Howe Sound & Stawamus River Integrated Stormwater Management Plan

Stormwater Review for Loggers East Neighbourhood Plan

Technical Memorandum

July 17, 2020 (Revised Draft)

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1. Introduction

1.1 Purpose of this Document

The District of Squamish (the District) is currently developing a Neighbourhood Plan (NP) for the Loggers East neighbourhood (referred to as "Loggers East" and "the Neighbourhood"). The neighbourhood is bound to the north by Raven Drive, to the east by undeveloped and forested land, to the south by Robin Drive, and to the west by Loggers Lane, as shown on Figure 1. Developing the NP involves making decisions on land use and servicing in the neighbourhood, and the NP will be used to inform decisions on development applications. It is important that these decisions consider:

- the constraints and opportunities that current watershed conditions (such as soil conditions and groundwater levels) have on further development
- the potential unmitigated impacts of development on watershed health, natural assets, and drainage infrastructure/servicing requirements
- strategies for mitigating impacts, and their implications for how and whether development proceeds in the neighbourhood

To provide information and direction to the District on the above, Urban Systems completed a stormwater management review of Loggers East. This document summarizes the main components and outcomes of the review.

1.2 Scope

This document was prepared as part of the process to develop an Integrated Stormwater Management Plan (ISMP) for the Howe Sound and Stawamus River watersheds, which includes Loggers East. The scope of the stormwater review was limited to that of the overall ISMP, but with early focus on Loggers East. The review generally aligns with the approach outlined in the District's Environmental Monitoring Program, which is included in the report *Improving Integrated Stormwater Service Deliver at the District of Squamish: Summary of Phase 1 Findings and Recommendations* (Urban Systems, 2019).

In alignment with the principles of integrated stormwater management planning, the review was conducted through multiple lenses. It included an assessment of the following:

- **physical conditions**, including topography, land use, and soil and groundwater conditions
- current **watershed health** and potential impacts due to proposed land use scenarios
- current **natural assets**, the value of the stormwater services they provide, and risks to the services those assets provide due to proposed land use changes
- current "pre-development" and potential future "post-development" **hydrologic and hydraulic performance**, and potential impacts due to proposed land use scenarios

For each component of the assessment, this document outlines the implications of the findings for land use and stormwater management in the neighbourhood.

2. Guiding Stormwater Management Goals

In 2019, the District developed goals to guide how stormwater service is provided across Squamish. The goals were documented in the District's Stormwater Level of Service (LOS) Framework, which is included in the report *Improving Integrated Stormwater Service Deliver at the District of Squamish: Summary of Phase 1 Findings and Recommendations* (Urban Systems, 2019). The goals include:

1. Public stormwater management practices should not result in negative impacts to private property
2. Nuisance flooding in backyards and low-lying areas is expected for minor rain events if it is generated on site
3. New developments should mitigate on-site and off-site impacts of runoff
4. Public property may be used as a floodway or storage for major storm events as appropriate
5. Public and private stormwater management practices should minimize negative impacts to water quality, water quantity, and ecosystem health on a watershed basis, relative to current conditions
6. The District should meet all Federal and Provincial regulations and guidelines for environmental protection
7. Drainage infrastructure is appropriately maintained for its intended function
8. District staff will be available to respond to stormwater management issues, and will respond to issues in order of highest to lowest priority
9. Residents are aware of what to expect in terms of stormwater levels of service
10. Residents know what they can do to help

It is important to acknowledge these goals for two key reasons:

- They inform the scope of the assessment conducted as part of the current study
- They provide guidance on how land use and stormwater management and servicing decisions should be made in the Neighbourhood

3. Physical Conditions

Several aspects of the physical conditions of the Neighbourhood (both current and proposed) have implications for land use planning and stormwater management. These include:

- Historical context
- Topography and natural drainage
- Existing watercourses
- Soil and groundwater

- Land use and associated impervious area

These are reviewed in the following sections.

3.1 Historical Context

To understand current and potential constraints, opportunities and impacts related to development and stormwater management in Loggers East, it is important to understand the area's historical context.

Prior to 1921, the Mamquam River discharged directly into Howe Sound east of what is now Downtown Squamish, via what is known as the Mamquam Blind Channel. An arm of the Mamquam River also extended from the north end of the Blind Channel at the Squamish Adventure Center, west under Highway 99 through what is now known as Dentville, and it drained into the Squamish River estuary. In 1921, the Mamquam River flooded during a heavy freshet and breached its banks, changing course towards the Squamish River. This diversion was made permanent in 1922 when the lower portion of the Mamquam River was diked north of Brennan Park along what is now known as Centennial Way. This redirected the Mamquam River into the Squamish River on the west side of Downtown Squamish. This dike offered protection for what is now the Loggers East neighbourhood from flooding of the Mamquam River, but it also dried out tidal channels, wetlands and critical fish spawning habitat.

Beginning in 2005, the "Mamquam Reunion Project" was initiated as a joint effort between the District, the Squamish River Watershed Society (SRWS), and the department of Fisheries and Oceans (DFO). The main goal of the project is to reconnect the Mamquam River with the Mamquam Blind Channel and the lower portion of the Squamish River estuary. The objectives are to improve the environmental health of the upper Mamquam Blind Channel and Loggers Lane Creek and reduce flooding of private and publicly owned lands in the watershed. Major works completed as part of the Mamquam Reunion project have included the installation of two intake structures to divert flows from the Mamquam River into Loggers Creek; an intake structure to connect Wilson Slough with the Central Estuary Channel; and new culverts across Highway 99. These works have served to help connect flows from the Mamquam River to the Mamquam Blind Channel and the Squamish Estuary as intended. However, much of Loggers East is low-lying and has known groundwater and drainage issues, with a high water table in low elevation properties. During coinciding high tides and heavy rainfall, drainage issues are evident in the Raven Drive/Robin Drive area. These conditions, and the need to balance environmental and flood protection objectives, present challenges to development in the area.

The Loggers East Neighbourhood Plan and the Howe Sound and Stawamus River ISMP will together establish a future land use scenario and stormwater management practices for the neighbourhood that recognize and address these challenges.

3.2 Topography and Drainage

The Neighbourhood is comprised of approximately 43.9 hectares (ha) in the broader Loggers East neighbourhood as shown on Figure 1. The Neighbourhood is located just north of the Mamquam Blind Channel, which is an inlet of Howe Sound and is therefore tidally influenced.

Topography in the area is generally very flat and low, with the exception of steep slopes in the eastern and southern portions of the Neighbourhood, as shown on Figure 2. The eastern and southern portions of the Neighbourhood are characterized by approximately 21 hectares (ha) of steep and rocky sloped land that offers approximately 6.7 to 9.5 ha of net developable land. The sloped topography was reviewed through a Slope Hazard Assessment (SFA Geotechnical, 2019), which indicated the area is mostly stable bedrock but with evidence of past rockfall and potential for future rockfall hazard. The District's Official Community Plan (OCP) sets out limitations for residential development in steeply sloping areas.

The area drains southwest to Loggers Creek, which converges with Wilson Slough and the Upper Mamquam Blind Channel. The location of the Neighbourhood places it in a designated flood hazard area, although the probability of flooding is considered low from the Mamquam River due to the existence of the dike along Centennial Way to the north of the Loggers East neighbourhood. Coastal flood hazard is also considered low in the Neighbourhood, but sea level rise over time will likely exacerbate any existing drainage issues. As per the District's Floodplain Management Bylaw, any new construction in flood hazard areas must meet flood construction levels (FCL).

3.3 Current Drainage Infrastructure

Current drainage infrastructure within the Neighbourhood consists of ditches and culverts as shown on Figure 3. Based on an environmental review conducted for the Neighbourhood (Cascade Environmental, 2019), many of the existing ditches have high habitat value.

On the western boundary of the Neighbourhood, stormwater pipes run along Loggers Lane and Kingfisher Road.

3.4 Existing Watercourses

Several watercourses that originate outside the Neighbourhood flow through it as shown on Figure 1. This includes Loggers Creek flowing from north to south along the western boundary, Finch Creek flowing approximately from north to south in the western Neighbourhood, and drainage channels originating off the mountains from the east. Loggers Creek and Finch Creek are connected through a series of watercourses upstream of the Neighbourhood and are the primary channels of conveyance through Loggers East from the contributing watershed. All watercourses in the area are considered fish-bearing.

3.5 Soil and Groundwater

Soil and groundwater conditions influence the infiltration capacity of soils. Infiltration capacity is an important consideration because it affects the watershed's response to rainfall (the extent to which it will generate runoff), and the type of stormwater management practices that may be suitable in a given area.

Urban Systems retained Waterline Resources Inc. (Waterline) to complete an assessment of the hydrogeological conditions and potential infiltration characteristics in the overall ISMP study area, including the Loggers East Neighbourhood. Groundwater levels, unsaturated zone thickness, and infiltration potential were estimated using a conceptual model of the hydrogeological conditions in the study area. As a separate exercise, the District retained Waterline to estimate unsaturated zone thicknesses and to develop groundwater contour maps across the District based on analysis of high-

high water tide and river stage data from a Mike 11 model prepared for the purpose of developing the District's Integrated Flood Hazard Management Plan. These inputs were considered static conditions. The findings from both assessments were similar for Loggers East and are summarized below. The detailed methodology and findings of the assessment are described in the final draft report provided as Attachment A. Below is a summary of key findings.

SURFICIAL GEOLOGY

- The Neighbourhood is underlain by glacio-fluvial (Unit 4a) and fluvial (Unit 4b) soils underlain by bedrock. These soils are considered moderately to highly permeable.

AQUIFER AND GROUNDWATER LEVEL MAPPING

- The Neighbourhood is underlain by two aquifers: Aquifer #398 and Aquifer #399, both of which are unconfined and their vulnerability to contamination is considered high.
- Groundwater levels in the Neighbourhood are influenced by the stage of the Mamquam River, surface topography, surface water in the creeks, and to some degree by tide levels, given the proximity of the Neighbourhood to the Mamquam Blind Channel. The movement of groundwater in and out of the area is expected to fluctuate seasonally and daily, with maximum hydraulic gradient occurring during low tide and minimum hydraulic gradient occurring during high tide.
- Depth to water in the Neighbourhood is shallow, based on data from 6 wells completed across the two aquifers. Groundwater elevation is expected to be approximately 5 masl at the center of the Neighbourhood, 3 masl near the western extent of the Neighbourhood, and as low as 2 masl in the southern portion of the Neighbourhood.
- Based on available data (which is limited), the depth of the unsaturated zone is very shallow: it has been documented at ground surface (seasonal) and generally expected to be less than 0.6 m below ground level (mbgl) in the eastern portion of Aquifer #398, with some vertical separation adjacent the Mamquam River. This quantitative information is supported by visual observations in the area – local residences have documented high groundwater levels and localized flooding at low-lying elevations in the eastern portion of the Neighbourhood. This is accentuated during heavy precipitation events in the winter months (seasonally) or during the simultaneous occurrence of high river stage (seasonally) and with high tide (daily).
- Based on the above, infiltration potential in the Neighbourhood is considered low. Implications of this for stormwater management are described in Section 3.7.

3.6 Land Use and Impervious Area

Total impervious area (TIA, expressed as percent impervious) is an indicator of how much runoff and pollutants a given study area may generate. It is also a cursory indicator of water quality and therefore of watershed health. In general terms, without mitigating measures, the greater the percent impervious area, the lower the watershed health and the greater the volume and rate of stormwater runoff. Managing the extent of the TIA through land use designations and onsite controls (such as green roofs, pervious pavement, and other techniques) is one of the strategies available to municipalities to mitigate undesirable impacts.

CURRENT LAND USE

The Neighbourhood currently contains pockets of developed areas including single family homes and rural uses such as kennels, home businesses, and industrial storage. The Neighbourhood is primarily zoned RL-1 (Rural Residential), which allows for single and two-unit dwellings, kennels and horse stables; and RS-1 (Residential One), which allows for single dwelling units. One property is zoned RMH-2 (Residential Modular Homes). These current designations represent relatively low-impact types of development as compared to typical high-density designations.

Surrounding areas to the south and east are mainly zoned Resource. Land directly south of Robin Drive on Loggers Lane is zoned I-7 (Rock Processing). Land directly to the north and west are zoned CD-38 (small lot single family) and CD-76 (sport facilities/recreation).

PROPOSED LAND USE SCENARIOS

The Loggers East Neighbourhood is designated *Residential Neighbourhood* in the District's OCP. These areas are intended to accommodate residential growth for Squamish with a diverse mix of housing forms with a focus on family-friendly and affordable housing.

At the time of preparing the Stormwater Review, the District was considering two land-use scenarios as potential futures for the Sub Area:

- Scenario #1 is defined by a Rural land use classification, which is unique to this scenario and is intended for future small-scale agricultural purposes. As shown on Figure 4 the Rural zoning is situated in the lowland part of the Neighbourhood. Other land uses include Light Industrial, Mixed-Use and Conservation Area.
- Scenario #2 is similar to Scenario #1 but excludes all Rural land use in favour of Residential land use as shown on Figure 5.

These early concepts were developed for discussion only and the final land use plan will be developed based on further consultation with Council and the community.

No specific density is established in the OCP for the Neighbourhood, but policies are intended to increase the proportion and size range of attached multi-family units through re-zoning. Therefore, for the purpose of this assessment, it is assumed that Residential areas on Figures 4 and 5 will be comprised of multi-family developments, which typically have a higher impervious area than single-family residential developments.

Both land use scenarios take into account riparian areas (30 m setbacks) and other areas recommended for preservation, resulting in a net developable area of approximately 20-26 ha (50-65 acres). These areas were identified based on an environmental review of the Neighbourhood (Cascade Environmental, 2019) and a review of slope constraints (SFA Geotechnical, 2019).

