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Re: Stadium Road Neighbourhood i-Tree Hydro Assessment

Diamond Head Consulting Ltd. (DHC) was asked by UBC Campus + Community Planning to assess the stormwater runoff in the proposed Stadium Road neighbourhood considering different development scenarios. In a first memo, DHC estimated the stormwater management contribution of the Ropes Course to the neighbourhood and estimated current stormwater runoff conditions that will serve as a baseline to evaluate future development scenarios. The purpose of this second memo is to summarize the work done on the following items:

- Evaluating changes to stormwater runoff with changes in future development options 1 and 2 in a business as usual condition where no green infrastructure is integrated
- Evaluating the feasibility of reaching a net zero increase in runoff in Option 1 with the use of individual green infrastructure including rain gardens, cisterns and green roofs

The next step in this project will involved developing a scenario that mixes the preferred types of green infrastructure to create a realistic development scenario that achieves UBC's net zero target: no increase in runoff into storm drains as compared to current conditions.

The results reported in this memo refer to three different types of runoff.

1. **Impervious runoff** refers to stormwater runoff generated on impervious surfaces; it is assumed to be the volume of runoff managed by UBC's stormwater infrastructure.
2. **Pervious runoff** refers to runoff generated on saturated soil.
3. **Surface runoff** refers to the combination of both types of runoff.

Business as usual future development scenarios:

DHC developed surface cover estimates for two development options provided by UBC: Option 1 and Option 2. These business as usual scenarios assumed that no green infrastructure would be included outside of the green space included in the neighbourhood plans. Maps for the current condition and business as usual for Option 1 and 2 are provided in Appendix 1, with detailed surface cover percentages in Appendix 2.

In the current condition's scenario, all streets, sidewalks, buildings and the sports field were assumed to be directly connected to the stormwater drainage infrastructure, while the compacted gravel area was assumed to be impervious but not directly connected. Given these assumptions, the business as usual scenarios assumed that 100% of impervious areas would be directly connected to the stormwater drainage infrastructure. This includes buildings, roads, sidewalks, plazas, the sports field and buildings. This model parameter has a strong impact on impervious runoff, and it should be noted that a small change in this assumption could result in significant difference in the results.

Both Option 1 and 2 for business as usual would result in a significant increase in impervious runoff as compared to the baseline conditions (see Table 1, and Figure 1 and Figure 2). As expected, given similar surface cover conditions (see Appendix 2), the two options would create a similar change in runoff, with Option 2 resulting in slightly higher impervious runoff than Option 1. The reduction of pervious runoff is mostly explained by the reduction of pervious areas in Options 1 and 2 as compared to current conditions.

Table 1. Changes in annual surface runoff for Option 1 and 2 (business as usual) as compared to current conditions

Annual runoff (2014)	Baseline conditions	Option 1 (BAU)	Option 2 (BAU)
Impervious runoff (m^3)	32,801	61,027	61,516
% change from baseline	-	↑ *86%*	↑ *88%*
Pervious runoff (m^3)	51,834	25,799	25,125
% change from baseline	-	↓ *50%*	↓ *52%*

