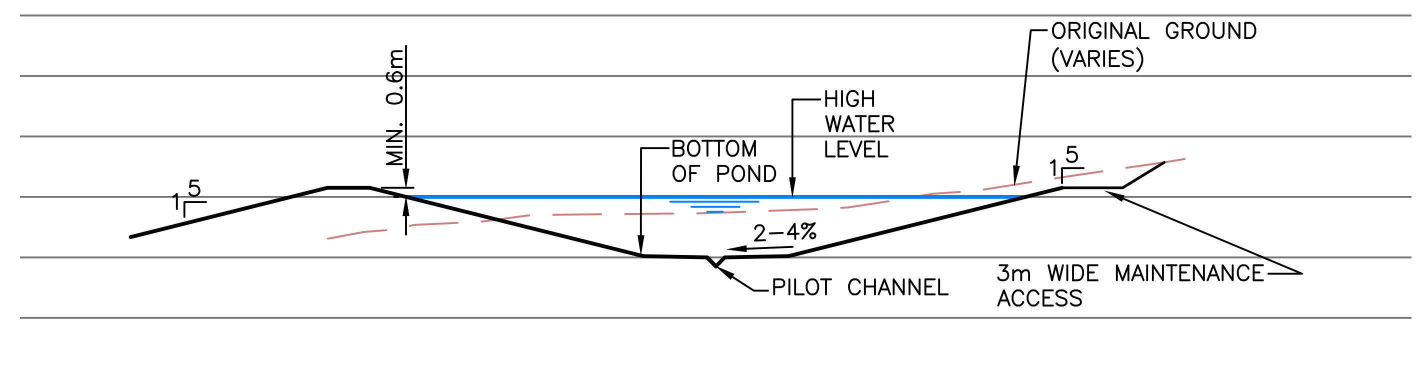
Plotted: February 01, 2016 , 16:46:22



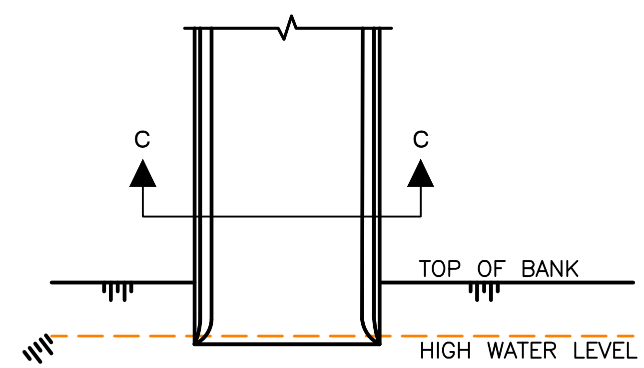
DETENTION POND - PLAN
N.T.S.



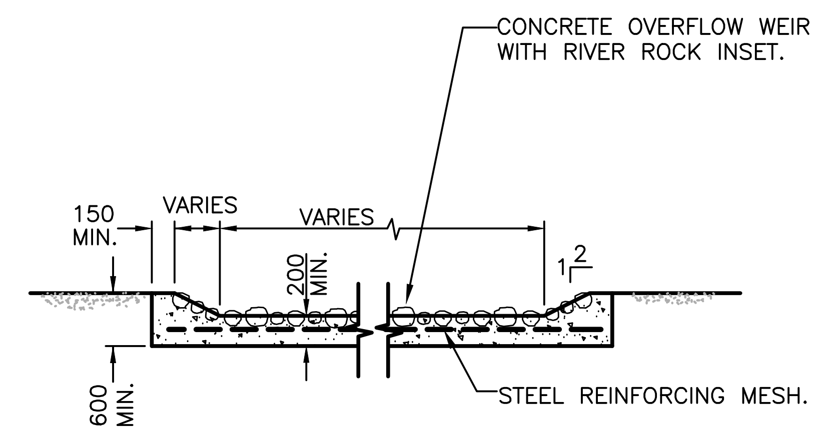
SECTION A - A
SCALE N.T.S.



SECTION B - B
SCALE N.T.S



POND OVERFLOW DETAIL
SCALE N.T.S.



SECTION C - C
SCALE N.T.S.

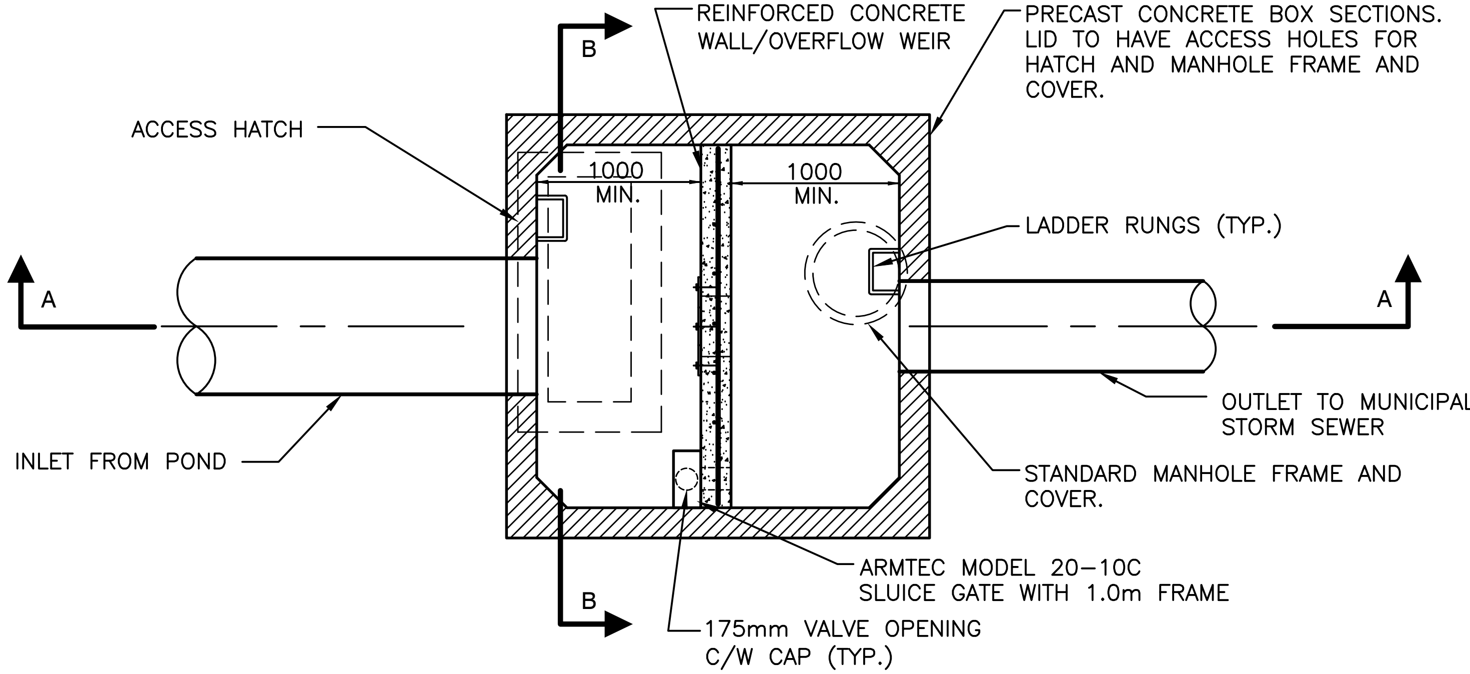
McElhanney
McElhanney Consulting Services Ltd.
495 SIXTH AVENUE
COURTENAY, B.C. V9N 6V4
PH (250) 338-5495