TOTAL IMPERVIOUS AREA

The TIA of the current Neighbourhood was estimated through a GIS image classification analysis (Interactive Supervised Classification) conducted on the District's 2019 aerial. The process involved drawing polygons over features on the aerial and associating various features with known surfaces (initially starting with classifications from the National Land Cover Database). Several of these drawn polygons were used to train the analysis to recognize similar surfaces and assign them as either pervious or impervious. The District's 2019 aerial is a high-quality multi-spectral image, which facilitated this step in the analysis.

Table 1 shows the results of the image classification of pervious and impervious coverage for current conditions in the Neighbourhood. It is important to note that the image classification can only give an indication of TIA, and not effective impervious area (EIA), which is the percent of the area that is directly connected to the piped stormwater system. The EIA is important for the purpose of assessing the capacity of the piped stormwater system and can only be estimated through modelling.

To estimate the TIA of the proposed future land use scenarios, "textbook[1]" percent impervious values were assigned to each land use as summarized in Table 1. The weighted average of these areas was then calculated to result in an overall TIA for the proposed scenario.

Table 1 Summary of Future Land Use Scenarios

Land Use	Percent Impervious	Future Land Use Scenario #1		Future Land Use Scenario #2	
		Total Area (ha)	Impervious Area (ha)	Total Area (ha)	Impervious Area (ha)
Light Industrial	90%	4.2	3.7	4.2	3.7
Mixed Use	78%	1.3	1.0	1.3	1.0
Residential	65%	16.4	10.7	22.5	14.6
Rural	30%	6.1	1.8	-	-
Conservation Area	20%	16.0	3.2	16.0	3.2
Grand Total	-	**43.9**	**20.4**	**43.9**	**22.5**

Estimated TIA for the current and future land use scenarios is summarized in Table 2.

Table 2 Comparison of Current and Future Total Impervious Area

	Current Land Use	Future Land Use Scenario #1	Future Land Use Scenario #2
Total Area (ha)	43.9		
Total Pervious Area (ha)	34.6	64.3	21.5
Total Impervious Area (ha)	9.3	20.4	22.5
Total Impervious Area (%)	**21%**	**47%**	**51%**

As shown above, either future land use scenario will result in an increase in TIA compared to current conditions. This has implications for stormwater management as described below.

3.7 Summary and Implications for the Neighbourhood Plan

Both proposed future land use scenarios will result in negative impacts on the receiving environment and will require new and upgraded stormwater infrastructure if no management techniques are

[1] Based on standard values in the Master Municipal Construction Documents (MMCD)

applied.

Given the expected development plans for the Neighbourhood, the impermeable land cover type is expected to increase, while the vegetated land cover will decrease. From a principles perspective, this will result in lower evapotranspiration, lower natural infiltration, and increased runoff. Further discussion and preliminary quantification of the impacts of land use changes on runoff is provided in Section 6.

Based on the results of soil, groundwater, and aquifer mapping, much of the Loggers East neighborhood appears to have a low potential for stormwater infiltration. Any infiltration-based stormwater management practices will likely need to be combined with subsurface storage.

Overall, despite soils in the Neighbourhood having a moderate to high infiltration capacity, parts of the Neighbourhood are underlain by an unconfined aquifer and the groundwater table is generally high and tidally influenced. Data to accurately determine the depth of the unsaturated zone was limited. Based on the available data, infiltration is generally not recommended as a method for disposing of stormwater runoff. However, infiltration still plays a role in regulating flow rates. Furthermore, infiltration of stormwater provides important water quality treatment functions, as discussed in Section 4. Therefore, there is still potential for application of infiltration-based stormwater management practices, such as 300 mm of amended topsoil and rain gardens/bioswales when combined with storage, which together would offer both some storage and treatment.

Groundwater monitoring is required to confirm baseline conditions and determine the suitability of engineered infrastructure which could enhance infiltration.

It is understood from the conceptual model and engineering theory that groundwater will fluctuate in the Neighbourhood seasonally and daily; however, the extent to which this occurs, as well as local variations in the unsaturated zone thickness, needs to be better understood before making any stormwater management design decisions. Recommendations for groundwater monitoring are discussed in Section 8.

4. Watershed Health

4.1 Current Watershed Health

As part of the current study, Urban Systems completed an environmental assessment of the Neighbourhood. The assessment focused on measuring watershed health using indicators that can be influenced through integrated stormwater management practices. A broader environmental review was conducted as part of the SAP planning process by Cascade Environmental, the results of which were summarized in a report titled *Loggers East Neighbourhood, Squamish, BC, Environmental Review* (Cascade Environmental, 2019). This report is meant to complement the current document, and together they should inform the District's decisions regarding land use, stormwater management, and environmental management in the Neighbourhood.

Indicators included in the current assessment are:

- Fish presence

- Riparian conditions
- Total impervious area (TIA)
- Water quality
- Stream flows
- Watershed health tracking score

The assessment was based on field observations from a September 19-20, 2019 site visit of Loggers Lane Creek and on desktop research and analysis. Key findings are summarized below.

It is worth noting that the Neighbourhood is located within the broader "Howe Sound" watershed that is bound by Centennial Way to the north, Howe Sound to the west, the Mamquam Blind Channel to the south, and the Stawamus River watershed to the east. For the purpose of this assessment, we have treated the Neighbourhood as its own catchment.

FISH PRESENCE

Stormwater runoff has the potential to negatively impact water quality in receiving waterbodies, and alterations to watercourses and the construction of drainage works such as culverts have the potential to affect fish passage. Therefore, fish presence is considered an indicator of watershed health as it relates to stormwater management.

Logger's Lane Creek is not mapped on Habitat Wizard[2] but there are multiple fish point observations in the location of the creek. Multiple species have been documented using the creek including juvenile coho salmon, coastal cutthroat trout, threespine stickleback, prickly sculpin, and western brook Lamprey. Spawning pink salmon were observed in Logger's Lane Creek during the September 2019 site visit. Numerous culverts were observed on Logger's Lane Creek, but none appeared to be a barrier to upstream fish passage.

RIPARIAN CONDITIONS

Riparian areas have an array of influences on watershed health, including intercepting and moderating runoff, providing shade and buffering temperature extremes (which can also reduce certain toxicities to fish), filtering pollutants in surface or subsurface runoff, providing woody debris to stream channels that enhances aquatic food webs, and stabilizing banks and floodplains.

The condition of the Loggers East Creek riparian was observed to be excellent overall during the September 19-29, 2019 field visit, although Logger's Lane limits the riparian area on the western edge of the stream. Typical riparian vegetation in the Neighbourhood consists of western redcedar and alder.

A desktop analysis of Riparian Forest Integrity (RFI) was conducted on all riparian corridors in the Neighbourhood using image classification methods similar to those previously described for the estimation of TIA. Riparian Forest Integrity, which is expressed as %RFI, is the percent of forested area within a 30 m boundary on either side of the watercourse.

The estimated current RFI for each watercourse in the Neighbourhood is summarized in Table 3.

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[2] Habitat Wizard is an online map-based tool developed and provided by the Province of British Columbia to enable users to access fish, wildlife, and ecosystem information.

Table 3 Estimated Current Riparian Forest Integrity of Watercourses in the Neighbourhood

Watercourse	Riparian Forest Integrity (%)
Finch Creek	41%
Unnamed Creek (no road)	81%
Unnamed Creek Along Finch Dr	31%
Overall RFI in the Neighbourhood	**53%**

The low RFI values within the Neighbourhood emphasizes the need for the existing riparian area to be maintained, and ideally improved, through the development of the Neighbourhood. As discussed further below, the overall biological condition of a watershed is a function of RFI and TIA: the higher the RFI and the lower the TIA, the better the overall the biological condition, typically. Therefore, enhancing RFI and minimizing TIA are two strategies for minimizing the impacts of development on the environment.

TOTAL IMPERVIOUS AREA

As previously discussed, impervious area is a cursory indicator of watershed health because it is an indicator of how much runoff and pollutants a given study area may generate. Typically, development of 5-10% of the overall watershed is expected to result in negative impacts to watershed health unless mitigating measures are taken.

The current TIA for the Neighbourhood is estimated to be 21% as previously described. Under the future proposed land use Scenario #1, TIA would increase to 47%, and under Scenario #2, to 51%. By these estimates, development under either scenario will result in negative environmental impacts. If the District aims to achieve its stormwater servicing goal to minimize environmental impacts, it will need to implement measures to minimize TIA. If this is not feasible from a development perspective, the District should strive to minimize the amount of impervious area that directly drains to a watercourse (the EIA).

WATER QUALITY

Stormwater can be a significant source of a wide range of pollutants including metals, nutrients, bacteria, and suspended solids that may impact fisheries and aspects of ecological health. Specific pollutants in a given water sample will depend on upstream land use; therefore, the parameters selected for inclusion in a water quality assessment should be focused on those that may be influenced by the specific type of development in that watershed, and on those that may be influenced through integrated stormwater management practices.

Water quality samples were taken under wet weather conditions from the location shown on Figure 6, which is downstream of the Neighbourhood. Sampling protocols generally aligned with the District's Environmental Monitoring Program, which is based on protocols outlined in Metro Vancouver's Monitoring and Adaptive Management Framework (MAMF). Samples were collected between March 5 and March 31, 2020, which is outside of the November-December window suggested in the MAMF but still qualifies as occurring under wet weather conditions in this area.

A total of five water quality samples were collected and analysed for the parameters summarized in Table 4:

Table 4 Summary of Parameters Included in Water Quality Analysis

Parameters	Field Measurement	Laboratory Measurement
General chemistry (dissolved oxygen, pH, temperature, conductivity, turbidity)	x	
Total metals (total iron, copper, lead, zinc, and cadmium)		x
Microbiological parameters (fecal coliforms and E.Coli)		x
Nutrients (nitrate, as nitrogen)		x

Results for general chemistry, total metals, and nutrients were compared against BC Water Quality Guidelines (BCWQG) for Freshwater Aquatic Life. Results for microbiological parameters were compared against the BCWQG for recreational primary contact. Results were also compared against the “classification of water quality results” in Metro Vancouver’s Monitoring and Adaptive Management Framework (MAMF).

In total, exceedances of BCWQG were observed in two parameters:

- Iron: Three out of five samples exceeded the guidelines (acute guidelines)
- Dissolved oxygen: Two out of five samples exceeded the guidelines (chronic guidelines)

Although these parameters showed exceedances of the BCWQG, for stormwater management purposes the District can look to the MAMF, which sets direction on the actions municipalities should take considering the dual objectives of protecting the environment while managing costs. Under this framework, results for both parameters are classified as “satisfactory” and do not warrant an immediate recommendation for corrective action. Furthermore, it is possible that the elevated levels of iron and DO in the watercourse are due to natural causes.

No other historical WQ data were available for this area. Samples will be collected again under dry weather conditions in late summer 2020, which will provide an indication of low-flow water quality and the extent to which water quality is a significant concern in the Neighbourhood.

STREAM FLOWS

Stream flows provide an indication of how a watershed is responding to changes in the watershed over time.

In late 2019, Urban Systems initiated hydrometric monitoring in Loggers Lane Creek (and in two other creeks outside of the Neighbourhood) as part of the Howe Sound and Stawamus River ISMP. At the time of reporting, insufficient data was available to establish a stage-discharge curve, which is required to determine flows. This had implications for calibrating the hydrologic/hydraulic model used to assess stormwater system performance, as discussed in Section 6. Flow data in Loggers Lane Creek will be considered in the development of the Howe Sound and Stawamus River ISMP throughout 2020 and results for the Neighbourhood will be updated to reflect the observed field data.

OVERALL BIOLOGICAL CONDITION

Metro Vancouver's Monitoring and Adaptive Management Framework (MAMF) suggests that municipalities can use the Benthic Index of Biotic Integrity (B-IBI) value as an indicator of the overall biological condition of a watershed. The B-IBI value is based on the benthic invertebrate species and assemblages/communities sampled from a watercourse. The presence of species sensitive to pollution in a given sample indicates good water quality, whereas the presence of species that are tolerant to pollution indicates poor water quality.

The type of benthic invertebrates used to calculate B-IBI are typically only found in rocky/gravelly substrate and as per the MAMF, samples are only collected in high-gradient streams with a suitable (rocky/gravelly) substrate. Therefore, benthic invertebrates samples were not collected from any watercourses in the Neighbourhood. However, Metro Vancouver also offers a tool for predicting what the B-IBI score would be, called the Watershed Health Tracking System (WHTS). The WHTS is introduced in Metro Vancouver's Template for Integrated Stormwater Management Planning (Kerr Wood Leidal, 2005). The WHTS provides users with the ability to predict B-IBI based on measurements for TIA and RFI in the watershed. The tool is calibrated to municipalities in Metro Vancouver, which the District is not a member of; however, for the purpose of this assessment the tool still serves as a useful lens for looking at the relationship between total impervious area, riparian forest integrity, and overall biological condition of a watershed.

B-IBI scores fall on a scale of between 10 and 50. Within that range, according to the MAMF, biological condition as indicated by B-IBI is interpreted as follows:

- Excellent – 46-50
- Good – 38-44
- Fair – 28-36
- Poor – 18-26
- Very Poor – 10-16

Current and future predicted B-IBI values were estimated for the Neighbourhood using the WHTS and the results are summarized in Table 5. Note that these calculations would typically be made for individual sub-catchments in a watershed based on the TIA and RFI for each subcatchment; however, for the purposes of this assessment it is reasonable to calculate what the B-IBI would be based on the average RFI and the TIA in the Neighbourhood.