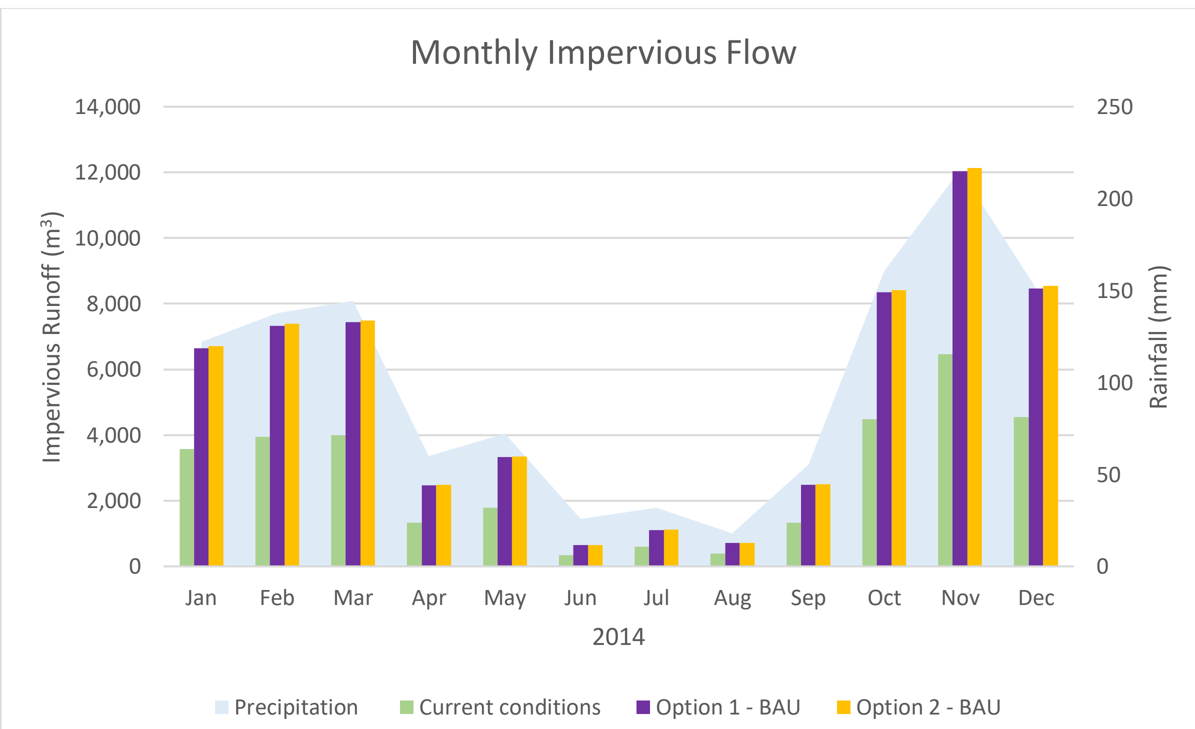

Figure 1. Impervious runoff in current conditions and future development Options 1 and 2 (business as usual)