NORTHEAST COMOX

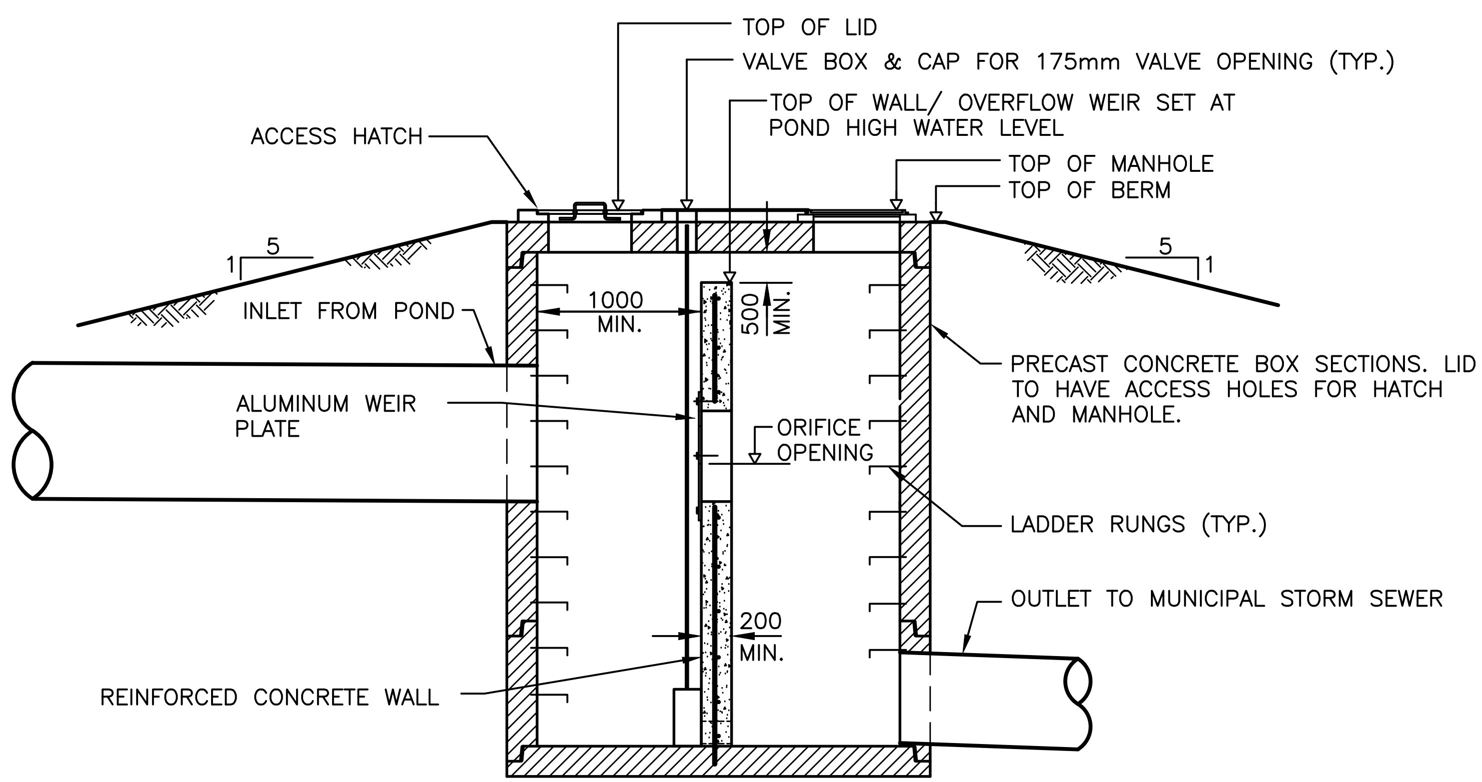
DRY DETENTION POND PLAN & SECTIONS

POND-101

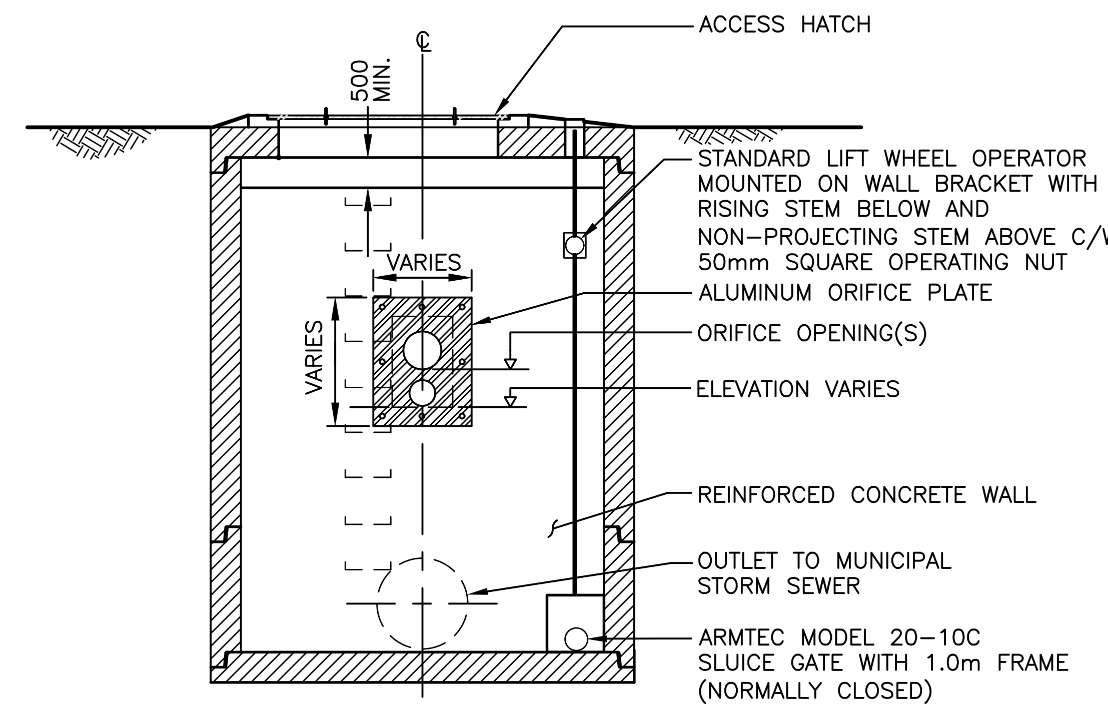
DATE JUNE



PLAN VIEW
N.T.S.



SECTION A - A
N.T.S.



SECTION B - B
N.T.S.

McElhanney

McElhanney Consulting Services Ltd.
495 SIXTH AVENUE
COURTENAY, B.C. V9N 6V4
PH (250) 338-5495

NORTHEAST COMOX

DRY DETENTION POND OUTLET CONTROL STRUCTURE
SECTIONS AND DETAILS

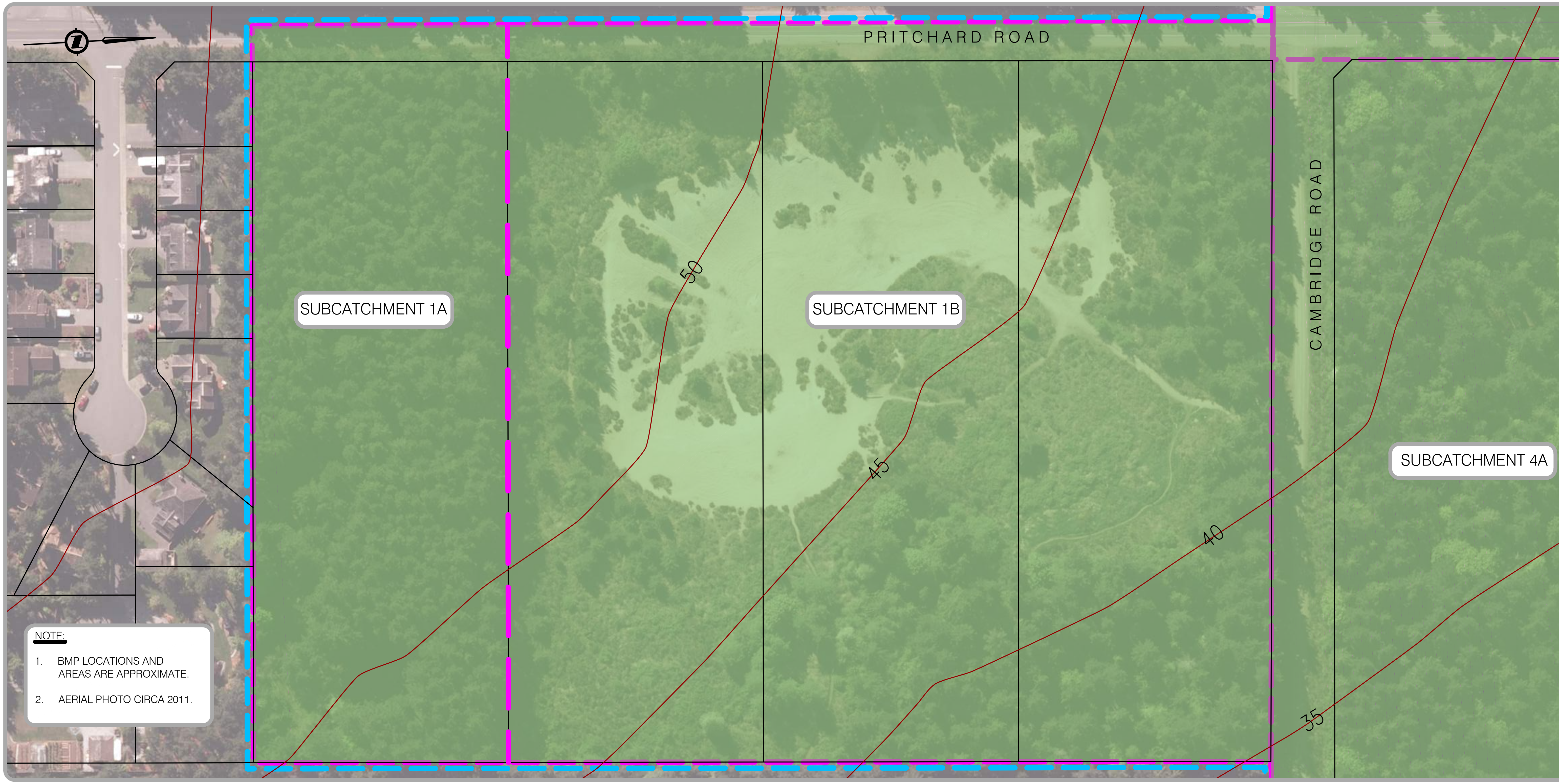
POND-102

DATE

Destroy all prints bearing previous number

Plotted: February 15, 2018 , 16:44:23 Filename: G:\2211 Engineering\46000 - 46999\46500-2\Reports - MCSL\Phase 3 report\PHASE 3 REPORT supporting docs\Standard Details\NE - POND SERIES 17-12-18.dwg\POND-102

APPENDIX D – BMP Locations



LEGEND

- STUDY AREA BOUNDARY
- SUBCATCHMENT BOUNDARY
- APPROXIMATE CONTOURS
- EXISTING PROPERTY LINE
- EXISTING OPEN CHANNEL DRAINAGE
- EXISTING PIPED DRAINAGE
- AREAS SUITABLE FOR DRY DETENTION PONDS
- AREAS SUITABLE FOR INFILTRATING BMPS