Table 5 Overall Biological Condition Under Current and Future Land Uses

	Current Land Use	Future Land Use Scenario 1	Future Land Use Scenario 2
Total Impervious Area (TIA) (%)	21%	47%	51%
Riparian Forest Integrity (RFI) (%)	53%	53%	53%
Predicted B-IBI	17.5	13.3	13.8
Overall Biological Condition (based on predicted B-IBI)	Poor	Very poor	Very poor

The classifications for overall biological condition outlined in Table 5 should not be taken as absolute. They provide a useful indication of the *trend* in biological condition that may be experienced in the

Neighbourhood due to future development. What the outcomes of this assessment show is that there is room for improving current watershed conditions (particularly RFI), and minimizing future TIA. These results also highlight the importance of protecting riparian corridors from further impacts, as is proposed by the future land use scenarios.

4.2 Summary and Implications for the Neighbourhood Plan

Current and potential future conditions in the watershed highlight the need for enhancing existing riparian areas and minimizing increases in imperviousness.

Based on an assessment of biological condition based on empirical relationships between TIA, RFI and B-IBI, the overall biological condition of the Neighbourhood is one that would benefit from enhancement. The key variables that the District can influence to enhance biological condition are TIA and RFI. Both of these can be influenced through land use decisions and development practices, and RFI can be influenced through dedicated enhancements to the riparian corridor.

The proposed land use scenarios take a step in the right direction in terms of limiting development to areas outside of 30 m setbacks from watercourses, which will limit further impacts to the riparian corridor. However, the overall biological condition of the Neighbourhood is still likely to decline without efforts to minimize TIA and enhance RFI under either future land use scenario.

The two future land use scenarios being considered for the Neighbourhood are likely to result in similar environmental impacts associated with runoff.

Using the WHTS and basing biological condition on predicted B-IBI, analysis suggests that there is likely not an appreciable difference between the two scenarios. This is due to the similar future TIA projected under both scenarios. Likewise, there is likely not a significant difference in the types of pollutants likely to exist in runoff under both scenarios. That said, both land use scenarios are likely to result in negative impacts, if unmitigated.

The results of wet-weather water quality monitoring suggest that there are no significant, immediate concerns with water quality in the Neighbourhood, but this will need to be evaluated further through the collection of dry-weather data in Summer 2020.

The dry-weather data together with the wet-weather data discussed here will provide a clearer indication on whether iron and DO are indeed concerns in the Neighbourhood and if mitigating actions should be taken.

5. Natural Assets

5.1 Current Natural Asset Inventory

Natural assets are environmental features that provide a valuable service to the community. The scope of the current assessment focuses on natural assets that provide a stormwater management service – in this case, wetlands, forests, and watercourses. Wetlands offer rainwater attenuation and stormwater quality treatment, and forests offer rainwater attenuation, evapotranspiration, and infiltration. Watercourses offer conveyance capacity. Existing natural assets in the Neighbourhood are shown on Figure 7. A summary of their quantity and the services they provide is provided in Table 6.

Table 6 Inventory of Natural Assests That Provide Stormwater Services

Natural Asset Class	Existing Quantity	Unit	Stormwater Services Provided	Other Core Services Provided
Wetland	0.7	ha	• Stormwater attenuation (flood protection and erosion prevention) • Stormwater quality treatment	• Groundwater flow recharge • Climate regulation (carbon storage) • Temperature regulation • Habitat • Recreation • Resilience to climate change (changes in precipitation)
Forest	21.0	ha	• Stormwater attenuation, evapotranspiration, infiltration (flood protection and erosion prevention)	• Water filtration • Groundwater flow recharge • Climate regulation (carbon storage) • Temperature regulation • Air quality • Habitat • Recreation • Tourism • Pollination • Resilience to climate change (precipitation and increased temperatures)
Watercourses	2,400	m	• Stormwater conveyance • Flood protection	• Habitat • Recreation • Tourism • Temperature regulation • Resilience to climate change (precipitation and increased temperatures)

Ditches were not included in the natural asset inventory. Although they provide stormwater and environmental services, they are built assets and are therefore differentiated from the natural assets included in the current inventory.

5.2 Natural Assets at Risk

Table 7 below presents the quantity of existing natural assets that are at risk due to the proposed future land use changes. The areas at risk are shown on Figure 8 and Figure 9 for future land use scenarios #1 and #2, respectively. For this assessment, it was conservatively assumed that if a given parcel with natural asset covered is slated for development, 100% of the natural asset is lost. In reality, some of the natural asset will likely be (and should be) preserved.

Table 7 Quantity of Natural Assets at Risk of Development

Natural Asset (type)	Existing Quantity	Quantity at Risk of Development	Unit	Percent at Risk (%)
Wetland	0.7	0.05	ha	7
Forest	21.0	10.0	ha	48
Watercourse	2,400	-	m	0

A low percentage of the wetland area is at risk as these areas are typical near creeks and riparian areas that are aiming to be preserved in future development plans. The existing forest is more dispersed throughout the Neighbourhood and is not easily maintained in conjunction with the proposed land use changes.

5.3 Valuation

Replacement value method was selected to estimate the financial value of the natural asset, in accordance with the approach outlined in the report *Improving Integrated Stormwater Service Deliver at the District of Squamish: Summary of Phase 1 Findings and Recommendations* (Urban Systems, 2019). In this method, the value of the service provided by the asset is estimated as the cost of replacing the service with an engineered infrastructure alternative. Table 8 summarizes the unit cost for each natural asset based on the unit cost of the engineered infrastructure alternative.

Table 8 Unit Rates for Value of Natural Assets Based on Stormwater Services Provided

Natural Asset (type)	Unit	Engineered Replacement for Stormwater Services	Unit Cost	Unit
Wetland	ha	Storage capacity services	$150	$/m3[1]
		Water treatment services	$1,500	$/ha
Forest	ha	on-site storage, controls, and conveyance system from downstream site of forest block	$3,950	$/ha
Watercourse	m	Conveyance	$2	m/mm

[1] Assuming 0.2m deep of storage in wetland areas

Assumptions and references:

Several general assumptions were made to develop the inventory valuation:

- All individual areas of a natural asset type (e.g., forest, wetland, etc.) provide the same quantity of services per unit, regardless of location. In reality, each individual wetland or forest block will provide different quantities of services based on location, site-specific hydrology, and integration with the existing drainage system.

- Site-specific geographical features are not considered in this valuation (e.g. depth of various wetland areas, specific type of forest, etc.).
- The impacts of losing natural assets on the downstream existing conveyance system were not considered. The impacts on runoff associating with losing vegetated ground cover are considered in the stormwater modelling discussed in Section 6.
- For valuation purposes, it was assumed that natural asset services would be provided by engineered infrastructure rather than through attempts to mimic natural functions through green infrastructure.

For wetland valuation:

- It was assumed that all wetland areas provide approximately 0.2 m depth of storage as well as treatment capacity. The total value of \$150/m^3 is the sum of the storage and treatment services and is based on recent contract costs for engineered storage capacity.
- Unit cost for treatment are referenced from "Natural Capital in BC's Lower Mainland: Valuing the benefits from nature" by the David Suzuki Foundation and Sara Wilson for the Pacific Parklands Foundation, 2010. The reported value of \$1,280/ha has been adjusted for 2% annual inflation. Final dollar values have been rounded. This unit cost is likely lower than actual costs in the Squamish area. Costs will be refined as the ISMP is developed.

For forest valuation:

- Unit cost referenced from "Natural Capital in BC's Lower Mainland: Valuing the benefits from nature" by the David Suzuki Foundation and Sara Wilson for the Pacific Parklands Foundation, 2010. Reported value of \$1,500/ha reflects a unit cost of constructed storage of \$57/m3 and has been adjusted to reflect a constructed storage cost of \$150/m3 (\$3,950/ha).

By applying the methods described above, the value of existing natural assets and assets that are at risk of development is summarized in Table 9.

Table 9 Valuation of Existing and At-Risk Natural Assets

Natural Asset (type)	Value of Existing Natural Assets	Value of Natural Assets at Risk
Wetland	$ 210,000	$15,000
	$ 1,000	$75
Forest	$ 83,000	$39,500
Watercourse	$5,040,000	-
Grand Total	**~$5,334,000**	**~$55,000**

As shown in Table 9, the value of the stormwater services provided by existing wetlands and forests in the Neighbourhood is approximately \$5.3 M. Given the percent of each type of natural asset that is at risk of development under either of the proposed future land use scenarios (as shown on Figures 8 and 9), the total value of natural assets at risk is \$55,000.

5.4 Summary and Implications for Land Use and Stormwater Management

Approximately half of the currently forested area in the Neighbourhood is at risk of development.

Results of the natural asset valuation show that forests (and the services they provide) are the natural assets most at risk, with nearly 50% of the currently forested area within the Neighbourhood at risk of development. It is worth noting that protection of natural assets has already been considered in the development of the proposed future land use scenarios (such as through the use of setbacks).

Impacts to these natural assets can be minimized through development practices.

Specifically, maximizing tree retention (as opposed to stripping the land bare) will retain some of the value they provide and minimize the need for other on-site and/or off-site stormwater management solutions.

6. Stormwater System Performance

6.1 Modelling Criteria

A stormwater model was developed in PCSWMM for the Howe Sound and Stawamus River watersheds as part of the ISMP. The primary objectives of this model are to assess the existing storm system's performance when subject to current and future design storm events, evaluate future system capacity and requirements under post-development conditions with future rainfall events and determine overflows in the most susceptible area of Downtown Squamish. The ISMP memo "Stormwater Model Development" (Urban Systems, 2020) attached in Attachment B outlines all the key model development assumptions, parameters, and criteria.

Model criteria are reiterated as follows, which includes design storms listed below to assess systems performance and model scenarios in Table 10 (originally presented in the Stormwater Model Development memorandum). At the time of preparing this document, modelling for Logger's East is based on an uncalibrated stormwater model, which has not been optimized to match observed field data. The complete set of model criteria and scenarios will be applied later in the project once the model has been calibrated.

- 1:10 year based on historical IDF values (current conditions)
- 1:10 year based on current SDC bylaw IDF values (future conditions)
- 1:100 year based on historical IDF values (current conditions)
- 1:100 year based on current SDC bylaw IDF values (future conditions)
- 24-hour Mean Annual Rainfall (MAR) event (equivalent to a 2-year, 24-hour event)

Table 10 Modelled Scenarios

Scenario	Design Storm[1]	Rainfall IDF Curve	Boundary Condition[2]	Scenario Purpose
1	1:10 year	Historical IDF	Existing Tide	Assess existing system capacity under current conditions
2	1:10 year	SDC Bylaw IDF	Future Tide with Sea Level Rise	Assess existing system capacity under future conditions and size infrastructure as necessary
3	1:100 year	Historical IDF	Existing Tide	Assess existing overland flow potential
4	1:100 year	SDC Bylaw IDF	Future Tide with Sea Level Rise	Assess overland flow potential of upside infrastructure
5	MAR	-	-	Flows to inform environmental assessment

1. The design storm duration will be the critical duration for pipe sizing of the minor system or overland flows for the major system.
2. Freeflowing conditions.

6.2 Loggers East Stormwater Model

The stormwater model developed for the Howe Sound and Stawamus River ISMP was refined with a focus on the Loggers East Neighbourhood. A notable revision is the delineation of model subcatchments into individual land parcels to more accurately assess stormwater routing and land use impacts. Separate “submodels” of only the Neighbourhood were also created to isolate the results occurring just within the development area, without the contribution from the upstream watershed. Results for the entire watershed and separate “submodel” are provided in Section 6.3.

Figure 10 shows the assumed routing of the Neighbourhood catchments, most of which outlet to existing watercourses through the Neighbourhood (bordered area of 36.7ha), while others are assumed to connect to existing stormwater infrastructure on Logger’s Lane and Finch Drive, which service recent developments further north in Loggers East. It is unknown whether this infrastructure was intended to also service future developments such as the Neighbourhood, so the potential implications are discussed in Section 6.4.

To obtain model results in the absence of calibration, several assumptions had to be made regarding existing conditions and future development conditions. The following are key assumptions and areas of uncertainty at this time, and they apply to both existing and future condition modelling unless otherwise stated:

- **Infiltration rate** – Waterline’s report “Hydrogeological Assessment for Groundwater Infiltration” (February, 2020) suggests typically moderate to high infiltration rates throughout the study area but states less infiltration potential on the eastern portion of the Neighbourhood. As a starting point, the infiltration rate is assumed to be 5 mm/hr on the eastern portion of the Neighbourhood and 15mm/hr elsewhere. This parameter will be included in the calibration.
- **Impervious routing** – The routing of impervious to pervious areas is assumed to be 0%, such that any impervious surface runoff routes directly to creeks or storm sewers (i.e., TIA equals EIA). This is a conservative starting point under the assumption that infiltration potential is not favourable. This parameter will be included in the calibration.
- **No groundwater interaction** – Groundwater analysis requires empirical matching of modelled and observed flow hydrographs to fully understand the system’s groundwater response

characteristics. This component is unlikely to govern peak flows generated within the Neighbourhood and will be included in calibration to observed flows.

- **Residential development density** – The future residential land use was conservatively assumed as "Medium Density" with a 65% imperviousness per MMCD Land Uses. This reflects a buildout scenario of multi-family residential development.
- **Culvert size** – The culvert shown on Figure 10 where results are presented is assumed to be adequately sized to convey the peak 100-year post-development flow without surcharging. This is assumed in order to present hydrographs of unconstrained flows. The potential development impacts on infrastructure are discussed in Section 6.4.

