Technical Memorandum

Date: May 20, 2025
To: Ting Pan, MSc., BEng, LEED AP, CEM
Manager, Sustainability
Planning and Development, City of Nanaimo
From: Luke Crevier, MSc.
File: 25-5157 |Version 1.4
Subject: **City of Nanaimo EMS Site Assessment**

1.0 INTRODUCTION

Ecoscape Environmental Consultants Ltd. (Ecoscape) has been retained by The City of Nanaimo to provide environmental consulting services related to previously measured water quality parameters to assist in the development of freshwater quality indicators in the City of Nanaimo's Monitoring Strategy.

The key outcome of this assessment is a rubric designed to assign an overall score to water quality monitoring sites. The rubric distills information on measured parameters, including relevant environmental guidelines and trends in measured parameter values, into a single value. This synthesis serves two key purposes: it provides insight into an individual site's overall water quality health and provides a structured framework for high-level comparisons between sites.

The purpose of this memorandum is to describe the rationale and application of the developed rubric to facilitate its use in future years or in the expansion of its application to additional sites.

1.1. Background

The Community Watershed Monitoring Network (CWMN) program was started in 2011 as part of a collaboration between the Regional District of Nanaimo (the RDN) and the British Columbia Ministry of Environment (Barlak, 2012). The CWMN program trains volunteers from stewardship groups on the collection and reporting of water quality parameters. The program consists of annual sampling in both the summer low flow period (August to September) and the fall flush period (October to November). This data collection program has continued yearly since 2011 and has expanded over time as additional sites were added to the list of monitored locations.

In 2018, Ecoscape performed a comprehensive analysis of the CWMN data that had been collected up to that point (Plewes et al., 2018). Since then, Ecoscape has provided yearly summary updates of varying scope to the RDN and has delivered an accompanying dataset comprising the measured water quality parameters from each yearly update. The most recent such update included data from 2011-2023 for sites across the RDN (Crevier and Hinz, 2024). The City of Nanaimo provided a list of sites upon which rubric development should focus (T. Pan, personal communication, 2024-12-05).; Ecoscape used this site list (Table 1) to initially filter the most recent RDN dataset to include only sites of interest for this assessment and to determine the study area .

Table 1. Sites of interest within the City of Nanaimo.

EMS ID	Site Label
E290469	Departure Ck @ Neyland Rd
E290470	Joseph's Creek off Newton
E290471	Departure Ck @ Woodstream Park
E290472	Departure Ck @ outlet
E290473	Cottle Creek @ Nottingham
E290475	Cottle Creek @ Stephenson Pt Rd
E290478	Millstone River @ Biggs Rd
E290479	McGarrigle Ck @ Jingle Pot Rd
E290480	Millstone River @ East Wellington
E290481	Millstone River in Barsby Park
E290483	Chase River @ Aebig
E290486	Cat Stream u/s Chase confluence
E290487	Beck Creek @ Cedar Rd
E306256	Walley Ck d/s Hammond Bay
E306257	Walley Ck @ Morningside Dr
E306294	Millstone River @ Jingle Pot Rd
E306434	Walley Ck u/s beach
E309186	Cottle Creek d/s Hammond Bay Rd
E318152	North Wexford Ck d/s Douglas Ave
E318153	North Wexford Ck d/s Tenth St
E318154	Wexford Ck d/s confluence of N and main arm
E318155	Wexford Ck @ Community Park (Glenford Pl)
E318172	North Wexford Ck u/s seniors complex
E318233	Walley Ck d/s McGuffie Rd
E321395	Richards Creek u/s Frames Rd
E325371	Cat Stream d/s Wakesiah Ave
E325372	Cat Stream u/s Pine St
E325373	Cat Stream @ end of Albion St

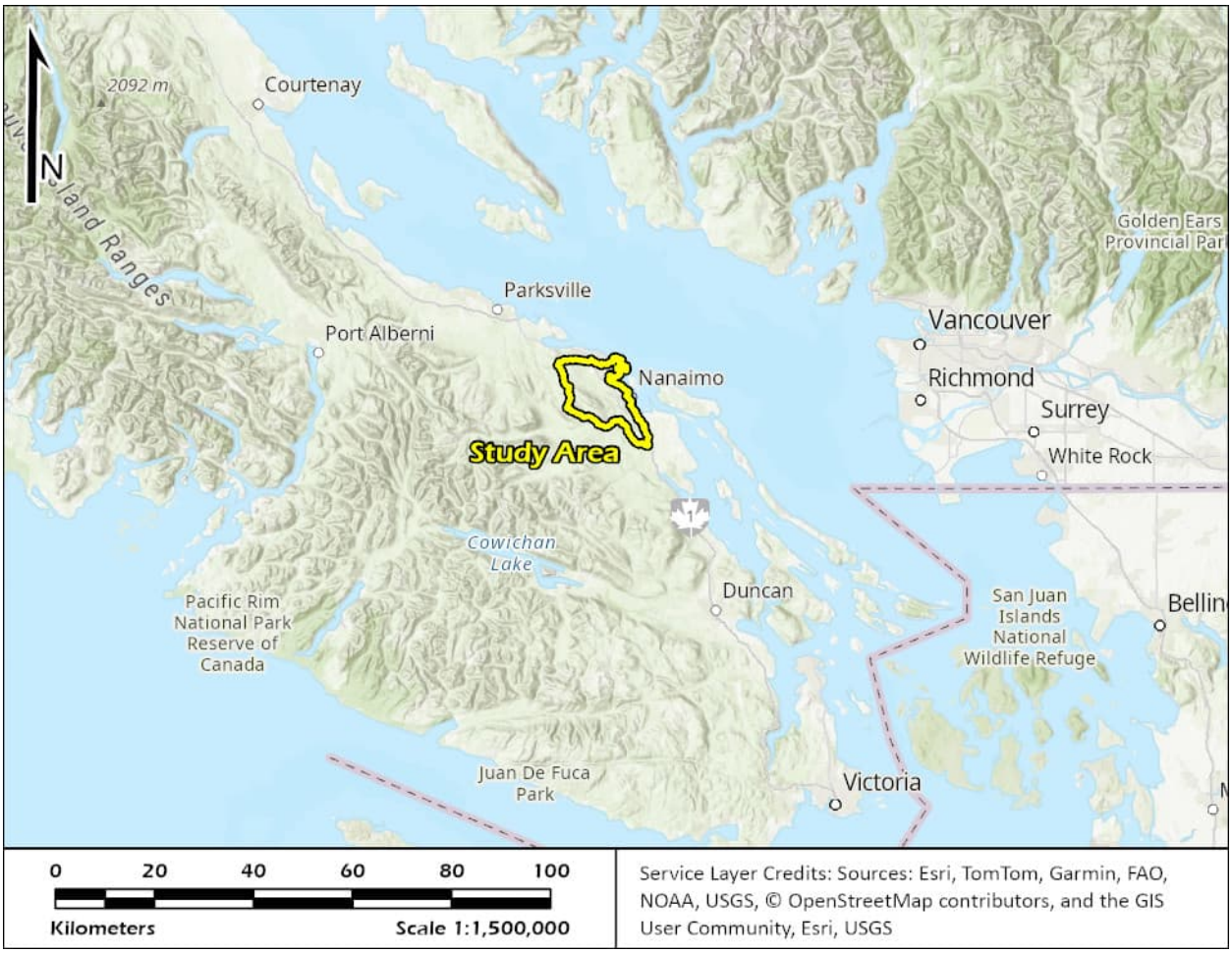

Figure 1. Location map indicating the study area (yellow border) on Vancouver Island in British Columbia.

2.0 SITE SCORING RUBRIC

2.1. Rubric Overview

The general philosophy guiding the development of this scoring rubric is that the rubric should be broadly applicable across sites in the region and be based on the parameters that have been measured consistently as a part of the CWMN program. The rubric should maximize the use of those data by incorporating the comparison of measured parameters to any applicable guidelines as well as by incorporating any detectable trends in parameter values over time. With those considerations in place, this rubric can be applied on a year-by-year basis to all sites within a given year for which appropriate data are available.

The incorporation of guidelines into a scoring system is relatively straightforward: for any given year and site, a parameter that is not compliant with some applicable guideline should affect the overall score of that site for that year. The incorporation of trends entails some additional complexity. The trend analysis applied in this approach (a Mann-Kendall trend analysis or Seasonal Mann-Kendall trend analysis, as appropriate) requires a

minimum span of observations in order to be appropriately applied; to meet that minimum requirement and for consistency with earlier works (Plewes et al., 2018), trend analysis was only applied to sites with at least six years of data from both the summer and fall sampling seasons. This requisite minimum sampling history length further filtered the sites of interest; sites without a sufficient sampling history for a given year were excluded from scoring in that year. This selective application ensures that the information with which a site's score is calculated is complete and consistent between years and between sites. See Table 2 for the list of sites with sufficient sampling history to qualify for trend analysis and the years in which they qualify, and see Figure B1 for a map of their locations.

The general approach to the application of the scoring rubric is as follows: for each year, determine the sites for which appropriate data are available then apply the scoring rubric to each of the sites to assign an overall score to each site with summer and fall sampling and with sufficient previous sampling history to accommodate a trend analysis.

Table 2. Length of site sampling history by year for sites with sufficient sampling history for trend analysis.

Site Identification		Sampling Span		Length of Complete Sampling History by Year[3]						
EMS ID	Site Label	Earliest Year[1]	Latest Year[2]	2017	2018	2019	2020	2021	2022	2023
E290469	Departure Ck @ Neyland Rd	2012	2023	6	7	8	9	10	11	12
E290470	Joseph's Creek off Newton	2012	2023	6	7	8	9	10	11	12
E290471	Departure Ck @ Woodstream Park	2012	2023	6	7	8	9	10	11	12
E290472	Departure Ck @ outlet	2012	2023	6	7	8	9	10	11	12
E290473	Cottle Creek @ Nottingham	2012	2023	6	7	8	9	10	11	12
E290475	Cottle Creek @ Stephenson Pt Rd	2012	2023	6	7	8	9	10	11	12
E290478	Millstone River @ Biggs Rd	2012	2023	6	7	8	9	10	11	12
E290479	McGarrigle Ck @ Jingle Pot Rd	2012	2023	6	7	-	8	9	10	11
E290480	Millstone River @ East Wellington	2012	2023	6	7	-	8	9	10	11
E290481	Millstone River in Barsby Park	2012	2023	6	7	-	8	9	10	11
E290483	Chase River @ Aebig	2012	2023	6	7	8	9	10	11	12
E290486	Cat Stream u/s Chase confluence	2012	2023	6	7	8	9	10	11	12
E290487	Beck Creek @ Cedar Rd	2012	2023	6	7	8	9	10	11	12
E306256	Walley Ck d/s Hammond Bay	2016	2023	-	-	-	-	6	7	8
E306257	Walley Ck @ Morningside Dr	2016	2023	-	-	-	-	6	7	8
E306294	Millstone River @ Jingle Pot Rd	2016	2023	-	-	-	-	6	7	8
E306434	Walley Ck u/s beach	2016	2023	-	-	-	-	-	6	7
E309186	Cottle Creek d/s Hammond Bay Rd	2017	2023	-	-	-	-	-	6	7

[1]The earliest year in which sampling occurred for a given site.
[2]The most recent year for which data have been cleaned and consolidated for a given site.
[3]The length in years of sampling history for a given site in the year indicated by the column header

2.2. Rubric Components

The final rubric score is determined by two categories: comparison to applicable guidelines and trends in parameter values. These categories are further subdivided to improve the differentiation between sites. Guideline comparisons are split into guidelines that apply to an individual parameter measurement (instantaneous guidelines) and guidelines that apply to the average value of a parameter measured over time (chronic guidelines). Trend analysis is separated based on whether parameters have established guidelines. These further subdivisions allow for more precise grading and nuance in the final score.

In the original conception of this rubric, only chronic guidelines were outlined for use in scoring. However, during rubric development it became clear that the additional resolution attainable through the comparison to instantaneous guidelines warranted their inclusion.

2.2.1 Guidelines

Water quality guidelines were queried initially from the BC Approved Water Quality Guidelines (BCAWQG) (B.C. Ministry of Environment and Climate Change Strategy, 2025a, 2024) and filtered to include those guidelines that apply to "Aquatic Life – Freshwater". Available guidelines from this source applied to three of the four parameters: dissolved oxygen, temperature, and turbidity. Guidelines for specific conductivity were not present in the BCAWQG, save for the application to "Agriculture – Irrigation".

Since no applicable guidelines for specific conductivity were available in the BCAWQG, two additional sources were queried for supplemental guidelines: the Canadian Council of Ministers of the Environment (CCME) Canadian Environmental Quality Guidelines (CEQGs) (Canadian Council of Ministers of the Environment, 2025a, 2025b) and the Federal Environmental Quality Guidelines (FEQGs) (Health Canada, 2024). No specific conductivity guidelines are available through either source.

In addition to water quality guidelines, some regions in British Columbia have water quality objectives that provide guidance to management decisions that may impact specific waterbodies and provide supplemental context to provincial or federal guidelines (B.C. Ministry of Environment and Climate Change Strategy, 2025b). The nearest regions with water quality objectives are the Englishman River and Chemainus River (B.C. Ministry of Environment and Climate Change Strategy, 2025c), but there are no water quality objectives applicable to the City of Nanaimo.

The final set of available guidelines are all taken from the BCAWQG; there are applicable guidelines for dissolved oxygen, temperature, and turbidity. Exceedances of either the instantaneous or the chronic guidelines reduce the overall score of a site.

2.2.1.1. Dissolved Oxygen

BCAWQG for dissolved oxygen guidelines are divided into instantaneous and chronic guidelines. For instantaneous guidelines applied to individual parameter measurements, the minimum dissolved oxygen value is 5 mg/L. For chronic guidelines applied to a 30 day average, the minimum dissolved oxygen value is 8 mg/L. These guidelines both apply to the protection of aquatic life for 'all life stages', excluding buried embryo/alevin (B.C. Ministry of Environment and Climate Change Strategy, 2025a).

2.2.1.2. Temperature

Applicable BCAWQG temperature guidelines for the protection of freshwater life are based on optimum temperature ranges for the most sensitive salmonid species present, given as "± 1 change beyond optimum temperature range" (B.C. Ministry of Environment and Climate Change Strategy, 2025a). The primary temperature consideration in the study area is water warming to the point that it exceeds the upper limit of temperature range for these reference species. The most commonly observed salmonid species in the freshwater streams in the study are coho and chum salmon (B.C. Ministry of Environment and Climate Change Strategy, 2025d). The upper temperature limit for rearing for these species is 14°C for chum salmon and 16°C for coho salmon (B.C. Ministry of Environment and Climate Change Strategy, 2025e). The derived water temperature upper limit guideline for these two species is therefore 15°C and 17°C. The 17°C upper limit for coho salmon matches the one used as a water quality objective for the Englishman River (Barlak et al., 2010), but since there are multiple observations of more sensitive chum salmon in the study area the inclusion of the 15°C upper temperature limit in the application of the rubric appropriate and may add additional resolution for sites with warmer water.

These temperature guidelines are used in the rubric application to identify both instantaneous and chronic exceedances; sites with only few instantaneous temperature exceedances are scored more highly than sites with chronic high temperatures.

2.2.1.3. Turbidity

BCAWQG turbidity guidelines are established in relation to the background turbidity values. During clear flows turbidity should not exceed background values at any time by more than 2 NTU and during higher flows or in naturally turbid water turbidity should not exceed background values by more than 5 NTU (B.C. Ministry of Environment and Climate Change Strategy, 2021). The establishment of background turbidity values for all sites of interest would require more extensive sampling (eg. once per day for 30 days) than has historically been undertaken as a part of regular sampling in the CWMN program. As such, measured turbidity in this assessment cannot be compared to a background value. Instead, individual measured turbidity values are compared to those maximum change values (2 NTU during summer sampling and 5 NTU during fall sampling) as a proxy. This comparison

is conservative as it assumes a perfectly clear background and so may over-penalize streams with naturally high turbidity. However, in the absence of established background this approach provides a consistent approach to assessing the turbidity of sites in the study area.

2.3. Trends

Mann-Kendall or Seasonal Mann-Kendall tests are commonly used to identify trends in water quality measurements over time (Ministry of Environment and Climate Change Strategy, 2022; Redmond, Laura, 2018). The Mann-Kendall test is a robust non-parametric analysis for which the assumptions required for an accurate analysis are easily met, and the results are straightforward to interpret as indicating either an increase, decrease, or no change in trend. The Seasonal Mann-Kendall test accounts for repeated variability and detects overall trends even when seasonal influences lead to cyclical within-year patterns (Hirsch et al., 1982).

The data collected as a part of the CWMN program is prone to seasonal effects as it is gathered in discrete summer and fall sampling efforts. Therefore, the Seasonal Mann-Kendall test is a more appropriate test to apply to each site/parameter combination, using the sampling season as the seasonal identifier. One of the assumptions of the Seasonal Mann-Kendall test is that any trends present in the data must be uniform in direction across the seasonal classes; if parameter X is increasing in the summer sampling effort, it should also be increasing in the fall sampling effort. If this condition is not met, the application of the seasonal test is not appropriate (Redmond, Laura, 2018). In such cases, the non-seasonal Mann-Kendall test is more appropriate, using median yearly values as the test values. For this assessment, the R EnvStats package (Millard, 2013) was used to test for monotonic seasonal trends, and the R Kendall package (McLeod, 2022) was used to perform the Seasonal Mann Kendall test or Mann Kendall test.