FIGURE □ - SUB-CATCHMENT □CONSTRUCTED BMP LOCATIONS

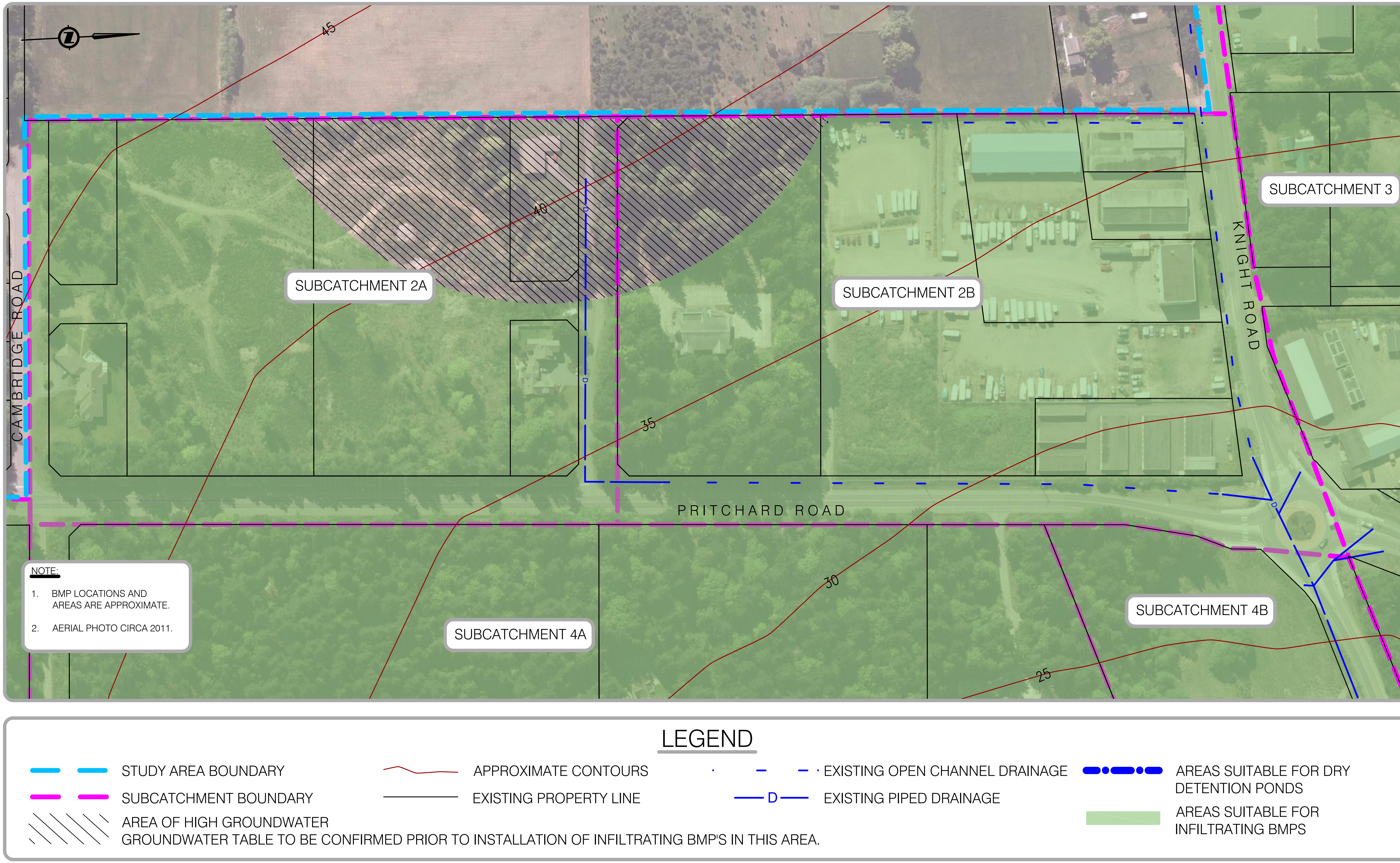


FIGURE □ - SUB-CATCHMENT □ CONSTRUCTED BMP LOCATIONS

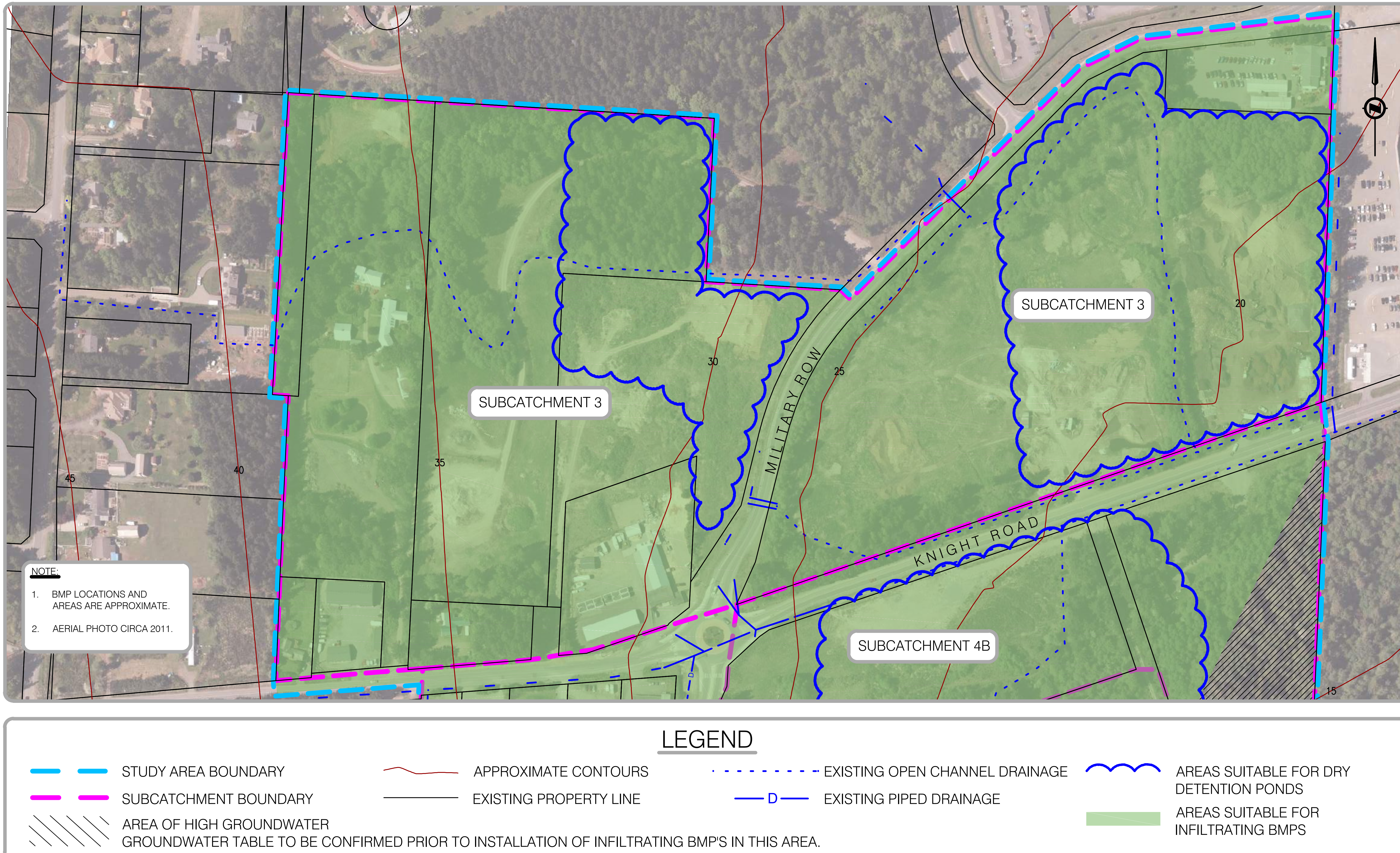
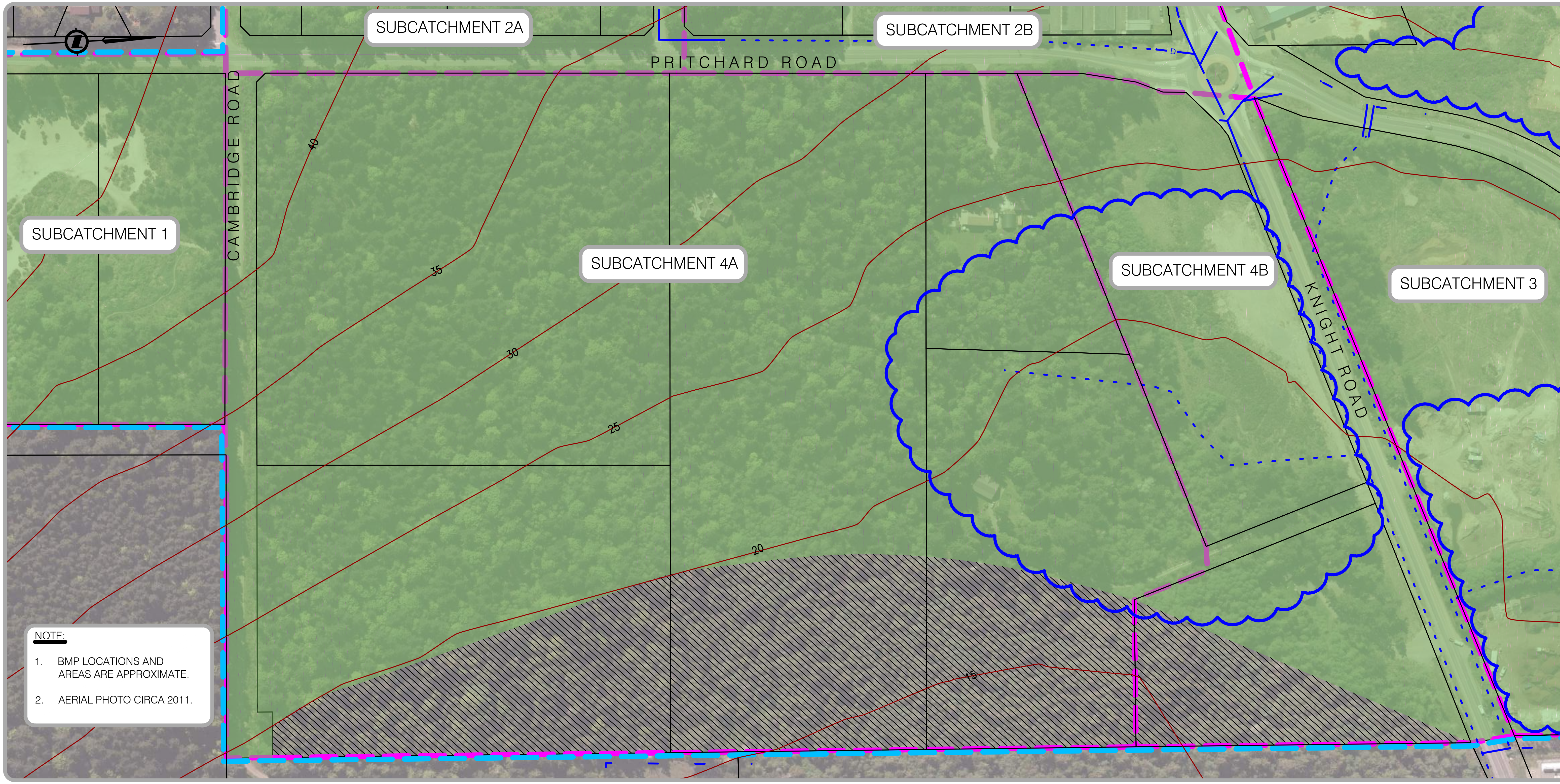


FIGURE □ - SUB-CATCHMENT □ CONSTRUCTED BMP LOCATIONS



LEGEND

- STUDY AREA BOUNDARY
- SUBCATCHMENT BOUNDARY
- AREA OF HIGH GROUNDWATER
  GROUNDWATER TABLE TO BE CONFIRMED PRIOR TO INSTALLATION OF INFILTRATING BMP'S IN THIS AREA.
- APPROXIMATE CONTOURS
- EXISTING PROPERTY LINE
- EXISTING OPEN CHANNEL DRAINAGE
- D EXISTING PIPED DRAINAGE
- AREAS SUITABLE FOR DRY DETENTION PONDS
- AREAS SUITABLE FOR INFILTRATING BMPS

FIGURE 4 - SUB-CATCHMENT 4 CONSTRUCTED BMP LOCATIONS

APPENDIX E – Cost Estimates for Selected BMPs

McElhanney

Revision Date: 8-Jul-15
Last Revision By: CD

NORTH EAST COMOX NEIGHBORHOOD STORM WATER MANAGEMENT PLAN

Class C Cost Estimate: Boulavard Infiltration Trench w/ Surface Collection

Based on standard detail drawing: SC-104 Revision: 1

	Length (m)	Width (m)	Depth (m)
Typical Dimensions:	20.0	3.0	1.0
Total Effective Storage Volume:	27 m^3		
Total Effective Infiltration Area:	60 m^2		

Item	Unit	Quantity	Unit Price	Sub total	Total
Estimated Construction Costs					
Excavation	m^3	96	$ 22	$ 2,112	
Geotextile	m^2	208	$ 5	$ 1,040	
Drain rock	m^3	60	$ 35	$ 2,100	
Control Manhole (1050)	ea.	1	$ 4,500	$ 4,500	
Cleanouts	ea.	1	$ 750	$ 750	
Observation wells	ea.	1	$ 500	$ 500	
Piping (150 dia.)	m	30	$ 100	$ 3,000	
Growing medium (450mm)	m^2	88	$ 10	$ 880	
Landscaping	ls	1	$ 2,000	$ 2,000	
Total Construction Costs (2015 Dollars)					***$ 16,882***

Item	Unit	Quantity	Unit Price	Sub total	Total
Estimated Annual O&M Costs (2015 Dollars)					
Inspection [3]	ea.	2	60	$ 120	
Perforate pipe flushing & manhole cleaning w/ vactor [4]	ea.	1	250	$ 250	
Landscaping maintenance [5]	ls	1	400	$ 400	
Total Annual O&M Costs (2015 Dollars)					***$ 770***

Item	Unit	Quantity	Unit Price	Sub total	Total
Estimated Replacement Costs (2015 Dollars)					
Excavation [6]	m^3	96	$ 40	$ 3,840	
Geotextile	m^2	208	$ 5	$ 1,040	
Drain rock	m^3	60	$ 35	$ 2,100	
Sand	m^3	30	$ 30	$ 900	
Cleanouts	ea.	1	$ 750	$ 750	
Observation wells	ea.	1	$ 500	$ 500	
Piping (150 dia.)	m	30	$ 100	$ 3,000	
Growing medium (450mm)	m^2	88	$ 10	$ 880	
Landscaping & private property restoration	ls	1	$ 8,000	$ 8,000	
Total Replacement Costs (2015 Dollars)					***$ 21,010***

Cost Summary (2015 Dollars)	
Construction Costs Per m^3 of storage:	$ 625
Construction Costs Per m^2 of infiltration:	$ 281
Replacement Costs Per m^3 of storage:	$ 778
Replacement Costs Per m^2 of infiltration:	$ 350
Annual O&M Costs Per m^3 of storage:	$ 29
Annual O&M Costs Per m^2 of infiltration:	$ 13

Notes:

1 *Class C cost estimate in 2015 dollars (+/- 25%).*

2 *Total effective storage based on a long-term drain rock porosity of 30%.*

3 *Assumes 2 inspections per year (October and May) - 2 staff completing a half hour inspection ($60/hr/person burdened labour cost including vehicles typical)*

4 *Assumes single vactor truck and labourer for 1 hour per manhole c/w disposal fee.*