6.3 Stormwater Modelling Results

To get a sense of the uncalibrated model results, design rainfall events of 2-year, 5-year and 100-year frequency were analyzed for a short duration of 2 hours and long duration of 24 hours, as well as for current and future climate conditions. All events are Chicago rainfall distributions that have been determined using IDF curve parameters derived from the District's Intensity Duration Frequency (IDF) curves, which were updated by Urban Systems in 2018. Chicago rainstorm distributions are commonly applied for short-duration high-intensity events, whereas SCS Type 1A distribution is often used for longer event durations. The SCS Type 1A is based on historical data and is to represent the actual rainfall distribution, while the Chicago event is a synthetic distribution reflective of IDF curves and represents storm events of all durations up to 24 hours. While the SCS Type 1A distribution can be scaled to consider climate change, it remains a fixed distribution (shape) over the length of the storm, which does not match observations. The other advantage of the Chicago distribution is that it represents all storm durations up to 24 hours whereas the SCS Type 1A requires a separate distribution for each storm duration. As such, we suggest that the District considers adopting the Chicago distribution for all events up to 24 hours. Moving forward with the ISMP analysis, we will demonstrate the differences between the two approaches and their implications for stormwater management planning.

Model results focus on an existing culvert crossing Robin Drive, which conveys flows from watercourses that are largely influenced by the Neighbourhood (shown on Figure 10). This location was chosen primarily for convenience at the downstream end of the Neighbourhood drainage system, but potential capacity implications will be touched on in this document and confirmed through model calibration. It is also the location most influenced by changes to the Neighbourhood, as demonstrated by catchment routing shown on Figure 10.

Hydrograph flow results at the noted culvert are shown for the entire watershed on Figure and the Neighbourhood only on Figure 12. The hydrographs compare results for the current land uses within the Neighbourhood against the two future land use scenarios with unmitigated stormwater responses. The 100-year 24-hour event is shown for each graph as this governed both peak flows and total volumes.

Figure 12 also shows a blue shaded area that is bound by the unmitigated future condition hydrographs above and a theoretical attenuated hydrograph on the bottom. A tool in the PCSWMM modelling software creates the attenuated hydrograph to peak at a user-specified flow, which in this case is the pre-development flow rate of about 2.3 m^3/s, and calculates the theoretical detention volume (blue shaded area) that would be required to attenuate the unmitigated post-development hydrograph to the desired limit. The resulting volume to mitigate *changes from the Neighbourhood catchment only* (as highlighted on Figure 12) is approximately 8,100 m³. Discussion on how this can be achieved in order for development to proceed in the Neighbourhood in a way that results in self-management of stormwater runoff is provided in Section 6.4.

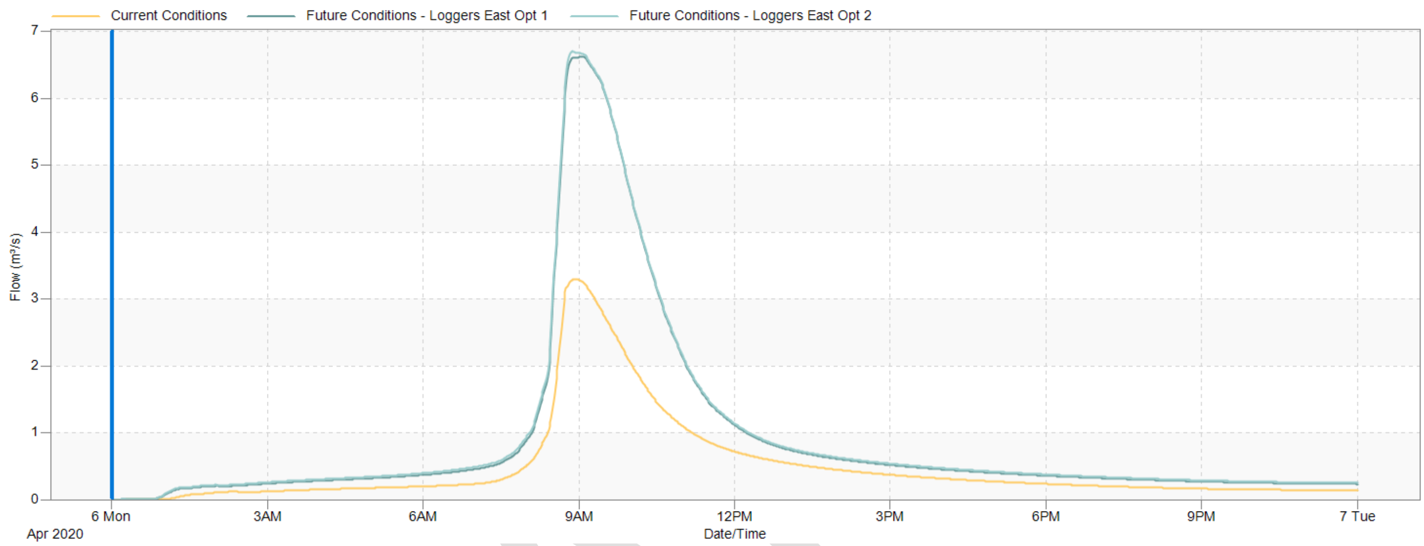


Figure 11 – Hydrograph Results for Entire Watershed

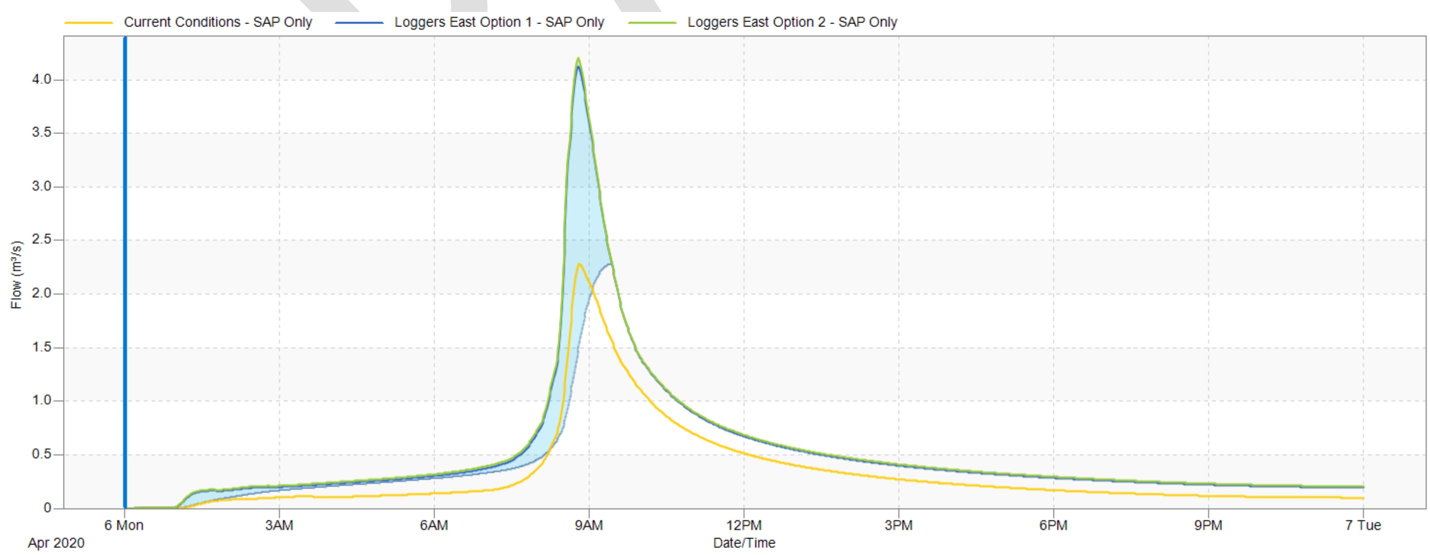


Figure 12 – Hydrograph Results for Loggers East Neighbourhood Only

6.4 Summary and Implications for Land Use and Stormwater Management

Land use changes in the Neighbourhood will have an impact on the outgoing flow response, if unmitigated.

This is clear from the resulting hydrographs and these results align with stormwater management principles and the expected impacts of urban development discussed in Section 3. Given the potential high groundwater and low infiltration potential of the area, it is recommended that infiltration-dependent source controls such as rain gardens are not fully relied upon for rainwater disposal in saturated conditions, at least in the absence of subsurface storage. Above or below ground detention facilities are likely a better solution for regulating discharge flow rate. With that said, while they may not have as high a value in saturated conditions, landscape-based source controls such as 300 mm of amended topsoil and raingardens/bioswales will still provide a benefit of pollution control/water quality treatment, and volume control during unsaturated conditions. This is increasingly important for the summer periods where there is a predicted increase in temperature and drought due to climate change.

Storage will be required to mitigate impacts of additional runoff attributed to development.

It was noted that approximately 8,100 m^3 of storage is required to detain runoff from the 36.7 ha of the Neighbourhood that was included in the model, in order to offset the impacts of development and climate change to match existing peak-flow conditions.

For an off-site communal detention pond with slopes of 4 (horizontal):1 (vertical), with 0.6 m freeboard and 7.5 m buffer (per the District's Subdivision and Development Control Bylaw), a footprint of 0.8 ha to 1.0 ha would be required (assuming live depths of 1.5 m or 2.5 m), which is a similar size of many of the parcels within the Neighbourhood. The District has stated that this is likely not the preferred approach given land acquisition and maintenance requirements and that on-site detention should be considered. However, it remains an option that can be explored further.

The preliminary total storage volume of 8,100 m^3 equates to approximately 220 m^3/ha of storage within the development. With high groundwater levels, a theoretical storage depth of 1.0 m means a storage footprint of about 220 m^2/ha, or 2.2% of a lot's area. The required area may be higher due to groundwater levels. With consideration for this unit storage rate, Figure 13 presents the total area and predicted storage volume of lots throughout the Neighbourhood, which range from 114 m^3 (0.52 ha lot) to 2,132 m^3 (9.69 ha lot). At a high-level estimate of \$150/m^3 of storage (as used in the natural asset valuation), this equates to a cost of just over \$17,000 per half-hectare lot. These results need to be validated through model calibration, and are expected to increase somewhat. The outcomes of Waterline's groundwater study will also inform the cost and feasility of certain types of stormwater management facilities, as disucssed below.

A construction challenge for detention (whether communal or on-site ponds or underground tanks) located in the natural saturated zone is that facilities will be prone to filling with groundwater unless sealed. Then, when empty with high groundwater surrounding it, will have an uplift force. These are design details that need to be considered by the developer, but its expected that any storage will need to be as shallow as possible (resulting in larger footprint) and that storage tanks will need to be sealed to limit the ingress of groundwater. Consideration may also be given to storages only being controlled by a pump that services as the regulator for discharge and can help keep the tank empty during dry weather periods. This may also serve as a cistern with connection to a hose bib for irrigation water during the summer. These are simply options to consider at a high level and will require additional thought on whether and how they are applied, as there are multiple objectives to meet in this area in a challenging and evolving setting.

It should also be recognized that at least the low-lying portion of the Neighbourhood will continue to be prone to high water table and saturated conditions. This is a regional condition based on topographic elevation and not unique to the Neighbourhood. Attempting to drain groundwater may be damaging to the surrounding habitats, and may simply be futile regardless. It is recommended that zones be established based on elevation that demark where infiltration and groundwater management systems may be permitted, and those areas where they are not. This can be integrated with the earlier recommendation for groundwater monitoring, as infiltration potential and groundwater table elevations would be confirmed through monitoring.

A lot grading template should be established in addition to existing flood construction levels (FCLs) to ensure buildings are appropriately placed to avoid nuissance flooding during normal saturated conditions, and catastrophic flooding during a design event. These should include an allowance for future sea level rise. In addition to these requirements, covenants should be used to protect the District.

Increases in runoff due to land use changes will also necessitate source controls to treat the additional pollutant loading.

As previously discussed, based on stormwater management principles, increased impervious surface (particularly those associated with the automobile) will result in an increase in pollutant loading, which may negatively impact water quality in receiving watercourses if no mitigating actions are taken. Efforts to minimize TIA and most importantly EIA (the runoff directly connected to a municipal system and discharging to a watercourse) is recommended. This will be more important for industrial land uses than residential uses but is still important, particularly for parking lots and parkades. The risk can also be controlled if parking facilities are under cover.

7.Summary and Conclusions

Both future land use scenarios will result in negative impacts to the environment and to the existing stormwater system, if unmitigated.

Through the lenses of watershed health, natural assets, and stormwater runoff, both future land use scenarios being considered for the Neighbourhood will result in negative impacts, if no mitigating measures are taken either directly by the District or by developers. This highlights the need to implement measures to mitigate impacts in order to achieve the District's goals for stormwater service delivery as outlined in its Level of Service Framework.

From a stormwater management perspective, neither future land use scenario is preferable over the other.

Based on the results of this assessment, there is not a significant difference between the two proposed future land use scenarios in terms of their impacts on the environment and the existing stormwater system. The difference in future impervious area and the likely pollutants that the land uses may introduce to stormwater runoff are negligible between the two land use scenarios.

Current watershed conditions suggest that the overall biological health of watercourses in the Neighbourhood will benefit from improvements to riparian corridors.

The existing RFI is around 50%; this means that only approximately half of the existing riparian corridors (30m buffer around watercourses) in the Neighbourhood are forested. Theoretically, the District will see an improvement in water quality and fish habitat, and a reduction in erosion, through improvements to the riparian corridor.

Stormwater management controls will be required to mitigate post-development peak runoff and overall volume and to provide water quality treatment in accordance with the stormwater management goals outlined in the District's Level of Service Framework.

As discussed in Section 4, future land use changes will increase the amount of pollutants in stormwater runoff and some form of water quality treatment (and likely source control) will be required. Furthermore, as discussed in Section 6, some form of stormwater management will be required to satisfy the principle of limiting post-development (climate change and land use change) peak flows to pre-development levels.

