REPORT

Regional District of North Okanagan

North Kalamalka Lake Vulnerability Mapping

February 2018

ISO 9001 and 14001 Certified | An Associated Engineering Company

Table of Contents

List of Tables

List of Figures

PAGE NO.

1 Introduction

1.1 BACKGROUND

Kalamalka Lake is one of the main sources of drinking water for the Greater Vernon area, along with Duteau Creek. Kalamalka Lake is used extensively for recreation, and the surrounding watershed is used for residential, commercial, agricultural, forestry, waste management, transportation, institutional, and other land uses. As part of the multiple-barrier approach to drinking water management, Greater Vernon Water (GVW) commissioned the North Kalamalka Lake Intake Assessment in 2011, and followed up with the North Kalamalka Lake Assessment Response Plan in 2017. This process was guided by a stakeholder advisory process with input from the Interior Health Authority. To further improve its ability to manage drinking water risks, GVW decided to develop a watershed vulnerability map to better manage watershed activities that present a drinking water hazard, and communicate risk to stakeholders and the broader community.

In fall 2017, the Regional District of North Okanagan (RDNO) retained Associated Environmental Consultants Inc. (Associated) to complete the North Kalamalka Lake vulnerability mapping. The mapping was completed for the project area shown in **Figure 1-1** (hereafter the “project area”). This draft report outlines the general approach and methods of the mapping process and describes the results that are shown on Map 1 (Watershed Vulnerability) and Map 2 (Water Quality Hazards), provided in Appendix A.

1.2 PROJECT OBJECTIVE

The overall objective of the vulnerability mapping was to identify areas within the North Kalamalka watershed where land use activities or natural events could impact the quantity and/or quality of the GVW water supply. Specific tasks to meet this overall objective were to:

1. Assemble and review relevant background reports, maps, and other materials;

2. Review similar source protection plans for lake-based drinking water sources in Canada and elsewhere;
3. In consultation with GVW staff, develop a vulnerability rating system for the North Kalamalka watershed, customized to the unique attributes of the lake, watershed, and drinking water treatment system;
4. Using the agreed-upon vulnerability rating system, develop the project-specific Geographic Information System (GIS) leading to the preparation of the draft watershed vulnerability map that classifies the watershed into qualitative categories (i.e., low, moderate, high, and very high vulnerability);
5. Using public information, identify and map existing drinking water hazards in the watershed;
6. Prepare the draft vulnerability and hazard maps and a draft technical report that describes the methodology and summarizes the outcomes of the mapping process; and
7. Finalize the maps and report based on comments from GVW staff and the Kalamalka Stakeholder Technical Advisory Committee (STAC).

Figure 1-1
North Kalamalka Lake Vulnerability Project Area

2 General Approach and Methods

2.1 APPROACH TO VULNERABILITY MAPPING

When planning for protection of surface water supplies, **vulnerability** is conventionally considered an intrinsic measure of how easily a surface water source can be contaminated from activities within the contributing watershed, based on the watershed's biophysical characteristics only.[1] In other words, it is an indication of the potential for contaminants to be transferred from points within the watershed to the intake (i.e., the contaminant transfer potential), independent of the contaminant sources that exist. In this way, it is part of the Likelihood factor in the general Risk equation:

Risk = Hazard × Likelihood × Consequence

For the Kalamalka source, the hazards are the activities that are taking place within the project area and on the lake within the Intake Protection Zone (IPZ; defined by the red line labelled "C" [GVW 2017]). If hazards occur in a vulnerable area, there is potential for the contaminant(s) to be transferred to the intake. Based on the scope of work in the RDNO request for proposal (RFP), the Kalamalka Lake vulnerability mapping project includes both the intrinsic **vulnerability and potential hazards** and provides a qualitative indication of potential risks to water quality:

Watershed Risk = Vulnerability × Hazard

Vulnerability mapping seeks to identify the potential routes through which contaminants can be mobilized and transported downstream towards the intake, which depend on a variety of factors including slope, land cover, susceptibility of soils to erosion, runoff generation, presence or absence of natural vegetation in riparian areas and floodplains, presence of ponds and wetlands (which promote sedimentation, photo-degradation, microbial degradation, and other contaminant removal processes), and proximity to the intake.

To develop the vulnerability map, key biophysical attributes were used in the project-specific GIS to generate an index of vulnerability that identified areas with high potential to transport contaminants towards the North Kalamalka Lake intake. The potential for contaminants to reach the intake was addressed in the process of defining level of vulnerability.

The assessment used spatial data to generate a map that categorized the landscape according to the potential for contaminants present in the watershed to move to the intake. This involved the completion of a GIS overlay analysis of the watershed to identify the vulnerable areas and their spatial relationship to the Kalamalka Lake IPZ. This approach is described in the Source Protection Handbook published by the Trust for Public Land and American Water Works Association (TPL and AWWA 2005), and has been used in other source water protection plans (e.g., Barten and Ernst 2004). Vulnerability mapping for lake intakes in

[1] This is consistent with the terminology used for groundwater sources, where vulnerability refers to the characteristics of the aquifer independent of land uses (e.g., Liggett and Talwar 2009).

Ontario also use a similar procedure for mapping the vulnerability of contributing watersheds (e.g., Halton-Hamilton Source Protection Region 2010). The process for this project included:

- Selecting spatial layers for the GIS that are indicative of source vulnerability (e.g., slope, terrain stability, land cover, surficial geology, and proximity to watercourses/waterbodies);
- Ranking the attributes of each layer using a standardized system of integer codes;
- Overlaying the layers in the GIS and summing the scores for each polygon generated;
- Ranking the summed scores into four vulnerability categories: Low, Moderate, High, and Very High (**Table 2-1**);
- Generating a “first cut” draft vulnerability map that shows the spatial distribution of the vulnerability categories; and
- Adjusting the draft map based on sensitivity analyses of the individual and overall categorization rankings.

In addition to the four categories generated by summed vulnerability scores, the process also used several default indicators (Section 2.2).

Table 2-1
Vulnerability category definitions

Vulnerability Category	Definition
Low	Negligible potential for contaminants to be mobilized and transported downstream or to enter connected aquifers. Although contaminants could be mobilized and transported downstream during high precipitation or runoff events, there is negligible potential for movement under most climatic conditions.
Moderate	Contaminants could be mobilized and transported downstream during most runoff-producing precipitation or snowmelt events, but time-of-travel is long enough for mitigation measures to be implemented. Spills and other accidental releases could enter watercourses or connected aquifers if not contained.
High	Contaminants are likely to be mobilized and transported downstream during most runoff-producing precipitation or snowmelt events. Time-of-travel to the main stem of Coldstream Creek or Kalamalka Lake is short, requiring prompt action to be effective. Spills and other accidental releases would likely enter watercourses or connected aquifers if not contained within a few hours.
Very High	Contaminants are likely to be mobilized and transported downstream during most runoff-producing precipitation or snowmelt events. Time-of-travel is potentially very short, making response to an event difficult. Spills and other accidental releases would likely enter the lake, watercourses, or connected aquifers if not contained immediately.