5 *Assumes 2 seasonal maintenance staff, 2 hours, twice annually ($50/hr/person burdened labour cost including vehicles + $100 for plants/materials per visit).*

6 *Assumes 30% over excavation to remove sediment buildup. Replaced with sand.*

7 *Assumes no re-use of drain rock.*

8 *O&M labour and equipment costs are based on the Town's 2014 contractor hourly rates.*

NORTH EAST COMOX NEIGHBORHOOD STORM WATER MANAGEMENT PLAN

Class C Cost Estimate: Street Infiltration Trench w/ Impervious Cover

Based on standard detail drawing: SC-105 Revision: 1

	Length (m)	Width (m)	Depth (m)
Typical Dimensions:	50.0	6.0	1.0
Total Effective Storage Volume:	90 m^3		
Total Effective Infiltration Area:	300 m^2		

Item	Unit	Quantity	Unit Price	Sub total	Total
Estimated Construction Costs					
Excavation	m^3	480	$ 22	$ 10,560	
Geotextile	m^2	890	$ 5	$ 4,450	
Drain rock	m^3	300	$ 35	$ 10,500	
Control manholes (1050)	ea.	1	$ 4,500	$ 4,500	
Cleanouts	ea.	1	$ 750	$ 750	
Observation wells	ea.	1	$ 500	$ 500	
Piping (150 dia.)	m	60	$ 100	$ 6,000	
Total Construction Costs (2015 Dollars)					**$ 37,260**
Estimated Annual O&M Costs (2015 Dollars)					
Inspection [3]	ea.	2	60	$ 120	
Perforated pipe flushing & manhole cleaning w/ vactor [4]	ea.	1	600	$ 600	
Total Annual O&M Costs (2015 Dollars)					**$ 720**
Estimated Replacement Costs (2015 Dollars)					
Excavation [5]	m^3	624	$ 30	$ 18,720	
Geotextile	m^2	890	$ 5	$ 4,450	
Drain rock	m^3	300	$ 35	$ 10,500	
Sand [6]	m^3	144	$ 30	$ 4,320	
Cleanouts	ea.	1	$ 750	$ 750	
Observation wells	ea.	1	$ 500	$ 500	
Piping (150 dia.)	m	100	$ 100	$ 10,000	
Asphalt	m^2	375	$ 50	$ 18,750	
Total Replacement Costs (2015 Dollars)					**$ 67,990**

Cost Summary (2015 Dollars)

Construction Costs Per m^3 of storage:	$	414
Construction Costs Per m^2 of infiltration:	$	124
Replacement Costs Per m^3 of storage:	$	755
Replacement Costs Per m^2 of infiltration:	$	227
Annual O&M Costs Per m^3 of storage:	$	8
Annual O&M Costs Per m^2 of infiltration:	$	2

Notes:

1. *Class C cost estimate in 2015 dollars (+/- 25%).*
2. *Typical dimensions are based on an average trench length of +/- 50m.*
3. *Assumes 2 inspections per year (October and May) - 2 staff completing a half hour inspection ($60/hr/person burdened labour cost including vehicles typical)*
4. *Assumes single vactor truck and labourer for 2.5 hours per infiltration trench c/w disposal fee.*
5. *Assumes 30% over excavation to remove sediment buildup. Replaced with sand.*
6. *Assumes no re-use of drain rock.*
7. *O&M labour and equipment costs are based on the Town's 2014 contractor hourly rates.*

McElhanney

Revision Date: 18-Apr-16
Last Revision By: CD

NORTH EAST COMOX NEIGHBORHOOD STORM WATER MANAGEMENT PLAN

Class C Cost Estimate: Dry Detention Pond

Based on standard detail drawing:	Pond-101 & 102		Revision: 2	
	Length (m)	Width (m)	Depth (m)	
Typical Dimensions:	60.0	50.0	1.6	
Total Effective Storage Volume:	3000 m^3			

Item	Unit	Quantity	Unit Price	Sub total	Total
Estimated Construction Costs					
Excavate and remove material	m^3	7800	$ 22	$ 171,600	
Shape berms	m^3	1530	$ 10	$ 15,300	
Sand base(100mm)	m^2	3000	$ 5	$ 15,000	
Rock surround	m^3	175	$ 100	$ 17,500	
Aquatic topsoil (150mm)	m^2	1200	$ 7	$ 8,400	
Aquatic planting	ls	1	$ 10,000	$ 10,000	
Topsoil (150mm)	m^2	1000	$ 6	$ 6,000	
headwalls	ea.	2	$ 3,500	$ 7,000	
Manhole (1050) @ inlet	ea.	1	$ 4,500	$ 4,500	
Control structure	ls	1	$ 45,000	$ 45,000	
Overflow Structure	ls	1	$ 10,000	$ 10,000	
Total Construction Costs (2015 Dollars)					***$ 310,300***
Estimated Annual O&M Costs (2015 Dollars)					
Inspection [4]	ea.	2	$ 60	$ 120	
Manhole cleaning w/ vactor [5]	ea.	2	200	$ 400	
Annual cleaning/landscaping [6]	ls	1/5	$ 13,700	$ 2,740	
Total Annual O&M Costs (2015 Dollars)					***$ 3,260***
Estimated Renewal Costs (2015 Dollars)					
Excavate and remove material	m^3	1000	$ 30	$ 30,000	
Shape berms	m^3	500	$ 12	$ 6,000	
Sand base(100mm)	m^2	3000	$ 6	$ 18,000	
Aquatic topsoil (150mm)	m^2	1200	$ 7	$ 8,400	
Aquatic planting	ls	1	$ 10,000	$ 10,000	
Topsoil (150mm)	m^2	1000	$ 6	$ 6,000	
Total Replacement Costs (2015 Dollars)					***$ 78,400***
				Construction Costs Per m^3 of storage:	*$ 103*
				Renewal Costs Per m^3 of storage:	*$ 26*
				Annual O&M Costs Per m^3 of storage:	*$ 1*

Notes:

1 *Class C cost estimate in 2015 dollars (+/- 25%).*

2 *Effective storage based on a minimum freeboard of 0.6m.*

3 *Costs are exclusive of land value, landscaping or other improvements surrounding the pond.*

4 *Assumes 2 inspections per year (October and May) - 2 staff completing a half hour inspection ($60/hr/person burdened labour cost including vehicles typical)*

5 *Assumes single vactor truck and labourer for 3/4 hour per manhole c/w disposal fee.*

6 *Assumes cleaning and landscaping to be completed once every 5 years and consists of:*
- 1 excavator, labourer and trucks for 1 day ($3,700)
- 1 landscaping crew for 2 days ($3,600), aquatic topsoil, topsoil and aquatic planting ($6,400)

7 *O&M labour and equipment costs are based on the Town's 2014 contractor hourly rates.*

APPENDIX F – Typical Service Record Cards and Lot Grading Plan

McElhanney

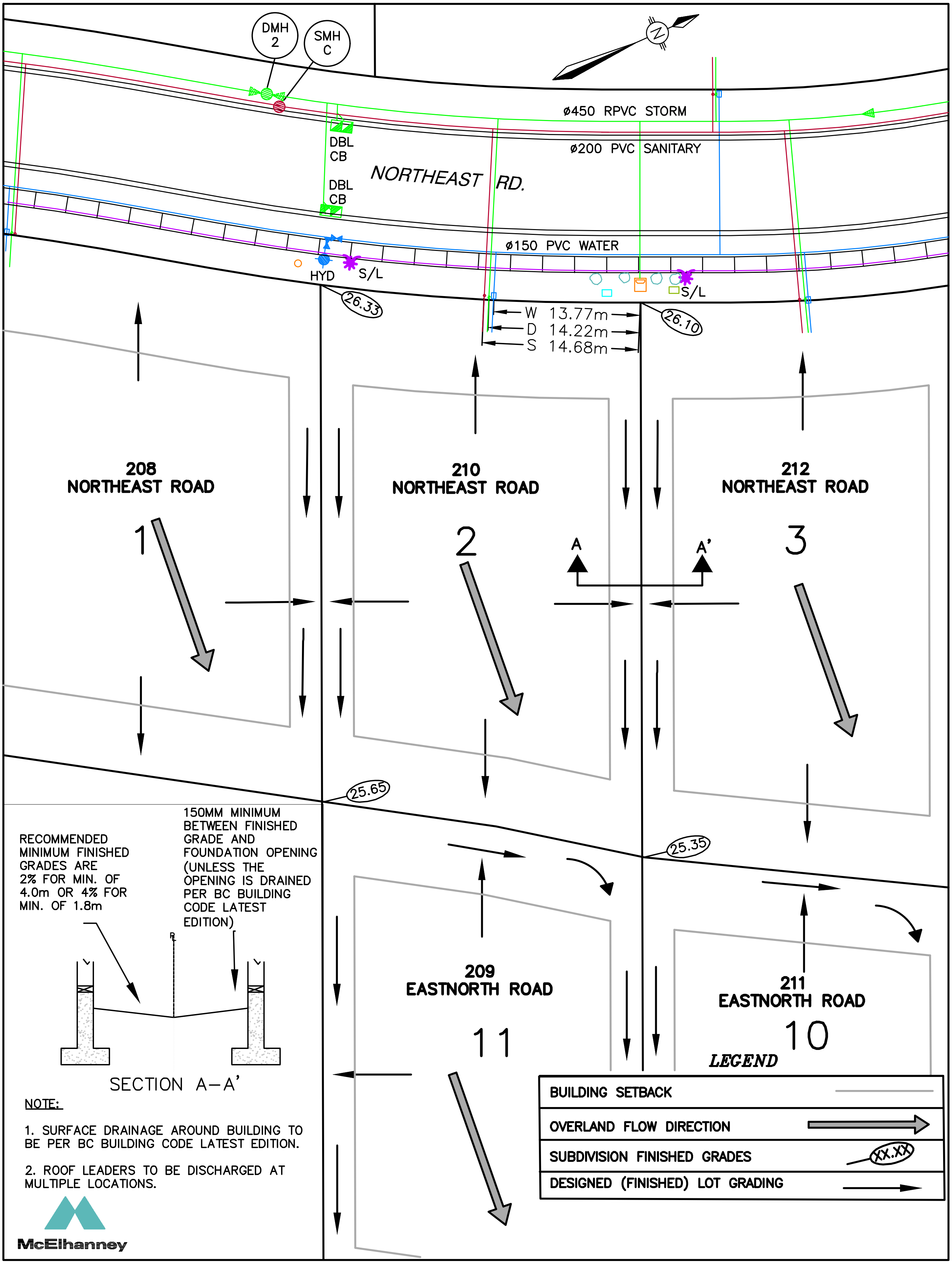
WATER & SEWER SERVICE CONNECTION RECORD CARD