There is flexibility in how these requirements could be met. Decisions to be made include:

- Whether stormwater management controls are onsite (on-lot), offsite, or a combination
- Ownership of infrastructure assets
- Responsibilities for the long-term operations, maintenance and replacement of infrastructure assets

The District has expressed a preference for onsite stormwater management and for private ownership and maintenance of any stormwater infrastructure (whether "grey" or "green"). The primary benefit of this approach is that it results in less overall cost to the District over the life of the development and any stormwater infrastructure on it. An important consideration is that the onus will be on the District to effectively enforce any requirements it places on developers and to enforce maintenance and replacement by homeowners. Anecdotal observations from other communities have shown that compliance with requirements for onsite management and the ongoing maintenance of infrastructure such as rain gardens and bioswales is as low as 50%. This may not be the case in Squamish, but it highlights the need to have measures in place to ensure compliance so that performance targets are actually met. Additionally, the District should design systems conservatively and predict a certain amount of failure. The risk is that if compliance is low and failure rates are higher than expected, negative impacts from the development may ultimately be observed, necessitating additional measures and costs.

The benefit of relying on offsite infrastructure that is owned and operated by the District is that the District has full control over its operations, maintenance, and replacement. This can lead to more reliable service from the asset over its lifecyle compared to private assets. Of course, the trade-off is that such an arrangement results in greater costs to the District over the long term.

Offsite stormwater infrastructure upgrades will be required if no onsite measures are taken.

Results from the uncalibrated model suggest that unmitigated flows through Finch Creek may require a 2.05 m diameter culvert or equivalent (the existing culvert is a 1.85 m by 0.9 m rectangular culvert), at Robin Drive and existing storm sewers along Finch Drive and Loggers Lane may be similarly impacted. Calibrated results will confirm infrastructure sizing, at which point climate change and development will be further examined to assign triggers to upgrades and cost estimates for upgrades will be developed.

If the District chooses to put the responsibility for detention (and water quality treatment) on the developer, it is recommended that responsibility is placed on the developer to achieve the desired pre-to-post development conditions outlined in this document, which is consistent with the District's current approach to stormwater management, and that the District takes adequate measures to ensure compliance with these requirements.

Approximately half of the currently forested area in the Neighbourhood is at risk of development; these impacts should be minimized through development practices.

Results of the natural asset valuation show that these at-risk assets have a value of approximately $55,000, solely from the perspective of the stormwater services they provide. Given the additional core services they provide, their value is even higher. Emphasis should be placed as the area develops on retaining natural assets (particularly forests).

8. Recommendations

Based on the findings from the current stormwater management review, the following recommendations are made to guide decisions on land use and stormwater management in the Loggers East Neighbourhood:

Recommendation #1: Proceed with development under either of the two proposed future land use scenarios, recognizing that it will take engineered solutions to achieve the stormwater management goals outlined in the District's Level of Service Framework.

Because there is not a significant difference in the impacts associated with the two proposed land use scenarios, the District may proceed with either. However, achieving the goals outlined in the LOS Framework will come at a cost.

Recommendation #2: Confirm the estimated storage and treatment requirements through further analysis and update the overall and per-lot cost estimates accordingly.

As discussed, the results presented in this memorandum are preliminary. It is our expectation that once the stormwater model is calibrated to actual field data, results for runoff and storage requirements will increase (as will associated costs). Furthermore, we have not yet gathered dry-weather water quality data, which may point to the need for treatment-focused stormwater management solutions, the costs of which will also need to be considered.

Water level and velocity data are currently being captured in Loggers Lane Creek, from which flow data will be derived and used to calibrate the model as part of the broader ISMP process. With this information, we will update storage requirements and associated costs. This will be done as part of Phase 3 of the ISMP development process, which focuses on identifying options to mitigate impacts.

At this point, we will also provide cost estimates for water quality treatment. This will be completed by late summer/early fall 2020.

Recommendation #3: That the District does not adopt policy or enter into any developer agreements until stormwater model calibration is complete and the District has a more fulsome understanding of storage requirements and associated costs.

We expect that once the stormwater model has been updated and storage requirements have been refined, the associated costs will increase. The District will need to consider whether the benefits of developing in this area outweigh the costs, considering both stormwater management as well as other community criteria. If costs are deemed to be too high, the District can consider loweing its LOS to something that is more affordable, recognizing that this comes with trade-offs.

Recommendation #4: If development proceeds in the Neighbourhood, ensure that it does so in accordance with the following principles:

a) *Minimize increases in TIA and EIA.*

Minimize increases in TIA through development practices where feasible (for example, through construction of green roofs) and minimize the EIA (the effective impervious area, or the area that drains directly to a watercourse or municipal system). The latter can be achieved through techniques such as disconnecting roof leaders from the municipal system and draining them to an aboveground or subsurface storage tank. Developers should include in their ISMP specific techniques they will implement to achieve this outcome.

b) *Maximize the use of landscape-based solutions to meet both storage and water quality treatment requirements*

To assist with flood control, it is expected given native soil conditions that detention storage is the most appropriate approach to managing future stormwater runoff from the Neighbourhood. Based on preliminary, uncalibrated results, an estimated minimum of 220 m^3/ha (to be confirmed through model calibration) is required to attenuate post-development flows to pre-development levels.

If the District seeks to avoid communal storage by way of detention ponds, this storage requirement can be met through distributed storage on each lot. However, pure detention storages will be ineffective at volume control through an annual cycle, so it is still recommended that impervious surfaces be as disconnected as possible and landscape-based solutions be maximized. Roof leader disconnects to shallow surface landscaping particularly graded for periodically saturated conditions is recommended. While function will be diminished in the saturated winter conditions, these facilities will provide meaningful service in non-saturated conditions, particularly during dry summer periods. Landscape-based solutions also provide water quality treatment, which is required to minimize impacts to the environment from increased pollutant loading that will be associated with increased runoff.

c) *Maintain and ideally enhance riparian forest integrity today and if/when the area develops*

The existing riparian corridors should be enhanced to improve the existing biological condition of the Neighbourhood and minimize the impacts of land use changes. This can be achieved through plantings/restoration of vegetation. This can be done prior to development and would be a logical project in which to engage local environmental stewardship groups. Alternatively, the District can leverage development to implement improvements as development occurs.

d) *Maximize tree canopy on each lot.*

This can be achieved through tree retention and/or by implementing a tree replacement program. This will help to retain the services provided by forests (natural assets) and minimize impervious area, which will reduce runoff under the developed condition.

e) *Ensure impacts to public infrastructure are considered, even if the District chooses to rely on onsite stormwater management.*

As shown in the uncalibrated hydrograph results, the combination of unmitigated development and climate change could approximately double the flows through the culvert of focus, likely beyond its existing capacity. Development will need to consider what extent of mitigation can be achieved on-lot, and what residual impact may occur off-lot.

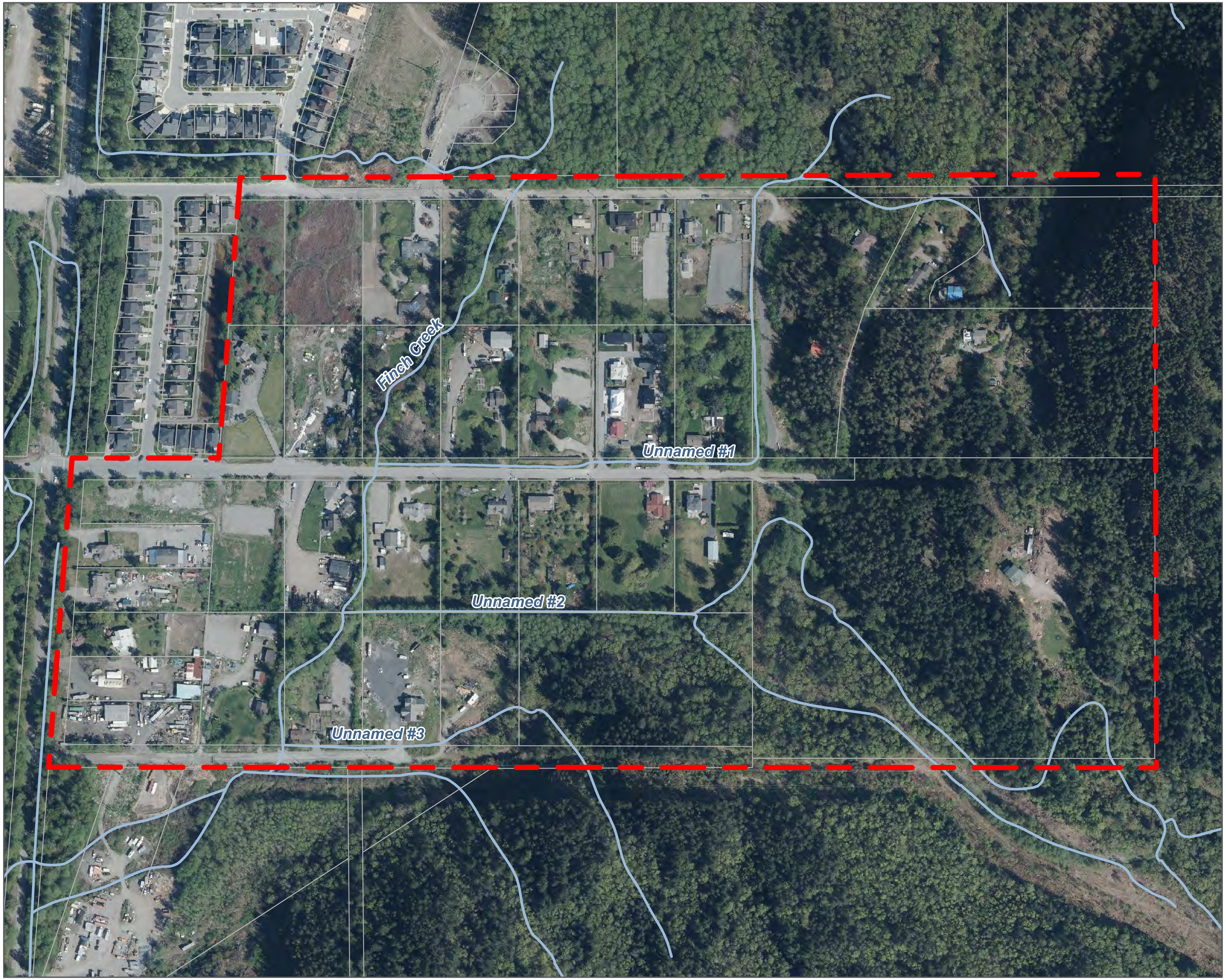
Recommendation #6: If development proceeds in the Neighbourhood, require that developers prepare site-specific stormwater control plans in accordance, at a minimum, with the preliminary requirements and principles outlined above and in the Howe Sound and Stawamus River ISMP. Consider establishing more detailed requirements for developers through a neighbourhood servicing plan.

The Howe Sound and Stawamus ISMP is a watershed-level study that will result in high-level direction on stormwater management in the study area, including high-level storage and treatment requirements and principles for stormwater management to meet the District's goals for LOS. At a minimum, developers should be required to demonstrate how they will meet those high-level requirements, and the District should enforce those requirements through the development application review process. The District should also ensure that development occurred in accordance wih the stormwater control plan by conducting inspections during and after development.

The District should also consider taking an interim step to provide developers with more specific direction on stormwater management in the Neighbourhood. The conditions in the Neighbourhood warrant a comprehensive, strategic approach to stormwater management that thoughtfully consider and integrate community-based solutions (such as constructed wetlands and greenways) and on-site stormwater management controls. Such decisions would typically be made through the development of a neighbourhood servicing plan. One option is for the District to develop a servicing plan as part of a separate process from the current ISMP; the other is to expand the scope of the current ISMP to include more detailed analysis and the development of a stormwater servicing plan for the Neighbourhood.

Recommendation #7: Conduct groundwater level monitoring to gather more data on fluctuations in groundwater level and unsatured zone thickness, to inform site-specific stormwater management design decisions.

This can be achieved either by requiring developers to gather groundwater level data on a site-specific basis or through a sentinel well network. More detail on this will be provided in Waterline's draft report to the District, which is expected in mid-June 2020.