For incorporation of trends into the scoring rubric, either the Seasonal Mann-Kendall or the Mann-Kendall test can be applied to each parameter for a site where sufficient sampling history exists. The test may detect an increasing trend, a decreasing trend, or no trend.

2.3.1 Trends for Parameters with Guidelines

Dissolved oxygen, temperature, and turbidity all have associated guidelines. Trends in any of these parameters are classified as degrading or improving with respect to those guidelines.

- A decreasing trend in dissolved oxygen (a high percentage of dissolved oxygen trending towards a low percentage of dissolved oxygen) is classified as degrading.

- An increasing trend in temperature (a low temperature trending towards a high temperature) is classified as degrading
- An increasing trend in turbidity (a low turbidity trending towards a high turbidity) is classified as degrading.

Any detected degrading trends reduce the overall score of a site.

2.3.2 Trends for Specific Conductivity

Specific conductivity does not have an associated guideline (see section 2.2.1). Accordingly, it is not strictly appropriate to classify a trend direction as degrading relative to a threshold value. However, increases in specific conductivity due to human activity may negatively impact freshwater species (Ministry of Environment and Climate Change Strategy, 2021; U.S. Environmental Protection Agency, 2016). An increase in conductivity in this assessment is therefore treated as a degrading trend but handled differently from those parameters with associated guidelines. In the absence of a specific guideline, separating out specific conductivity trends from the other parameters allows for reduced weighting the impact of a 'degrading' trend on the derived scoring value.

2.4. Rubric Application

The four components of the final rubric score are based on: instantaneous guidelines, chronic guidelines, trends for parameters with guidelines, and trends in specific conductivity. These four components are integrated to assign a final score to each individual site.

2.4.1 Guideline Scoring

In 2001, the CCME established a water quality index (CCME WQI) framework for scoring water quality based on guideline exceedances (Canadian Council of Ministers of the Environment, 2017); the CCME WQI has since been used extensively for the evaluation of water quality. The CCME WQI scores water quality in three dimensions: the number of parameters that exceed guidelines; how often those exceedances occur, and the magnitude by which those cases exceed their relative guidelines. This framework is simple in its application and provides a single value as a final score for evaluated sites. However, the CCME recommends a minimum of eight parameters for application of the WQI, with emphasis that that CCME WQI should not be run in cases with fewer than four parameters and fewer than four sampling events per year (Canadian Council of Ministers of the Environment, 2017). Since CWMN data collection only measures four parameters with two sampling seasons scores in this assessment are accordingly not directly comparable to CCME WQI values derived through the recommended application. However, since the same four parameters are measured consistently throughout the CWMN sites, some

modification to the general CCME WQI framework still provides a useful approach to scoring sites within the context of the CWMN program.

Calculation of the final score generally follows the computation outlined in the CCME WQI user manual; see that reference document for a full exploration of the computation and a more complete explanation of the formulae listed below (Canadian Council of Ministers of the Environment, 2017). To differentiate between temperature exceedances based on chum salmon and coho salmon in this derived approach, the two different temperature guidelines were counted separately for the purposes of index calculation. The modified scores for scope, frequency, and amplitude are therefore computed with reference to individual guidelines rather than to parameters. Scope assesses the unique number of guidelines that a site exceeds by comparing the number of unique failed guidelines to the total number of guidelines (Equation 1). Frequency evaluates the total number of times that any guideline is exceeded (Equation 2).

$$Scope = \left(\frac{Number\ of\ failed\ guidelines}{Total\ number\ of\ guidelines}\right) \times 100 \quad (1)$$

$$Frequency = \left(\frac{Number\ of\ failed\ tests}{Total\ number\ of\ tests}\right) \times 100 \quad (2)$$

Amplitude assesses the degree by which guidelines are exceeded. Calculation of this component requires computing the magnitude of individual exceedances (an 'excursion') either above a guideline (Equation 3a) or below a guideline (Equation 3b), normalizing the total magnitudes (Equation 4), and then finally scaling that value to determine the amplitude score (Equation 5).

$$excursion_i = \left(\frac{Failed\ Test\ Value_i}{Guideline\ Value_j}\right) - 1 \quad (3a) \qquad excursion_i = \left(\frac{Guideline\ Value_j}{Failed\ Test\ Value_i}\right) - 1 \quad (3b)$$

$$nse = \frac{\sum_u^n excursion_i}{number\ of\ tests} \quad (4)$$

$$Amplitude = \left(\frac{nse}{0.01(nse) + 0.01}\right) \quad (5)$$

The scope, frequency, and amplitude values are then scaled to derive a guideline site score from zero to one hundred (Equation 6).

$$Guideline\ Site\ Score = 100 - \left(\frac{\sqrt{Scope^2 + Frequency^2 + Amplitude^2}}{1.732}\right) \quad (6)$$

To separately treat instantaneous guidelines and chronic guidelines, guideline site scores are calculated for both guideline types based on the guidelines outlined in section 2.2.1.

2.4.2 Trend scoring

The computation of trend scoring in this assessment is simpler than the computation of guideline scoring. For each site, a degrading trend reduces the final score of the site. Since specific conductivity is the only parameter assessed with no applicable guideline, its scoring is treated separately from the other parameters.

2.4.2.1. Scoring Trends for Parameters with Guidelines

Degrading trends for dissolved oxygen, temperature, and turbidity indicate that the measured parameter may have an increased negative effect on freshwater aquatic life over time. However, a parameter with a degrading trend may still be in compliance with applicable guidelines or that parameter may already be of concern due to guideline exceedances. Accordingly, a parameter with a degrading trend at a site with guideline exceedances for that parameter reduces the final site score more than a parameter with a degrading trend without a corresponding guideline exceedance. The weighting factor used in this assessment is five. This value was chosen to strongly penalize sites where degrading trends and guideline exceedances occur. The computation of the trend score for a given site is indicated in Equation 7.

$$Guideline\ Trend\ Score = 100\left(1 - \left(\frac{\sum(Degrading\ Trend_i \times Compliance\ Weight_i)}{5 \times (Number\ of\ Parameters)}\right)\right) \quad (7)$$

2.4.2.2. Scoring Specific Conductivity Trends

Degrading trends for specific conductivity is a simple binary as there are no reference guidelines to assess for possible exceedances. Accordingly, a degrading trend for specific conductivity (see section 2.3.2) detracts a fixed amount from the final site score. For consistency with other subcomponent scores, the specific conductivity trend score is initially scored as one hundred if no degrading trend is indicated and 50 if a degrading trend is indicated.

2.4.3 Aggregate Site Score

There are four subcomponents available for the computation of the final site score: the instantaneous guideline score, the chronic guideline score, the guideline trend score, and the specific conductivity trend score. For each site in each year, these subcomponent

scores are calculated and scaled such that each site is assigned a score from zero to one hundred. As a part of that scaling, some weighting adjustments are applied to more accurately reflect the relative impacts of the individual components.

2.4.3.1. Weighting Adjustments

Regardless of the presence or absence of an applicable guideline, final trend scores are weighted based on the length of the sampling history; longer time series for trend analysis increases the likelihood of detection of a true trend signal (Wang et al., 2020). To incorporate the higher likelihood of accurate detection with a longer time series, a degrading trend for a site whose sampling history spans 2012-2023 detracts more strongly from the final site score than a degrading trend from a site with only a six year sampling history. This time series length scales the possible impact from a factor of 0.75 for a shorter (six year) time series up to a factor of 1.00 for a maximum length (12 year) time series.

For trends in parameters with guidelines this length scaling factor is applied directly to their trend score (section 2.4.2.12.3.1). It is likewise applied to trend score for specific conductivity, but to accommodate the lack of guidelines associated with specific conductivity the impact of specific conductivity trends on the final site score is further attenuated: it contributes to the final site score at a factor of one tenth of the other subcomponents. This reduced weighting suppresses the impact of specific conductivity but still confers a minor reduction in the final score for sites with degrading specific conductivity.

2.4.3.2. Final Site Score Computation

The final score for a site in a given year includes the weighting adjustments described in section 2.4.3.1 and is therefore computed as the weighted sum of the instantaneous guideline score, the chronic guideline score, the length-scaled guideline trend score, and the scaled specific conductivity trend score, all divided by a weight-scaled maximum score (Equation 8). See Appendix C for a worked example of the computation of the final site score for E309186 (Cottle Creek d/s Hammond Bay Road) in 2023.

$$Site\ Score = 100 \times \left(\frac{\left(\begin{matrix}Instantaneous\\ Guideline\\ Score\end{matrix}\right) + \left(\begin{matrix}Chronic\\ Guideline\\ Score\end{matrix}\right) + \left(\begin{matrix}Time\\ Series\\ Length\\ Scale\end{matrix} \times \begin{matrix}Guideline\\ Trend\\ Score\end{matrix}\right) + \left(\frac{\begin{matrix}Time\\ Series\\ Length\\ Scale\end{matrix} \times \begin{matrix}Conductivity\\ Trend\\ Score\end{matrix}}{10} \right)}{Scale\ Adjusted\ Maximum\ Score} \right) \quad (8)$$

The final site score that is produced by Equation 8 is a scaled value from zero to one hundred. Due to the time-series length scaling factor (section 2.4.3.1), the maximum contribution of each individual subcomponent ranges based on the length of the sampling history (Table 3).

Table 3. Percentage of contribution by sub-component scores to the final score across different lengths of sampling history.

Instantaneous Score	Chronic Score	Trends with Guidelines Score	Conductivity Score
35.4 – 32.3	35.4 – 32.3	26.5 – 32.3	2.7 – 3.2

The final site score is intended to distill information from four index sub-components into a single value for comparison and therefore represents an overall score relative to other sites sampled in the CWMN program. A score of one hundred would indicate a site with no instantaneous or chronic guideline exceedances and no degrading trends. Any instances of guideline exceedances or degrading trends detract from that perfect score of one hundred: a lower-scored site would be one with some combination of exceeding chronic guidelines, exceeding instantaneous guidelines, or a degrading trend; a very low-scored site would likely have many exceedances in instantaneous and chronic guidelines along with one or more degrading trends. For each year, all sites for which a sufficient sampling history is available have been scored according to this approach. See Figure 2 for an overview of the scores sites that have been assigned a score. See Tables A1 through A7 for a more comprehensive tabulation of the individual elements that contribute to the final score for each site / year and see Figure A1 for a graphical explanation of the individual elements of those tables. For each of the scored sites, upslope area maps have been created to contextualize the site scores relative to the land use or other local factors (Figures B2:B19); those upslope areas were previously delineated for the RDN (Crevier and Cid Yanez, 2024) and their use for this project was kindly permitted by the RDN (T. Pan, personal communication, 2024-12-12).

3.0 CONCLUSION

The rubric in this assessment integrates water quality guidelines and trends in the measured water quality parameters to generate an annual site-specific score. This standardized scoring system facilitates direct comparisons between monitored sites across the City of Nanaimo. To ensure broad applicability, the rubric employs a general framework that uniformly evaluates all sites based on water quality parameters collected as a part of the CWMN. While this approach enhances consistency, it may overlook site-specific nuances that warrant independent investigation. However, by systematically converting

multi-year water quality data into a single index value, the rubric simplifies interpretation and can serve as a guide for prioritizing management actions for low-scoring sites.

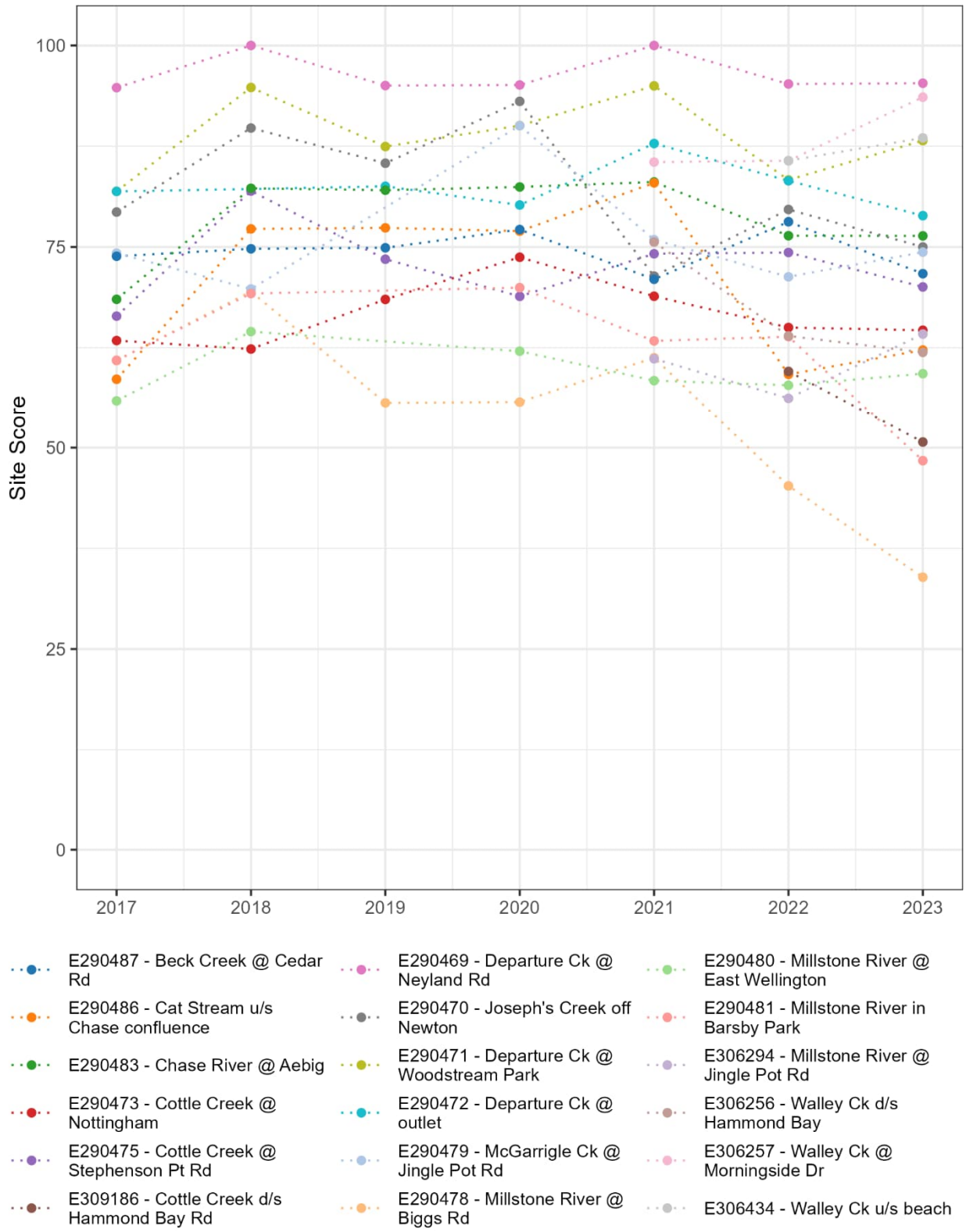

Figure 2. Site scores calculated for all applicable sites of interest from 2017 to 2023.

CLOSURE

We trust that this memo satisfies the present requirements. Should you have any questions or comments, please contact the undersigned at your convenience.

Respectfully Submitted,

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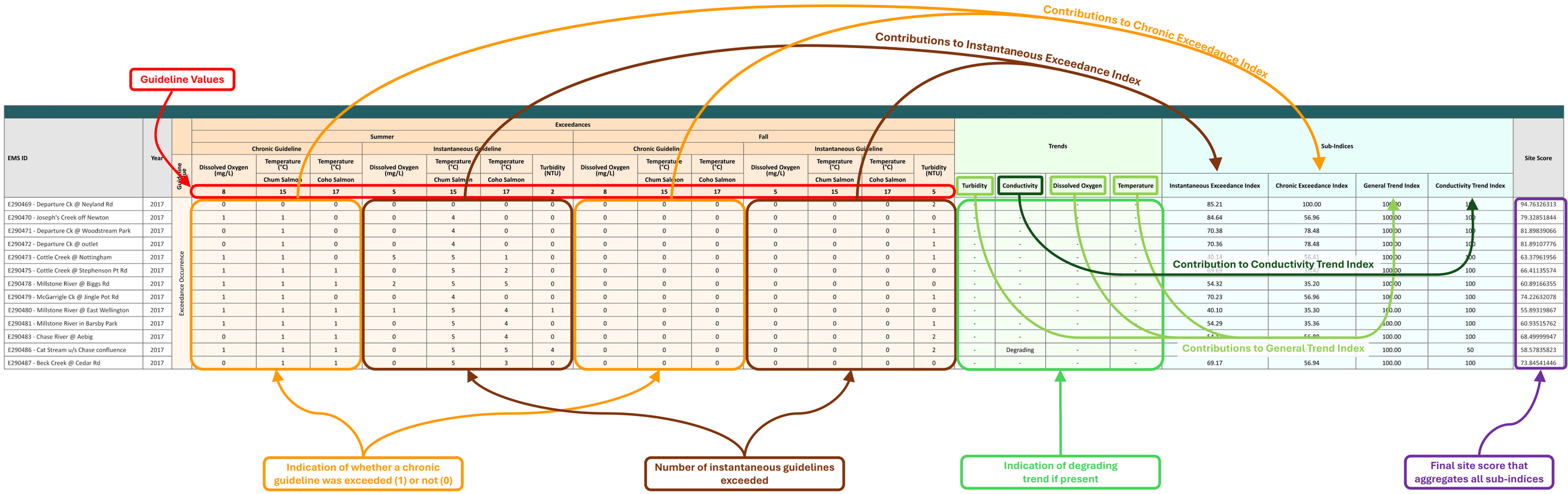
5.0 LIMITATIONS

This report has been prepared by Ecoscape and is intended for the sole and exclusive use of The City of Nanaimo, for the purposes set out in this report. Ecoscape has prepared this report with the understanding that all available information on the past, present, and proposed conditions of the subject property have been disclosed. Ecoscape has relied upon personal communications with The City of Nanaimo and other information sources to corroborate the documents and other records available for the subject property. The City of Nanaimo has also acknowledged that in order for Ecoscape to properly provide the professional service, Ecoscape is relying upon full disclosure and accuracy of this information.