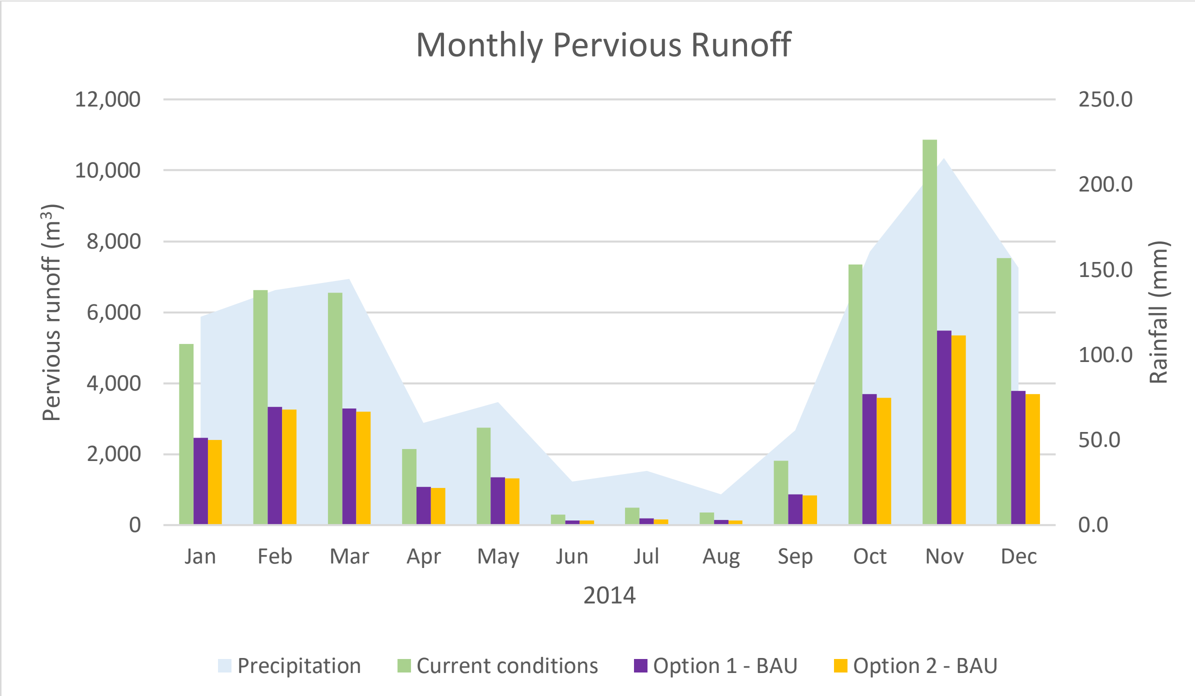

Figure 2. Pervious runoff in current conditions and future development Options 1 and 2 (business as usual)

Green infrastructure in Option 1:

The Option 1 business as usual scenario was used to test the effectiveness of green infrastructure for reducing stormwater runoff. The green infrastructure tested included rain gardens, cisterns and green roofs. They were tested individually to estimate how much of each infrastructure type would be required to achieve a net zero target. The net zero target assumes, as compared to current conditions:

- No increase in monthly and annual surface runoff (both pervious and impervious) for 2014 weather
- No increase in impervious runoff peak flow for the 2-year storm event

Rain gardens:

The model indicates that UBC could achieve a net zero increase in surface runoff in Stadium Road neighbourhood by using existing pervious surface (herbaceous and shrubs) for water retention with the following interventions:

- Draining 47% of the area's impervious surfaces into its pervious surfaces
- Providing 178 m^3 of pervious depression storage in existing pervious areas to manage the runoff, which corresponds to a 6.5 mm depth over all 27,334 m^2 of pervious areas

This storage would allow for maintaining current annual runoff as well as impervious peak flow for a 2-year rain event. However, it would result in an increase in total pervious runoff and peak flow due to the draining of impervious surfaces onto pervious areas.

Green roofs:

UBC would be 2% shy of achieving their net zero target for impervious runoff by making a 100% of their building rooftops, and underground parking into green roofs. This represents a 31% reduction of impervious surfaces in the neighbourhood and would increase total neighbourhood pervious runoff back to the current conditions level.

However, approximately 25,000 m^3 of that pervious runoff would be generated by saturated green roof surfaces. If the green roofs' runoff was to be drained into UBC's stormwater drainage infrastructure, green roofs would not allow for reaching the net zero target; they would reduce runoff by nearly 10% as compared to the business as usual scenario, which would still represent a 78% increase from current conditions.

Cisterns and dry ponds:

Cisterns and dry ponds are both estimated using the impervious depression storage in the i-Tree Hydro. The net zero target could be reached by:

- Draining 44% of impervious areas into cistern or dry pond storage
- Providing 140 m^3 of storage in cistern(s) or dry pond(s)

Comparative efficiency of green infrastructure options:

As a measure of the efficiency of each treatment, we calculated the approximate changes in surface runoff from each unit area or volume of interventions as compared to the business as usual scenario for Option 1. We added a natural forest stand contribution per square metre which is based on the contribution of the Ropes course to stormwater management in the neighbourhood. These results were presented in the previous memo. Table 2 summarizes the results from that analysis. The comparison was conducted using surface runoff to account for reductions in impervious flow as well as increases in pervious flow from saturated soils which would be produced by green roofs.

Table 2. Relative impact of green infrastructure options on surface runoff

Impact	Rain gardens	Green roofs	Cisterns	Dry ponds	Natural forest stand
Total green infrastructure area or volume in the neighbourhood	27,334 m^2 (depth of 6.5 mm)	25,886 m^2	140 m^3	140 m^3	15,286 m^2
Total change of surface runoff (m^3)	-4,482	-2,793	-1,803	-1,803	-2,223
Change of surface runoff (m^3) per square or cubic metre of green infrastructure	**-1.26 m^3**	**-0.11 m^3**	**-12.85 m^3**	**-12.85 m^3**	**-1.06 m^3 (*)**
Change in water quality (pollutant load)	-3%	-3%	-2%	-2%	-3%

*Note: the natural forest stand change in runoff only accounts for the change in impervious runoff, as it is assumed that pervious runoff for the forest stand drains into other pervious areas outside of the project boundary such as the Botanical garden. This is in contrast with pervious runoff generated from green roofs, which would require to be drained from the roofs.