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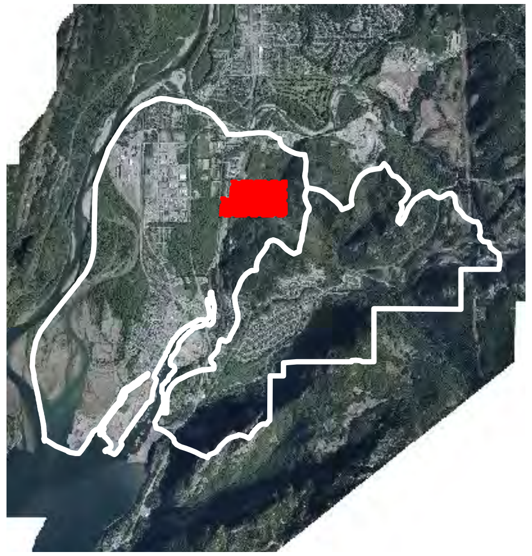
Loggers East Stormwater Review

Loggers East Sub-Area

ISMP Phase 2 Study Area
Loggers East Plan Area
Watercourses



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Meters

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Coordinate System:

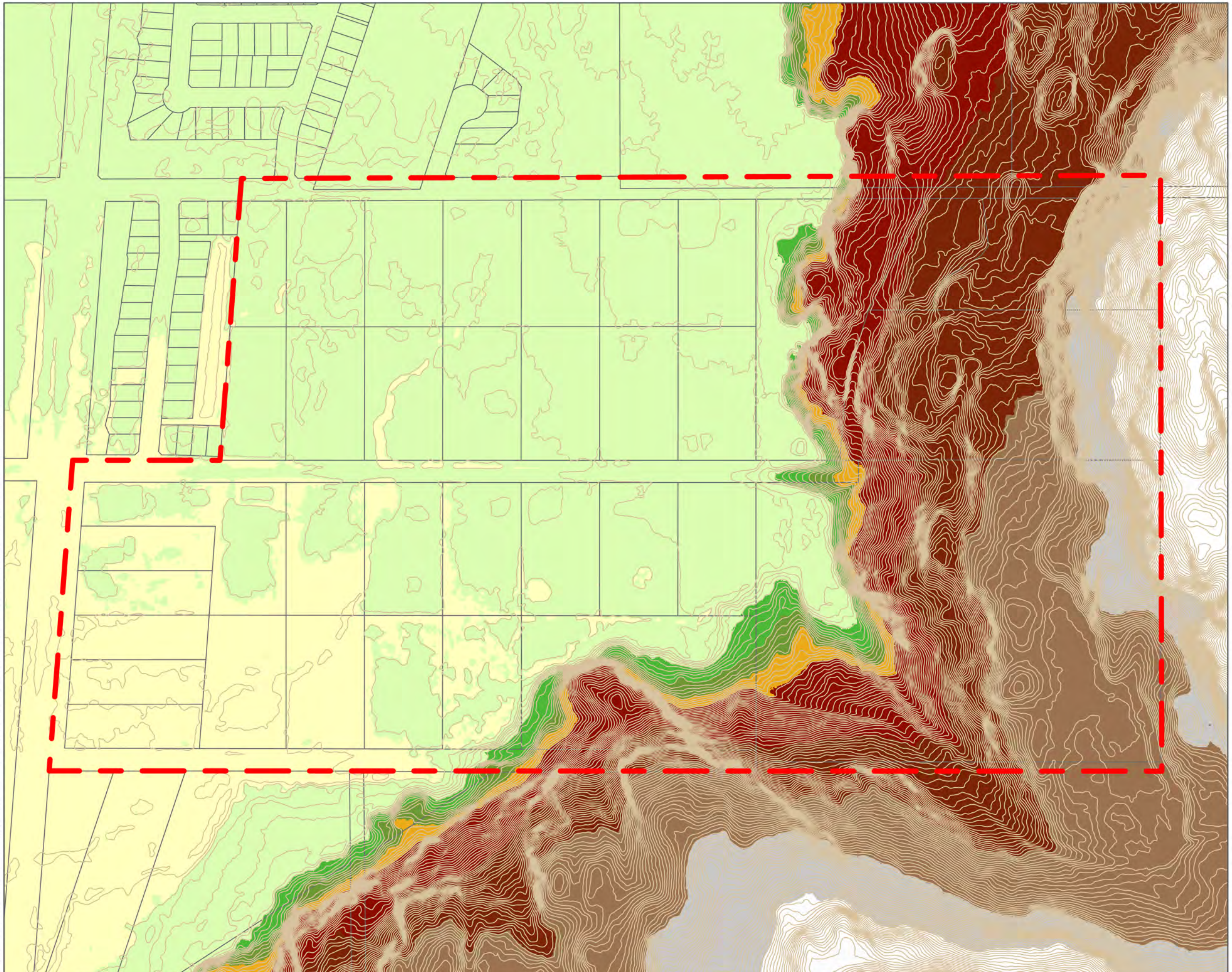
NAD 1983 UTM Zone 10N

Data Sources:
- District of Squamish

Project #:	1928.0032.01
Author:	SQ
Checked:	BD
Status:	Draft
Revision:	A
Date:	2020 / 5 / 15

URBAN systems

FIGURE 1



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Loggers East Stormwater Review

Topography

- Loggers East Plan Area
- 1m Contours

Surface Elevation (m)

- ≤ 5
- ≤ 10
- ≤ 15
- ≤ 20
- ≤ 25
- ≤ 50
- ≤ 75
- ≤ 100
- ≤ 125
- >125

0 50 100
Meters

Coordinate System:

NAD 1983 UTM Zone 10N

Data Sources:
- District of Squamish

Project #: 1928.0032.01
Author: SQ
Checked: BD
Status: Draft
Revision: A
Date: 2020 / 5 / 15

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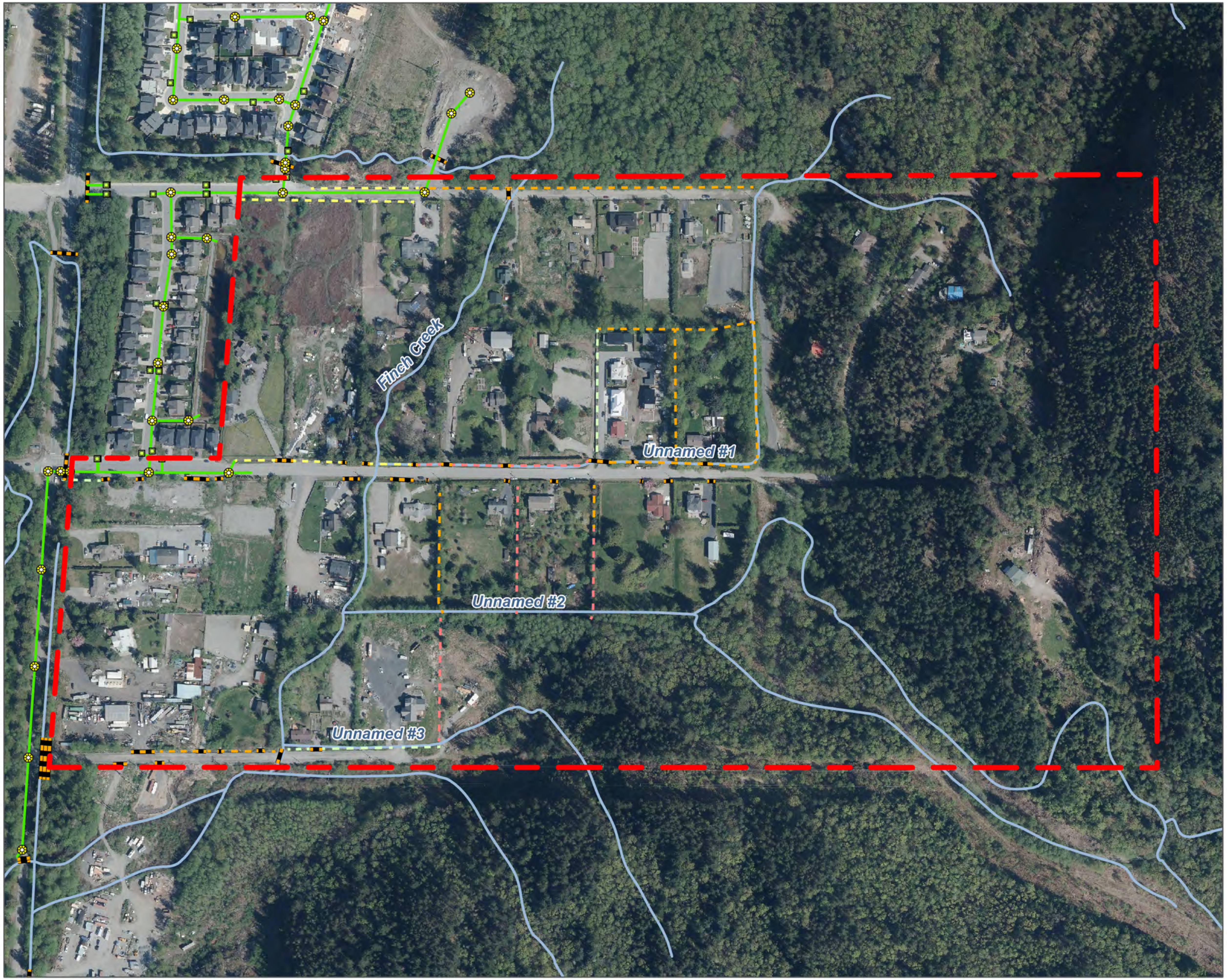
FIGURE 2



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Loggers East Stormwater Review

Existing Drainage Infrastructure

- Loggers East Plan Area
- Storm Manhole
- Catchbasin
- Storm Main
- Culvert

DOS - Ditch Classification

- Minimally Productive Habitat
- Moderately Productive Habitat
- Highly Productive Habitat
- Isolated
- Watercourses

0 50 100
Meters

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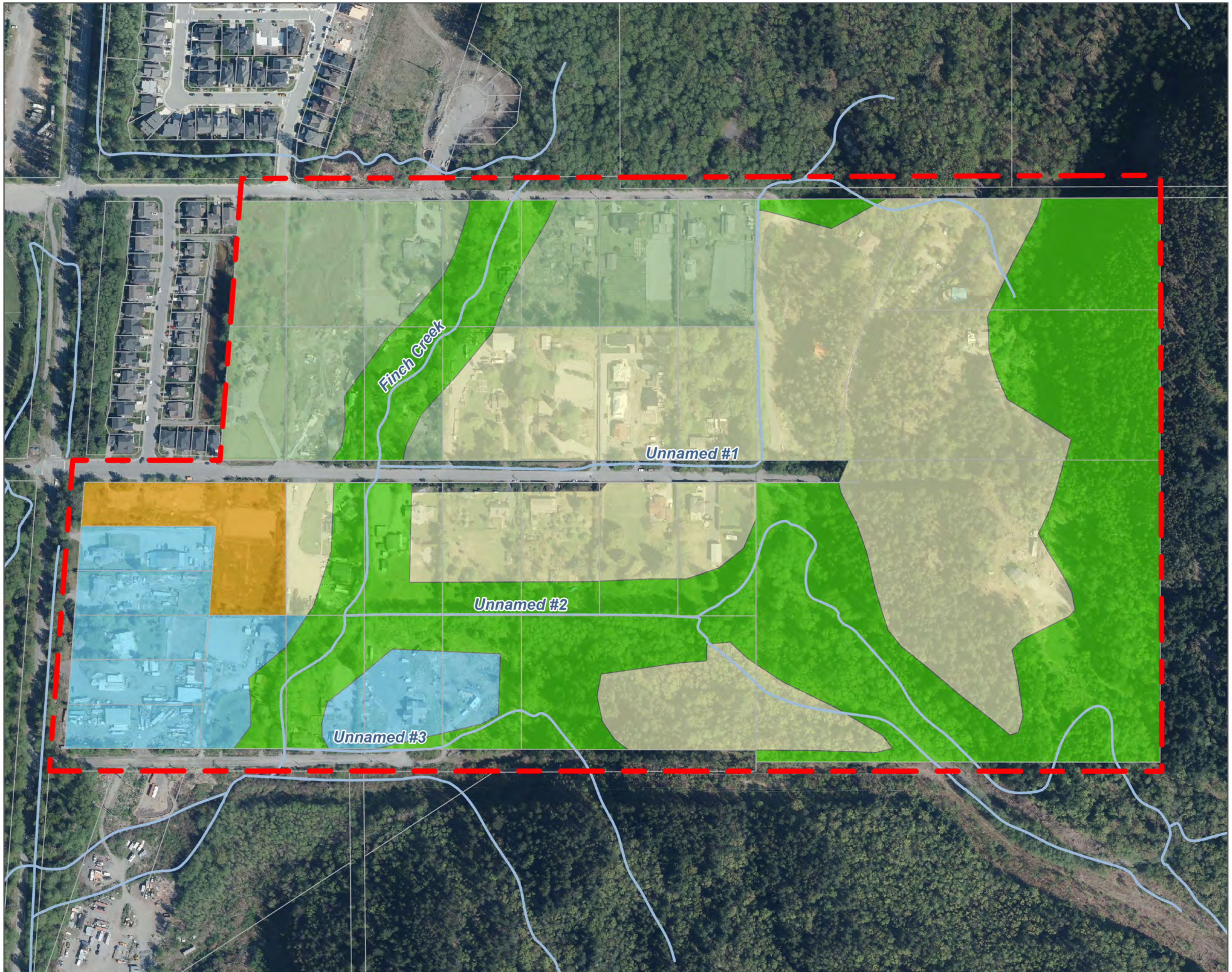
FIGURE 3



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Loggers East Stormwater Review

Proposed Future Land Use Scenario 1

Loggers East Plan Area
Watercourses

Option 1 Land Use

Light Industrial
Mixed Use
Residential
Conservation Area
Rural

NOTE: The future land uses shown on this map reflect early concepts for the purpose of this study and do not indicate the future land uses which will be determined in the Neighbourhood Plan.

