

Appendix II: Analytical Summaries

Figures 651957-101-106 (see below) illustrate the likelihood, consequence, and risk for each of the hazards and hydrologically sensitive areas (HSAs). These risk assessments were used to inform the analytical summaries for each CVRD watershed, which provide a descriptive summary of the Stage 2, 3, and 4 assessments for each of the hazards and HSAs. The intention of the analytical summaries is to inform decision-making for each of CVRD's watersheds and be used in conjunction with the results of the Stage 2, 3, and 4 assessments. Analytical summaries for each watershed are provided below, including identification of the areas of greatest concerns and how projected population changes may adjust the rankings.

Projected population changes will influence the likelihood, consequence, and overall risk for hazards and HSAs. To help better understand general population trends by watershed, the census division centroids were intersected with the watershed boundaries for the years with census population numbers; 2001, 2006, 2011, 2016. These numbers were compared to the regional population projections presented in Appendix C of Lam & Co., 2015¹. Each watershed was estimated to be largely in one of the four sub-regions (i.e. central, north, south, and west) outlined in the report. The proportionate difference between the populations in the medium scenario were applied to the populations derived by intersecting the census division centroids to each watershed, and used to create approximate population projections for the years 2021, 2026, 2031, and 2036, presented in Table II-1. Population growth is expected for each of the CVRD's watersheds with the exception of Chemainus River, which is estimated to maintain its current population. The projected populations for each watershed can be used to assess spatial risk assessment of natural hazards, hydrologically sensitive features, and development, as well as developing environmental targets (see Section 5).

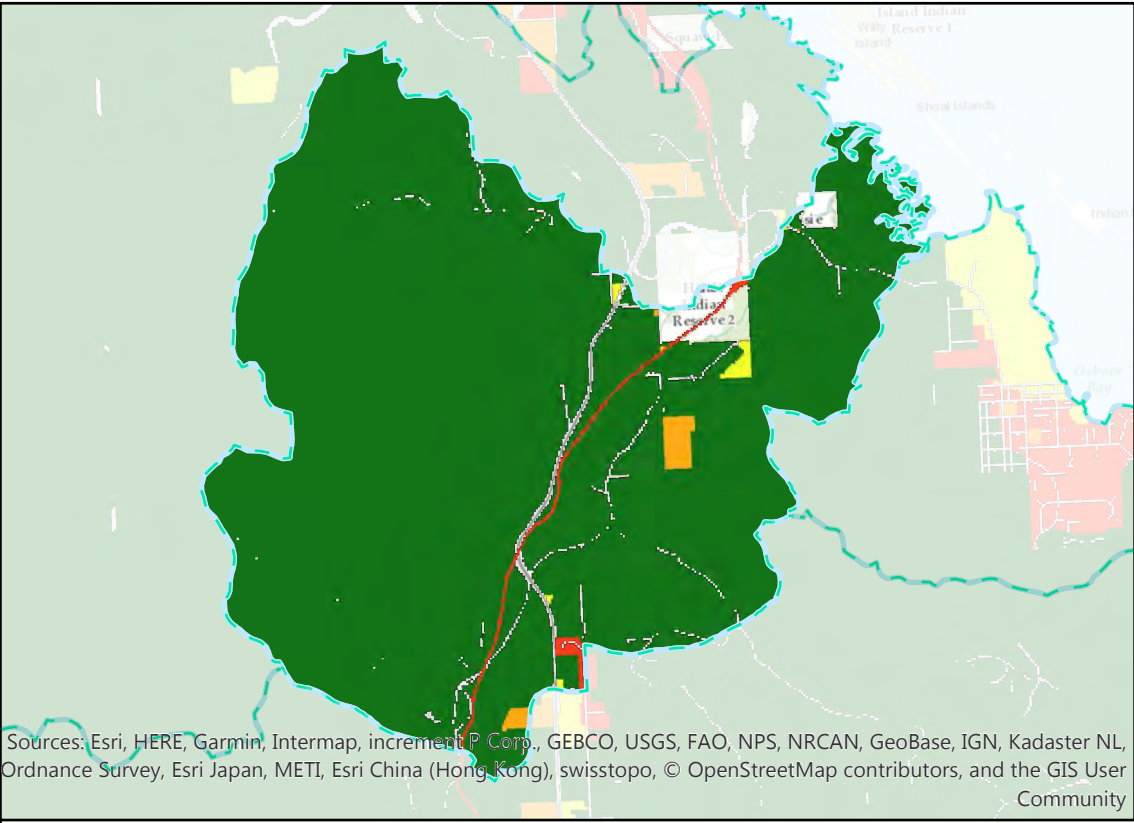
¹ CVRD Regional Population, Housing, and Employment Projection, Lam and Co. Consulting, Oct. 30, 2015.