NAME	ADDRESS	PLAN		LOT
	210 NORTHEAST ROAD			1

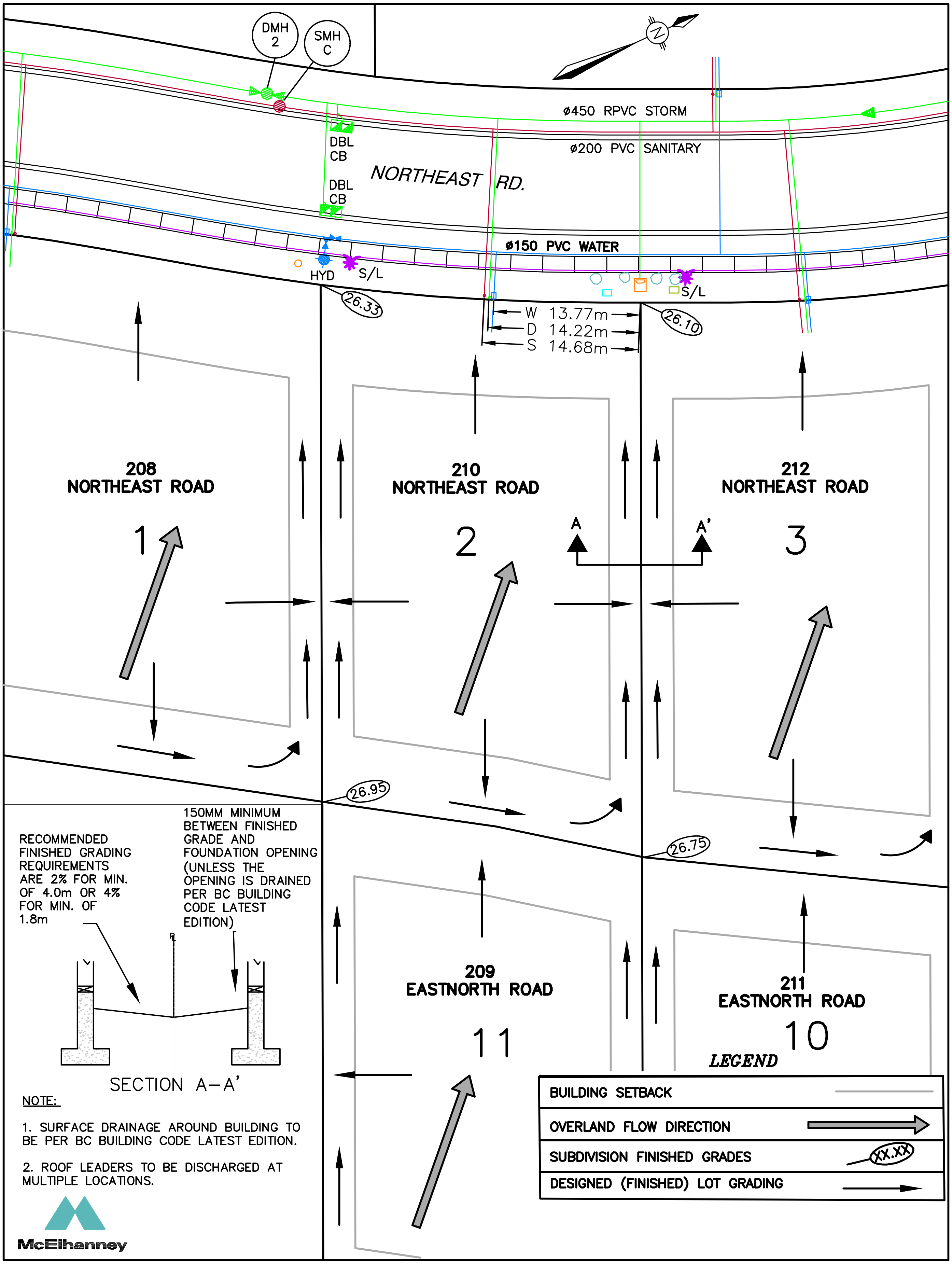
STORM SEWER		WATER		SANITARY SEWER	
INSTALLATION DATE: AUGUST 2010		INSTALLATION DATE: AUGUST 2010		INSTALLATION DATE: AUGUST 2010	
SIZE	150	SIZE	19	SIZE	100
LENGTH	18.1	DISTANCE FROM MAIN TO CURB STOP	11.5	LENGTH	17.2
TYPE OF PIPE	PVC	CORP. STOP	COMP.	TYPE OF PIPE	PVC
FITTING AT MAIN	WYE	CURB STOP	COMP.	FITTING AT MAIN	WYE
45° BENDS	NO	COUPLINGS	NO	45° BENDS	NO
RISER	NO	REDUCER	NO	RISER	YES
INVERT ELEVATION AT PROPERTY LINE	25.20			INVERT ELEVATION AT PROPERTY LINE	25.20
GROUND ELEV. AT P. L.	26.20			GROUND ELEV. AT P. L.	26.20
DISTANCE FROM MANHOLE TO FITTING ON MAIN	19.3			TO FITTING ON MAIN	18.1
MEASURED FROM MANHOLE	DMH 2	PRIOR TO STRIKING FLOOR SLAB OR JOIST ELEVATIONS, IT IS RECOMMENDED THAT THE BUILDING CONTRACTOR EXPOSE THE SERVICE CONNECTIONS TO CONFIRM THEY ARE OF ADEQUATE DEPTH		MEASURED FROM MANHOLE	SMH C
DEPTH OF FITTING	2.5			DEPTH OF FITTING	2.0

MAINTENANCE RECORD

DATE	WORK DONE	COST



DMH
2
SMH
C
ø450 RPVC STORM
ø200 PVC SANITARY
DBL
CB
DBL
CB
NORTHEAST RD.
ø150 PVC WATER
HYD
S/L
S/L
26.33
26.10
W 13.77m
D 14.22m
S 14.68m
208
NORTHEAST ROAD
1
210
NORTHEAST ROAD
2
212
NORTHEAST ROAD
3
A
A'
25.65
25.35
209
EASTNORTH ROAD
11
211
EASTNORTH ROAD
10
RECOMMENDED MINIMUM FINISHED GRADES ARE 2% FOR MIN. OF 4.0m OR 4% FOR MIN. OF 1.8m
150MM MINIMUM BETWEEN FINISHED GRADE AND FOUNDATION OPENING (UNLESS THE OPENING IS DRAINED PER BC BUILDING CODE LATEST EDITION)
SECTION A—A'
NOTE:
1. SURFACE DRAINAGE AROUND BUILDING TO BE PER BC BUILDING CODE LATEST EDITION.
2. ROOF LEADERS TO BE DISCHARGED AT MULTIPLE LOCATIONS.
McElhanney
LEGEND
BUILDING SETBACK
OVERLAND FLOW DIRECTION
SUBDIVISION FINISHED GRADES
XX.XX
DESIGNED (FINISHED) LOT GRADING



DMH 2
SMH C
ø450 RPVC STORM
ø200 PVC SANITARY
DBL CB
DBL CB
NORTHEAST RD.
ø150 PVC WATER
HYD
S/L
S/L
26.33
26.10
W 13.77m
D 14.22m
S 14.68m
208 NORTHEAST ROAD
1
210 NORTHEAST ROAD
2
212 NORTHEAST ROAD
3
A
A'
26.95
26.75
RECOMMENDED FINISHED GRADING REQUIREMENTS ARE 2% FOR MIN. OF 4.0m OR 4% FOR MIN. OF 1.8m
150MM MINIMUM BETWEEN FINISHED GRADE AND FOUNDATION OPENING (UNLESS THE OPENING IS DRAINED PER BC BUILDING CODE LATEST EDITION)
SECTION A–A'
209 EASTNORTH ROAD
11
211 EASTNORTH ROAD
10
LEGEND
BUILDING SETBACK
OVERLAND FLOW DIRECTION
SUBDIVISION FINISHED GRADES
XX.XX
DESIGNED (FINISHED) LOT GRADING
NOTE:
1. SURFACE DRAINAGE AROUND BUILDING TO BE PER BC BUILDING CODE LATEST EDITION.
2. ROOF LEADERS TO BE DISCHARGED AT MULTIPLE LOCATIONS.
McElhanney

APPENDIX G – Professional Certification Statements

I, Jim Richard, Professional Agrologist, have reviewed the North East Comox Neighbourhood Stormwater Management Plan as prepared by Bob Hudson, P.Eng. and dated March 2018, hereafter referred to as the SWMP. The SWMP will not adversely impact the existing agricultural potential of down-slope lands within the Agricultural Land Reserve.

Submitted by,

Soil Matters Consulting Ltd.

I certify this to be report prepared by

BRITISH COLUMBIA INSTITUTE OF AGROLOGISTS 1960 Jam 2018-03-15 P.Ag.

Jim Richard, P.Ag., Professional Agrologist

I, Cindy Lipp, Registered Professional Biologist have reviewed the North East Comox Neighbourhood Stormwater Management Plan as prepared by Bob Hudson, P.Eng and dated March 2018, hereafter referred to as the SWMP. The SWMP will not adversely impact the existing downstream fish habitat or the environmental integrity of Lazo Marsh.

Submitted by,

McElhanney Consulting Services Limited

I certify this to be report prepared by

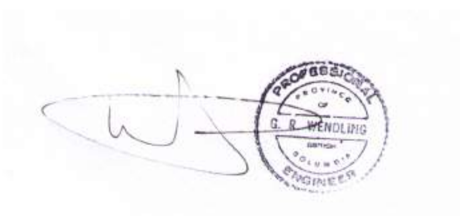
Cindy Lipp, RPBio, Registered Professional Biologist

I, Gilles Wendling, P.Eng. Ph.D, Professional Hydrogeologist have reviewed the North East Comox Neighbourhood Stormwater Management Plan as prepared by Bob Hudson, P.Eng. and dated March 2018, hereafter referred to as the SWMP. The SWMP will not adversely impact the existing agricultural potential of down-slope lands within the Agricultural Land Reserve.

Submitted by,

GW Solutions

I certify this to be report prepared by



____

Gilles Wendling, P.Eng. Ph.D, Professional Hydrogeologist

The purpose of this Storm Water Management Plan (the "SWMP") is to ensure that when and if all those lands within the Town of Comox identified in the SWMP (the "Water Management Area") are ultimately improved and developed as contemplated by the SWMP and either current zoning or the current Official Community Plan, the impact of surface and ground water flows originating from the Water Management Area on downstream and down-slope flood frequency and flood duration for up to and including the 100 year runoff event will be the same or less as of the date of this SWMP and ground water flows and quality originating from the Water Management Area will be substantially the same as of the date of this SWMP including ground water flows and quality to Hilton Springs, Lazo Marsh and down-slope lands. This statement is made on the basis that historic rainfall patterns remain consistent into the future with an allowance for climate change adaptation limited to using the climate change projections from the Pacific Institute for Climate Solutions, the lands in the Water Management Area are developed in accordance with either the current zoning or the current Official Community Plan of the Town of Comox; that the Town adopts as recommended in this SWMP such drainage regulations and requirements as are recommended in the SWMP; and that the SWMP is fully implemented by the Town of Comox in respect of the future development of the lands in the Water Management Area.

Notwithstanding any other statement in this SWMP, this SWMP may be relied upon by the Town of Comox in establishing storm water management requirements for the Water Management Area.

Submitted by,

McElhanney Consulting Services Ltd.

I certify this to be report prepared by

Bob Hudson, P.Eng, Professional Engineer

APPENDIX H – GW Solutions Hydrogeological Review

McElhanney Consulting Services Ltd.
495 Sixth Street
Courtenay, BC V9N 6V4

(Via email)

Attention: Chris Durupt, P.Eng.

Re: NE Comox Storm Water Management Plan – Phase 3 of 3 – Hydrogeological Review (update)

The present document is an update of NE Comox Storm Water Management Plan – Phase 3 of 3 – Hydrogeological Review, GW Solutions, 2015. It reflects the recent updates of the North East Comox Neighbourhood Storm Water Management Plan – Phase 3 of 3, dated March 1, 2018, hereafter referred to as the SWMP.