0 50 100
Meters

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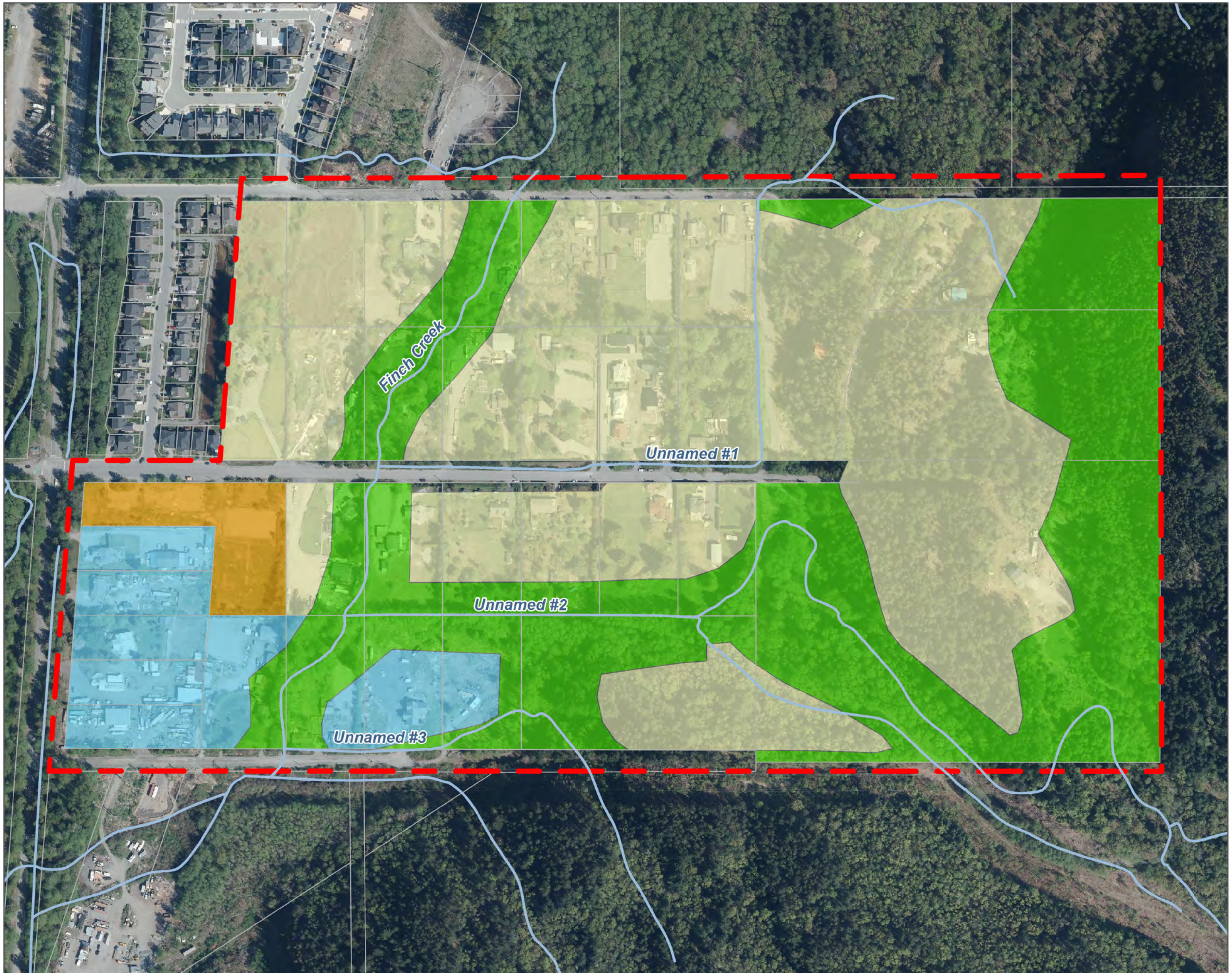
FIGURE 4



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Loggers East Stormwater Review

Proposed Future Land Use Scenario 2

Watercourses

Loggers East Plan Area

Option 2 Land Use

Light Industrial

Mixed Use

Residential

Conservation Area

NOTE: The future land uses shown on this map reflect early concepts for the purpose of this study and do not indicate the future land uses which will be determined in the Neighbourhood Plan.

0 50 100

Meters

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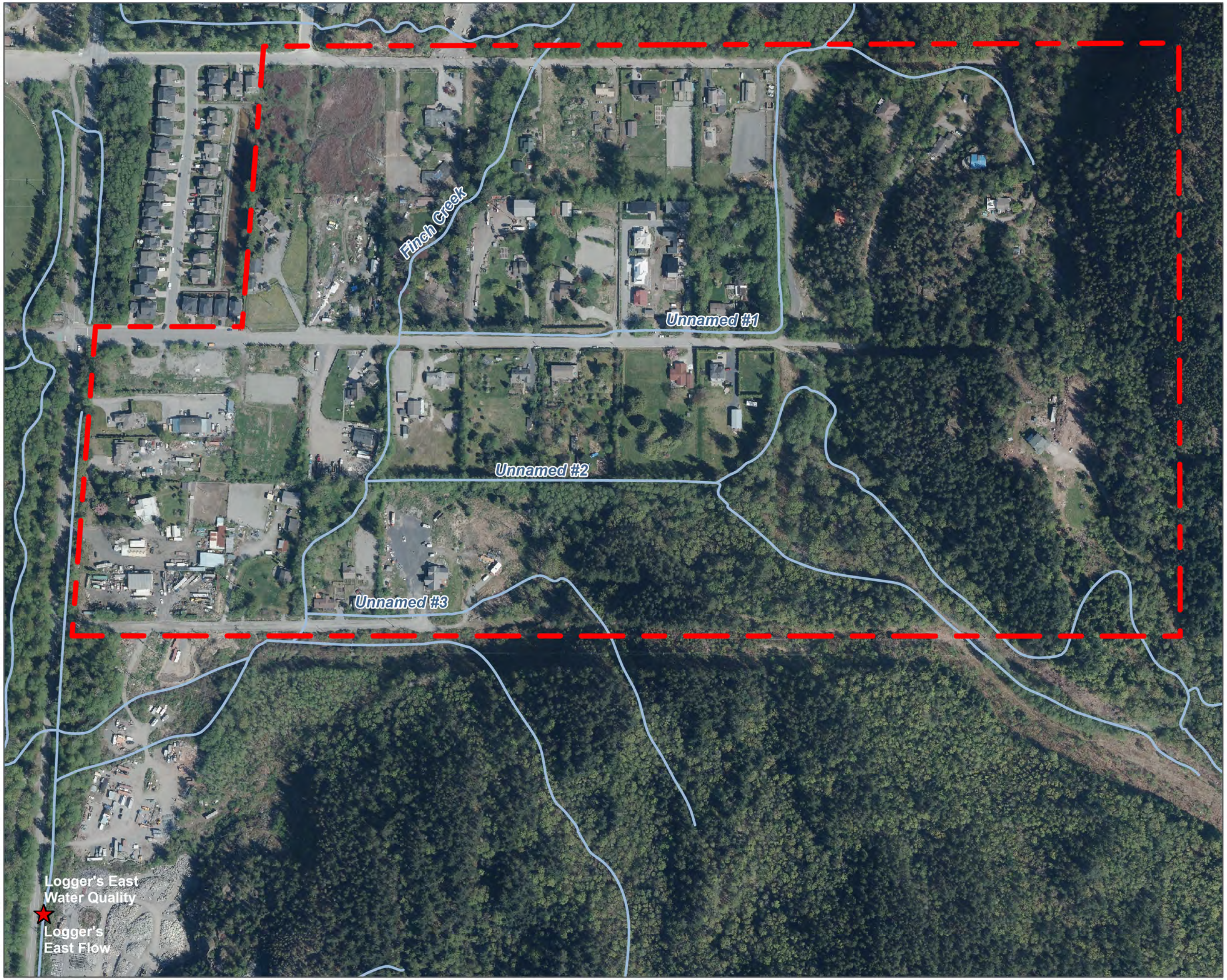
FIGURE 5



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Loggers East Stormwater Review

Environmental Monitoring Locations

- Environmental Monitors
- Loggers East Plan Area
- Watercourses

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0 50 100
Meters

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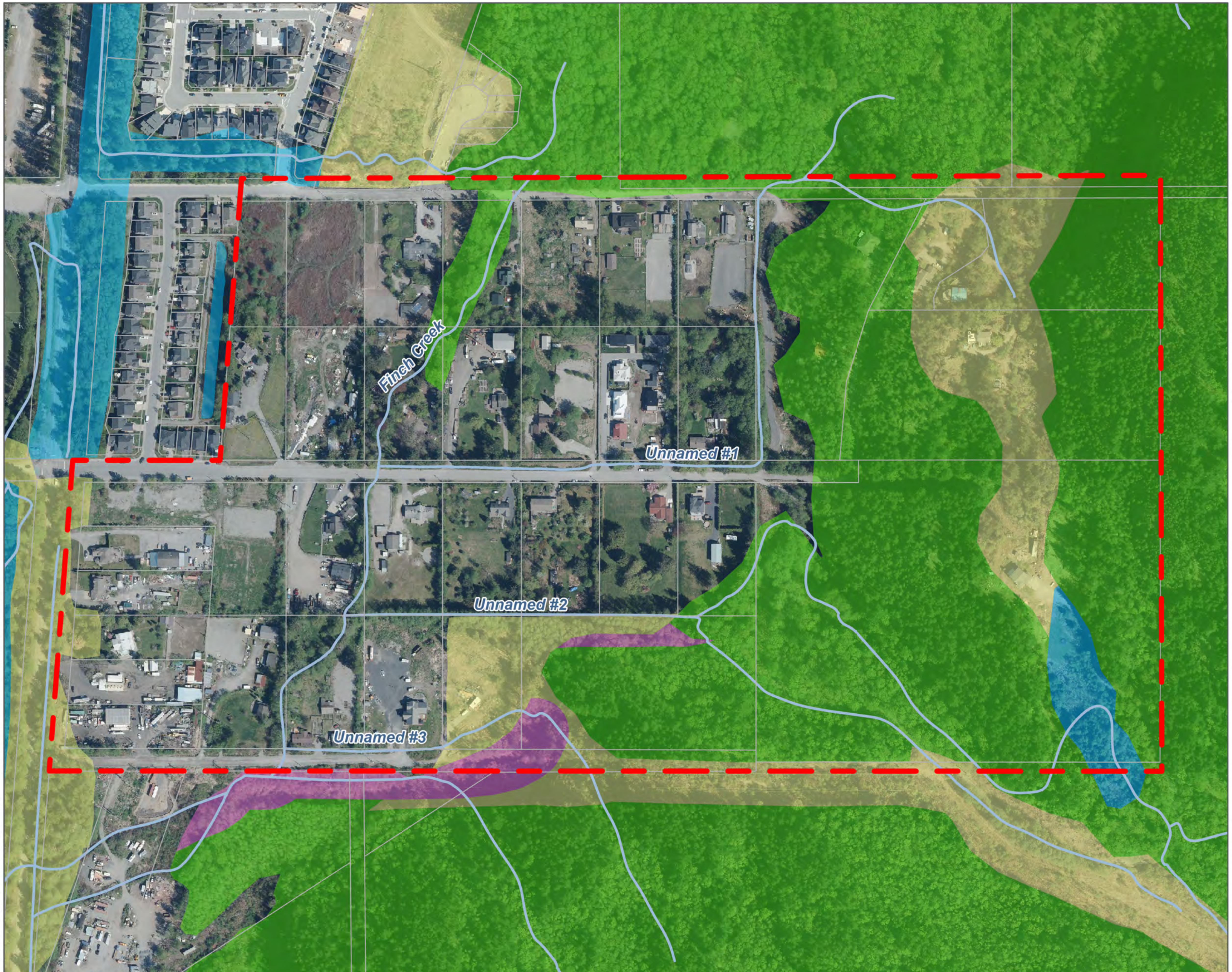
FIGURE 6

Last updated by squalie on Friday, May 15, 2020 at 7:42 AM
Last exported by squalie on Friday, May 15, 2020 7:42 AM
U:\Projects_EDM\9999\Temp Working Projects\Squamish NA (VAN 1928.0032.01)\GIS\Projects\Pro_Projects\Natural Asset Valuation\Natural Asset Valuation.aprx\Enviro Monitor



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Loggers East Stormwater Review

Existing Natural Assets

Loggers East Plan Area

Watercourses

Natural Assets Class

Riparian

Forest

Wetland

Disturbed Ecosystem

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0 50 100

Meters

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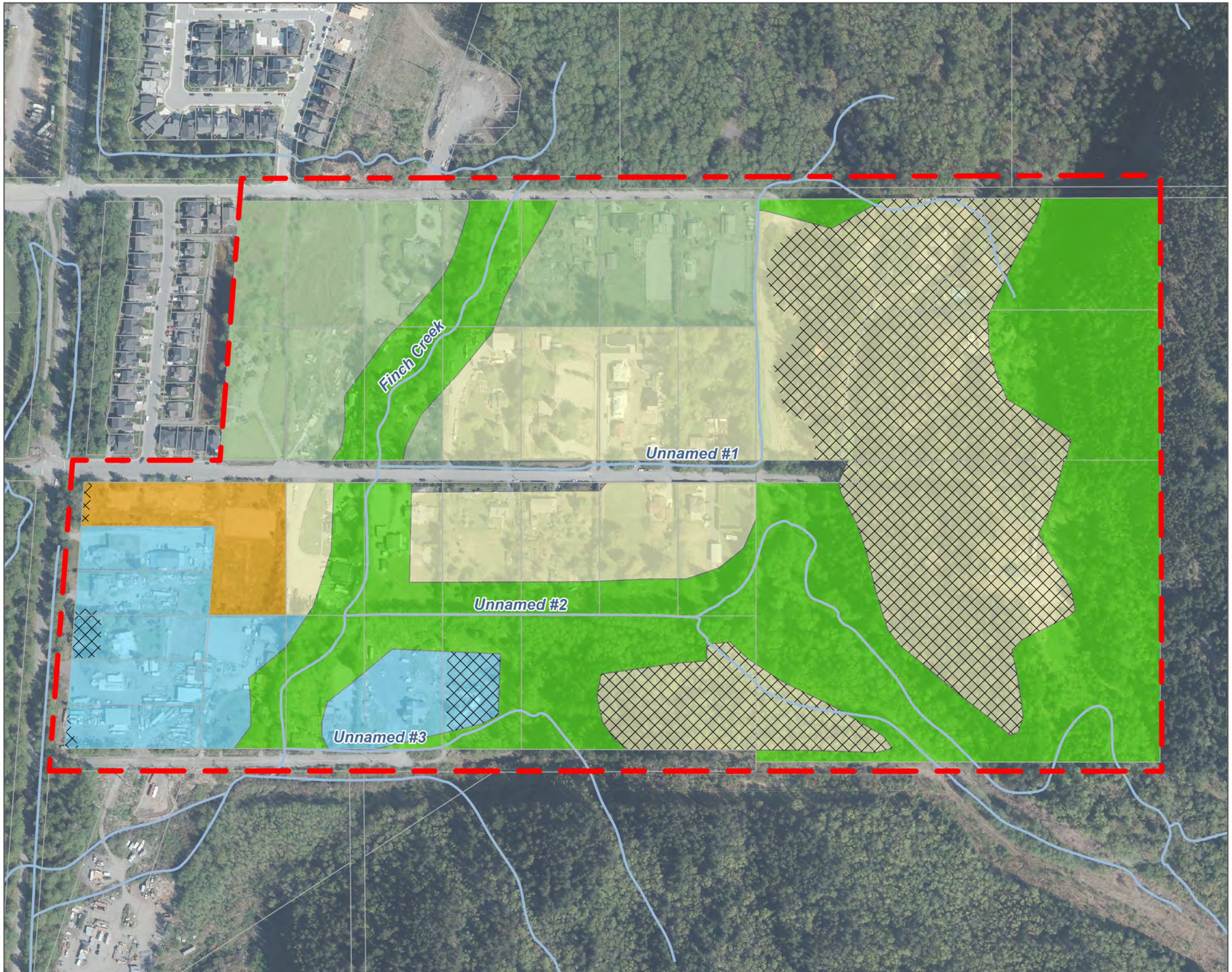
FIGURE 7