2.2 VULNERABILITY MAPPING

Table 2-2 lists the GIS layers that were used to calculate the vulnerability categories and the criteria for scoring. The data sources and the rationales for their inclusion are summarized in **Table 2-3**. The vulnerability ratings were set as:

- Low – 0 to 5
- Moderate – 6 to 9
- High – 10 to 13 (plus the defaults noted in Section 3.2)
- Very High – 14 to 18 (plus the defaults noted in Section 3.2)

Table 2-2
GIS overlay system used to calculate vulnerability category

Criteria	Score			
	3 Very High	2 High	1 Moderate	0 Low
Proximity to watercourse or Kalamalka Lake	≤30 m	31 – 120 m	121 – 500 m	>500 m
Slope	≥30%	10 – 29%	5 – 9%	<5%
Soil texture/surficial geology	Lacustrine, Glacio-lacustrine, Aeolian, Organic	Glaciofluvial, Fluvial	Moraine, Anthropogenic, and missing values	Colluvium, Bedrock
Terrain stability	Terrain Stability Class V	Terrain Stability Class IV	Terrain Stability Class III	Terrain Stability Classes I and II, and missing values
Precipitation	≥800 mm	601 – 800 mm	401 – 600 mm	≤400 mm
Land cover	Developed, Exposed	Agriculture	Rock/Rubble, Snow/Ice	Forest (all types), Grassland, Shrubland, Wetlands

Note: See Table 2-3 for rationale for the use of these data in the vulnerability mapping.

Table 2-3
Vulnerability mapping data sources

Criteria	Data	Method and Rationale
Proximity to watercourse	Defined by buffering the Freshwater Atlas stream layer, and SHIM	Stream centerline was buffered 30, 120, and 500 m. “Very High” category (≤30 m) based on riparian assessment area definition under BC Riparian Areas Regulation. The storm drain networks with outfalls directly to the IPZ were treated as “streams” and the same buffers applied.
Slope	Percent slope calculated using the standard 20 m Geobase Digital Elevation Model (DEM)	Slopes were classed into <5, 5-9, 10-29, and ≥30%. Slope categories serve as indication of potential for runoff to be routed to streams. Slope categories were based on the US Natural Resource Conservation Service Engineering Handbook (cited by Hudson 1981).
Soils	Soil layer with soil type sourced from the BC Government GIS data catalogue	Surficial geology information indicates runoff generation and soil erodibility potentials. Categories were adapted from the erosion potential mapping criteria published by BC Ministry of Forests (1999).
Terrain stability	Terrain stability mapping previously completed by the BC Government and the DoC. Where there was overlap, DoC data were used.	Classification system from Mapping and Assessing Terrain Stability Guidebook (BC Ministry of Forests 1999).
Precipitation	Downscaled climate data on 500 m grid generated by the OBWB Water Supply & Demand Study.	Precipitation is an indication of relative runoff-generation, erosion, and contaminant transfer potential.
Land cover	Local zoning codes for parcels within the RDNO and assumed zoning to be representative of land use/cover. Areas where there was no zoning (e.g., upper watershed areas) were assumed to be forested.	Forests and other ecosystems with native vegetation cover typically generate little overland flow and act to filter or otherwise reduce the transfer of contaminants. Lands developed for agricultural use have less capacity to retain runoff and sediments, and developed areas are more likely to route rainwater and snowmelt directly to watercourses.

Note: DoC: District of Coldstream; OBWB: Okanagan Basin Water Board

After an initial map was generated, the spatial distribution and coverage of the five categories was reviewed and the results considered based on the available information and our knowledge of the North Kalamalka watershed. A minor adjustment was made in the threshold between the “Low” and “Moderate” vulnerability categories. The results following the adjustment appeared reasonable (Section 3.1) are presented in draft Map 1 for RDNO’s review.

In addition to the vulnerability classes, the proposed defaults and data sources are defined in **Table 2-4**. Areas defined by the defaults were ‘bumped up’ one category (e.g., a “High” vulnerability map polygon became a “Very High” polygon).

Table 2-4
Vulnerability default definitions

Default	Data Source and Rationale
Within 100 m of Kalamalka Lake within the IPZ	Buffer the Kalamalka Lake shoreline 100 m.
Area within the catchment of a stormwater outfall directly discharging to IPZ	Catchments defined by RDNO. Included as a default because contaminants may be routed quickly to the lake.
All areas mapped by BC as a High Vulnerability aquifer that is bisected or bordered by a watercourse (i.e., a “connected aquifer”) and within 300 m of that watercourse.	Aquifer boundaries and vulnerability ratings from BC Water Resources Atlas. This default would identify areas where groundwater contamination could affect surface water quality. The 300-m buffer is the Arbitrary Fixed Radius for wellhead protection defined in MELP (2004), and is used here for consistency.

Note: IPZ: Intake Protection Zone

2.3 TIME OF TRAVEL ESTIMATES AND VULNERABILITY ADJUSTMENTS

Travel times within the IPZ have already been estimated during development of the North Kalamalka Lake Response Plan (GVW 2017). For the current project, travel times in Coldstream Creek were estimated from the velocity measurements collected by the Okanagan Nation Alliance for the Environmental Flow Needs (EFN) study and GIS measurements of the distance from the measurement site. **Figure 2-1** shows the locations of the EFN transects. The minimum, maximum, and mean velocity from each transect was then divided by the distance to Kalamalka Lake to give an estimate, in minutes, of the time of travel from each transect.

Figure 2-1
Environmental flow needs transect locations

2.4 HAZARD MAPPING DATA SOURCES

The following land uses, point sources, and activities were mapped:

- Highways and major local roads (35 stream crossings);
- Active railways (5 stream crossings);
- Resource or rough roads, outside Coldstream boundary (197 stream crossings);
- Recent and proposed forest cutblocks (only those from the last 10 years);
- Stormwater drainage network and outfalls;
- Sanitary sewer lift stations;
- Lost Lagoon (Kalavista Lagoon);
- Gravel pits and quarries (as identified from imagery);
- Feedlots and other intensive agricultural facilities (as identified from imagery);
- Agricultural Land Reserve boundaries;
- Marinas, boat launches, and campgrounds;
- Golf courses;
- Industries with liquid waste discharge authorizations (from the provincial database);

- Areas used by the City of Vernon spray irrigation program (sourced from previously created OBWB data);
- Solid waste and composting facilities (as identified from imagery); and
- Residential areas not serviced by municipal wastewater systems (by default, the non-serviced areas are assumed to use private on-site systems). These were identified as the inverse of lots within 25 m of sanitary sewer lines. Lot sizes larger than one hectare were not included, because the intent was to identify on-site systems only.

3 Results and Discussion

3.1 WATERSHED VULNERABILITY

The project area defined for this analysis includes the Coldstream watershed as well as the residual areas that drain directly into Kalamalka Lake within the RDNO boundary. Map 1 shows the vulnerability analysis results for the project area (Appendix A).

The proportion of the watershed assigned to each vulnerability category is summarized in **Table 3-1**. A large proportion of the watershed, almost 73%, is assigned a Moderate vulnerability rating. A Low rating is assigned to 5.7%, a High rating to 14.2%, and a Very High rating to 0.2% of the total area.