Any use of this report by a third party, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Ecoscape accepts no responsibility for damages, if any, suffered by any third party as a result of actions or decisions made based on this report.

APPENDIX A: Yearly Site Scores



EMS ID	Year	Guideline Value / Exceedance Occurrence	Exceedances														Trends				Sub-Indices				Site Score
			Summer							Fall															
			Chronic Guideline			Instantaneous Guideline				Chronic Guideline			Instantaneous Guideline												
			Dissolved Oxygen (mg/L)	Temperature (°C) Chum Salmon	Temperature (°C) Coho Salmon	Dissolved Oxygen (mg/L)	Temperature (°C) Chum Salmon	Temperature (°C) Coho Salmon	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C) Chum Salmon	Temperature (°C) Coho Salmon	Dissolved Oxygen (mg/L)	Temperature (°C) Chum Salmon	Temperature (°C) Coho Salmon	Turbidity (NTU)	Turbidity	Conductivity	Dissolved Oxygen	Temperature	Instantaneous Exceedance Index	Chronic Exceedance Index	General Trend Index	Conductivity Trend Index	
			8	15	17	5	15	17	2	8	15	17	5	15	17	5									
E290469 - Departure Ck @ Neyland Rd	2017		0	0	0	0	0	0	0	0	0	0	0	0	0	2	-	-	-	-	85.21	100.00	100.00	100	94.76326313
E290470 - Joseph's Creek off Newton	2017		1	1	0	0	4	0	0	0	0	0	0	0	0	0	-	-	-	-	84.64	56.96	100.00	100	79.32851844
E290471 - Departure Ck @ Woodstream Park	2017		0	1	0	0	4	0	0	0	0	0	0	0	0	1	-	-	-	-	70.38	78.48	100.00	100	81.89839066
E290472 - Departure Ck @ outlet	2017		0	1	0	0	4	0	0	0	0	0	0	0	0	1	-	-	-	-	70.36	78.48	100.00	100	81.89107776
E290473 - Cottle Creek @ Nottingham	2017		1	1	0	5	5	1	0	0	0	0	0	0	0	1	-	-	-	-	40.14	56.41	100.00	100	63.37961956
E290475 - Cottle Creek @ Stephenson Pt Rd	2017		1	1	1	0	5	2	0	0	0	0	0	0	0	0	-	-	-	-	69.66	78.48	100.00	100	66.41135574
E290478 - Millstone River @ Biggs Rd	2017		1	1	1	2	5	5	0	0	0	0	0	0	0	0	-	-	-	-	54.32	35.20	100.00	100	60.89166355
E290479 - McGarrigle Ck @ Jingle Pot Rd	2017		1	1	0	0	4	0	0	0	0	0	0	0	0	1	-	-	-	-	70.23	56.96	100.00	100	74.22632078
E290480 - Millstone River @ East Wellington	2017		1	1	1	1	5	4	1	0	0	0	0	0	0	0	-	-	-	-	40.10	35.30	100.00	100	55.89319867
E290481 - Millstone River in Barsby Park	2017		1	1	1	0	5	4	0	0	0	0	0	0	0	1	-	-	-	-	54.29	35.36	100.00	100	60.93515762
E290483 - Chase River @ Aebig	2017		0	1	1	0	5	4	0	0	0	0	0	0	0	2	-	-	-	-	54.[illegible]	56.80	100.00	100	68.49999947
E290486 - Cat Stream u/s Chase confluence	2017		1	1	1	0	5	5	4	0	0	0	0	0	0	2	-	Degrading	-	-	69.17	56.94	100.00	50	58.57835823
E290487 - Beck Creek @ Cedar Rd	2017		0	1	1	0	5	3	0	0	0	0	0	0	0	0	-	-	-	-	69.17	56.94	100.00	100	73.84541446

Figure A1. Overview of appendix table components.

Table A1. Final site scores for sites assessed in 2017. Summaries for individual subcomponent elements are included.

EMS ID	Year		Exceedances														Trends				Sub-Indices				Site Score
			Summer							Fall															
			Chronic Guideline			Instantaneous Guideline				Chronic Guideline			Instantaneous Guideline												
		Guideline Value	Dissolved Oxygen (mg/L)	Temperature (°C) Chum Salmon	Temperature (°C) Coho Salmon	Dissolved Oxygen (mg/L)	Temperature (°C) Chum Salmon	Temperature (°C) Coho Salmon	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C) Chum Salmon	Temperature (°C) Coho Salmon	Dissolved Oxygen (mg/L)	Temperature (°C) Chum Salmon	Temperature (°C) Coho Salmon	Turbidity (NTU)	Turbidity	Conductivity	Dissolved Oxygen	Temperature	Instantaneous Exceedance Index	Chronic Exceedance Index	General Trend Index	Conductivity Trend Index	
			8	15	17	5	15	17	2	8	15	17	5	15	17	5									
E290469 - Departure Ck @ Neyland Rd	2017	Exceedance Occurrence	0	0	0	0	0	0	0	0	0	0	0	0	0	2	-	-	-	-	85.21	100.00	100.00	100	94.76326313
E290470 - Joseph's Creek off Newton	2017		1	1	0	0	4	0	0	0	0	0	0	0	0	0	-	-	-	-	84.64	56.96	100.00	100	79.32851844
E290471 - Departure Ck @ Woodstream Park	2017		0	1	0	0	4	0	0	0	0	0	0	0	0	1	-	-	-	-	70.38	78.48	100.00	100	81.89839066
E290472 - Departure Ck @ outlet	2017		0	1	0	0	4	0	0	0	0	0	0	0	0	1	-	-	-	-	70.36	78.48	100.00	100	81.89107776
E290473 - Cottle Creek @ Nottingham	2017		1	1	0	5	5	1	0	0	0	0	0	0	0	1	-	-	-	-	40.14	56.41	100.00	100	63.37961956
E290475 - Cottle Creek @ Stephenson Pt Rd	2017		1	1	1	0	5	2	0	0	0	0	0	0	0	0	-	-	-	-	69.69	35.42	100.00	100	66.41135574
E290478 - Millstone River @ Biggs Rd	2017		1	1	1	2	5	5	0	0	0	0	0	0	0	0	-	-	-	-	54.32	35.20	100.00	100	60.89166355
E290479 - McGarrigle Ck @ Jingle Pot Rd	2017		1	1	0	0	4	0	0	0	0	0	0	0	0	1	-	-	-	-	70.23	56.96	100.00	100	74.22632078
E290480 - Millstone River @ East Wellington	2017		1	1	1	1	5	4	1	0	0	0	0	0	0	0	-	-	-	-	40.10	35.30	100.00	100	55.89319867
E290481 - Millstone River in Barsby Park	2017		1	1	1	0	5	4	0	0	0	0	0	0	0	1	-	-	-	-	54.29	35.36	100.00	100	60.93515762
E290483 - Chase River @ Aebig	2017		0	1	1	0	5	4	0	0	0	0	0	0	0	2	-	-	-	-	54.12	56.89	100.00	100	68.49999947
E290486 - Cat Stream u/s Chase confluence	2017		1	1	1	0	5	5	4	0	0	0	0	0	0	2	-	Degrading	-	-	51.45	35.28	100.00	50	58.57835823
E290487 - Beck Creek @ Cedar Rd	2017		0	1	1	0	5	3	0	0	0	0	0	0	0	0	-	-	-	-	69.17	56.94	100.00	100	73.84541446

Table A2. Final site scores for sites assessed in 2018. Summaries for individual subcomponent elements are included.

EMS ID	Year	Guideline Value	Exceedances														Trends				Sub-Indices				Site Score
			Summer							Fall															
			Chronic Guideline			Instantaneous Guideline				Chronic Guideline			Instantaneous Guideline												
			Dissolved Oxygen (mg/L)	Temperature (°C)	Temperature (°C)	Dissolved Oxygen (mg/L)	Temperature (°C)	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Temperature (°C)	Dissolved Oxygen (mg/L)	Temperature (°C)	Temperature (°C)	Turbidity (NTU)									
				Chum Salmon	Coho Salmon		Chum Salmon	Coho Salmon			Chum Salmon	Coho Salmon		Chum Salmon	Coho Salmon									
			8	15	17	5	15	17	2	8	15	17	5	15	17	5	Turbidity	Conductivity	Dissolved Oxygen	Temperature	Instantaneous Exceedance Index	Chronic Exceedance Index	General Trend Index	Conductivity Trend Index	
E290469 - Departure Ck @ Neyland Rd	2018	Exceedance Occurrence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	100.00	100.00	100.00	100	100.00000000
E290470 - Joseph's Creek off Newton	2018		0	0	0	0	3	0	1	0	0	0	0	0	0	0	-	-	-	-	70.58	100.00	100.00	100	89.75236267
E290471 - Departure Ck @ Woodstream Park	2018		0	0	0	0	3	0	0	0	0	0	0	0	0	0	-	-	-	-	85.04	100.00	100.00	100	94.78798593
E290472 - Departure Ck @ outlet	2018		0	1	0	0	3	0	2	0	0	0	0	0	0	0	-	-	-	-	70.37	78.48	100.00	100	82.18396811
E290473 - Cottle Creek @ Nottingham	2018		1	1	0	5	4	2	2	0	0	0	0	0	0	0	-	Degrading	-	-	39.69	56.12	100.00	50	62.32963420
E290475 - Cottle Creek @ Stephenson Pt Rd	2018		0	1	0	0	4	3	0	0	0	0	0	0	0	0	-	-	-	-	69.69	78.47	100.00	100	81.94077635
E290478 - Millstone River @ Biggs Rd	2018		1	1	0	0	5	2	2	0	0	0	0	0	0	0	-	-	-	-	55.54	56.80	100.00	100	69.46606745
E290479 - McGarrigle Ck @ Jingle Pot Rd	2018		1	1	0	0	3	1	1	0	0	0	0	0	0	0	-	-	-	-	56.27	56.96	100.00	100	69.77738110
E290480 - Millstone River @ East Wellington	2018		1	1	0	1	5	2	1	0	0	0	0	0	0	0	-	-	-	-	41.24	56.83	100.00	100	64.49416334
E290481 - Millstone River in Barsby Park	2018		0	1	1	0	6	3	2	0	0	0	0	0	0	0	-	-	-	-	54.67	56.94	100.00	100	69.21280361
E290483 - Chase River @ Aebig	2018		0	1	0	0	3	1	0	0	0	0	0	0	0	0	-	-	-	-	70.63	78.48	100.00	100	82.27604718
E290486 - Cat Stream u/s Chase confluence	2018		0	1	0	0	3	1	1	0	0	0	0	0	0	0	-	-	-	-	56.18	78.48	100.00	100	77.23876426
E290487 - Beck Creek @ Cedar Rd	2018		1	1	0	0	3	1	0	0	0	0	0	0	0	0	-	-	-	-	70.63	56.94	100.00	100	74.76984406

Table A3. Final site scores for sites assessed in 2019. Summaries for individual subcomponent elements are included.

EMS ID	Year		Exceedances														Trends				Sub-Indices				Site Score
			Summer							Fall															
			Chronic Guideline			Instantaneous Guideline				Chronic Guideline			Instantaneous Guideline												
		Guideline Value	Dissolved Oxygen (mg/L)	Temperature (°C)	Temperature (°C)	Dissolved Oxygen (mg/L)	Temperature (°C)	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Temperature (°C)	Dissolved Oxygen (mg/L)	Temperature (°C)	Temperature (°C)	Turbidity (NTU)									
				Chum Salmon	Coho Salmon		Chum Salmon	Coho Salmon			Chum Salmon	Coho Salmon		Chum Salmon	Coho Salmon		Turbidity	Conductivity	Dissolved Oxygen	Temperature	Instantaneous Exceedance Index	Chronic Exceedance Index	General Trend Index	Conductivity Trend Index	
			8	15	17	5	15	17	2	8	15	17	5	15	17	5									
E290469 - Departure Ck @ Neyland Rd	2019	Exceedance Occurrence	0	0	0	0	1	0	0	0	0	0	0	0	0	0	-	-	-	-	85.49	100.00	100.00	100	95.02644498
E290470 - Joseph's Creek off Newton	2019		0	1	0	0	4	0	0	0	0	0	0	0	0	0	Improving	-	-	-	84.45	78.48	93.33	100	85.38632842
E290471 - Departure Ck @ Woodstream Park	2019		0	1	0	0	3	0	0	0	0	0	0	0	0	0	-	-	-	-	84.93	78.48	100.00	100	87.45580280
E290472 - Departure Ck @ outlet	2019		0	1	0	0	3	0	0	0	0	0	0	0	0	1	-	-	-	-	70.55	78.48	100.00	100	82.52687612
E290473 - Cottle Creek @ Nottingham	2019		1	1	0	1	5	1	0	0	0	0	0	0	0	0	-	Degrading	-	-	55.52	56.73	100.00	50	68.48771024
E290475 - Cottle Creek @ Stephenson Pt Rd	2019		1	1	0	0	5	1	0	0	0	0	0	0	0	0	-	Degrading	-	-	69.85	56.95	100.00	50	73.47311544
E290478 - Millstone River @ Biggs Rd	2019		1	1	1	1	5	4	2	0	0	0	0	0	0	0	-	Degrading	-	-	39.65	35.14	100.00	50	55.64361947
E290483 - Chase River @ Aebig	2019		0	1	0	0	4	0	0	0	0	0	0	0	0	1	-	-	-	-	69.14	78.47	100.00	100	82.03910442
E290486 - Cat Stream u/s Chase confluence	2019		0	1	0	0	5	1	1	0	0	0	0	0	0	0	-	-	-	-	55.53	78.47	100.00	100	77.36850065
E290487 - Beck Creek @ Cedar Rd	2019		1	1	0	1	5	0	0	0	0	0	0	0	0	0	-	-	-	-	69.86	56.90	100.00	100	74.88906063

Table A4. Final site scores for sites assessed in 2020. Summaries for individual subcomponent elements are included.

EMS ID	Year	Guideline Value	Exceedances														Trends				Sub-Indices				Site Score
			Summer							Fall															
			Chronic Guideline			Instantaneous Guideline				Chronic Guideline			Instantaneous Guideline												
			Dissolved Oxygen (mg/L)	Temperature (°C) Chum Salmon	Temperature (°C) Coho Salmon	Dissolved Oxygen (mg/L)	Temperature (°C) Chum Salmon	Temperature (°C) Coho Salmon	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C) Chum Salmon	Temperature (°C) Coho Salmon	Dissolved Oxygen (mg/L)	Temperature (°C) Chum Salmon	Temperature (°C) Coho Salmon	Turbidity (NTU)	Turbidity	Conductivity	Dissolved Oxygen	Temperature	Instantaneous Exceedance Index	Chronic Exceedance Index	General Trend Index	Conductivity Trend Index	
			8	15	17	5	15	17	2	8	15	17	5	15	17	5									
E290469 - Departure Ck @ Neyland Rd	2020	Exceedance Occurrence	0	0	0	0	0	0	0	0	0	0	0	0	0	1	-	-	-	-	85.48	100.00	100.00	100	95.10024892
E290470 - Joseph's Creek off Newton	2020		0	0	0	0	2	0	0	0	0	0	0	0	0	0	Improving	-	-	-	85.28	100.00	93.33	100	93.06173290
E290471 - Departure Ck @ Woodstream Park	2020		0	0	0	0	2	0	0	0	0	0	0	0	0	2	-	-	-	-	70.54	100.00	100.00	100	90.05689959
E290472 - Departure Ck @ outlet	2020		0	0	0	0	2	0	0	0	0	0	0	0	0	2	Improving	-	-	-	70.51	100.00	66.67	100	80.19987390
E290473 - Cottle Creek @ Nottingham	2020		1	1	0	0	3	0	0	0	0	0	0	0	0	2	-	Degrading	-	-	69.72	56.79	100.00	50	73.71819710
E290475 - Cottle Creek @ Stephenson Pt Rd	2020		1	1	0	0	3	2	0	0	0	0	0	0	0	2	-	Degrading	-	-	55.19	56.96	100.00	50	68.86928378
E290478 - Millstone River @ Biggs Rd	2020		1	1	1	3	5	4	3	0	0	0	0	0	0	0	-	Degrading	-	-	38.18	35.07	100.00	50	55.73746317
E290479 - McGarrigle Ck @ Jingle Pot Rd	2020		0	0	0	0	2	0	0	0	0	0	0	0	0	2	-	-	-	-	70.51	100.00	100.00	100	90.04541320
E290480 - Millstone River @ East Wellington	2020		1	1	1	0	5	3	3	0	0	0	0	0	0	2	-	-	-	-	52.24	35.36	100.00	100	62.05687052
E290481 - Millstone River in Barsby Park	2020		0	1	1	0	5	2	0	0	0	0	0	0	0	2	-	-	-	-	54.03	56.94	100.00	100	69.94528613
E290483 - Chase River @ Aebig	2020		0	1	0	0	3	0	0	0	0	0	0	0	0	2	-	-	-	-	69.50	78.48	100.00	100	82.44055423
E290486 - Cat Stream u/s Chase confluence	2020		0	1	0	0	5	2	2	0	0	0	0	0	0	2	-	-	-	-	53.28	78.46	100.00	100	76.95913166
E290487 - Beck Creek @ Cedar Rd	2020		0	1	0	0	5	2	2	0	0	0	0	0	0	2	-	-	-	-	53.85	78.47	100.00	100	77.15463523

Table A5. Final site scores for sites assessed in 2021. Summaries for individual subcomponent elements are included.