1 BACKGROUND INFORMATION

GW Solutions Inc. (GW Solutions) has completed this review based on stratigraphic and hydrogeological information provided in the following documents and studies:

- Regional District of Comox-Strathcona Aquifer Classification Project Report, BC Ministry of Environment (G. Humpfrey), 2000
- Supplementary Report – Comox Valley Air Terminal Relocation Project, Levelton Engineering Solutions, 2002.
- Hydrogeological Assessment for Development of Block 71 and DL. 185, Courtenay BC, Piteau and Associates, 2004
- Hydrogeological Investigation Comox Lands, Comox, BC, GW Solutions, 2006
- Pritchard Road, Comox – Detailed Hydrogeology, GW Solutions, 2010
- Hydrogeology- Staffored Road, Lot1, District Lot110, Comox District Plan VIP 72347, GW Solutions, 2015
- NE Comox Storm Water Management Plan – Phase 3 of 3 – Hydrogeological Review, GW Solutions, 2015

The SWMP area proposes six sub-catchments based on zoning, topography, and geological conditions. The Google Earth photo (Figure 1) shows the SWMP area (red lines), sub-catchments (green lines) and three dry detention ponds (blue lines).

2 OBJECTIVE

The objective of GW Solutions was to assess the adequacy and potential performance of the dry detention ponds as proposed in the SWMP and evaluate if they have potential to have negative impacts on Hilton Springs and agricultural lands downstream.

3 METHODOLOGY

A 3D hydrostratigraphical model was developed in 2015 using LeapFrog based on the BC MOE Wells Database and complementary information from other subsurface investigations and was updated in 2018 for this update. The modelled area is shown in Figure 2.

4 TYPICAL STRATIGRAPHY

In the study area, the typical stratigraphic sequence includes, from top to bottom:

- Marine sediments;
- Hard packed sand, gravel and silt (Vashon Drift);
- Sand, gravel and silts (Quadra Sands); and
- Sand, gravel or till (Pre-Quadra Sands); over
- Bedrock.

The infiltration capacity of the subsurface will be a function of both the presence and thickness of these layers, and the piezometric conditions (i.e., elevation of the water table).

Taking this into account, the units listed above can be simplified into three main horizons:

1. Overburden sand/gravel (permeable - potential aquifer);
2. Vashon Till (low permeability – aquitard); and
3. Quadra Sands (aquifer).

Based on the previous studies, there are two groundwater regimes under the site. A shallow groundwater regime in the surficial sand and gravel, and a deep groundwater regime in the Quadra Sands. The Quadra Sands constitute an important aquifer in the region.

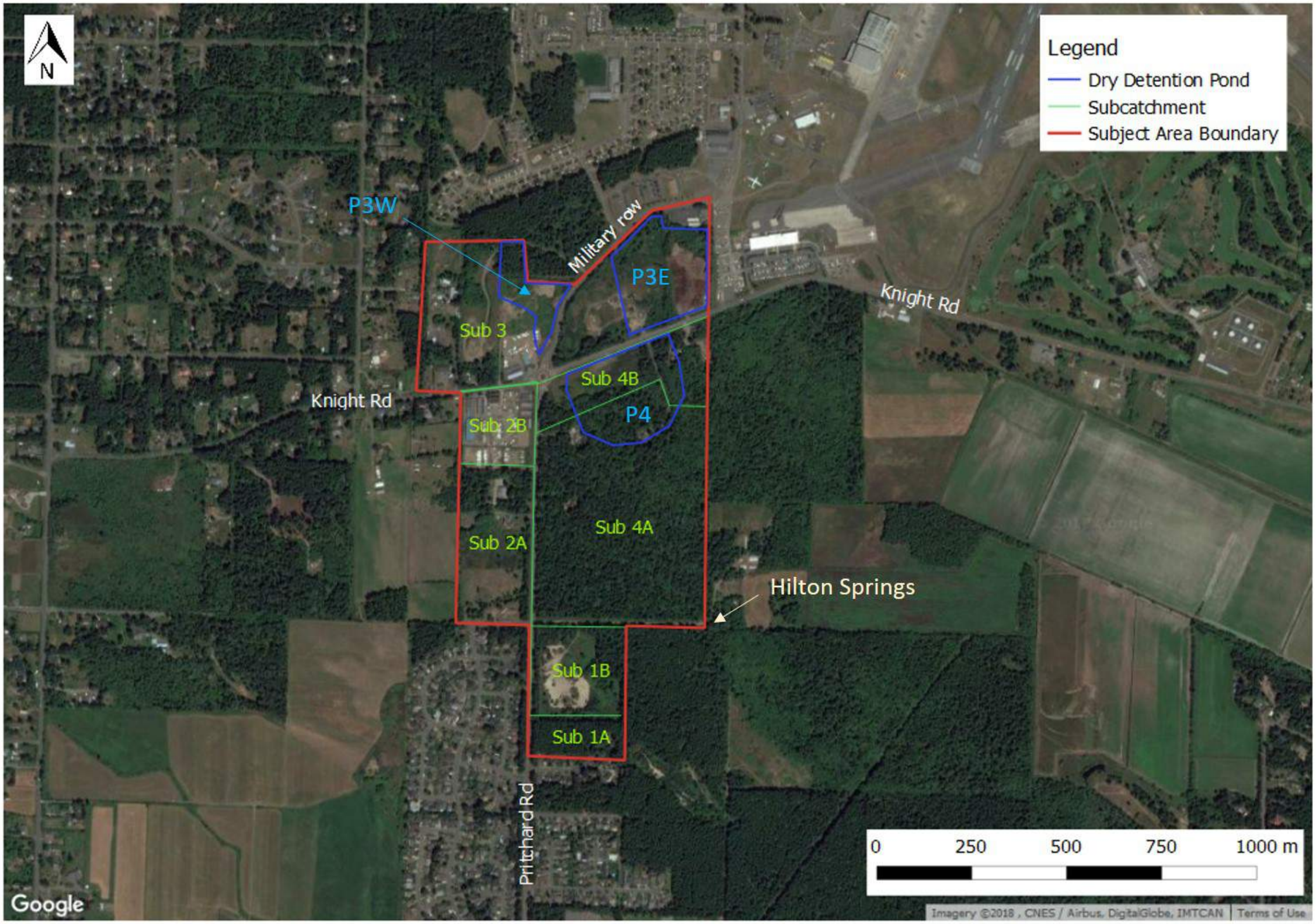


Figure 1. Location of the Storm Water Management Plan area

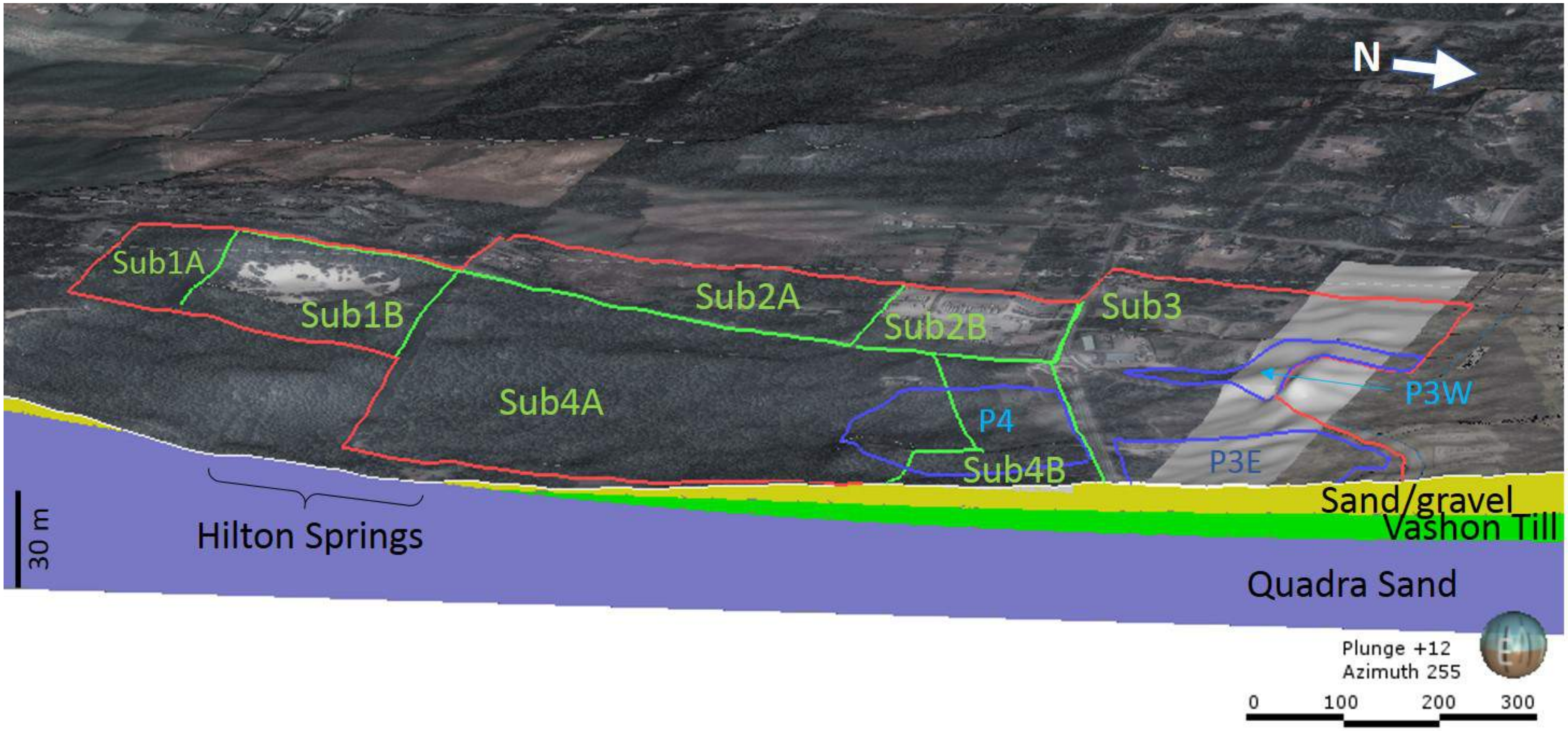


Figure 2. Modelled area. Cross-section of the model at P3E, looking West.

5 RESULTS

The hydrogeological conditions under each sub-catchment and pond were assessed based on the developed 3D model. GW Solutions understands that the dry detention ponds shall be about 1 m deep and must be above the seasonal groundwater elevation to avoid saturation in winter.

- Under **Pond 3 East (P3E)**, the minimum thickness of sand and gravel is 5 m (Figure 2). The till has a minimum thickness of about 7 m. The saturation conditions are unknown within the sand and gravel sediments but the water table is likely to be greater than 1 m deep (to be confirmed with on-site investigation), with a lateral hydraulic gradient towards the East following topography and the top of the till layer. Therefore, the proposed P3E is at a suitable location for promoting storm water infiltration and it should not affect agricultural lands downstream.

- Under **Pond 3 West (P3W)**, the minimum thickness of sand and gravel ranges approximately between 2.5 m (southern portion of proposed pond) to 13 m (Figure 3). The till has a minimum thickness of 10 m. The saturation conditions are unknown in the sand and gravel sediments. However, the water table is expected to be greater than 1 m deep (to be confirmed with on-site investigation), with a lateral hydraulic gradient towards the East following topography and the top of the till layer. Therefore, the proposed P3W is at a suitable location for promoting storm water infiltration and it should not affect agricultural lands downstream.

- Under **Pond 4 (P4)** (Figure 4), the sand and gravel layer is thinner and can be absent or less than 1 m thick in the southern half of the proposed area for P4. The till is underlying and has a minimum thickness of 7 m which will limit vertical infiltration of storm water mostly in the southern half portion. The till will provide a capping layer to the Quadra Sands that is not expected to be breached, should shallow excavations be completed. Therefore, artesian conditions should not be encountered. The saturation conditions are unknown within the upper sediments, and one should make the assumption that a shallow water table might be encountered due to the thin sand and gravel layer. GW Solutions recommends to investigate the saturation conditions in winter at this specific location (i.e., monitoring wells should be installed and monitored).