Table 3-1
Project Areas within each Vulnerability Category

Rating	Area (ha)	Proportion of the Watershed (%)
Low	1,565	5.7
Moderate	19,968	72.6
High	3,907	14.2
Very High	47	0.2
Water	2,016	7.3
Total	**27,504**	**100.0**

In the GIS, an overlay analysis was performed by combining each of the input layers listed in **Table 2-2** (Section 2.2) and shown in **Figure 3-1**. By combining the cumulative scores for all the inputs, a final score was calculated and assigned to the class ranges listed in Section 2.1. **Figure 3-1** shows the scoring results for each of the six layers that contribute to the overall vulnerability rating: zoning (i.e., surrogate for land cover), terrain stability, stream proximity, soils, slope, and precipitation. Full-page copies are provided in Appendix A. The Moderate overall vulnerability rating for a large portion of the project area is the result of two factors: 1) many of the individual input categories fell into the Moderate rating (i.e., score of 1 in **Table 2-2**), and 2) categories rated as High in one input are often offset by a Low rating in another. For example, the vulnerability created by a steep slope is offset if that slope is forested. The outcome is that approximately 73% of the project area is rated as Moderate.

The spatial distribution of vulnerability in the project area most strongly reflects the influences of slope and proximity to watercourses. The upper parts of the tributaries to Coldstream Creek (e.g., King Edward Creek) are situated on rolling terrain with modest slopes, indicating an overall Moderate rating (Map 1, Appendix A). The streams then flow through steep canyons as they drop to the valley bottom, indicating an overall High rating.

The Low classification (i.e., green polygons on Map 1), which makes up 5.7% of the project area, is distributed in small pockets around the project area. Because the individual input layers tended to be rated at least Moderate, only those areas where the Low coincided for several categories (GIS layers) generated an overall Low rating.

The High classification, which makes up 14.2% of the project area, is distributed among the steeper and streamside areas as well as the steeper urbanized areas of the project area; in particular, the northwest corner of Kalamalka Lake (Map 1) along the south-facing slopes in Coldstream Valley, and in the tributary gullies along Coldstream Creek above Noble Canyon. This reflects the combined effects of proximity to watercourses and steeper slopes.

The Very High classification, which makes up only 0.2% of the project area, is concentrated on the northwest tip of Kalamalka Lake, close to the intake. This reflects the presence of urbanized areas in direct contact with the IPZ, and poses the greatest risk to the IPZ as anthropogenic activity is concentrated with the presence of typically-sized single residential lots and paved surfaces.

It is important to note that the vulnerability mapping was completed at the watershed scale and is intended to be used for source protection planning at that scale. Assessments of risks to drinking water at the sub-basin or site scale should consider the information provided in the individual vulnerability category maps (**Figure 3-1** and Appendix A). Also, the vulnerability mapping emphasizes the potential for contaminants to be transferred by surface runoff. However, land use activities could also contribute to contamination in tributaries or lakes via shallow groundwater flow (Western Water 2017). The mapping system included the high vulnerability aquifers mapped by the Ministry of Environment (MoE) to assess this risk. This area is very small because MoE mapping has focused on aquifers that are used for water supply, so there may be value in making use of surficial geology information to further assess vulnerability to shallow groundwater flow in areas close to tributaries and the lake (e.g., within 300 m).

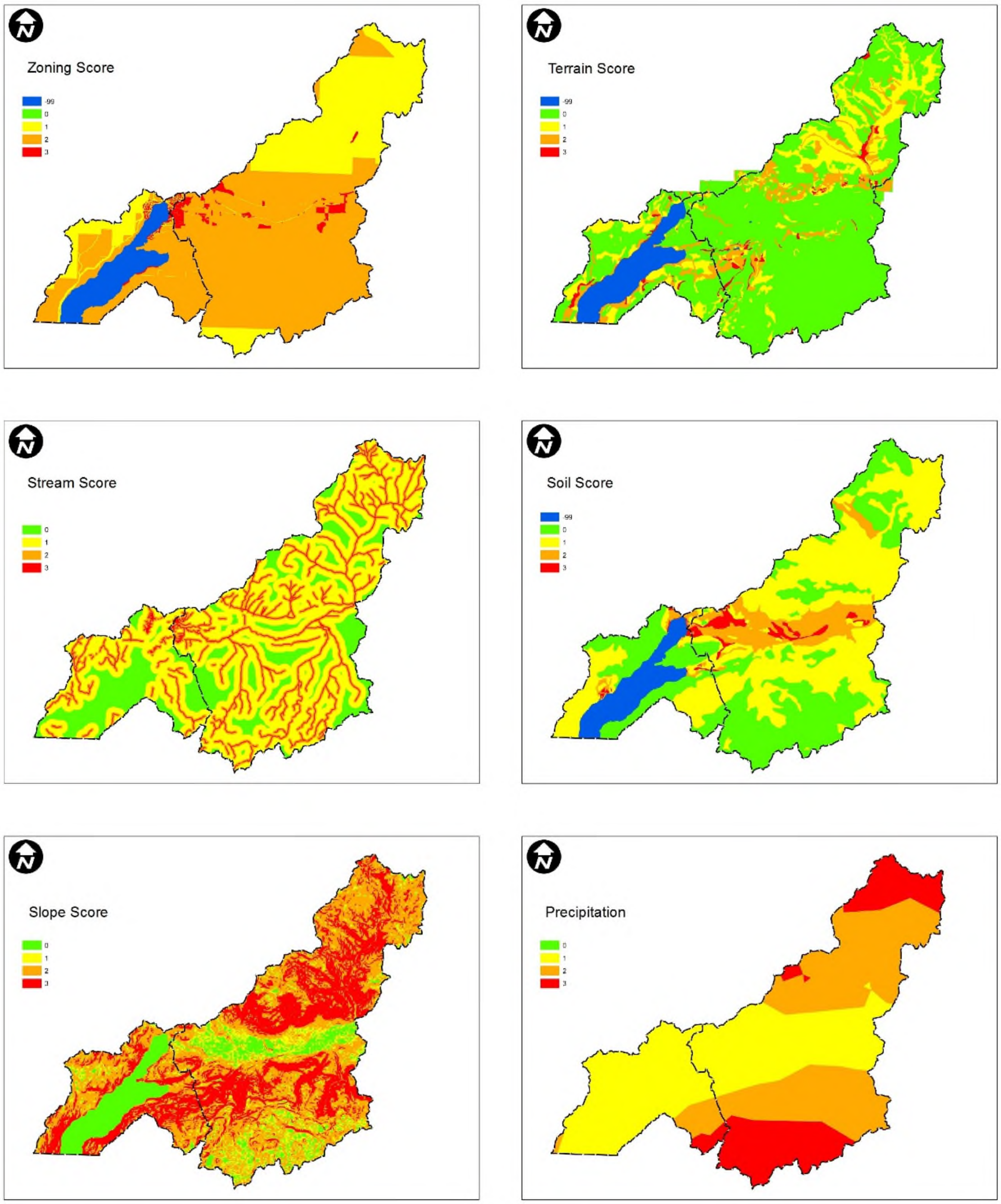


Figure 3-1
Input layer scoring values

3.2 ESTIMATES OF COLDSTREAM CREEK TIME-OF-TRAVEL

To further evaluate vulnerability in the valley bottom of the Coldstream Creek watershed, preliminary estimates of travel time for water in the stream were calculated from flow velocity measurements obtained during recent EFN studies. The measurements were obtained to determine stream flow at four locations on 11 dates between August 2016 and August 2017. The maximum velocity is the most relevant indicator of time-of-travel for responding to environmental emergencies, whereas the average velocity is more relevant for consideration of the potential for contaminants to be degraded while in transit to Kalamalka Lake. Since the velocity measurements were ‘spot’ measurements rather than continuous, the field crews may not have captured the maximum discharge or velocity during the 2016-2017 study period. However, the maximum recorded velocity was in the month of June, during freshet, and therefore provided an indication of the shortest likely travel time.