Table II-1: Population Projections by Watershed

Watershed Number	Watershed	Sub-region	2006 Population	2011 Population	2016 Population	2021 Population	2026 Population	2031 Population	2036 Population
1	Bonsall Creek	Central	830	815	890	934	974	1,019	1,073
2	Bush Creek	North	-	-	-	-	-	-	-
3	Chemainus Benchlands	Central	3,129	3,085	3,490	3,663	3,818	3,997	4,207
4	Chemainus River	West	1,395	1,497	1,514	1,490	1,461	1,439	1,421
5	Cowichan River	Central	32,673	34,075	34,647	36,368	37,905	39,683	41,766
6	Holland Creek	North	1,114	1,169	1,245	1,302	1,368	1,446	1,537
7	Koksilah River	South	4,808	4,954	5,157	5,463	5,851	6,315	6,850
8	Ladysmith - Saltair Benchlands	North	7,488	7,541	8,042	8,410	8,834	9,342	9,929
9	Malahat Benchlands	South	2,472	2,548	2,671	2,829	3,030	3,271	3,548
10	Sansum Narrows - Cowichan Bay Benchlands	Central	4,221	4,500	4,707	4,941	5,150	5,391	5,674
11	Satellite Channel Benchlands	South	3,902	3,989	4,144	4,390	4,701	5,074	5,504
12	Shawnigan Creek	South	8,439	8,925	9,484	10,047	10,760	11,613	12,598
13	Stocking Creek	North	1,003	1,354	1,464	1,531	1,608	1,701	1,807
14	Yellow Point Benchlands	North	1,958	2,021	2,141	2,239	2,352	2,487	2,643
	Total Population		73,432	76,473	79,596	83,607	87,811	92,779	98,557