Further consideration should be given to pond design if the highest water table is monitored to be above the bottom of the pond.

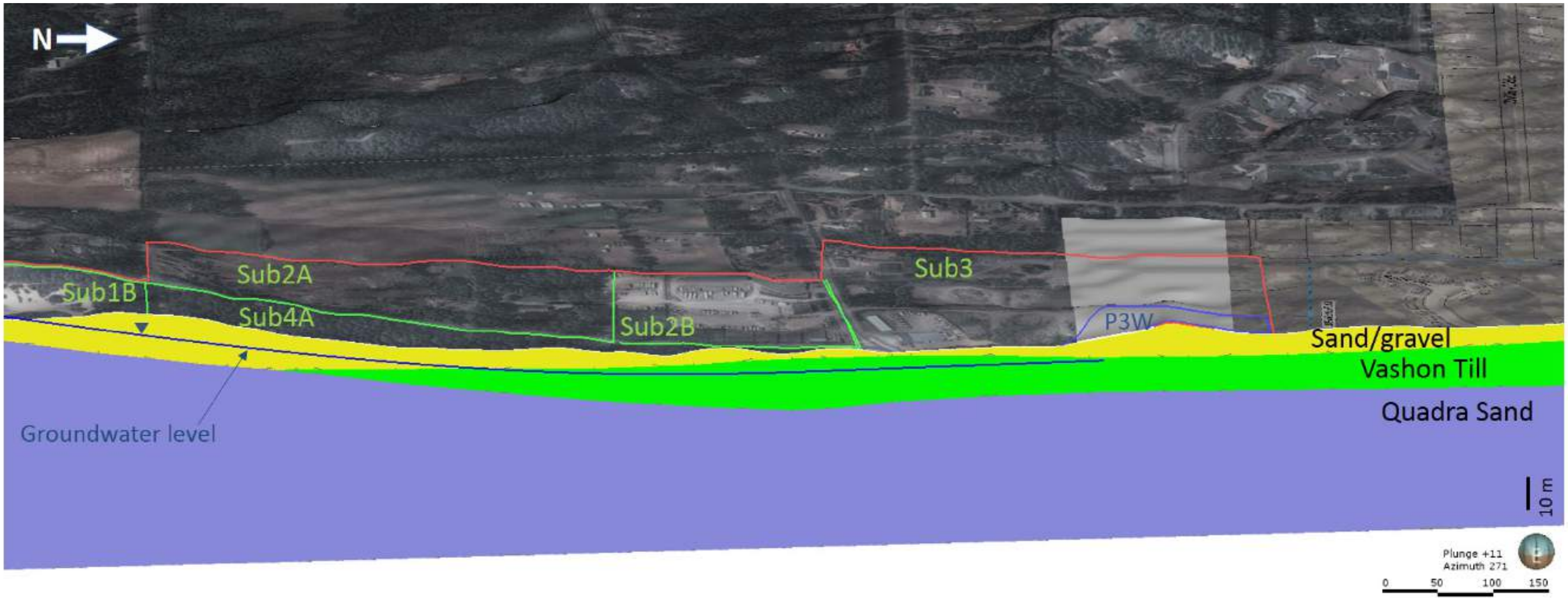


Figure 3. Cross-section of the model at P3W, looking West.

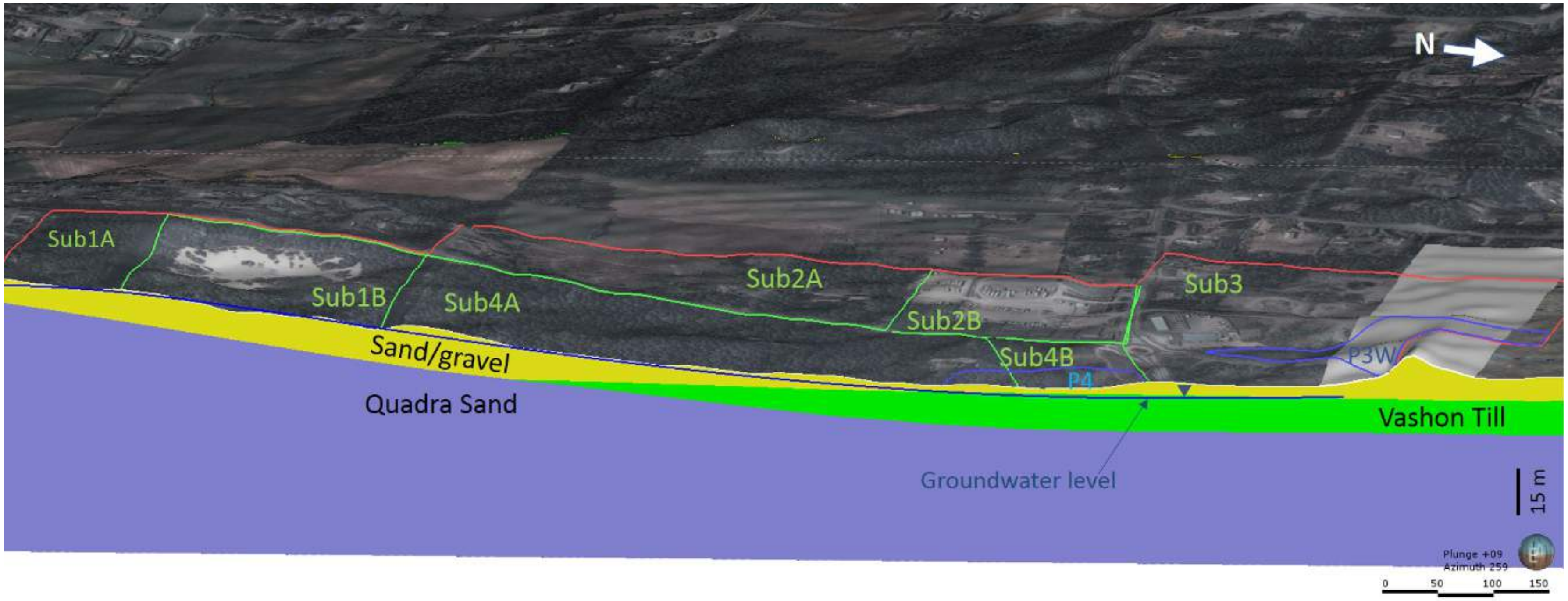


Figure 4. Cross-section of the model at P4, looking West.

6 CONCLUSIONS

The proposed locations of the ponds seem appropriate, as they are located where sand and gravel sediments are present over the till layer, except at the southern part of P4, where the sand and gravel layer is thinner or absent. When entering the ponds, some part of the water will infiltrate into the sand and gravel layer and some of it will be redirected to the municipal storm sewer via the pilot channel; therefore, the agricultural lands located downgradient should not be affected by the proposed measures. The Hilton Springs should not be affected by the management and infiltration of storm water using the proposed BMPs because groundwater flows to the east in the upper sand and gravel aquifer.

These conclusions are based on current available local and regional knowledge. Water level information was limited in the area of the proposed ponds leading to uncertainty in the actual saturation conditions. Detailed local information on both soil and groundwater conditions have to be collected to confirm assumptions and to adjust the rainwater management plan to the actual local subsurface conditions.

7 LIMITATIONS

This document was prepared for the exclusive use of McElhanney Consulting Services Ltd. The inferences concerning the data, site and receiving environment conditions contained in this document are based on information obtained during investigations conducted at the site by GW Solutions and others, and are based solely on the condition of the site at the time of the site studies. Soil, surface water and groundwater conditions may vary with location, depth, time, sampling methodology, analytical techniques and other factors.

In evaluating the subject study area and water quality data, GW Solutions has relied in good faith on information provided. The factual data, interpretations and recommendations pertain to a specific project as described in this document, based on the information obtained during the assessment by GW Solutions on the dates cited in the document, and are not applicable to any other project or site location. GW Solutions accepts no responsibility for any deficiency or inaccuracy contained in this document as a result of reliance on the aforementioned information.

The findings and conclusions documented in this document have been prepared for the specific application to this project, and have been developed in a manner consistent with that level of care normally exercised by hydrogeologists currently practicing under similar conditions in the jurisdiction.

GW Solutions makes no other warranty, expressed or implied and assumes no liability with respect to the use of the information contained in this document at the subject site, or any other site, for other than its intended purpose. Any use which a third party makes of this document, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. GW Solutions accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or action based on this document. All third parties relying on this document do so at their own risk. Electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore no party can rely upon the electronic media versions of GW Solutions' document or other work product. GW Solutions is not responsible for any unauthorized use or modifications of this document.

GW Solutions makes no other representation whatsoever, including those concerning the legal significance of its findings, or as to other legal matters touched on in this document, including, but not limited to, ownership of any property, or the application of any law to the facts set forth herein.

If new information is discovered during future work, including excavations, sampling, soil boring, predictive geochemistry or other investigations, GW Solutions should be requested to re-evaluate the conclusions of this document and to provide amendments, as required, prior to any reliance upon the information presented herein. The validity of this document is affected by any change of site conditions, purpose, development plans or significant delay from the date of this document in initiating or completing the project.

The produced graphs, images, and maps, have been generated to visualize results and assist in presenting information in a spatial and temporal context. The conclusions and recommendations presented in this document are based on the review of information available at the time the work was completed, and within the time and budget limitations of the scope of work.

McElhanney Consulting Services Ltd. may rely on the information contained in this memorandum subject to the above limitations.

8 CLOSURE

Conclusions and recommendations presented herein are based on available information at the time of the study. The work has been carried out in accordance with generally accepted engineering practice. No other warranty is made, either expressed or implied. Engineering judgement has been applied in producing this letter-report.

This letter report was prepared by personnel with professional experience in the fields covered. Reference should be made to the General Conditions and Limitations attached in Appendix 1.

GW Solutions was pleased to produce this document. If you have any questions, please contact me.

Yours truly,

GW Solutions Inc.

Gilles Wendling, Ph.D., P.Eng.

President

APPENDIX 1

GW SOLUTIONS INC. GENERAL CONDITIONS AND LIMITATIONS

This report incorporates and is subject to these "General Conditions and Limitations".

1.0 USE OF REPORT

This report pertains to a specific area, a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment. This report and the assessments and recommendations contained in it are intended for the sole use of GW SOLUTIONS's client. GW SOLUTIONS does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than GW SOLUTIONS's client unless otherwise authorized in writing by GW SOLUTIONS. Any unauthorized use of the report is at the sole risk of the user. This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of GW SOLUTIONS. Additional copies of the report, if required, may be obtained upon request.

2.0 LIMITATIONS OF REPORT

This report is based solely on the conditions which existed within the study area or on site at the time of GW SOLUTIONS's investigation. The client, and any other parties using this report with the express written consent of the client and GW SOLUTIONS, acknowledge that conditions affecting the environmental assessment of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive. The client, and any other party using this report with the express written consent of the client and GW SOLUTIONS, also acknowledge that the conclusions and recommendations set out in this report are based on limited observations and testing on the area or subject site and that conditions may vary across the site which, in turn, could affect the conclusions and recommendations made. The client acknowledges that GW SOLUTIONS is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the client.