Table 3-2 shows the estimated time-of-travel from the middle (Site 2) and upper-most (Site 4) EFN study transect locations to Kalamalka Lake at the mouth of the creek. Travel times were calculated by dividing the stream channel distance by the maximum, minimum, and mean recorded velocities in each of the riffle and glide habitats at each site, with the average of the riffle and glide used as the indicator of average velocity at that site. For the minimum time-of-travel, a theoretical drop of water in Coldstream Creek would take approximately 35 minutes (0.6 hr) to reach the lake from Site 2 (near McClounie Road) and 65 minutes (1.1 hrs) from Site 4 (near Coldstream Elementary School). The average travel times are estimated to be 55 minutes (0.9 hr) and 99 minutes (1.7 hrs), respectively. Site 4 is about twice as far from the lake as Site 2 and the minimum travel time is about 1.9 times larger, so the estimates are consistent. The average minimum rate of travel for the two sites is 20.1 minutes/km. Extrapolating this rate upstream, the approximate shortest travel time from the mouth of King Edward Creek (distance 13.36 km) is approximately 4.5 hours.

These travel times are only estimates, since the velocity measurements were obtained for a different purpose and velocity in other locations could vary depending on channel roughness and the presence of meanders and natural or human-made channel obstructions. They do, however, provide a preliminary indication of the time it would take to reach the intake when combined with the estimates for travel time in the lake developed by Larratt (2011). The estimated minimum (worst case) travel time to the intake from the mouth of Coldstream Creek is approximately 2.0 hours (GVW 2017). Therefore, for example, a spill near Coldstream Elementary School could reach the intake in as little as approximately 3.1 hours (1.1 hours in Coldstream Creek plus 2.0 hours in Kalamalka Lake).

These lake and stream minimum travel time estimates provide reasonable worst case estimates of the time available to respond to an environmental emergency that introduces a contaminant to Coldstream Creek. The actual travel time would vary depending on several factors including stream discharge rate, wind direction, wind speed, lake and lake stratification, and operation of the Kalamalka Lake outlet. There may be value in developing estimates of the frequency distribution of travel times to support risk management (e.g., percent of days each year with travel time <4 hours, 4-6 hours, 6-8 hours, and >8 hours). Suggestions for refining the estimates are provided in Section 4.

Table 3-2
Approximate water travel time to Kalamalka Lake from two sites on Coldstream Creek

Distance	m		Time from Site 2 to Kalamalka Lake (minutes)		
			Glide 2	Riffle 2	Average
From Site 2 – Coldstream Cr. At McCLounie Rd., to the mouth	1,696	max	110	63	87
		mean	64	46	55
		min	38	33	35

Distance	m		Time from Site 4 to Kalamalka Lake (minutes)		
			Glide 4	Riffle 4	Average
From Site 4, below Coldstream Elementary, to the mouth	3,326	max	165	137	151
		mean	102	95	99
		min	61	69	65

3.3 HAZARDS AND SPATIAL RELATIONSHIP TO VULNERABILITY

Map 2 shows the locations of the water quality hazards that were identified from the inventory of published information. **Table 3-3** lists the land use activities in the areas mapped as having Very High, High, or Moderate vulnerability. **Figure 3-2** shows the vulnerability rating and the mapped hazards for the area.

An area of specific interest is the area directly connected or adjacent to the IPZ at the north end of Kalamalka Lake. It is noteworthy that the Very High vulnerability ranking only occurs in this area due to the scoring generated by the high level of anthropogenic activity, the slope, and the potential for delivery of contaminants directly to the IPZ (specifically, the land cover and proximity to watercourses criteria). The Coldstream municipal storm drainage network was treated the same as a natural stream by the GIS analysis (**Table 2-2**).

The IPZ is an area of great concern because it represents a zone within which, if a deleterious substance is introduced, the intake supplying Greater Vernon is at risk. With that in mind, it makes sense that the land area draining directly into or near the IPZ is considered to have a combination of High and Very High vulnerability.

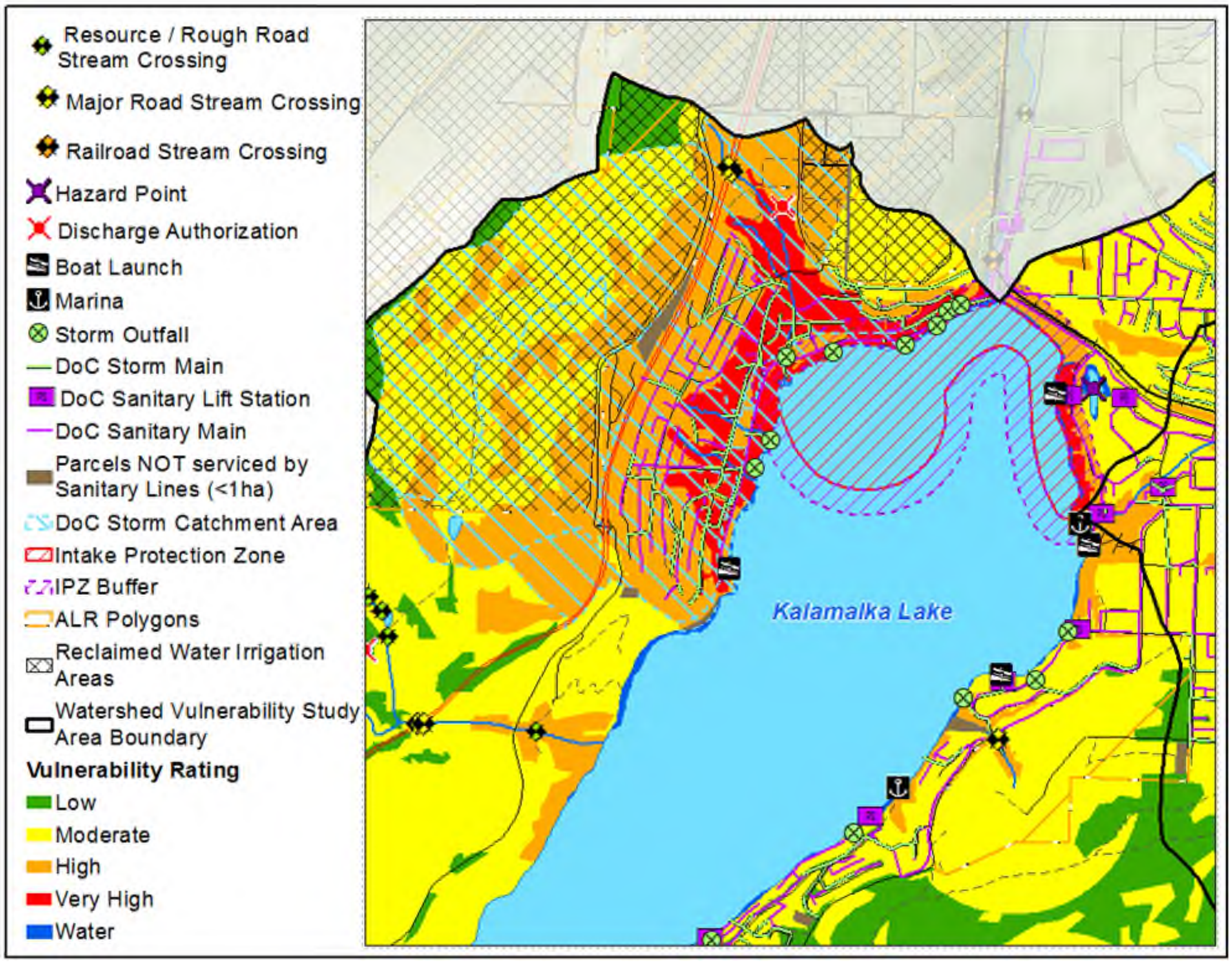


Figure 3-2
Vulnerability and hazards near the IPZ

Table 3-3 lists some of the activities occurring directly within the Very High vulnerability area, and some of the potential hazards associated with this area are located in and around the IPZ. For example, Highway 97 passes through the catchment area of the storm network draining directly into the IPZ. With the high volume of traffic and potentially dangerous goods in transit, any motor vehicle accident on Highway 97 within this area should be considered as a serious risk to the IPZ.