Overall, cisterns and dry ponds provide the most efficient reduction in surface runoff, followed by rain gardens. Green roofs are less effective at reducing surface runoff due to the generation of runoff from the saturated soils.
Cisterns and a combination of open drainage ditches that could be engineered to overflow into surrounding depressed, permeable surfaces would be ideal to help meet both the stormwater goals and biodiversity objectives.

This memo will be followed-up by a final analysis of a mixed green infrastructure scenario for Option 1 which will integrate policy options of interest to UBC Campus + Community Planning. This scenario will be designed to achieve a net zero target and will also be tested to a climate change 2-year rain event in order to test for the possibility to achieve net zero given the expected changes in weather patterns.

Please do not hesitate to call us if you have any questions regarding the material discussed in this report.

Sincerely,

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General Liability:	Northbridge General Insurance Corporation - Policy #CBC1935506, $10,000,000
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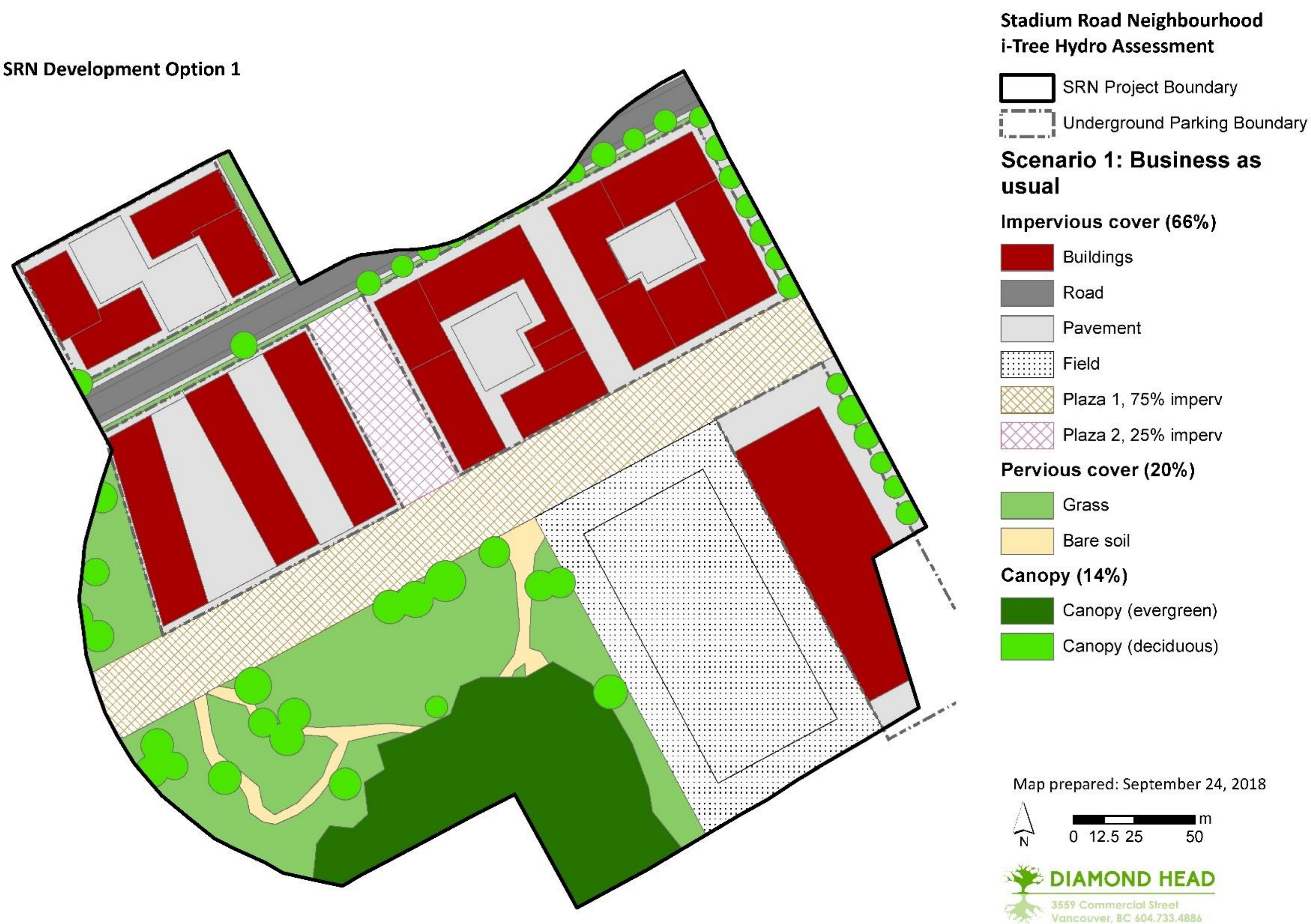
Appendix 1 Maps of Site Conditions