2.1 INFORMATION PROVIDED TO GW SOLUTIONS BY OTHERS

During the performance of the work and the preparation of this report, GW SOLUTIONS may have relied on information provided by persons other than the client. While GW SOLUTIONS endeavours to verify the accuracy of such information when instructed to do so by the client, GW SOLUTIONS accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

3.0 LIMITATION OF LIABILITY

The client recognizes that property containing contaminants and hazardous wastes creates a high risk of claims brought by third parties arising out of the presence of those materials. In consideration of these risks, and in consideration of GW SOLUTIONS providing the services requested, the client agrees that GW SOLUTIONS's liability to the client, with respect to any issues relating to contaminants or other hazardous wastes located on the subject site shall be limited as follows:

(1) With respect to any claims brought against GW SOLUTIONS by the client arising out of the provision or failure to provide services hereunder shall be limited to the amount of fees paid by the client to GW SOLUTIONS under this Agreement, whether the action is based on breach of contract or tort;

(2) With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject site, the client agrees to indemnify, defend and hold harmless GW SOLUTIONS from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by GW SOLUTIONS, whether the claim be brought against GW SOLUTIONS for breach of contract or tort.

4.0 JOB SITE SAFETY

GW SOLUTIONS is only responsible for the activities of its employees on the job site and is not responsible for the supervision of any other persons whatsoever. The presence of GW SOLUTIONS personnel on site shall not be construed in any way to relieve the client or any other persons on site from their responsibility for job site safety.

5.0 DISCLOSURE OF INFORMATION BY CLIENT
The client agrees to fully cooperate with GW SOLUTIONS with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The client acknowledges that in order for GW SOLUTIONS to properly provide the service, GW SOLUTIONS is relying upon the full disclosure and accuracy of any such information.

6.0 STANDARD OF CARE
Services performed by GW SOLUTIONS for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

7.0 EMERGENCY PROCEDURES
The client undertakes to inform GW SOLUTIONS of all hazardous conditions, or possible hazardous conditions which are known to it. The client recognizes that the activities of GW SOLUTIONS may uncover previously unknown hazardous materials or conditions and that such discovery may result in the necessity to undertake emergency procedures to protect GW SOLUTIONS employees, other persons and the environment. These procedures may involve additional costs outside of any budgets previously agreed upon. The client agrees to pay GW SOLUTIONS for any expenses incurred as a result of such discoveries and to compensate GW SOLUTIONS through payment of additional fees and expenses for time spent by GW SOLUTIONS to deal with the consequences of such discoveries.

8.0 NOTIFICATION OF AUTHORITIES
The client acknowledges that in certain instances the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by GW SOLUTIONS in its reasonably exercised discretion.

9.0 OWNERSHIP OF INSTRUMENTS OF SERVICE
The client acknowledges that all reports, plans, and data generated by GW SOLUTIONS during the performance of the work and other documents prepared by GW SOLUTIONS are considered its professional work product and shall remain the copyright property of GW SOLUTIONS.

10.0 ALTERNATE REPORT FORMAT
Where GW SOLUTIONS submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed GW SOLUTIONS's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by GW SOLUTIONS shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by GW SOLUTIONS shall be deemed to be the overall original for the Project. The Client agrees that both electronic file and hard copy versions of GW SOLUTIONS's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except GW SOLUTIONS. The Client warrants that GW SOLUTIONS's instruments of professional service will be used only and exactly as submitted by GW SOLUTIONS. The Client recognizes and agrees that electronic files submitted by GW SOLUTIONS have been prepared and submitted using specific software and hardware systems. GW SOLUTIONS makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

APPENDIX I – Glossary of Terms

Adaptive Management Strategy (AMS): An process for the ongoing review and adjustment of the North East Comox Stormwater Management Plan to ensure proper functionality.

Amended Soil: Topsoil /Organic Mulch which meets the requirements of Guidelines and Resources for Implementing Soil Quality and Depth BMP T5.13 in WDOE Stormwater Manual for Western Washington with the organic matter requirements modified as outlined in section 4.2.1.4 of this document.

Best Management Practices (BMPs): Stormwater management infrastructure used to mitigate post-development runoff quantity and quality.

Discharge: Also know as *Runoff* or *Surface Runoff*, is the combination of surface flow and interflow which represents either the instantaneous rate or cumulative volume of stormwater runoff. The term "total discharge" or "total runoff" or "total surface runoff" refers to the cumulative volume of discharge over a specific time period.

Dry Detention Pond: A stormwater detention pond per Standard Drawings Pond-101 and 102, that is normally dry, used to detain storm water runoff.

Groundwater Re-charge: a hydrologic process where water moves downward from surface water to an aquifer.

Infiltration: the process by which water on the ground surface enters the soil.

Infiltration Trench: Either a boulevard or street infiltration trench per Standard Drawing 1 SC-104 or SC-105 used to infiltrate and store runoff.

Interflow: the lateral movement of water in the unsaturated zone, or vadose zone, that first returns to the surface or enters a stream prior to entering an aquifer.

Low Impact Development (LID): systems and practices that use or mimic natural processes that result in the infiltration, evapotranspiration or use of stormwater in order to protect water quality and associated aquatic habitat

Maintenance Period: As defined by the Towns Erosion and Sediment Control Bylaw.

Minor Development: means the construction of, addition to or alteration of a coach house, secondary suite, bed and breakfast accommodation, home occupation, maximum of one single- or two-family dwelling per parcel, or accessory buildings and structures thereto where Comox Zoning Bylaw 1850 does not permit more than one single- or two-family dwelling on a parcel.

Significant Rainfall Event: rainfall greater than or equal to 25 mm in a period of 24 hours.

McElhanney

APPENDIX J – Public Consultation

NE COMOX

INTEGRATED STORMWATER MANAGEMENT PLAN

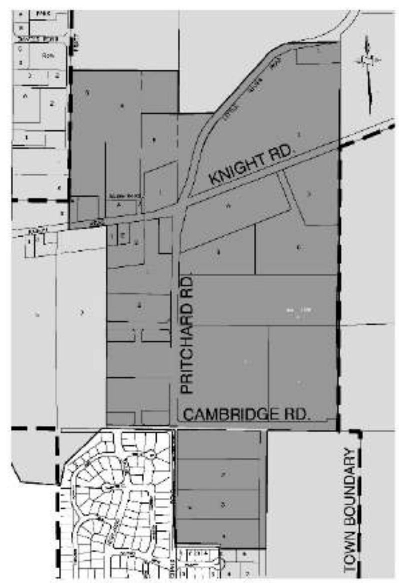
PUBLIC INFORMATION MEETING #5

An Integrated Stormwater Management Plan is being developed for NE Comox (shaded area in the map below). The purpose of the Plan is to address ground and surface water implications for down slope agricultural development, Lazo Marsh and Hilton Springs recharge, and Queen's Ditch capacity limitations and fish habitat.

Residents are invited to a Public Information Meeting to review the final Phase 3 Report Development of Design Standards. Phase 3 of the report provides a synopsis of the rainfall model; formalizes the design criteria and design details used during subdivision servicing; and details the "Adaptive Management Plan" within the study area.

Location: **Highland School – Multi-Purpose Room**
750 Pritchard Road, Comox, BC

When: **Thursday, April 26, 2018**
4:00 pm to 7:00 pm



If you have questions regarding this upcoming meeting please contact:
McElhanney Consulting Services Ltd.
by email: neciswmp@mcelhanney.com

April 12, 2018

Our File: 2211-46500-2

Department of National Defence
Attention: Alex Bissinger

Agricultural Land Commission
Attention: Liz Sutton

K'omoks First Nations
Attention: Tina McLean

Comox Valley Regional District
Attention: Marc Rutten, P.Eng.

Ministry of Environment
Attention: Jenna Cragg

Ministry of Agriculture
Attention: Jill Hatfield

Ministry of Transportation & Infrastructure
Attention: Alycia Traas

Department of Fisheries and Oceans
Attention: Al Magnan

Dear Sirs/Mesdames,

NORTH EAST COMOX INTEGRATED STORMWATER MANAGEMENT PLAN

Affected stakeholders within the NE Comox (Lazo Marsh/Queen's Ditch) catchment are invited to discuss the NE Comox Integrated Stormwater Management Plan Phase 3 report.

The Phase 3 report is available for viewing at the following link:
https://dl.mcelhanney.com/2018/04/12_vJqW/12_L8PluW0/201803Mar01NEComoxReportPhase3FINALsigned.pdf

The meeting is to be held at 1:00 pm, Thursday, April 26, 2018, at the Comox Valley Economic Development Centre, Unit 200 – 580 Duncan Avenue, Courtenay. Kindly confirm your attendance with our office by email or phone.

Yours truly,

McELHANNEY CONSULTING SERVICES LTD.

Bob Hudson, P.Eng.
Branch Manager

cc: MCSL, Mark DeGagne, P.Eng.
Town of Comox, Shelley Ashfield, P.Eng.
Town of Comox, Marvin Kamenz
Town of Comox, Glenn Westendorp, AScT
Town of Comox, Richard Kanigan

COMMENT SHEET

NE COMOX INTEGRATED STORMWATER MANAGEMENT PLAN
NEIGHBOURHOOD MEETING #5

Name & Address Andy Frost

1063 Kincova Lane

Comox, BC. V9M 4C5

Comments Welcome:

Comments can also be submitted by email to:

neciswmp@mcelhanney.com

McElhanney

TOWN OF COMOX

April 26, 2018

SIGN IN SHEET FOR
NE COMOX INTEGRATED STORMWATER MANAGEMENT PLAN
NEIGHBOURHOOD MEETING #5

Name	Address	Email
RICK MERCHANT	912 HILLBANK RD	silentshoe@gmail.com
Roy + Elaine Semenchuk	1351 Knight Road	misslainers@gmail.com
RICK JULYAN	1689 KNIGHT RD	BITTERSWEET2@SHAW.CA
BARRIE Mitchell	999 KNIGHT RD	N/A
TIM ENNIS	COMOX VALLEY CONS. PARTNERSHIP	tim@cvlandtrust.ca
Erin Nowak	Comox Valley Conservation Partnership	erin@cvlandtrust.ca.
BERNIE Poole	642 Sky View Pl. Comox	berniepoole@shaw.ca
Bob & Charlene Sieffert	720 Knight Rd Comox	lazo-tyee.sieffert@shaw.ca
Hugh MACKINNON	1447 Ridgemount Dr.	MACKINNONS6@SHAW.CA
Maureen Swift	#26-1220 Guthrie Rd	
Richard Swift	"	
Ken Chant	1831 Hemlock Cres	

McElhanney

TOWN OF COMOX

April 26, 2018

SIGN IN SHEET FOR
NE COMOX INTEGRATED STORMWATER MANAGEMENT PLAN
NEIGHBOURHOOD MEETING #5

Name	Address	Email
Marg Grant.		
BILL TOEWS	138 DONNAN DRIVE	
Barb Cousineau	"	
GUY WASSICK	Comox	
Darren Richards	4	watsonandash@shaw.ca

McElhanney

TOWN OF COMOX

April 26, 2018

SIGN IN SHEET FOR
NE COMOX INTEGRATED STORMWATER MANAGEMENT PLAN
NEIGHBOURHOOD MEETING #5

Name	Address	Email
DARRY MONTEITH	COMOX VALLEY RD.	
Jill Hatfield	BC Ministry of Agriculture	Jill.Hatfield@gov.bc.ca
Carl Morrison	BC MFLNRORD	Carl.D.Morrison@gov.bc.ca
Alycia Traas	MOTI	alycia.traas@gov.bc.ca
Shelley Ashfild	Town of Comox	ashfield@comox.cc
MARC DEGAGNE	MESL	mdegagne@mcelhanney.com
B.S.		
Marvin Kamenz	Town of Comox	Kamenz@comox.ca
Monty Horton	KFN	lands.manager@komoks.ca

McElhanney

TOWN OF COMOX

April 26, 2018