The proximity of the active railway just north of the lake should be given the same consideration. While outside the Very High vulnerability area, it still poses some level of risk, depending on the freight carried on this line (e.g., lumber poses a low risk, but process chemicals for industrial operations in Lavington or Lumby pose a high risk). The presence of boat launches, marinas, and private moorings along the north end of the lake may also be a potential risk to the IPZ. Multiple stormwater outfalls draining near and within the IPZ are also a concern as they can quickly deliver contaminants to the lake.

Scattered on the northeast side of the lake are several sanitary lift stations, each with the potential for failure and introduction of untreated waste water either directly into the lake or overland to a watercourse that flows into the lake. Residential lots not serviced by the sanitary system also exist in proximity to (or within) the catchments draining into the lake, with the potential for the transfer of partially untreated wastewater towards the IPZ. Finally, within the area just north and west of the IPZ and within the catchments draining into the IPZ is land designated as Agricultural Land Reserve (ALR). In addition to the routine contaminants associated with agriculture (e.g., nutrients, coliform bacteria), some agricultural areas upstream of the IPZ are irrigated by reclaimed water from the City of Vernon. That water is treated to an advanced standard and disinfected, and stored in the McKay Reservoir before being used for agriculture. The City of Vernon carries out annual monitoring to assess potential risks to downgradient water quality, and operates the treatment and irrigation program to meet provincial and federal requirements and minimize risk.

In terms of the larger project area shown on Map 2, **Table 3-3** lists some of the land use activities that could pose a risk to the watershed, as these activities could be considered a risk and occur within areas rated as Moderate to Very High vulnerability. As described above, there are several activities in proximity to the IPZ that should be considered potential risks regardless of the vulnerability class within which they fall. As with Highway 97 northwest of the IPZ, Highway 6 and the railway line traverse the project area with the potential to deliver deleterious substances to nearby stream courses and ultimately to the IPZ. However, the presence of a hazard within a High vulnerability area does not necessarily indicate a serious risk to drinking water. If control measures are in place, the likelihood of a contaminant reaching the lake in sufficient quantities to affect health may be low.

For those areas located further away from the mouth of Coldstream Creek, the preliminary travel time analysis (Section 3.2) shows that travel times for contaminants entering the creek as the result of an environmental emergency may be sufficiently long to provide emergency response teams with enough time implement an appropriate response, as described in the North Kalamalka Lake Assessment Response Plan (GVW 2017).

The hazard map (Map 2) shows the resource roads and road crossings (e.g., culverts and bridges) that are located on Crown land in the watershed, as well as the forest cutblocks that were harvested between 2010 and 2014, based on the available data. Protection of water quality and aquatic habitat in forest operations is the responsibility of the tenure holder (e.g., BC Timber Sales and Tolko Industries) under the *Forest and Range Practices Act*. Forestry firms periodically carry out watershed assessments to assess risk to water quality and guide forest development (e.g., WaterSmith Research 2012 for Coldstream Creek). In general, the forest road network has more potential for direct effects on water quality (i.e., erosion and sedimentation, potential slope instability) than cutblocks, where ground disturbance is minimized and the trees are re-planted within 1-5 years. Therefore, the presence of roads on High/Very High vulnerability areas is more of an indication of potential risks to water quality than cutblocks. This is why only the cutblocks harvested since 2010 are shown on Map 2. The spatial data for older cutblocks are available to support any finer-scale assessments.

Table 3-3
Land use activities present in Very High, High and Moderate vulnerability areas

Vulnerability Category	Land Use Activities
Very High (47 ha, 0.2% of project area)	• Urban residential zoning • Residential recreation zoning • Residential estate zoning • Resort commercial zoning • Large holding zoning • Rural / non-urban zoning • Residential roads • Okanagan Rail Trail • Public beaches • District of Coldstream storm network including outfalls • Agricultural Land Reserve land
High (3,907 ha, 14.2% of project area)	• Urban residential zoning • General commercial zoning • General industrial zoning • Highway and tourist commercial zoning • Parks and open space zoning • Recreation commercial zoning • Country residential zoning • Comprehensive development 1 & 2 zoning • Residential bed and breakfast zoning • Residential manufactured home zoning • Resource industrial zoning • Town centre mixed use commercial zoning • Large holding zoning • Rural / non-urban zoning • Commercial and Agricultural zoning • Residential roads • Resource roads • Highway 97 • Railway (active) • Okanagan Rail Trail • Agricultural Land Reserve land • Reclaimed Water Spray Irrigation • Major road stream crossings • Resource road stream crossing • Environmental discharge authorizations • Boat launch • Storm network including outfalls • Sanitary network and lift station • Small residential zoning not serviced by sanitary system • Recently logged areas

Vulnerability Category	Land Use Activities
Moderate (19,968 ha, 72.6% of project area)	• Urban residential zoning • General commercial zoning • General industrial zoning • Highway and tourist commercial zoning • Parks and open space zoning • Recreation commercial zoning • Country residential zoning • Comprehensive development 1 & 2 zoning • Residential bed and breakfast zoning • Residential recreation zoning • Residential manufactured home zoning • Resource industrial zoning • Town centre mixed use commercial zoning • Large holding zoning • Rural / non-urban zoning • Commercial and agricultural zoning • Assembly and private hospital zoning • Residential roads • Resource roads • Highway 97 • Railway (active) • Okanagan Rail Trail • Agricultural Land Reserve land • Reclaimed Water Spray Irrigation • Major road stream crossings • Resource road stream crossing • Railroad stream crossing • Environmental discharge authorizations • Storm network including outfalls • Sanitary network and lift station • Small residential parcels not serviced by sanitary system • Recently logged areas • Gravel pit, golf course, campground, feedlots • Service stations (3) • Waste disposal facility • Composting facility

4 Recommendations

This report and the accompanying Maps 1 and 2 (Appendix A) provide the results of the vulnerability and water quality hazard mapping completed for the North Kalamalka Lake water source, and is intended to support source protection planning. The mapping was completed using GIS data that are in the public domain or was provided by RDNO. The vulnerability mapping is based on a customized GIS overlay approach that combines the effects of land use/cover, precipitation, slope, soils, terrain stability, and proximity to watercourses to generate a four-category vulnerability index (Low, Moderate, High, and Very High). The following are suggestions to refine the mapping to help set priorities for source protection.