The maps below depict the current Stadium Road neighbourhood conditions, followed by maps of the future development business as usual for Options 1 and 2.

SRN Development Option 1



SRN Development Option 2

Appendix 2 Surface Conditions

1.1 Current baseline conditions

	Current Conditions		
Surface Cover Type	**Percent**	**Sub-category**	**Percent**
Tree canopy	22.59%	Over pervious soil	21.29%
		Over impervious surfaces	1.30%
		total	22.59%
		Evergreen tree	18%
Shrubs	2.65%	Evergreen shrub	50%
Herbaceous (lawn)	28.00%		
Water	0.00%		
Impervious	46.67%	Directly connected impervious areas	76%
Bare soil	0.08%		
TOTAL	**100%**		

1.2 Future development scenarios

Option 1 (Business as usual)			
Surface Cover Type	**Percent**	**Sub-category**	**Percent**
Tree canopy	13.94%	Over pervious soil	12.23%
		Over impervious surfaces	1.71%
		total	13.94%
		Evergreen tree	9.05%
Shrubs	1.84%	Evergreen shrub	50%
Herbaceous (lawn)	16.59%		
Water	0.00%		
Impervious	66.10%	Directly connected impervious areas	100%
Bare soil	1.52%		
TOTAL	**100%**		

Option 2 (Business as usual)			
Surface Cover Type	**Percent**	**Sub-category**	**Percent**
Tree canopy	18.01%	Over pervious soil	15.02%
		Over impervious surfaces	2.99%
		total	18.01%
		Evergreen tree	13.24%
Shrubs	1.59%	Evergreen shrub	50%
Herbaceous (lawn)	14.33%		
Water	0.00%		
Impervious	65.48%	Directly connected impervious areas	100%
Bare soil	0.59%		
TOTAL	**100%**		

Appendix 3 Baseline & Business as Usual Scenarios Model Assumptions

Hydrological Parameter	Input value
Soil type	Sandy loam
Upper soil conditions	
Depth of soil under soil zone (m)	1
Initial soil saturation (%)	85
Advanced settings	
Leaf transition period	28
Leaf on day (Day of year)	122
Leaf off day (Day of year)	285
Tree bark area index	1.7
Shrub bark area index	0.5
Leaf storage (mm)	0.2
Pervious depression storage (mm)	1.0
Impervious depression storage (mm)	2.5
Scale Parameter of Soil Transmissivity	0.023
Transmissivity at Saturation (m_2/h)	0.13
Unsaturated Zone Time Delay (h)	10
Time Constants for Surface Flows: Alpha (h)	40.0
Time Constants for Surface Flows: Beta (h)	40.0
Time Constant for Subsurface Flow: B (h)	120.0
Soil Macropore Percentage	0.000001
Watershed area where rainfall rate can exceed infiltration rate (%)	100