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Loggers East Stormwater Review

Natural Assets at Risk (Future Land Use Scenario 1)

Loggers East Plan Area

Watercourses

At Risk Natural Assets

Logger's East Option 1 Land Use

Light Industrial

Mixed Use

Residential

Sensitive Design

Resource

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0 50 100

Meters

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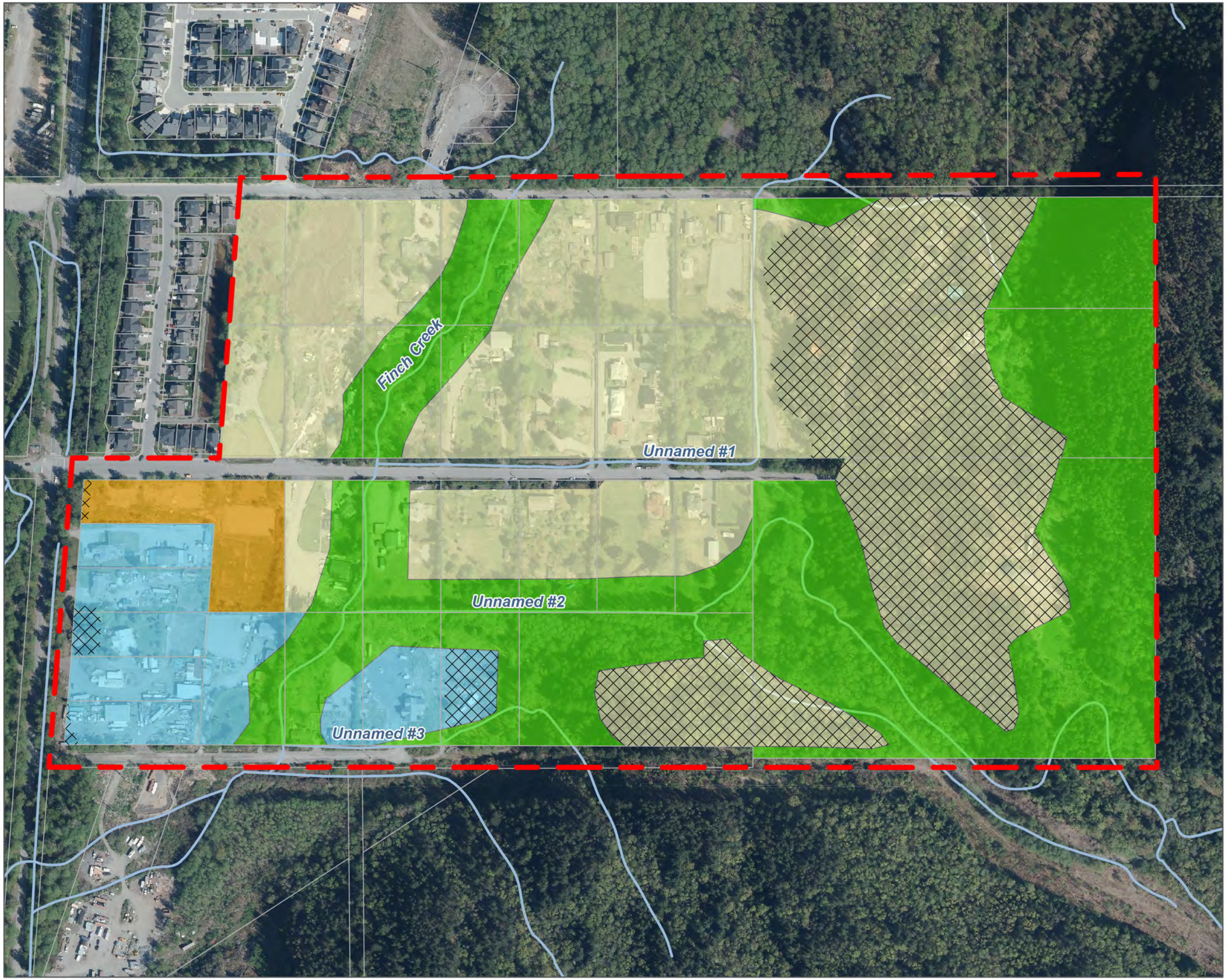
FIGURE 8



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Loggers East
Stormwater Review

Natural Assets at Risk
(Future Land Use Scenario 2)

- Loggers East Plan Area
- At Risk Natural Assets

Logger's East Option 2 Land Use

- Light Industrial
- Mixed Use
- Residential
- Sensitive Design
- Watercourses

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0 50 100
Meters

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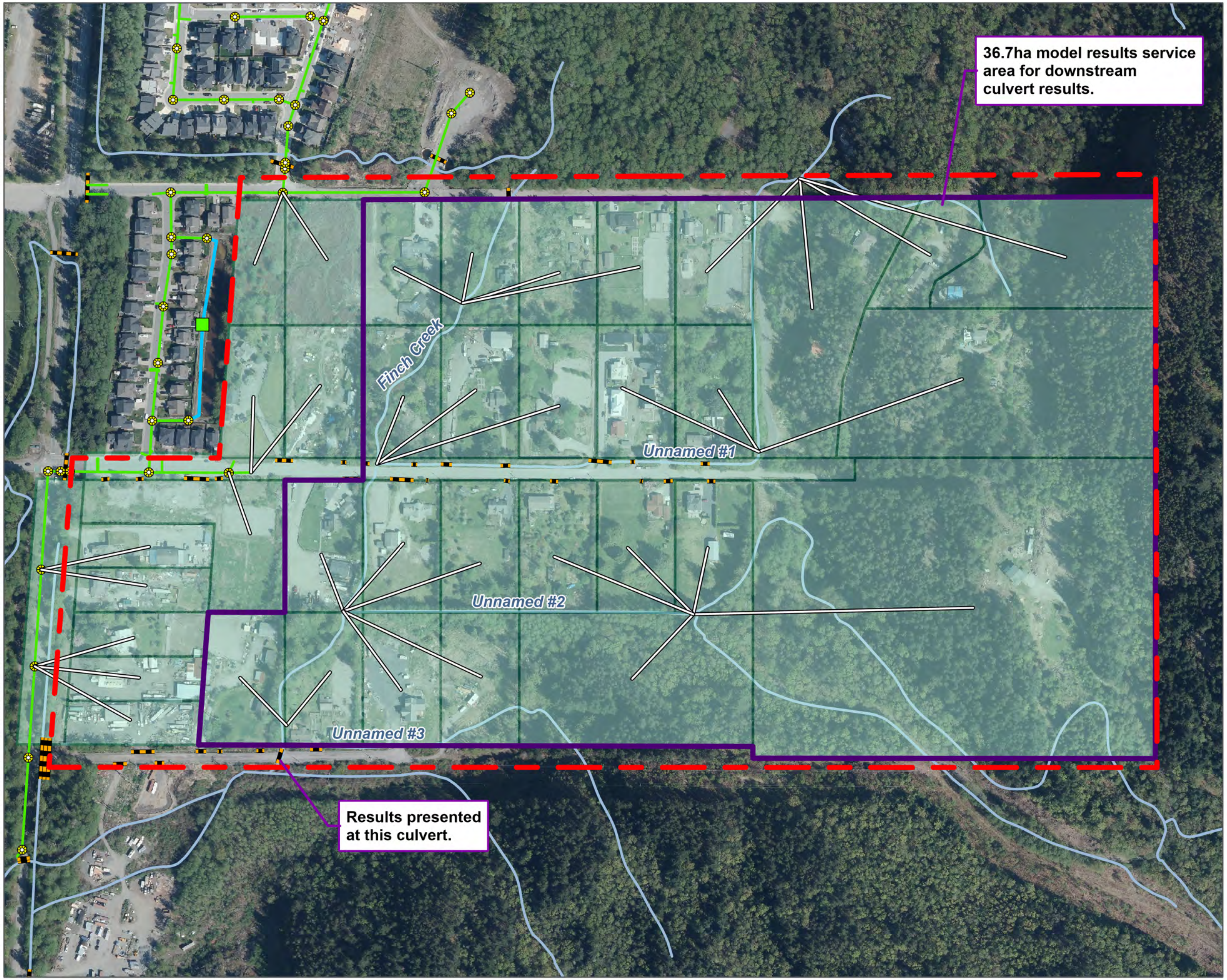
FIGURE 9



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Loggers East Stormwater Review

Stormwater Model Catchments

- Loggers East Plan Area
- Model Results Service Area
- Parcel Routing
- Storages
- Storm Manhole
- Weirs
- Storm Main
- Culvert
- Subcatchments
- Watercourses

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0 50 100
Meters

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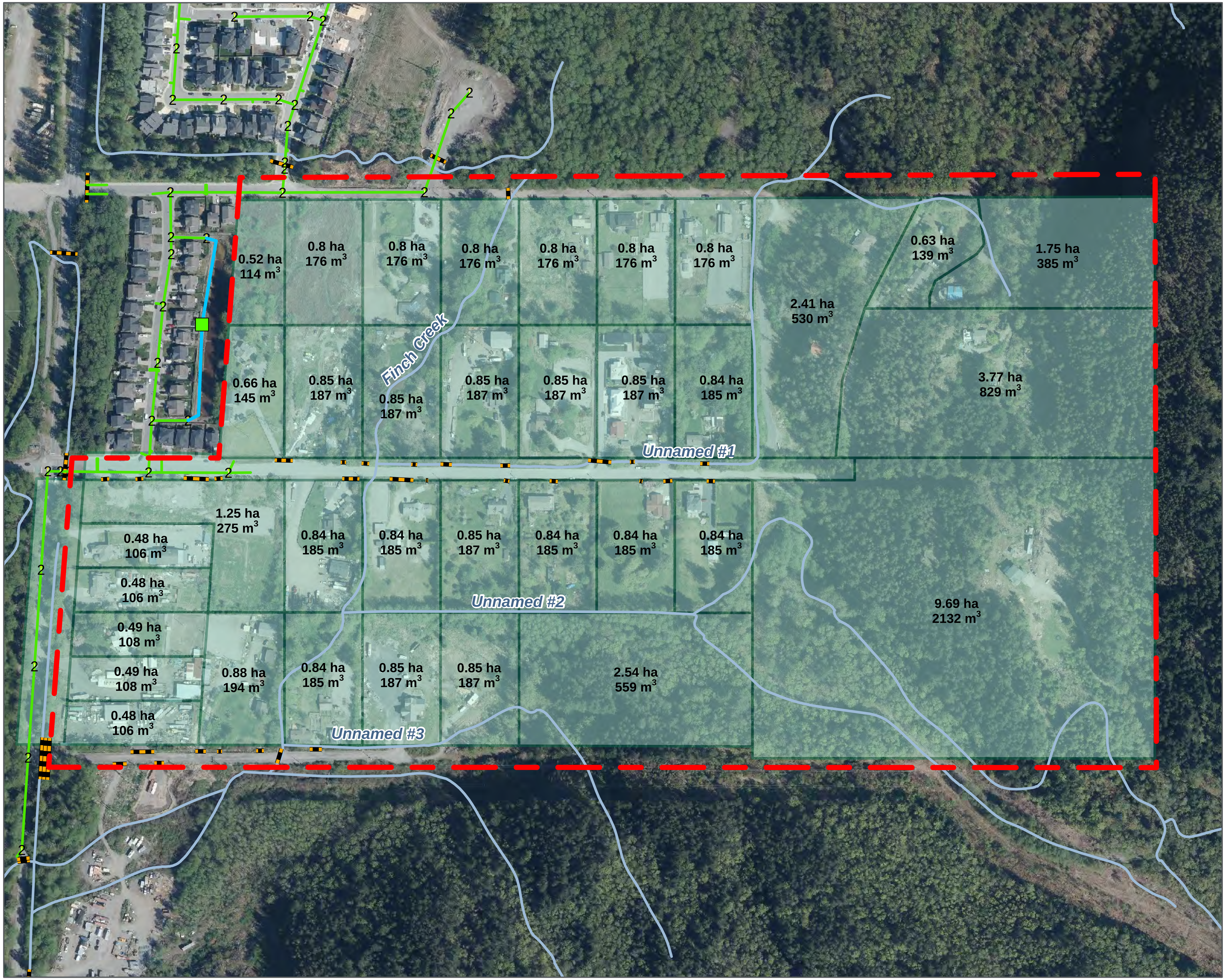
FIGURE 10



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Loggers East Stormwater Review

Detention Storage Requirements Per Lot

- Loggers East Plan Area
- Storages
- Weirs
- 2 Storm Manhole
- Storm Main
- Culvert
- Watercourses
- Subcatchments

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0 50 100
Meters

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FIGURE 13