- Build on the existing hazard mapping by meeting with the District of Coldstream, stakeholders and local residents to confirm what has been mapped and potentially identify other known hazards in the Very High and High vulnerability areas.
- Consider conducting risk assessments of high priority hazards that include a specific evaluation of the likelihood (probability) that the contaminant(s) of concern will reach the IPZ. As noted in Section 3.3, the presence of a hazard in a High or Very High vulnerability area does not necessarily indicate a high risk to drinking water if controls are in place.
- Conduct a more quantitative assessment of erosion risk (e.g., using the RUSLEFAC model[2]), which may be of value to prioritize mitigation methods such as riparian buffers, grassed waterways, retention ponds or constructed wetlands, and on-farm conservation measures. The GIS soil and slope data already compiled for this study can be directly used for the assessment. The vulnerability mapping provides an indication of potential risks from soil erosion and sediment transfer from agricultural land because the vulnerability index includes soil, precipitation, and slope characteristics.
- If more precise estimates of hydrologic travel time in Coldstream Creek are needed to inform emergency response planning, obtain additional stream velocity measurements during worst case conditions including freshet and during summer thunderstorms. This would involve taking mid-channel measurements at about 10-15 sites over the lower 10 km of the creek. Additional precision may be obtained through a tracer study (e.g., with an approved fluorescent dye) and mathematical modelling. The modelling could also be used to estimate the frequency distribution of travel times (e.g., percent of days each year with travel time <4 hours, 4-6 hours, 6-8 hours, and >8 hours).
- When floodplain mapping is available, consider using the floodplain (e.g., 50-year return interval flood elevation) as a default criterion for updating the vulnerability maps.
- Consider augmenting the current vulnerability mapping, which emphasizes surface runoff, with an assessment of vulnerability from shallow groundwater flow near Coldstream Creek and Kalamalka Lake within the project area (i.e., within 300 m) (**Table 2-4**).

[2] Revised Universal Soil Loss Equation for Application in Canada (Wall et al. 2002).

5 Closure

This report was prepared for the Regional District of North Okanagan. The services provided by Associated Environmental Consultants Inc. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Environmental Consultants Inc.

Reviewed by:

Signature on final	*Signature on final*
Dan Austin, MGIS GIS Analyst	Hugh Hamilton, P.Ag. Senior Environmental Scientist

References

Barten, P.K., and C. Ernst. 2004. Land Conservation and Watershed Management for Source Protection. American Water Works Association Journal. 98:4. April 2004.

BC Ministry of Environment, Lands and Parks (MELP). 2004. Well Protection Toolkit. Water Stewardship Division. Victoria. Online at: http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/wells/well_protection/pdfs/intro.pdf. Accessed June 2015.

BC Ministry of Forests. 1999. Mapping and Assessing Terrain Stability Guidebook. Second Edition. Forest Practices Code. Victoria. Online at: https://www.for.gov.bc.ca/TASB/LEGSREGS/FPC/FPCGUIDE/terrain/zipped/terrain.pdf. Accessed June 2, 2015.

Greater Vernon Water (GVW). 2017. North Kalamalka Lake Response Plan. Prepared for Interior Health by Regional District of North Okanagan.

Halton-Hamilton Source Protection Region. 2010. Drinking Water Source Protection Website – Vulnerable Areas. Online at: http://www.protectingwater.ca/index.cfm#. Accessed May 2014.

Hudson, N. 1981. Soil Conservation. Second Edition. Cornell University Press. Ithaca, New York.324 pp.

Larratt Aquatic. 2011. Source Assessment of the Regional District of North Okanagan – Great Vernon Water Utility North Kalamalka Lake Intake – Final Report. Prepared for Regional District of North Okanagan by Larratt Aquatic, 2011.

Liggett, J.E., and S. Talwar. 2009. Groundwater Vulnerability Assessments and Integrated Water Resource Management. Streamline: Watershed Management Bulletin 13(1).

Trust for Public Land (TPL) and American Water Works Association (AWWA). 2005. Source Protection Handbook: Using Land Conservation to Protect Drinking Water Supplies. Funded by US Environmental Protection Agency. Washington. Online at: https://www.tpl.org/sites/default/files/cloud.tpl.org/pubs/water_source_protect_hbook.pdf

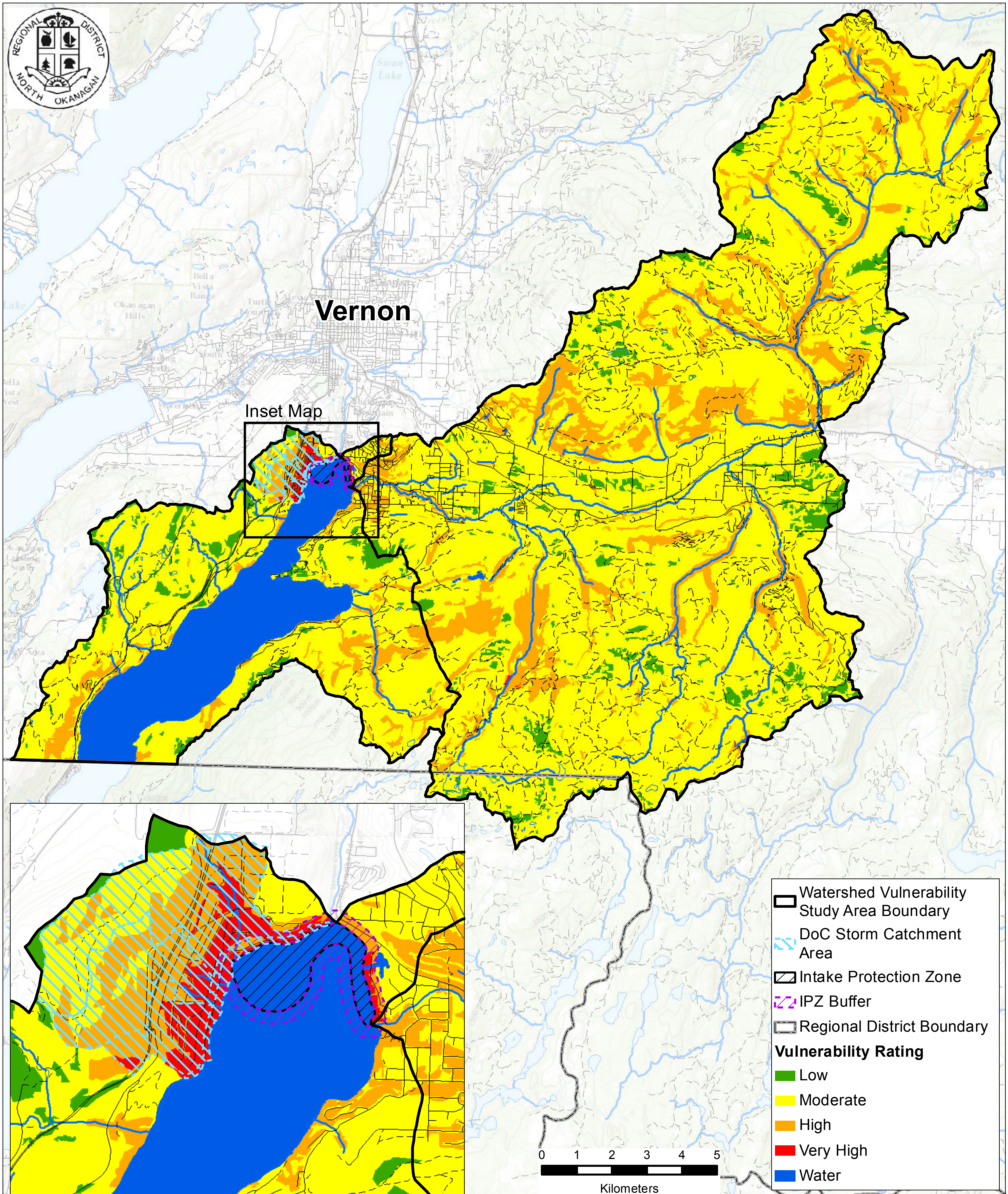
Western Water Associates. 2017. Final Coldstream Creek Water Quality and Land Use Study, Phase II. Prepared for the Society for Preservation of Kalamalka Lake.