EMS ID	Year		Exceedances														Trends				Sub-Indices				Site Score
			Summer							Fall															
			Chronic Guideline			Instantaneous Guideline				Chronic Guideline			Instantaneous Guideline												
		Guideline Value	Dissolved Oxygen (mg/L)	Temperature (°C) Chum Salmon	Temperature (°C) Coho Salmon	Dissolved Oxygen (mg/L)	Temperature (°C) Chum Salmon	Temperature (°C) Coho Salmon	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C) Chum Salmon	Temperature (°C) Coho Salmon	Dissolved Oxygen (mg/L)	Temperature (°C) Chum Salmon	Temperature (°C) Coho Salmon	Turbidity (NTU)	Turbidity	Conductivity	Dissolved Oxygen	Temperature	Instantaneous Exceedance Index	Chronic Exceedance Index	General Trend Index	Conductivity Trend Index	
			8	15	17	5	15	17	2	8	15	17	5	15	17	5									
E290469 - Departure Ck @ Neyland Rd	2021	Exceedance Occurrence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	100.00	100.00	100.00	100	100.00000000
E290470 - Joseph's Creek off Newton	2021		0	1	0	0	3	0	1	0	0	0	0	0	0	0	Improving	Degrading	-	-	70.55	78.48	66.67	50	71.37706525
E290471 - Departure Ck @ Woodstream Park	2021		0	0	0	0	3	0	0	0	0	0	0	0	0	0	-	-	-	-	84.93	100.00	100.00	100	94.99013653
E290472 - Departure Ck @ outlet	2021		0	1	0	0	3	0	0	0	0	0	0	0	0	0	-	-	-	-	84.93	78.48	100.00	100	87.83718342
E290473 - Cottle Creek @ Nottingham	2021		1	1	0	4	3	2	0	0	0	0	0	0	0	0	-	Degrading	-	-	54.74	56.23	100.00	50	68.88259200
E290475 - Cottle Creek @ Stephenson Pt Rd	2021		1	1	0	0	4	2	0	0	0	0	0	0	0	0	-	Degrading	-	-	69.85	56.96	100.00	50	74.14676971
E290478 - Millstone River @ Biggs Rd	2021		1	1	1	2	5	5	0	0	0	0	0	0	0	0	-	Degrading	-	-	53.22	34.79	100.00	50	61.25026897
E290479 - McGarrigle Ck @ Jingle Pot Rd	2021		1	1	0	0	3	1	0	0	0	0	0	0	0	0	-	-	-	-	70.56	56.92	100.00	100	75.89352123
E290480 - Millstone River @ East Wellington	2021		1	1	1	1	5	3	3	0	0	0	0	0	0	0	-	-	-	-	39.68	35.18	100.00	100	58.40371841
E290481 - Millstone River in Barsby Park	2021		1	1	1	0	5	3	1	0	0	0	0	0	0	1	-	-	-	-	54.30	35.41	100.00	100	63.33691178
E290483 - Chase River @ Aebig	2021		0	1	0	0	3	1	0	0	0	0	0	0	0	0	-	-	-	-	70.55	78.48	100.00	100	83.05619310
E290486 - Cat Stream u/s Chase confluence	2021		0	1	0	0	3	2	0	0	0	0	0	0	0	0	-	-	-	-	70.23	78.47	100.00	100	82.94870996
E290487 - Beck Creek @ Cedar Rd	2021		1	1	0	0	3	1	2	0	0	0	0	0	0	0	-	-	-	-	55.79	56.94	100.00	100	70.99081510
E306256 - Walley Ck d/s Hammond Bay	2021		0	1	0	0	3	1	5	0	0	0	0	0	0	3	-	-	-	-	52.59	78.48	100.00	100	75.59802488
E306257 - Walley Ck @ Morningside Dr	2021		0	1	0	0	4	0	0	0	0	0	0	0	0	0	-	Degrading	-	-	84.40	78.48	100.00	50	85.53080561
E306294 - Millstone River @ Jingle Pot Rd	2021		1	1	1	0	5	3	1	0	0	0	0	0	0	0	-	-	-	-	54.76	35.40	100.00	100	61.11841442

Table A6. Final site scores for sites assessed in 2022. Summaries for individual subcomponent elements are included.

EMS ID	Year	Guideline Value	Exceedances														Trends				Sub-Indices				Site Score
			Summer							Fall															
			Chronic Guideline			Instantaneous Guideline				Chronic Guideline			Instantaneous Guideline												
			Dissolved Oxygen (mg/L)	Temperature (°C)	Temperature (°C)	Dissolved Oxygen (mg/L)	Temperature (°C)	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Temperature (°C)	Dissolved Oxygen (mg/L)	Temperature (°C)	Temperature (°C)	Turbidity (NTU)									
				Chum Salmon	Coho Salmon		Chum Salmon	Coho Salmon			Chum Salmon	Coho Salmon		Chum Salmon	Coho Salmon									
			8	15	17	5	15	17	2	8	15	17	5	15	17	5	Turbidity	Conductivity	Dissolved Oxygen	Temperature	Instantaneous Exceedance Index	Chronic Exceedance Index	General Trend Index	Conductivity Trend Index	
E290469 - Departure Ck @ Neyland Rd	2022	Exceedance Occurrence	0	0	0	0	0	0	0	0	0	0	0	0	0	1	-	-	-	-	85.41	100.00	100.00	100	95.22166447
E290470 - Joseph's Creek off Newton	2022		0	1	0	0	3	1	0	0	0	0	0	0	0	0	Improving	Degrading	-	-	70.56	78.48	93.33	50	79.65099572
E290471 - Departure Ck @ Woodstream Park	2022		0	1	0	0	3	0	0	0	0	0	0	0	0	1	-	-	-	-	70.56	78.48	100.00	100	83.31421983
E290472 - Departure Ck @ outlet	2022		0	1	0	0	3	0	1	0	0	0	0	0	0	1	-	-	-	-	70.24	78.48	100.00	100	83.20896646
E290473 - Cottle Creek @ Nottingham	2022		1	1	0	1	4	1	2	0	0	0	0	0	0	0	-	Degrading	-	-	41.10	56.80	100.00	50	64.99994406
E290475 - Cottle Creek @ Stephenson Pt Rd	2022		1	1	0	0	4	3	0	0	0	0	0	0	0	0	-	Degrading	-	-	69.39	56.94	100.00	50	74.31120229
E290478 - Millstone River @ Biggs Rd	2022		1	1	1	3	4	3	2	1	0	0	0	0	0	0	-	Degrading	Degrading	-	39.49	30.01	66.67	50	45.24559292
E290479 - McGarrigle Ck @ Jingle Pot Rd	2022		0	1	0	0	3	1	0	1	0	0	2	0	0	0	-	-	-	-	55.61	56.70	100.00	100	71.29054927
E290480 - Millstone River @ East Wellington	2022		1	1	1	3	5	3	5	0	0	0	0	0	0	0	-	-	-	-	36.17	35.03	100.00	100	57.82588801
E290481 - Millstone River in Barsby Park	2022		1	1	1	1	5	3	0	0	0	0	0	0	0	0	-	-	-	-	54.31	35.34	100.00	100	63.86783536
E290483 - Chase River @ Aebig	2022		0	1	0	0	3	2	0	0	0	0	0	0	0	1	-	-	Improving	-	55.81	78.47	93.33	100	76.39103762
E290486 - Cat Stream u/s Chase confluence	2022		1	1	0	0	4	3	0	0	0	0	0	0	0	1	-	Degrading	Improving	-	55.12	56.95	66.67	50	59.18187660
E290487 - Beck Creek @ Cedar Rd	2022		0	1	0	0	3	3	3	0	0	0	0	0	0	0	-	-	-	-	54.72	78.46	100.00	100	78.12168770
E306256 - Walley Ck d/s Hammond Bay	2022		1	1	0	1	4	2	4	0	0	0	0	0	0	1	-	-	-	-	39.67	56.85	100.00	100	63.95472124
E306257 - Walley Ck @ Morningside Dr	2022		0	1	0	0	4	0	0	0	0	0	0	0	0	0	-	Degrading	-	-	84.40	78.48	100.00	50	85.69067634
E306294 - Millstone River @ Jingle Pot Rd	2022		1	1	1	1	3	3	4	0	0	0	1	0	0	1	-	-	-	-	38.93	35.34	100.00	100	56.20123196
E306434 - Walley Ck u/s beach	2022		0	1	0	0	4	0	0	0	0	0	0	0	0	0	-	Degrading	-	-	84.45	78.48	100.00	50	85.70821353
E309186 - Cottle Creek d/s Hammond Bay Rd	2022		1	1	0	0	4	3	4	0	0	0	0	0	0	0	Degrading	-	-	-	53.80	56.93	66.67	100	59.55123638

Table A7. Final site scores for sites assessed in 2023. Summaries for individual subcomponent elements are included.

EMS ID	Year		Exceedances														Trends				Sub-Indices				Site Score
			Summer							Fall															
			Chronic Guideline			Instantaneous Guideline				Chronic Guideline			Instantaneous Guideline												
		Guideline Value	Dissolved Oxygen (mg/L)	Temperature (°C)	Temperature (°C)	Dissolved Oxygen (mg/L)	Temperature (°C)	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Temperature (°C)	Dissolved Oxygen (mg/L)	Temperature (°C)	Temperature (°C)	Turbidity (NTU)	Turbidity	Conductivity	Dissolved Oxygen	Temperature	Instantaneous Exceedance Index	Chronic Exceedance Index	General Trend Index	Conductivity Trend Index	
				Chum Salmon	Coho Salmon		Chum Salmon	Coho Salmon			Chum Salmon	Coho Salmon		Chum Salmon	Coho Salmon										
			8	15	17	5	15	17	2	8	15	17	5	15	17	5									
E290469 - Departure Ck @ Neyland Rd	2023	Exceedance Occurrence	0	0	0	0	0	0	0	0	0	0	0	0	0	1	-	-	-	-	85.49	100.00	100.00	100	95.32007253
E290470 - Joseph's Creek off Newton	2023		1	1	0	0	3	1	0	0	0	0	0	0	0	0	-	Degrading	-	-	70.53	56.95	100.00	50	74.99363882
E290471 - Departure Ck @ Woodstream Park	2023		0	1	0	0	3	0	0	0	0	0	0	0	0	0	-	-	-	-	84.93	78.48	100.00	100	88.19673232
E290472 - Departure Ck @ outlet	2023		0	1	0	0	3	1	1	0	0	0	0	0	0	0	-	-	-	-	56.05	78.48	100.00	100	78.87937490
E290473 - Cottle Creek @ Nottingham	2023		1	1	0	3	5	2	3	0	0	0	0	0	0	0	-	Degrading	-	-	38.94	56.51	100.00	50	64.65856187
E290475 - Cottle Creek @ Stephenson Pt Rd	2023		1	1	0	0	5	2	1	0	0	0	0	0	0	0	-	Degrading	-	-	55.17	56.93	100.00	50	70.03177052
E290478 - Millstone River @ Biggs Rd	2023		1	1	1	5	5	3	3	1	0	0	1	0	0	1	Degrading	Degrading	Degrading	-	37.21	29.59	33.33	50	33.91365925
E290479 - McGarrigle Ck @ Jingle Pot Rd	2023		1	1	0	0	3	2	0	0	0	0	0	0	0	0	Degrading	-	-	-	70.23	56.93	93.33	100	74.35474783
E290480 - Millstone River @ East Wellington	2023		1	1	1	2	5	2	5	0	0	0	0	0	0	0	-	-	-	-	38.51	35.22	100.00	100	59.26964329
E290481 - Millstone River in Barsby Park	2023		1	1	1	1	5	3	3	0	0	0	0	0	0	2	Degrading	-	-	-	37.99	35.32	66.67	100	48.38059355
E290483 - Chase River @ Aebig	2023		1	1	0	0	4	2	0	0	0	0	0	0	0	0	-	-	-	-	69.84	56.92	100.00	100	76.37330605
E290486 - Cat Stream u/s Chase confluence	2023		1	1	1	0	5	2	4	0	0	0	0	0	0	2	-	Degrading	-	-	52.40	35.43	100.00	50	62.20379977
E290487 - Beck Creek @ Cedar Rd	2023		1	0	0	1	2	1	4	0	0	0	0	0	0	2	-	-	-	-	34.12	78.09	100.00	100	71.67914077
E306256 - Walley Ck d/s Hammond Bay	2023		1	1	0	4	3	2	3	1	0	0	0	0	0	1	-	-	-	-	38.18	50.74	100.00	100	61.91612019
E306257 - Walley Ck @ Morningside Dr	2023		0	0	0	0	0	0	1	0	0	0	0	0	0	0	-	Degrading	-	-	85.45	100.00	100.00	50	93.58276117
E306294 - Millstone River @ Jingle Pot Rd	2023		1	1	0	3	3	2	5	0	0	0	0	0	0	1	-	-	-	-	38.91	56.63	100.00	100	64.18579111
E306434 - Walley Ck u/s beach	2023		0	0	0	0	1	0	1	0	0	0	0	0	0	0	-	Degrading	-	-	70.72	100.00	100.00	50	88.53387194
E309186 - Cottle Creek d/s Hammond Bay Rd	2023		1	1	0	0	3	2	5	0	0	0	0	0	0	0	Degrading	-	Degrading	-	54.31	56.92	33.33	100	50.69475850

APPENDIX B: Maps

City of Nanaimo

EMS Site Upslope Area Overview

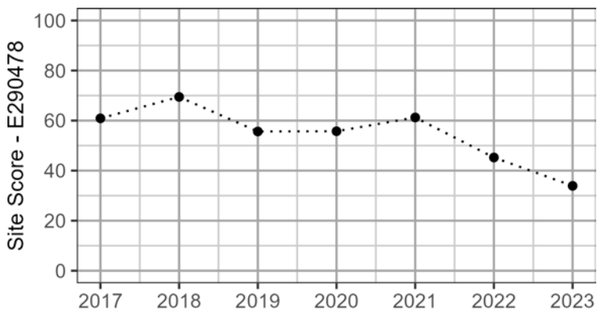
Figure B. E290478 - Millstone Creek at Biggs Rd

Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	Esri, NASA, NGA, USGS, Earthstar Geographics, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

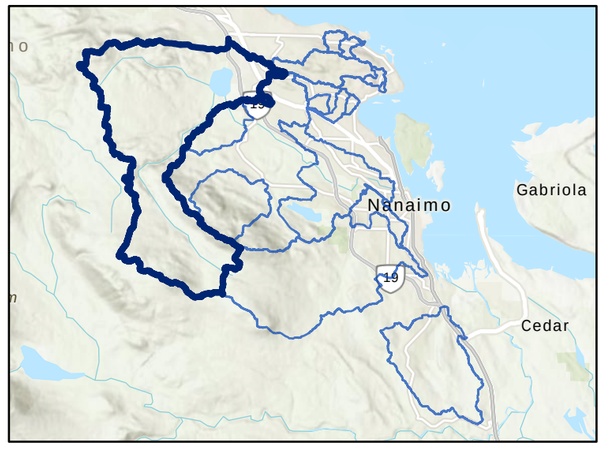
LEGEND

- Focal EMS Site (E290478)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION



DISCLAIMER

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City of Nanaimo

EMS Site Upslope Area Overview

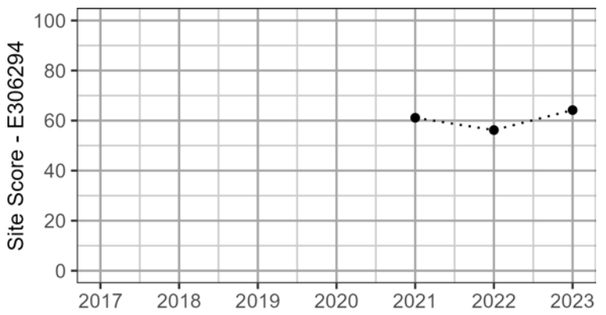
Figure B. E306294 - Millstone River at Jingle Pot Rd

Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	Esri, NASA, NGA, USGS, Earthstar Geographics, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

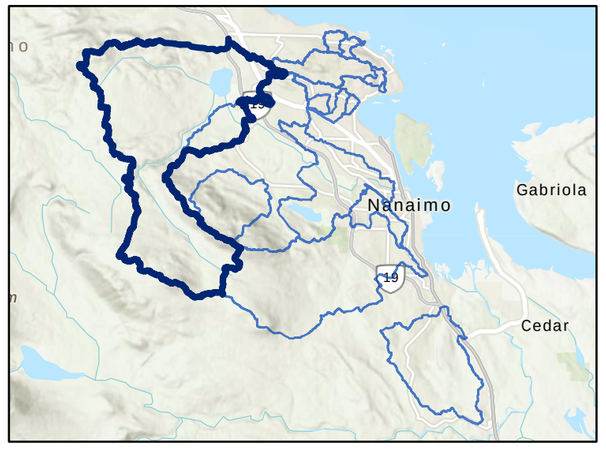
LEGEND

- Focal EMS Site (E306294)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION



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City of Nanaimo

EMS Site Upslope Area Overview

Figure B. E290479 - McGarrigle Creek at Jingle Pot Rd

Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	Esri, NASA, NGA, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community, City of Nanaimo, BC, Maxar

421500 422000 422500 423000 423500 424000 424500 425000 425500

5448000 5447500 5447000 5446500 5446000 5445500 5445000 5444500

N

E290479
McGarrigle Ck @
Jingle Pot Rd

JINGLE RD

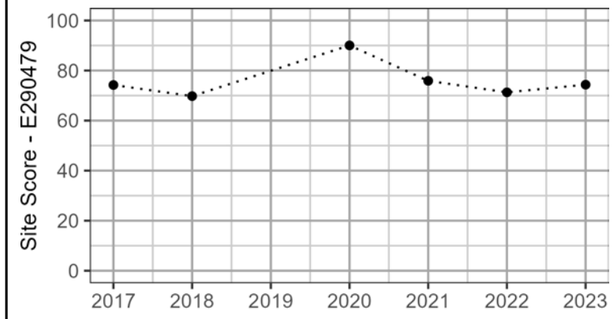
McGarrigle Creek

0 500 1,000
Meters

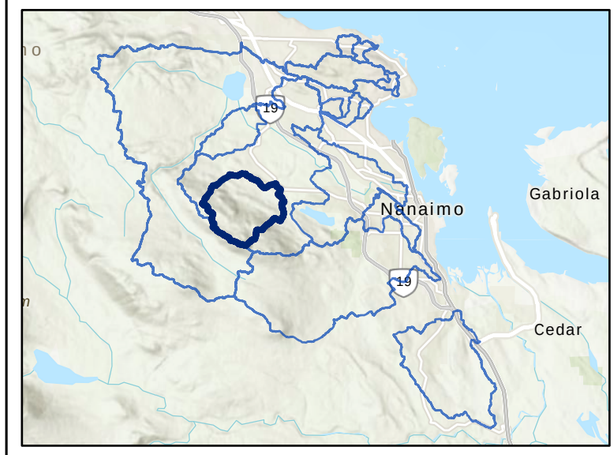
LEGEND

- Focal EMS Site (E290479)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION



DISCLAIMER

City of Nanaimo

EMS Site Upslope Area Overview

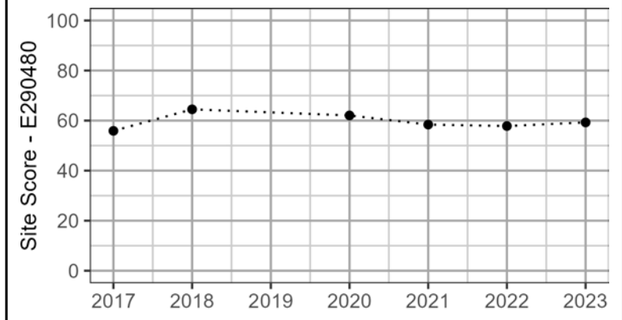
Figure B. E290480 - Millstone River at East Wellington

Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	Esri, NASA, NGA, USGS, City of Nanaimo, BC, Earthstar Geographics, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

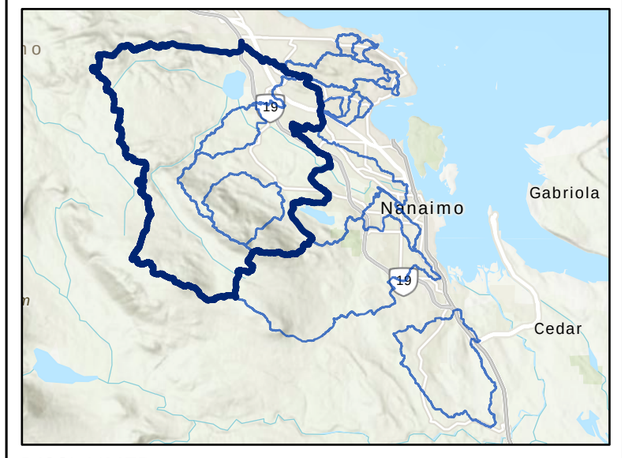
LEGEND

- Focal EMS Site (E290480)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION



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City of Nanaimo

EMS Site Upslope Area Overview

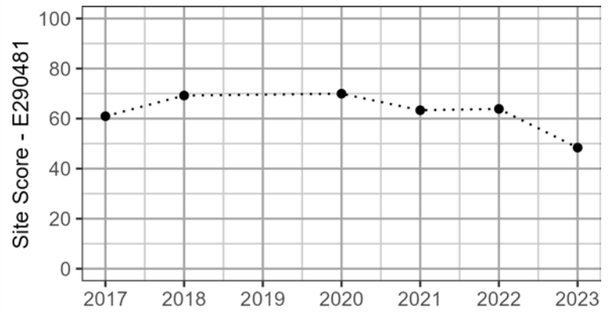
Figure B. E290481 - Millstone River in Barsby Park

Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	Esri, NASA, NGA, USGS, City of Nanaimo, BC, Earthstar Geographics, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

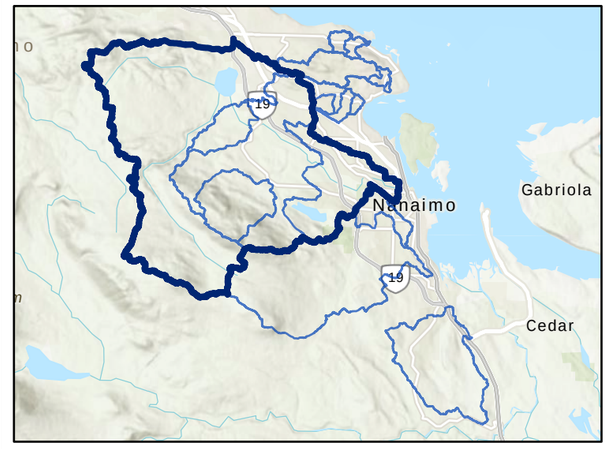
LEGEND

- Focal EMS Site (E290481)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION



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City of Nanaimo

EMS Site Upslope Area Overview

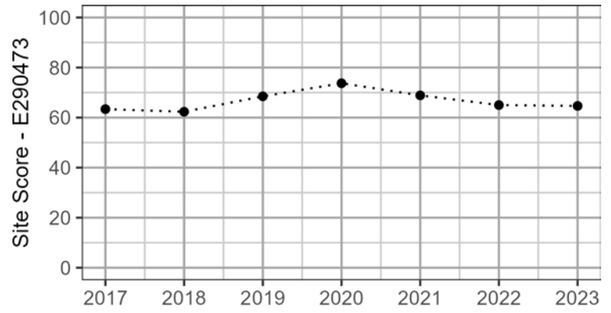
Figure B. E290473 - Cottle Creek at Nottingham

Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	City of Nanaimo, BC, Earthstar Geographics, Esri, CGIAR, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

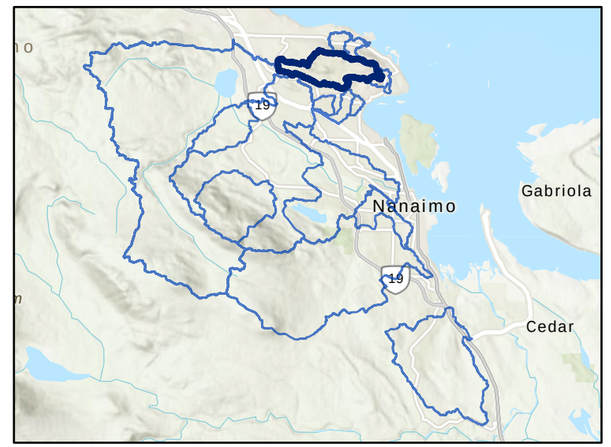
LEGEND

- Focal EMS Site (E290473)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION



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City of Nanaimo

EMS Site Upslope Area Overview

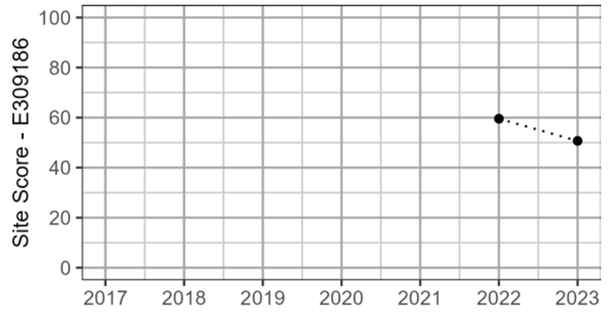
Figure B. E309186 - Cottle Creek d/s Hammond Bay Rd

Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	City of Nanaimo, BC, Earthstar Geographics, Esri, CGIAR, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

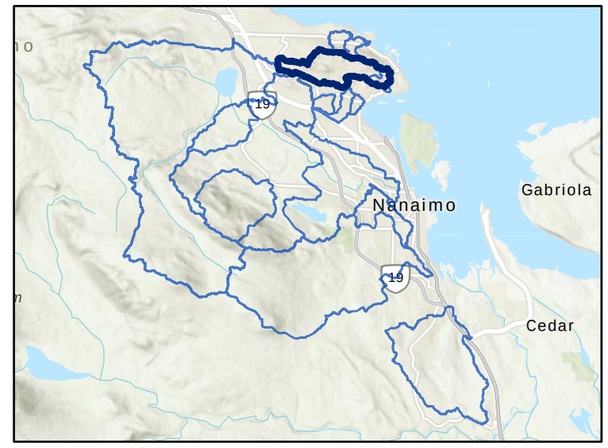
LEGEND

- Focal EMS Site (E309186)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION



DISCLAIMER

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City of Nanaimo

EMS Site Upslope Area Overview

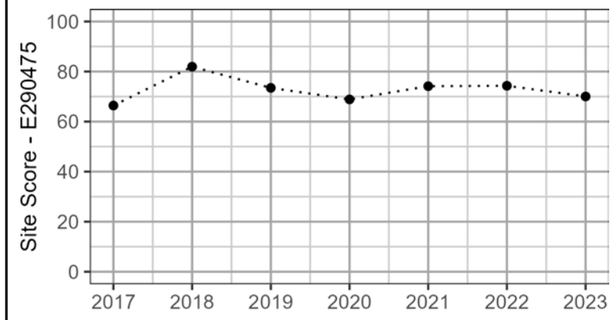
Figure B. E290475 - Cottle Creek at Stephenson Pt Rd

Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	City of Nanaimo, BC, Earthstar Geographics, Esri, CGIAR, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

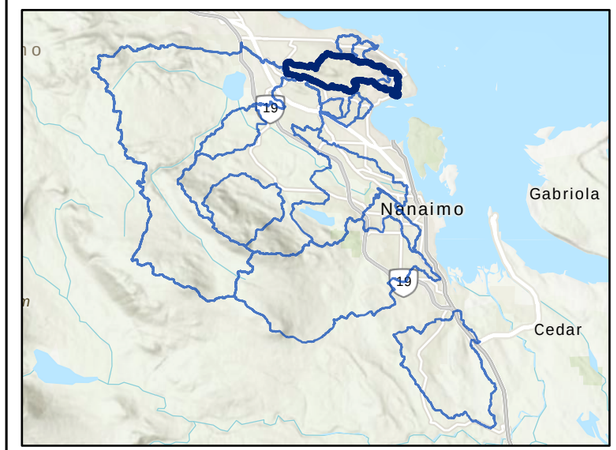
LEGEND

- Focal EMS Site (E290475)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION



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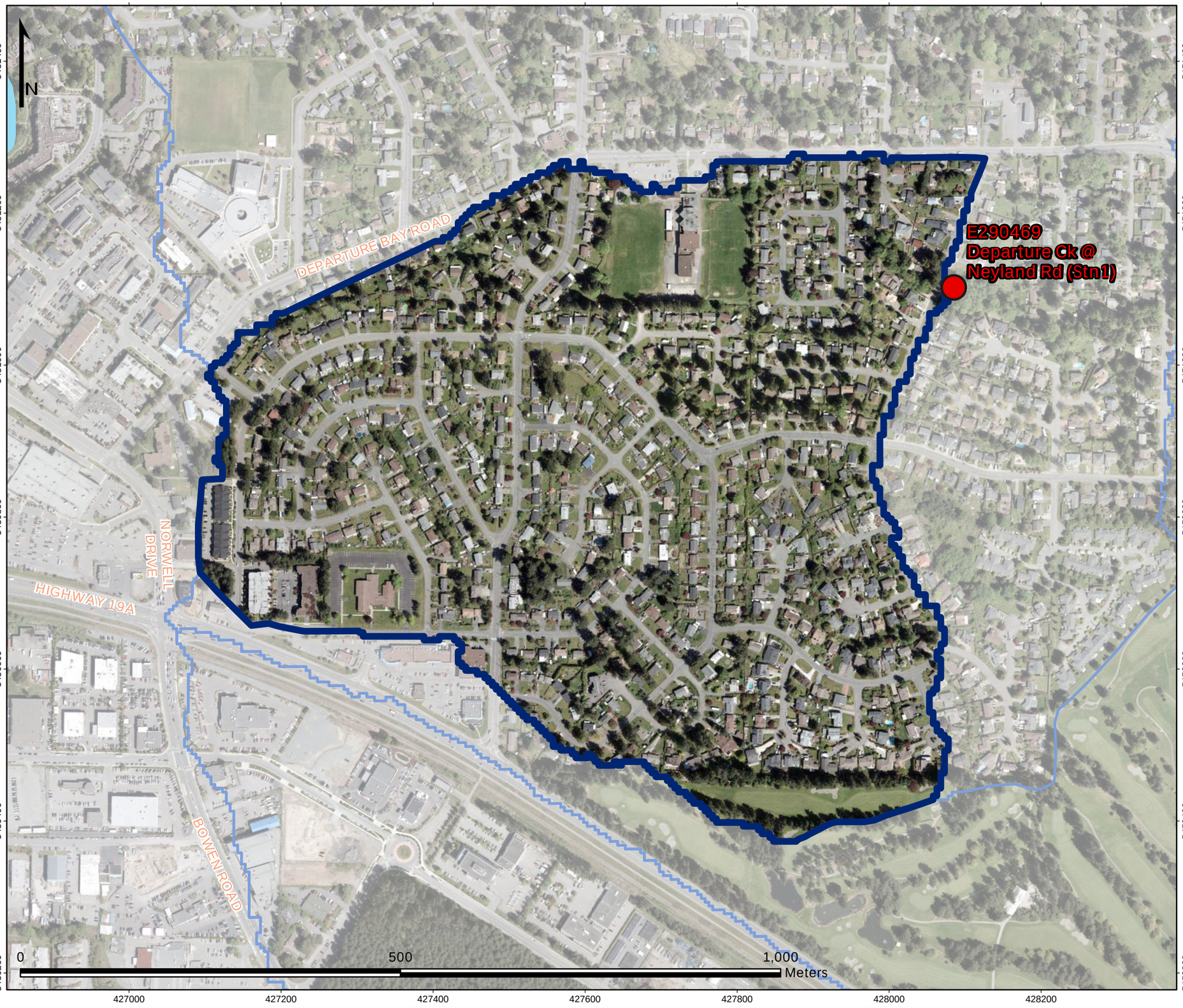
City of Nanaimo

EMS Site Upslope Area Overview

Figure B. E290469 - Departure Creek at Neyland Rd

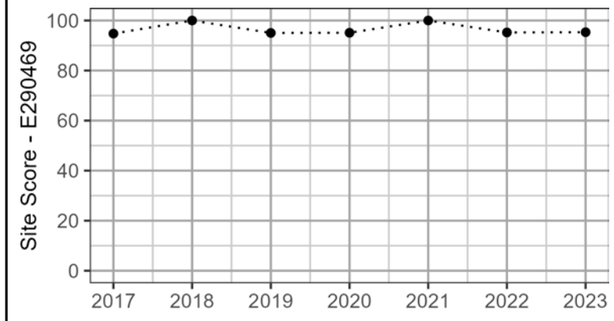
Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	Esri, CGIAR, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community, City of Nanaimo, BC, Maxar



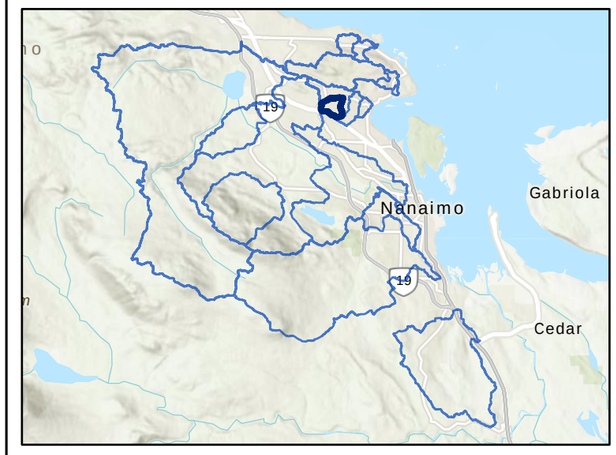
LEGEND

- Focal EMS Site (E290469)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION



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City of Nanaimo

EMS Site Upslope Area Overview

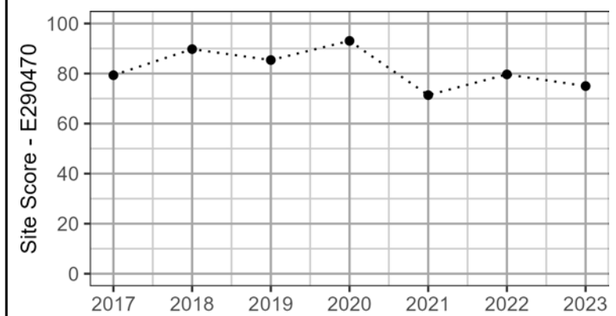
Figure B. E290470 - Departure Creek off Newton St

Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	Esri, CGIAR, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community, City of Nanaimo, BC, Maxar

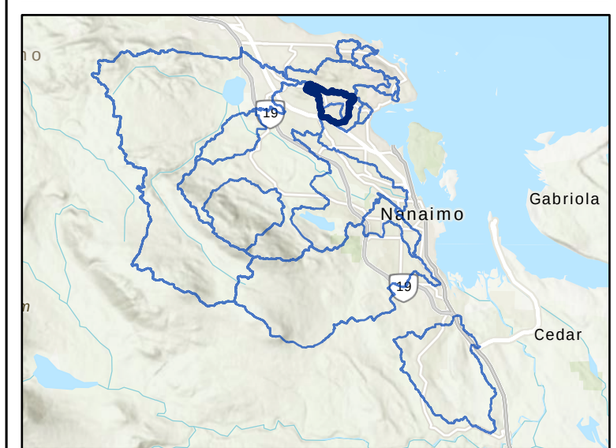
LEGEND

- Focal EMS Site (E290470)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION



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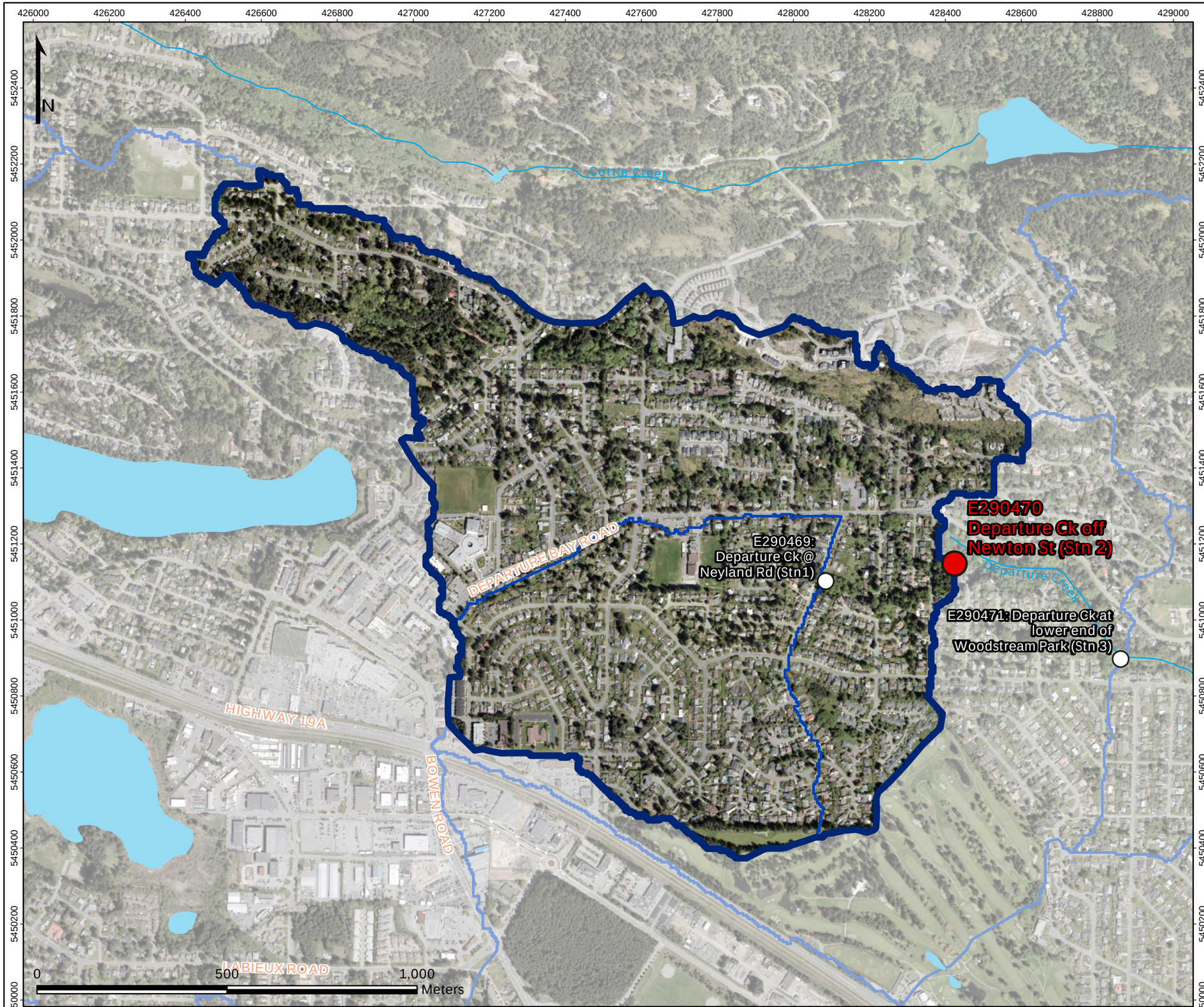


City of Nanaimo

EMS Site Upslope Area Overview

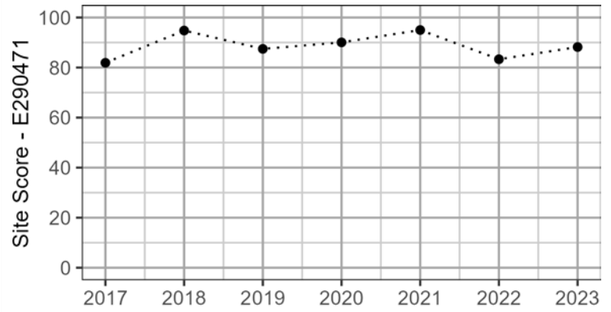
Figure B. E290471 - Departure Creek at Woodstream Park

Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	Esri, CGIAR, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community, City of Nanaimo, BC, Maxar

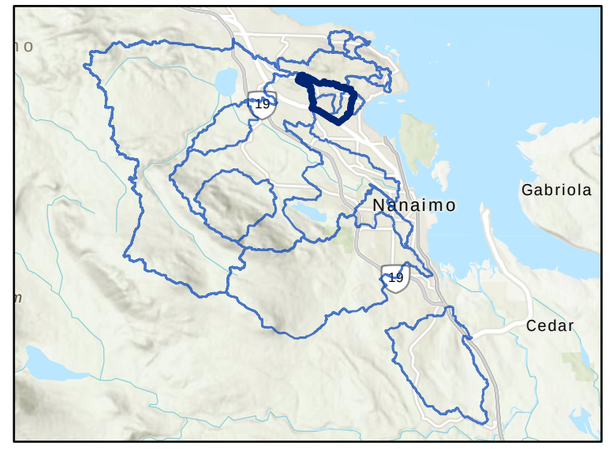
LEGEND

- Focal EMS Site (E290471)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION



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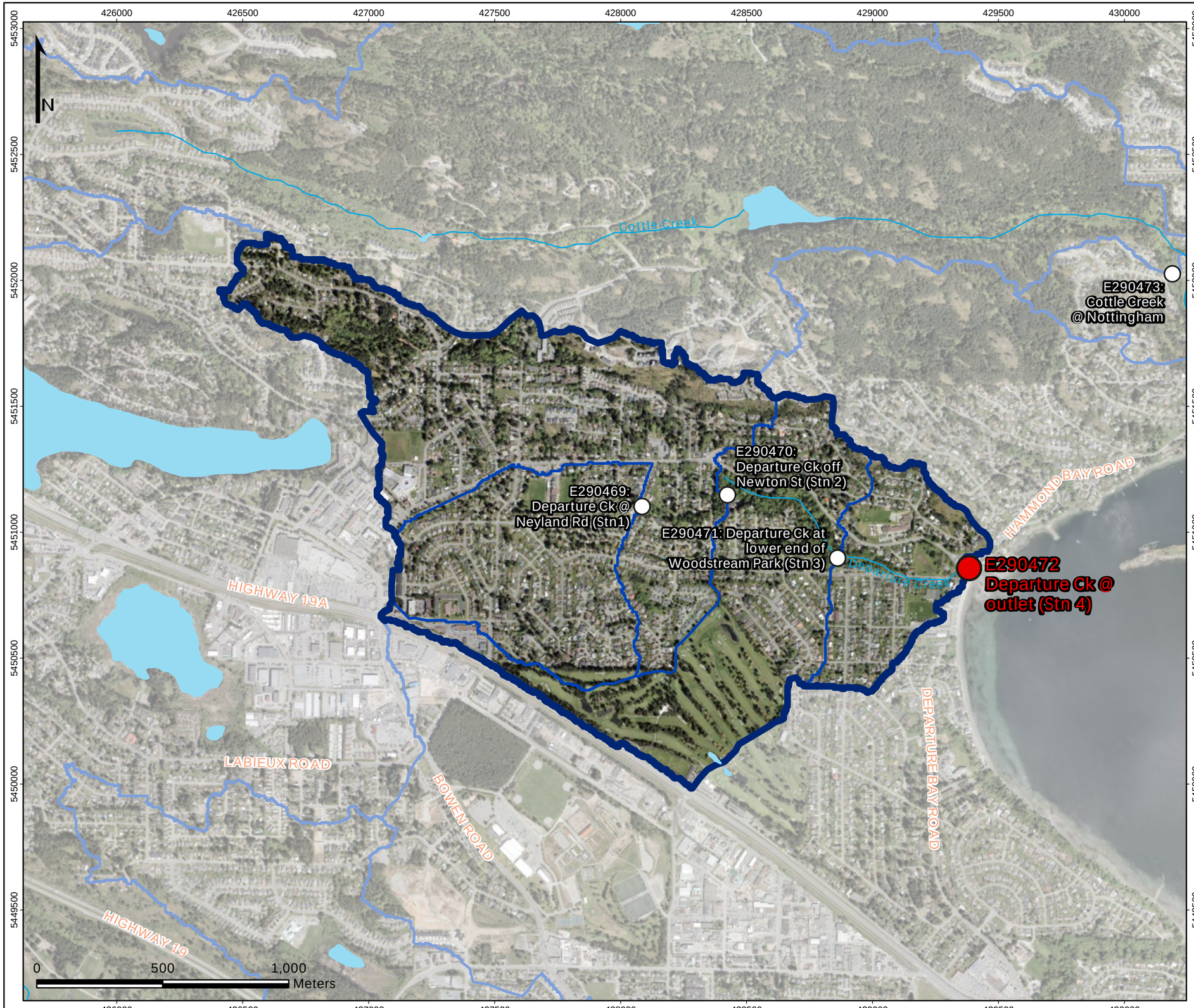
City of Nanaimo

EMS Site Upslope Area Overview

Figure B. E290472 - Departure Creek at outlet

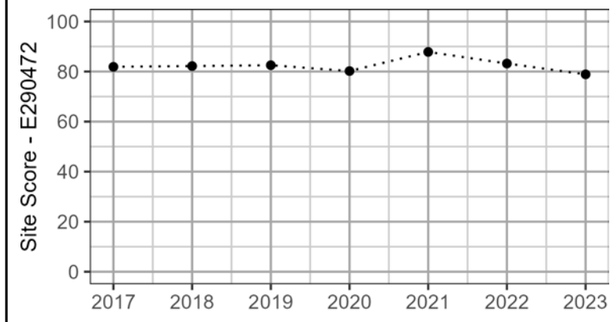
Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	Esri, CGIAR, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community, City of Nanaimo, BC, Maxar



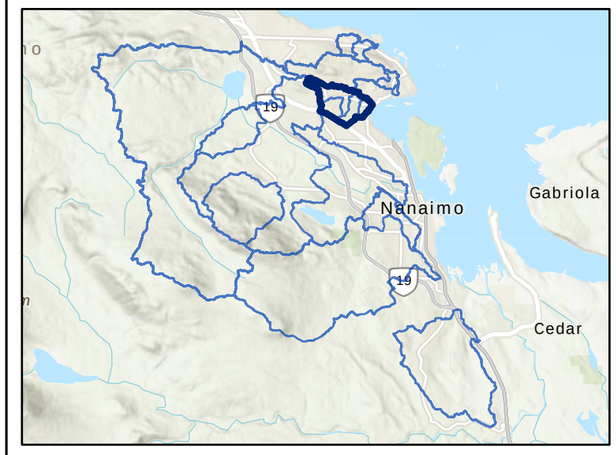
LEGEND

- Focal EMS Site (E290472)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION



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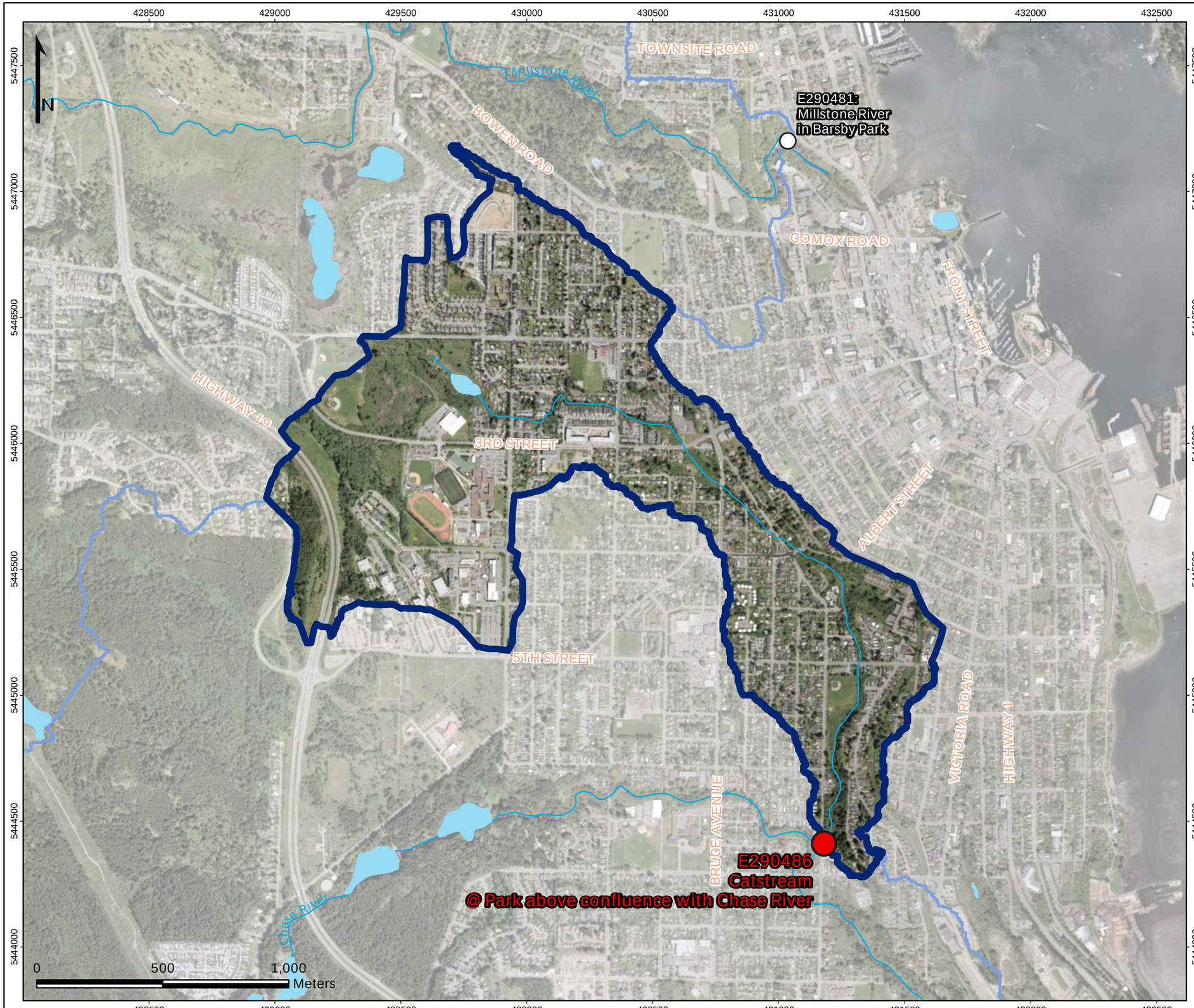
City of Nanaimo

EMS Site Upslope Area Overview

Figure B. E290486 - Cat Stream u/s Chase confluence

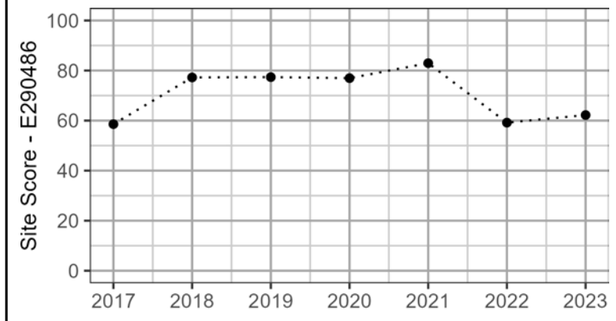
Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	Esri, CGIAR, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community, City of Nanaimo, BC, Maxar