Wall, G.J., D.R. Coote, E.A. Pringle, and I.J. Shelton (editors). 2002. RUSLEFAC — Revised Universal Soil Loss Equation for Application in Canada: A Handbook for Estimating Soil Loss from Water Erosion in

Canada. Research Branch, Agriculture and Agri-Food Canada. Ottawa. Contribution No. AAFC/AAC2244E. 117 pp.

WaterSmith Research Inc. 2012. Hydrologic Assessment of Coldstream Creek Community Watershed. Prepared for BC Timber Sales, Okanagan-Columbia. 27 pp. plus maps and appendices.

Appendix A – Individual Vulnerability Maps



Final Results 022818.mxd / 2/28/2018 / 1:36:56 PM

Associated Environmental

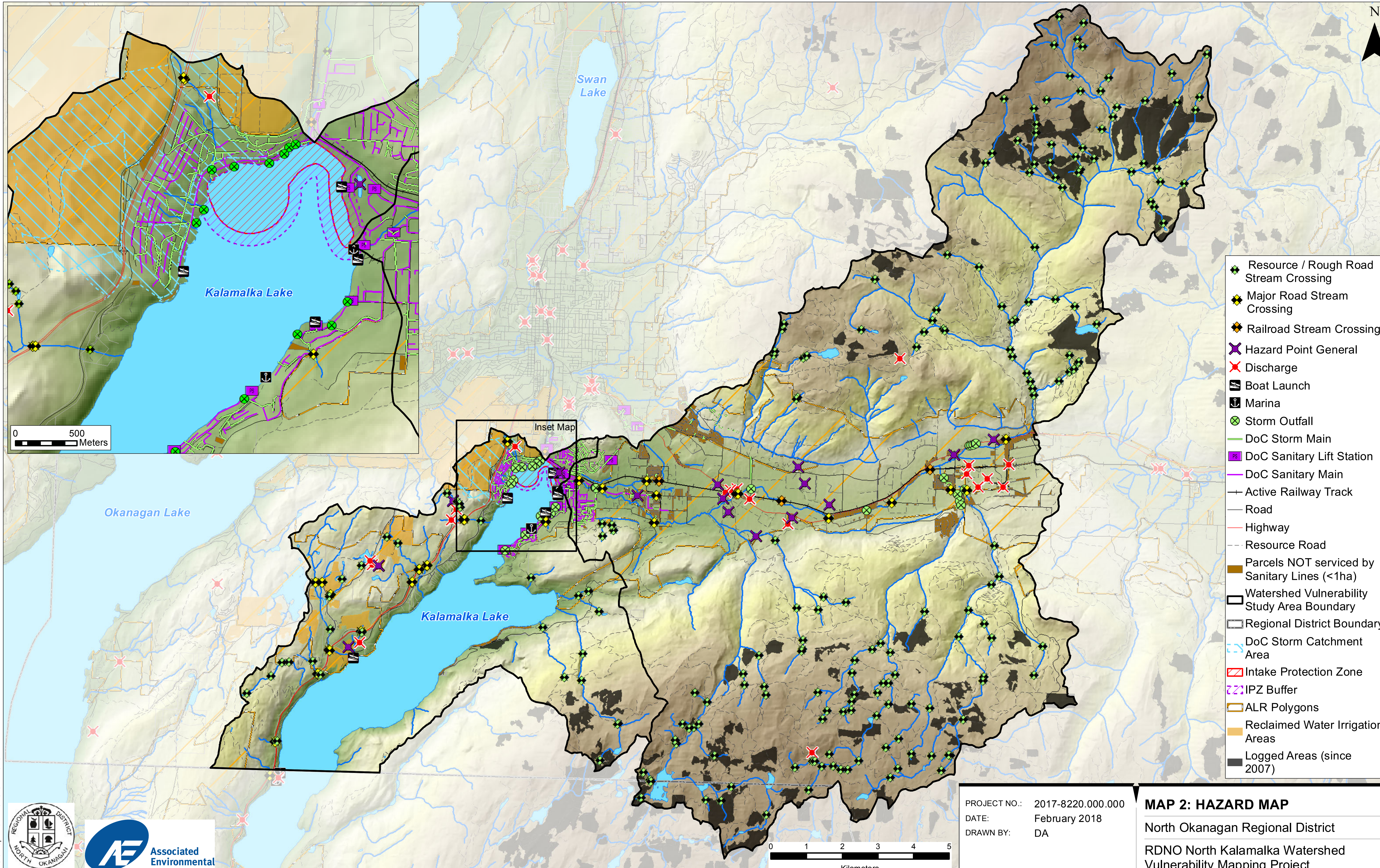
PROJECT NO.:	2017-8220.000.000
DATE:	February 2018
DRAWN BY:	DA