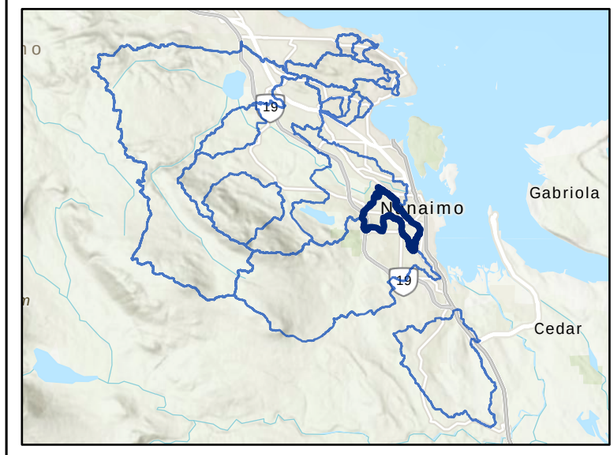
LEGEND

- Focal EMS Site (E290486)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION



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City of Nanaimo

EMS Site Upslope Area Overview

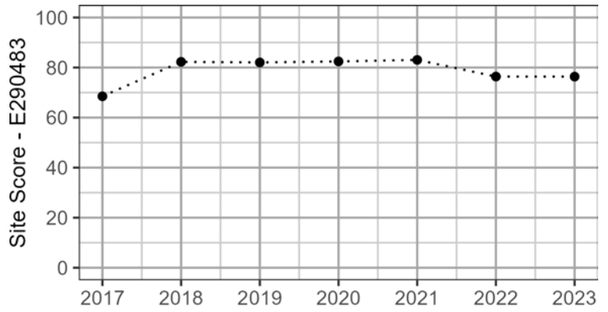
Figure B. E290483 - Chase River at Aebig

Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	City of Nanaimo, BC, Earthstar Geographics, Esri, CGIAR, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

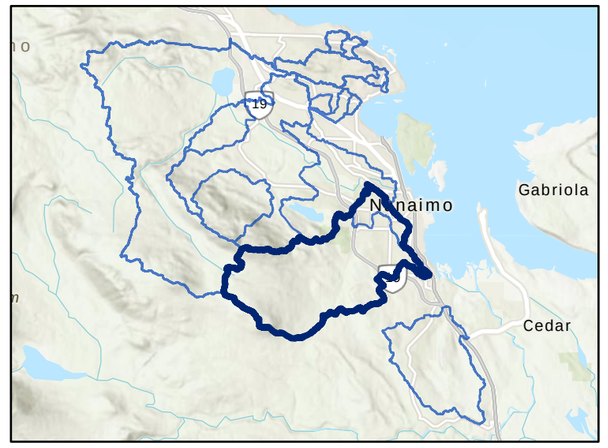
LEGEND

- Focal EMS Site (E290483)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION



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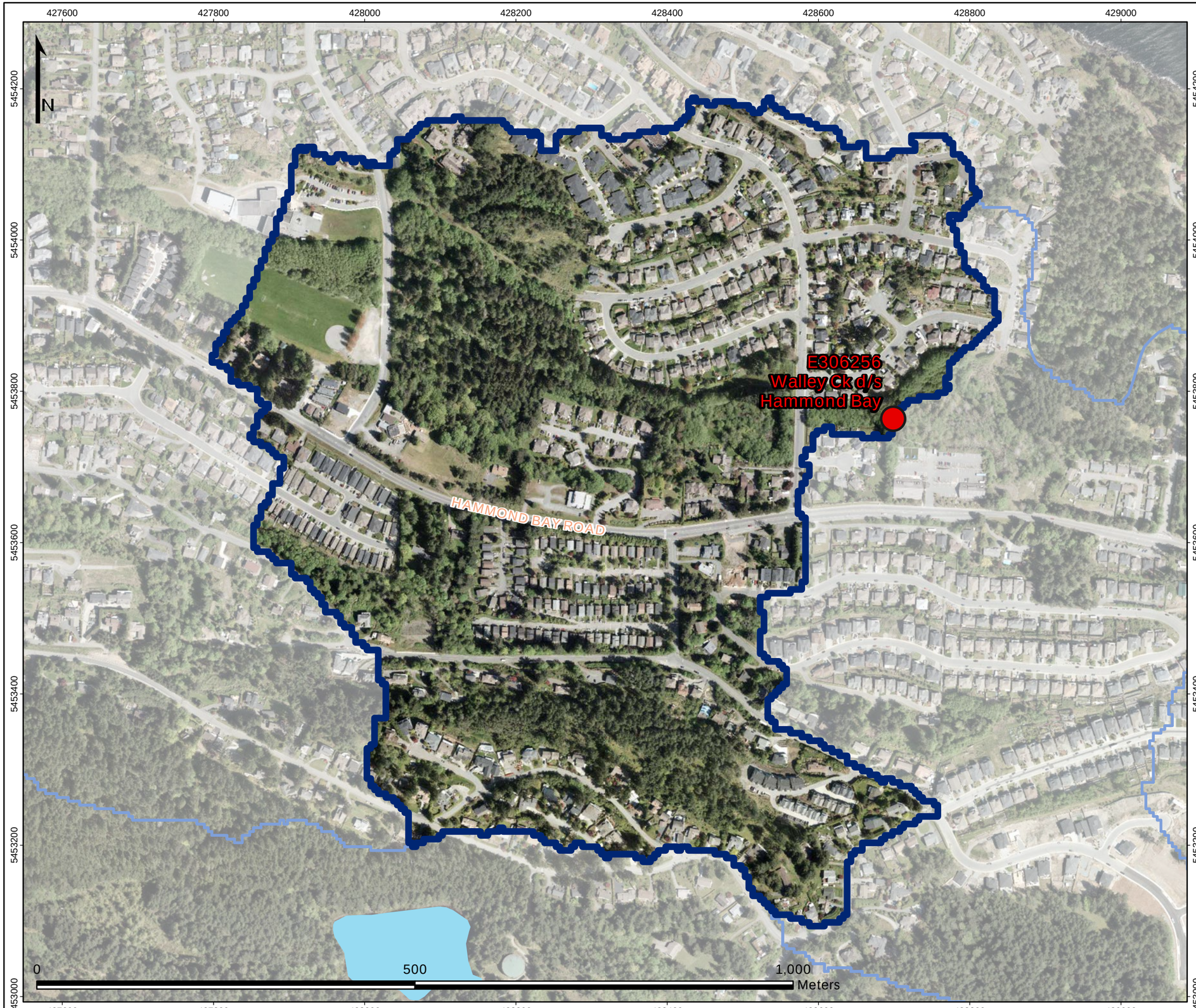
City of Nanaimo

EMS Site Upslope Area Overview

Figure B. E306256 - Walley Creek d/s Hammond Bay

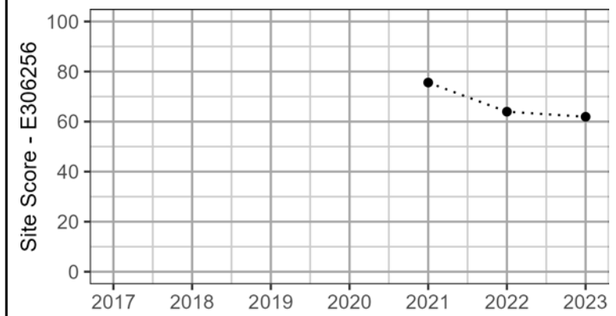
Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	Esri, CGIAR, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community, City of Nanaimo, BC, Maxar



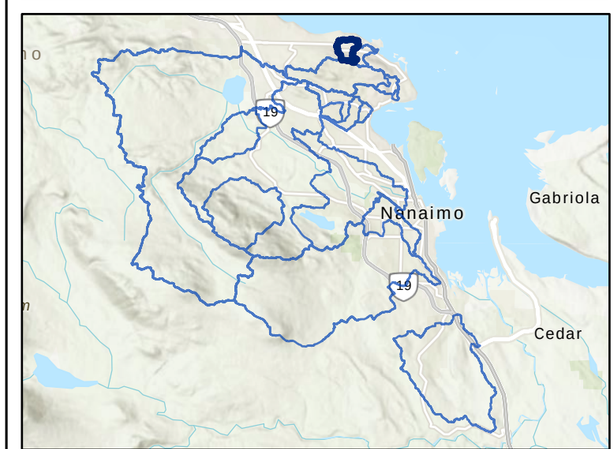
LEGEND

- Focal EMS Site (E306256)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION



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City of Nanaimo

EMS Site Upslope Area Overview

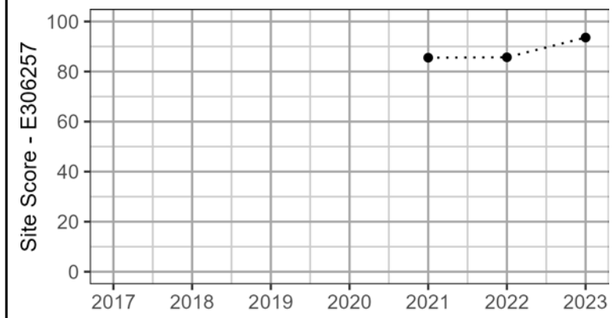
Figure B. E306257 - Walley Creek at Morningside Dr

Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	Esri, CGIAR, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community, City of Nanaimo, BC, Maxar

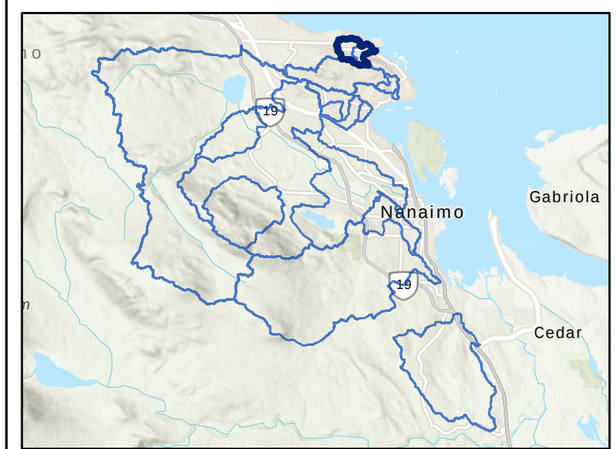
LEGEND

- Focal EMS Site (E306257)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION



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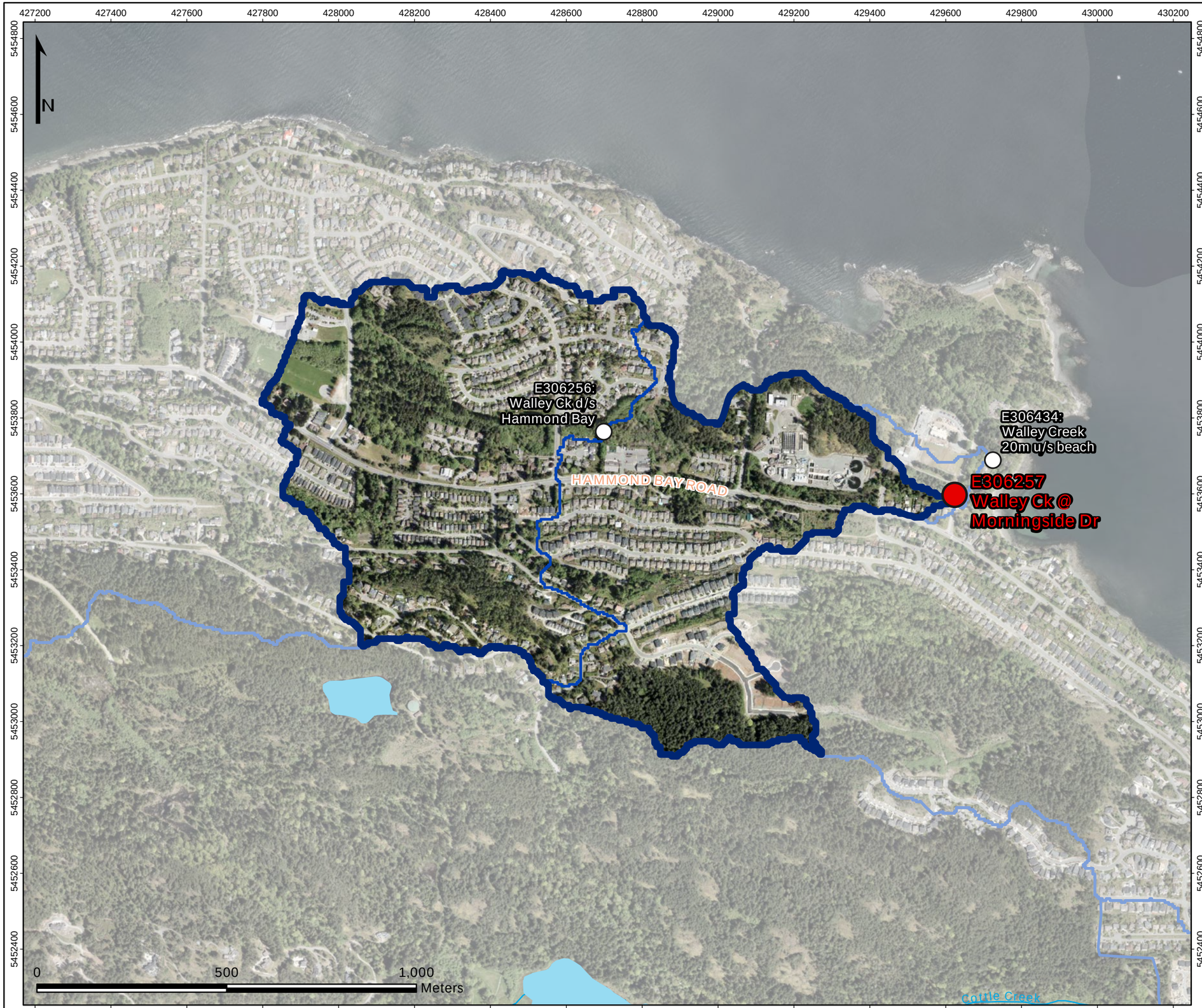


City of Nanaimo

EMS Site Upslope Area Overview

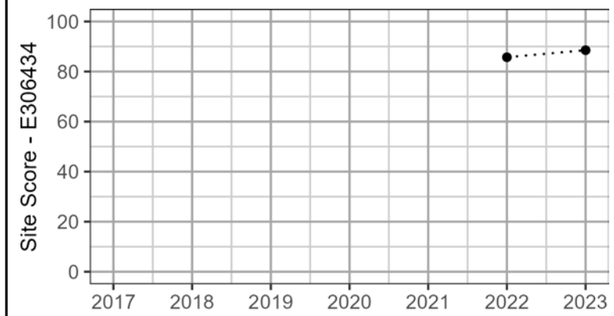
Figure B. E306434 - Walley Creek u/s beach

Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	Esri, CGIAR, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community, City of Nanaimo, BC, Maxar

LEGEND

- Focal EMS Site (E306434)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION

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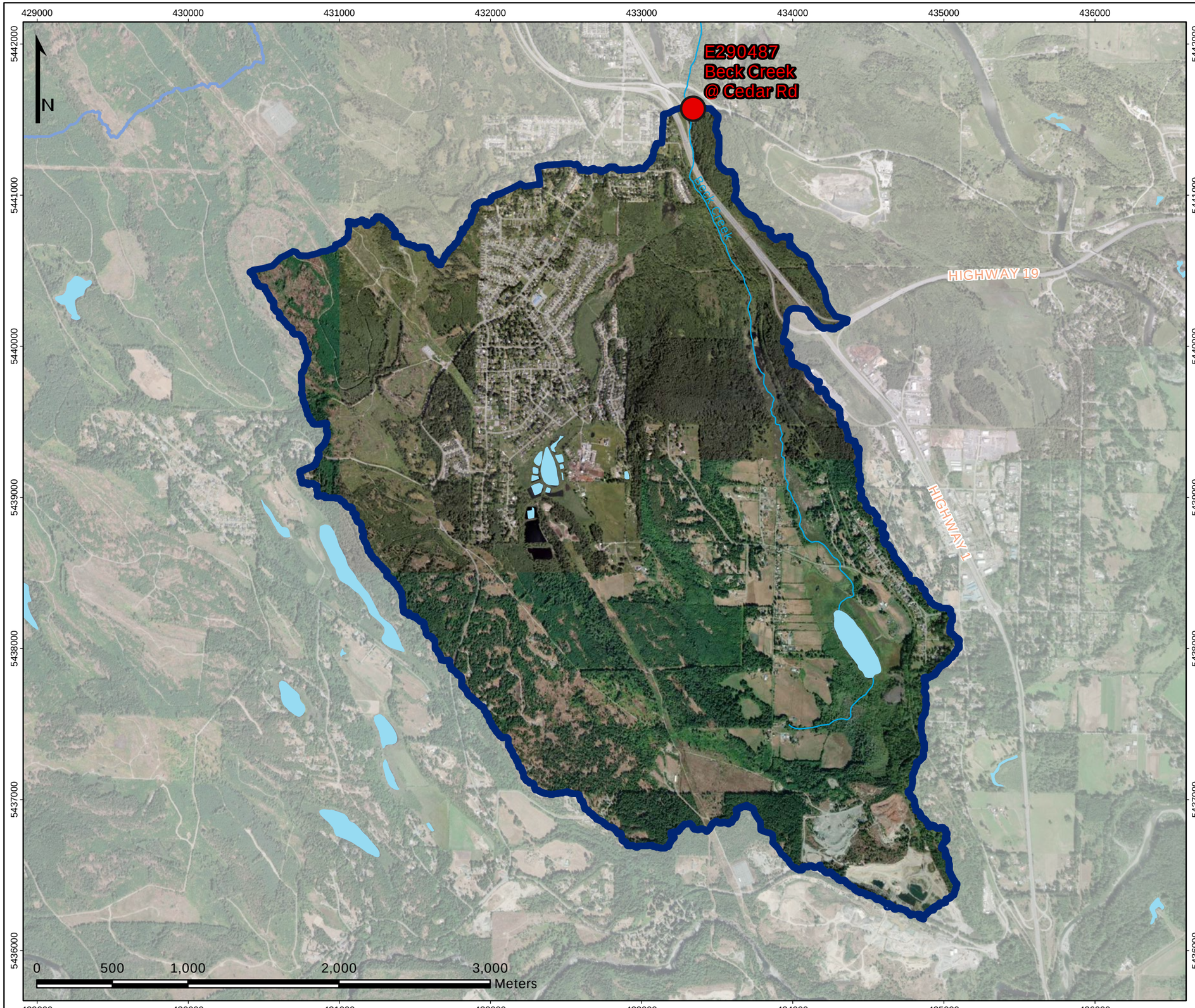
City of Nanaimo

EMS Site Upslope Area Overview

Figure B. E290487 - Beck Creek at Cedar Rd

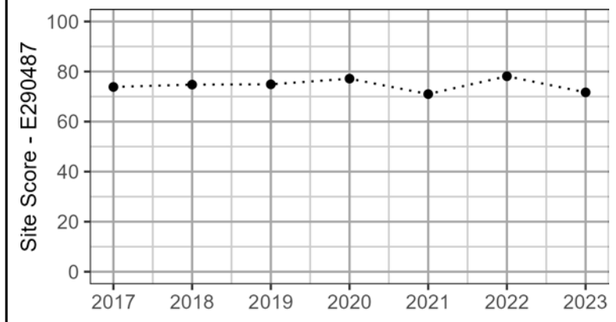
Location:	City of Nanaimo, BC
Project No.:	25-5157
Prepared for:	Sustainability Section Planning and Development City of Nanaimo
Prepared by:	Ecoscape Environmental Consultants Ltd.
Coordinate System:	NAD83-UTM Zone 10
Imagery:	Earthstar Geographics, Esri, CGIAR, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community



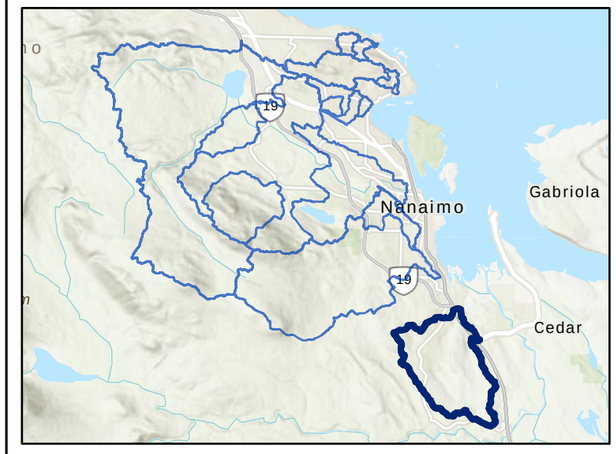
LEGEND

- Focal EMS Site (E290487)
- EMS Site
- Freshwater Atlas Stream
- Highway
- Freshwater Atlas Lake
- Focal Drainage Basin
- Drainage Basin

SAMPLE SITE SCORE HISTORY



SAMPLE SITE REGIONAL LOCATION



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APPENDIX C: Worked Example

This appendix details a worked example of Equation 8 for a single site. It is intended to demonstrate the process of using site data for a given year to calculate all individual sub-indices, determine weights, and compute the final site score. This worked example steps through the rubric evaluation for E309186 (Cottle Creek d/s Hammond Bay Rd) in 2023. See Table C1 for the measured results for that site in 2023.

Table C1. Measured values for E309186 (Cottle Creek d/s Hammond Bay Rd) in 2023.

EMS ID	Season	Date	Parameter	Unit	Result
E309186	Summer	2023-08-08	Dissolved Oxygen	mg/L	7.1
			Specific Conductance	µS/cm	261.8
			Temperature	°C	17.7
			Turbidity	NTU	2.6
		2023-08-15	Dissolved Oxygen	mg/L	6.6
			Specific Conductance	µS/cm	263.3
			Temperature	°C	18.9
			Turbidity	NTU	2.5
		2023-08-22	Dissolved Oxygen	mg/L	8.0
			Specific Conductance	µS/cm	271.6
			Temperature	°C	14.9
			Turbidity	NTU	2.1
		2023-08-29	Dissolved Oxygen	mg/L	7.7
			Specific Conductance	µS/cm	248.1
			Temperature	°C	16.4
			Turbidity	NTU	2.2
		2023-09-05	Dissolved Oxygen	mg/L	7.0
			Specific Conductance	µS/cm	269.2
			Temperature	°C	14.9
			Turbidity	NTU	2.2
	Fall	2023-10-03	Dissolved Oxygen	mg/L	9.6
			Specific Conductance	µS/cm	154.8
			Temperature	°C	12.2
			Turbidity	NTU	1.4
		2023-10-10	Dissolved Oxygen	mg/L	8.8
			Specific Conductance	µS/cm	157.8
			Temperature	°C	12.5
			Turbidity	NTU	1.6
		2023-10-17	Dissolved Oxygen	mg/L	10.1
			Specific Conductance	µS/cm	200.4
			Temperature	°C	11.5
			Turbidity	NTU	0.9
		2023-10-24	Dissolved Oxygen	mg/L	10.2
			Specific Conductance	µS/cm	193.2
			Temperature	°C	9.1
			Turbidity	NTU	2.3
		2023-10-31	Dissolved Oxygen	mg/L	12.1
			Specific Conductance	µS/cm	150.7
			Temperature	°C	5.5
			Turbidity	NTU	1.2

Step 1: Compute Instantaneous Guideline Site Score

a) Identify all instantaneous guideline exceedances for the year. See Table C2 for the exceeded instantaneous guidelines for E309186 in 2023. There were ten instances where a guideline was exceeded; guidelines for temperature and for turbidity were exceeded.

Table C2. Instantaneous exceeding values for E309186 (Cottle Creek d/s Hammond Bay Rd) in 2023.

Season	Parameter	Unit	Date	Guideline Description	Guideline Value	Result
Summer	Temperature	°C	2023-08-08	Aquatic Life Guideline for Chum Rearing	15	17.70
			2023-08-08	Aquatic Life Guideline for Coho Rearing	17	17.70
	Turbidity	NTU	2023-08-08	Jan-Sept Max	2	2.62
	Temperature	°C	2023-08-15	Aquatic Life Guideline for Chum Rearing	15	18.90
			2023-08-15	Aquatic Life Guideline for Coho Rearing	17	18.90
	Turbidity	NTU	2023-08-15	Jan-Sept Max	2	2.49
			2023-08-22	Jan-Sept Max	2	2.10
	Temperature	°C	2023-08-29	Aquatic Life Guideline for Chum Rearing	15	16.40
	Turbidity	NTU	2023-08-29	Jan-Sept Max	2	2.23
			2023-09-05	Jan-Sept Max	2	2.23

b) Compute scope. Scope in this rubric is the number of unique guidelines with a failed exceedance divided by the total number of guidelines, multiplied by 100 (see Equation 1). In this case, three unique guidelines were associated with an exceedance: the aquatic life guidelines for temperature (for coho rearing and for chum rearing) and the guideline for turbidity. There were four possible instantaneous guidelines (one for turbidity, one for dissolved oxygen, and two for temperature), so the instantaneous scope in this example is calculated as follows:

$$Scope = \left(\frac{3}{4}\right) \times 100 = 75$$

c) Compute frequency. Frequency in this rubric is the count of instances when a guideline was exceeded divided by the total number of comparisons to a guideline, multiplied by 100 (see Equation 2). In this case, measured values exceeded a guideline ten times. There were a total of 40 comparisons made:

- 10 dissolved oxygen measurements compared to the DO guideline
- 10 turbidity measurements compared to the turbidity guideline
- 10 temperature measurements compared to two temperature guidelines

Accordingly, the frequency in this example is calculated as follows:

$$Frequency = \left(\frac{10}{40}\right) \times 100 = 25$$

d) Compute amplitude. Amplitude in this rubric is based on the magnitude of individual exceedances scaled to the number of guidelines assessed (see Equations 3a, 3b, 4, and 5).

1. First, compute the excursions. Since the temperature guidelines in this example are upper limits, the excursion values are computed using Equation 3a. For example, on

2023-08-08, the measured temperature value was 16.5 °C. The excursion for that value relative to the guideline value of 15 °C is computed as follows:

$$excursion_i = \left(\frac{17.7}{15}\right) - 1 = 0.180$$

See Table C3 for the computed excursions for all ten exceedances at site E309186 in 2023.

Table C3. Instantaneous excursion values for E309186 (Cottle Creek d/s Hammond Bay Rd) in 2023.

Season	Parameter	Unit	Date	Guideline Description	Guideline Value	Result	Excursion
Summer	Temperature	°C	2023-08-	Aquatic Life Guideline for Chum	15	17.70	0.180
			2023-08-	Aquatic Life Guideline for Coho	17	17.70	0.041
	Turbidity	NTU	2023-08-	Jan-Sept Max	2	2.62	0.310
	Temperature	°C	2023-08-	Aquatic Life Guideline for Chum	15	18.90	0.260
			2023-08-	Aquatic Life Guideline for Coho	17	18.90	0.112
	Turbidity	NTU	2023-08-	Jan-Sept Max	2	2.49	0.245
			2023-08-	Jan-Sept Max	2	2.10	0.050
	Temperature	°C	2023-08-	Aquatic Life Guideline for Chum	15	16.40	0.093
	Turbidity	NTU	2023-08-	Jan-Sept Max	2	2.23	0.115
			2023-09-	Jan-Sept Max	2	2.23	0.115

2. Sum the excursions and normalize relative to the to the number of comparisons made (Equation 4)

$$nse = \frac{\sum_u^n excursion_i}{number\ of\ tests} = \frac{(0.180 + 0.041 + \cdots + 0.115 + 0.115)}{40} = 0.038$$

3. Scale the normalized sum of the excursions (Equation 5) to obtain the amplitude

$$Amplitude = \left(\frac{nse}{0.01(nse) + 0.01}\right) = \frac{0.038}{0.01 \times 0.038 + 0.01} = 3.66$$

e) Compute the overall instantaneous score (Equation 6)

$$Instantaneous\ Site\ Score = 100 - \left(\frac{\sqrt{Scope^2 + Frequency^2 + Amplitude^2}}{1.732}\right)$$

$$Instantaneous\ Site\ Score = 100 - \left(\frac{\sqrt{75^2 + 25^2 + 3.66^2}}{1.732}\right) = 54.31 \quad (6)$$

Step 2: Compute Chronic Guideline Site Score

a) Determine the average value for each parameter for which there is an applicable chronic guideline. See Table C4 for the average value in summer and fall for dissolved oxygen and temperature at E309186 in 2023.

Table C4. Average values for E309186 (Cottle Creek d/s Hammond Bay Rd) in 2023 for parameters with chronic guidelines.			
Season	Parameter	Unit	Mean Value
Summer	Dissolved Oxygen	mg/L	7.3
	Temperature	°C	16.6
Fall	Dissolved Oxygen	mg/L	10.1
	Temperature	°C	10.2

b) Identify the instances where these averaged values exceed a chronic guideline. See Table C5 for the averaged values that exceeded an applicable parameter.

Table C5. Averaged values for E309186 (Cottle Creek d/s Hammond Bay Rd) in 2023 that exceeded a guideline.					
Season	Parameter	Unit	Guideline Description	Guideline Value	Mean Value
Summer	Dissolved Oxygen	mg/L	30 Day Average	8	7.286
	Temperature	°C	Aquatic Life Guideline for Chum Rearing	15	16.560

c) Compute scope. Scope in this rubric is the number of unique guidelines with a failed exceedance divided by the total number of guidelines, multiplied by 100 (see Equation 1). In this case, two unique guidelines were associated with an exceedance: the temperature guideline associated with chum rearing, and the 30-day average for dissolved oxygen. There were three possible guidelines (one for dissolved oxygen, two for temperature), so the chronic scope in this example is calculated as follows:

$$Scope = \left(\frac{2}{3}\right) \times 100 = 66.\bar{6}$$

d) Compute frequency. Frequency in this rubric is the count of instances when a guideline was exceeded divided by the total number of comparisons to a guideline, multiplied by 100 (see Equation 2). In this case, measured values exceeded a guideline two times. There were a total of 6 comparisons made:

- 2 dissolved oxygen measurements compared to the DO guideline
- 2 temperature measurements compared to two temperature guidelines

Accordingly, the frequency in this example is calculated as follows:

$$Frequency = \left(\frac{2}{6}\right) \times 100 = 33.\bar{3}$$

e) Compute amplitude. Amplitude in this rubric is based on the magnitude of individual exceedances scaled to the number of guidelines assessed (see Equations 3a, 3b, 4, and 5).

4. First, compute the excursions. The dissolved oxygen guideline in this example are lower limits, so the excursion values are computed using Equation 3b. The average measured dissolved oxygen value in the summer at E309186 was 7.286 mg/L. The excursion for that value relative to the minimum guideline value of 8 mg/L is computed as follows:

$$excursion_i = \left(\frac{8}{7.286}\right) - 1 = 0.098$$

See table C6 for the computed excursions for the two exceedances at site E309186 in 2023.

Table C6. Chronic excursion values for E309186 (Cottle Creek d/s Hammond Bay Rd) in 2023.

Season	Parameter	Unit	Guideline Description	Guideline Value	Mean Value	Excursion
Summer	Dissolved	mg/L	30 Day Average	8	7.286	0.098
	Temperature	°C	Aquatic Life Guideline for Chum	15	16.560	0.104

5. Sum the excursions and normalize relative to the to the number of comparisons made (Equation 4)

$$nse = \frac{\sum_u^n excursion_i}{number\ of\ tests} = \frac{(0.098 + 0.104)}{6} = 0.034$$

6. Scale the normalized sum of the excursions (Equation 5) to obtain the amplitude

$$Amplitude = \left(\frac{nse}{0.01(nse) + 0.01}\right) = \frac{0.034}{0.01 \times 0.034 + 0.01} = 3.26$$

f) Compute the overall chronic score (Equation 6)

$$Chronic\ Site\ Score = 100 - \left(\frac{\sqrt{Scope^2 + Frequency^2 + Amplitude^2}}{1.732}\right)$$

$$Chronic\ Site\ Score = 100 - \left(\frac{\sqrt{66.\overline{6}^2 + 33.\overline{3}^2 + 3.26^2}}{1.732}\right) = 56.92$$

Step 3. Compute guideline trend score

a) Identify parameters with associated guidelines that also have guidelines trending in a degrading direction. In the example of E309186 in 2023, there were two parameters with guidelines (instantaneous or chronic) that also had degrading trends; both turbidity and dissolved oxygen trends indicated a degrading state. In addition, there were exceedances identified for both of those parameters in 2023, so additional weighting (called compliance weight here, see Equation 7) is associated with those trends to further penalize the degrading trend. The guideline trend score is computed as per Equation 7. In the example below, the sum of the two degrading trends is multiplied by their compliance weights (in the numerator) and divided by the total number of parameters with guidelines multiplied by the maximum weight (in the denominator):

$$Guideline\ Trend\ Score = 100\left(1 - \left(\frac{\sum(Degrading\ Trend_i \times Compliance\ Weight_i)}{5 \times (Number\ of\ Parameters)}\right)\right)$$

$$Guideline\ Trend\ Score = 100\left(1 - \left(\frac{5 \times 1 + 5 \times 1}{5 \times 3)}\right)\right) = 33.\overline{3}$$

Step 4. Compute specific conductivity score

a) In this example, there was no trend identified in conductivity at E309186 in 2023. There is therefore no deduction due to degrading conductivity and the base conductivity trend score of 100 is maintained.

Step 5. Compute overall site score

a) Determine the time series length to scale the trend scores according to the length of data available. In 2023, there were 7 total years for E309186. The maximum number of years across all sites was 12, so the time series length scale for E309186 is scaled (see section 2.4.3.1) as below:

1 - ((12 - 7) / 12 / 2)

$$Time\ Series\ Length\ Scale = 1 - \frac{\left(\frac{(12-7)}{12}\right)}{2} = 0.792$$

b) Compute the Site Score according to Equation 8

$$Site\ Score = 100 \times \left(\frac{\left(\begin{matrix}Instantaneous\\Guideline\\Score\end{matrix}\right) + \left(\begin{matrix}Chronic\\Guideline\\Score\end{matrix}\right) + \left(\begin{matrix}Time\\Series\\Length\\Scale\end{matrix} \times \begin{matrix}Guideline\\Trend\\Score\end{matrix}\right) + \left(\frac{\begin{matrix}Time\\Series\\Length\\Scale\end{matrix} \times \begin{matrix}Conductivity\\Trend\\Score\end{matrix}}{10}\right)}{Scale\ Adjusted\ Maximum\ Score}\right)$$

$$Site\ Score = 100 \times \left(\frac{(54.31) + (56.92) + \left(0.792 \times 33.\overline{3}\right) + \left(\frac{0.792 \times 100}{10}\right)}{100 + 100 + (0.729 \times 100) + \left(\frac{0.792 \times 100}{10}\right)} \right)$$

$$Site\ Score = 100 \times \left(\frac{145.55}{287.08}\right)$$

$$Site\ Score = 50.70$$

The final site score in 2023 for E309186 (Cottle Creek d/s Hammond Bay Rd) is 50.70.