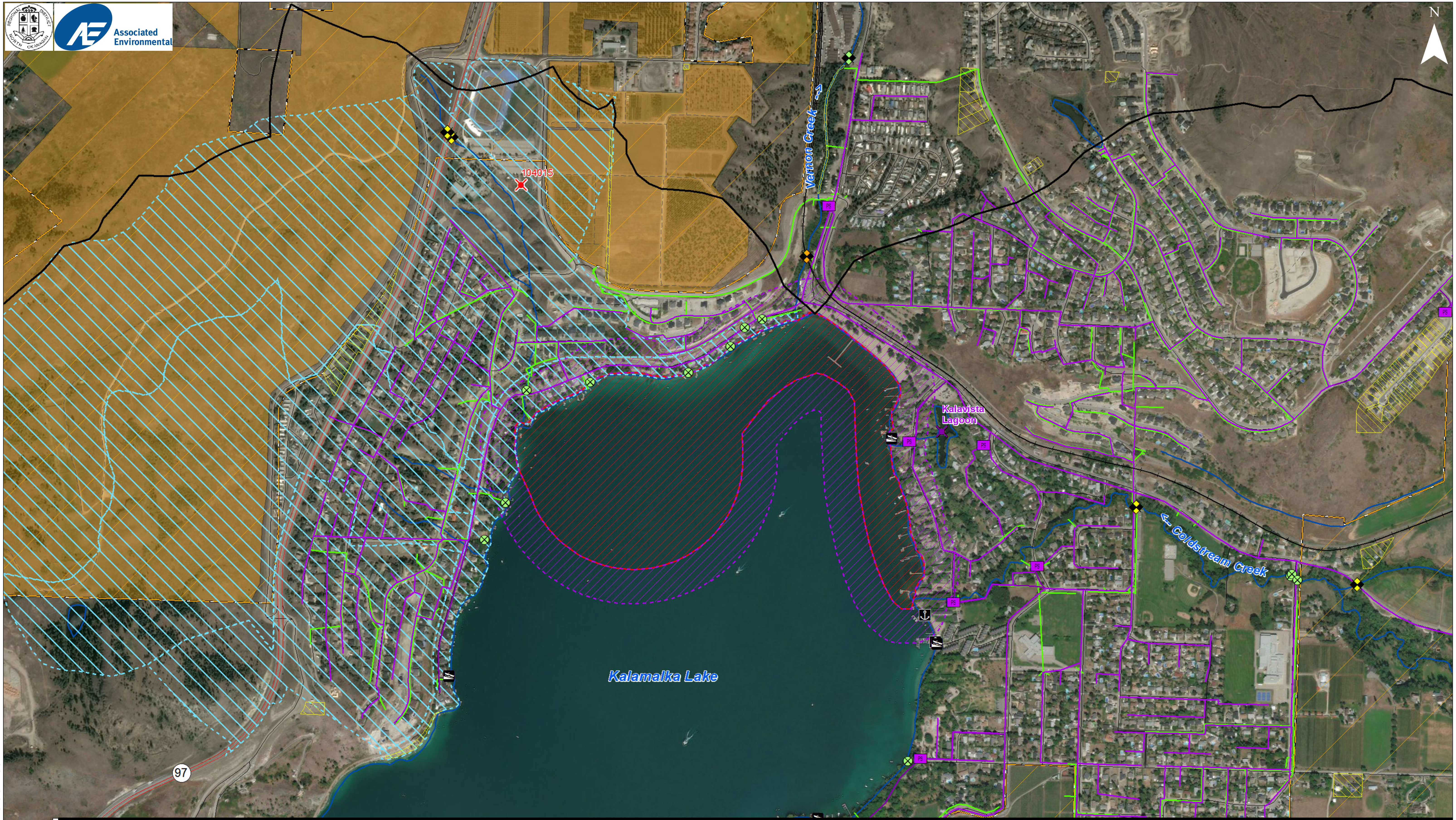
N

MAP 1: VULNERABILITY ANALYSIS RESULTS

North Okanagan Regional District

RDNO North Kalamalka Watershed Vulnerability Mapping Project


N
Swan Lake
Okanagan Lake
Kalamalka Lake
Inset Map
0 500 Meters
Resource / Rough Road Stream Crossing
Major Road Stream Crossing
Railroad Stream Crossing
Hazard Point General
Discharge
Boat Launch
Marina
Storm Outfall
DoC Storm Main
DoC Sanitary Lift Station
DoC Sanitary Main
Active Railway Track
Road
Highway
Resource Road
Parcels NOT serviced by Sanitary Lines (<1ha)
Watershed Vulnerability Study Area Boundary
Regional District Boundary
DoC Storm Catchment Area
Intake Protection Zone
IPZ Buffer
ALR Polygons
Reclaimed Water Irrigation Areas
Logged Areas (since 2007)
0 1 2 3 4 5
Kilometers
PROJECT NO.: 2017-8220.000.000
DATE: February 2018
DRAWN BY: DA
MAP 2: HAZARD MAP
North Okanagan Regional District
RDNO North Kalamalka Watershed Vulnerability Mapping Project
Associated Environmental
hazard map.mxd / 2/20/2018 / 4:26:45 PM



- Resource / Rough Road Stream Crossing
- Major Road Stream Crossing
- Railroad Stream Crossing
- Hazard Point - General
- Discharge Authorization
- Boat Launch
- Marina
- Storm Outfall
- DoC Storm Main
- DoC Sanitary Lift Station
- DoC Sanitary Main
- Active Railway Track
- Road
- Highway
- Resource Road
- Parcels NOT serviced by Sanitary Lines (<1ha)
- DoC Storm Catchment Draining into IPZ
- Intake Protection Zone
- IPZ Buffer
- ALR Polygon
- Reclaimed Water Irrigation Areas
- Watershed Vulnerability Study Area Boundary

0 250 500
Meters

PROJECT NO.:	2017-8220.000.000
DATE:	February 2018
DRAWN BY:	DA

HAZARD MAP 1 OF 4

North Okanagan Regional District

RDNO North Kalamalka Watershed Vulnerability Mapping Project

hazard map strip map.mxd / 2/20/2018 / 4:49:34 PM

Associated Environmental

Resource / Rough Road Stream Crossing
Major Road Stream Crossing
Railroad Stream Crossing
Hazard Point - General
Discharge Authorization
Boat Launch
Marina
Storm Outfall
DoC Storm Main
DoC Sanitary Lift Station
DoC Sanitary Main
Active Railway Track
Road
Highway
Resource Road
Parcels NOT serviced by Sanitary Lines (<1ha)
DoC Storm Catchment Draining into IPZ
Intake Protection Zone
IPZ Buffer
ALR Polygon
Reclaimed Water Irrigation Areas
Watershed Vulnerability Study Area Boundary

PROJECT NO.:	2017-8220.000.000
DATE:	February 2018
DRAWN BY:	DA

0 250 500
Meters

HAZARD MAP 2 OF 4

North Okanagan Regional District

RDNO North Kalamalka Watershed Vulnerability Mapping Project

hazard map strip map.mxd / 2/20/2018 / 4:50:49 PM

- Resource / Rough Road Stream Crossing
- Major Road Stream Crossing
- Railroad Stream Crossing
- Hazard Point - General
- Discharge Authorization
- Boat Launch
- Marina
- Storm Outfall
- DoC Storm Main
- DoC Sanitary Lift Station
- DoC Sanitary Main
- Active Railway Track
- Road
- Highway
- Resource Road
- Parcels NOT serviced by Sanitary Lines (<1ha)
- DoC Storm Catchment Draining into IPZ
- Intake Protection Zone
- IPZ Buffer
- ALR Polygon
- Reclaimed Water Irrigation Areas
- Watershed Vulnerability Study Area Boundary

PROJECT NO.:	2017-8220.000.000
DATE:	February 2018
DRAWN BY:	DA

0 250 500
Meters

HAZARD MAP 3 OF 4

North Okanagan Regional District

RDNO North Kalamalka Watershed Vulnerability Mapping Project

hazard map strip map.mxd / 2/20/2018 / 4:51:58 PM

Resource / Rough Road Stream Crossing
Major Road Stream Crossing
Railroad Stream Crossing
Hazard Point - General
Discharge Authorization
Boat Launch
Marina
Storm Outfall
DoC Storm Main
DoC Sanitary Lift Station
DoC Sanitary Main
Active Railway Track
Road
Highway
Resource Road
Parcels NOT serviced by Sanitary Lines (<1ha)
DoC Storm Catchment Draining into IPZ
Intake Protection Zone
IPZ Buffer
ALR Polygon
Reclaimed Water Irrigation Areas
Watershed Vulnerability Study Area Boundary

PROJECT NO.:	2017-8220.000.000
DATE:	February 2018
DRAWN BY:	DA

0 250 500
Meters

HAZARD MAP 4 OF 4

North Okanagan Regional District

RDNO North Kalamalka Watershed Vulnerability Mapping Project

hazard map strip map.mxd / 2/20/2018 / 4:57:30 PM