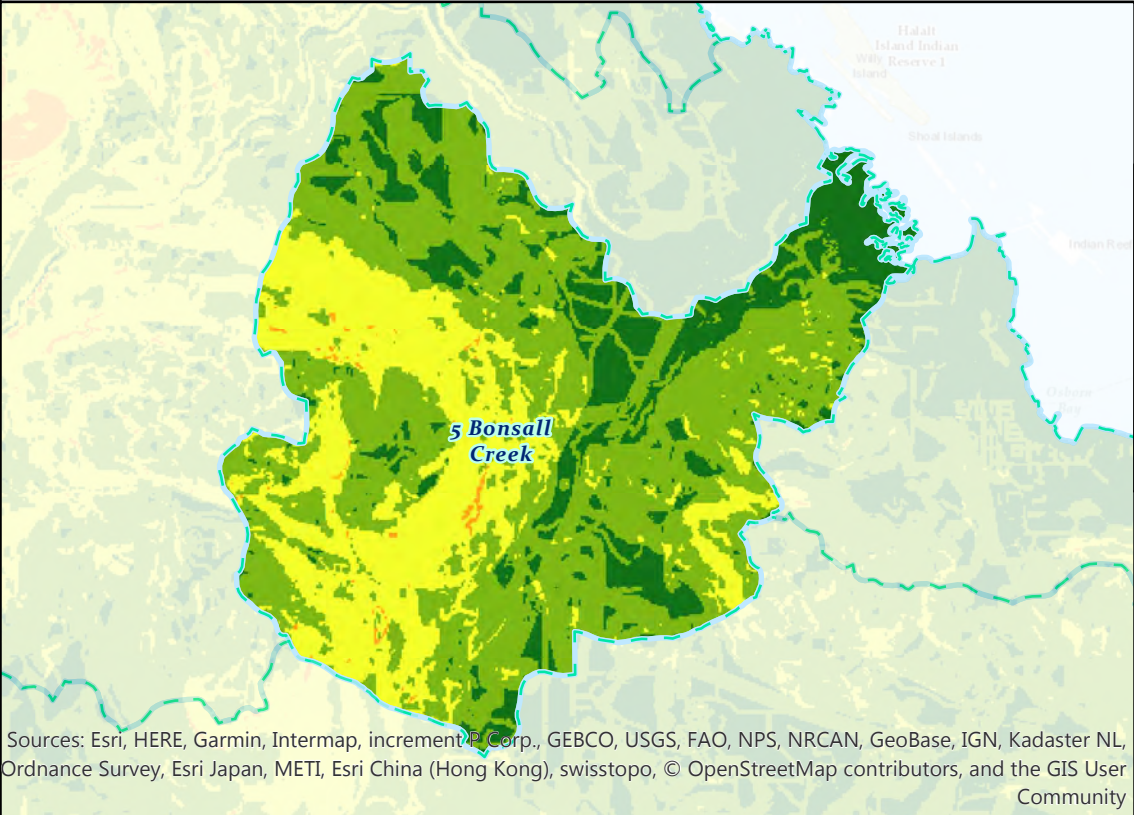
1. Bonsall Creek	
Topic	Discussion
Slope Failure	<p>Hazard was determined qualitatively at a high level to describe areas based on the degree to which they may be prone to landslides and other mass movements using terrain characteristics. Hazard classifications were generated to show relative comparisons between terrain units within the CVRD watershed study area. Risk ratings derived from this analysis are relative, and should be used to guide prioritization of further detailed studies.</p> <p>Hazard is generally highest on the western side of the Bonsall Creek watershed along the steep valley slopes heading down from Little Sicker and Big Sicker mountains. Consequence is considered low for the majority of the watershed, isolated areas of moderate to high consequence in populated areas through the center of the watershed. Risk is considered low through most of the watershed.</p>
Flooding	<p>Creeks within the watershed pose hazard to the immediately adjacent areas but consequence and risk are very low due to the land use. Flood risks are relatively low throughout the watershed and greatest within a small residential community situated adjacent to a creek. There is an additional flood risk from coastal flooding in the area of the Tsussie Indian Reserve 6, where Bonsall Creek meets the ocean. This risk is shared with the bordering Chemainus River watershed to the north.</p>
Groundwater Contamination	<p>Likelihood varies greatly throughout the watershed. Likelihood is highest in several zones within the central region of the watershed at the base of Big Sicker Mountain and throughout the northeastern portion by Crofton Road and the coast. Some municipal water supply wells are located along the central portion of the watershed that reflect the sites of greatest consequence. The locations of highest risk span the central region of the watershed and throughout the northeastern portion by Crofton Road and the coast and are due to the combination of high vulnerability, high demand and the presence of municipal supply water wells.</p>
Surface Water Quality	<p>Hazard is greatest along developed areas that span Highway 1 and the agricultural areas in the northern portions of the watershed. Lower order streams are more prevalent in western portions and towards the north-eastern region of the watershed where consequence is greatest. Risk is greatest along a lower order stream spanning Westholme and in some zones within the north-west and north-east corners of the wetland. Projected population growth in the watershed will place greater stress on surface water supply / stream health, slightly enhancing the extents of higher risk areas.</p>
Surface Water Supply	<p>Hazard is greatest in the lowlands of the watershed through the agricultural zones, with lower hazard southeast of Westholme. Consequence is variable across the watershed, and is greatest south of Westholme, and along stream reaches in the northwest section of the watershed. Risk is greatest in small zones near the center of the watershed, south of Westholme and along sections of Westholme Creek in the northwest section of the watershed. Moderate risk is more widespread along the lower reaches of the watershed, northeast of Westholme. Projected population increase for the watershed may add pressures on groundwater sources in some low-lying areas along the valley bottoms, potentially increasing the level of hazard and risk.</p>
General Data Notes	<p>Detailed flood risk data was available for a small part of the North Eastern edge of the watershed, where Bonsall Creek and Chemainus River meet and drain into the ocean this is also the area with the most concentrated population in this watershed. The detailed inundation data in this region has only been mapped for the marine hazard. As part of the Central region Bonsall Creek is expected to grow by approximately 20% over the next 20 years. Additional refinement of consequences and risk is recommended to better understand how to plan for this growth. Contributions to risk are focused around surface water quality, and, in the east, groundwater contamination and surface water supply, with little or no contribution from flooding and slope failure.</p>

CONSEQUENCE



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

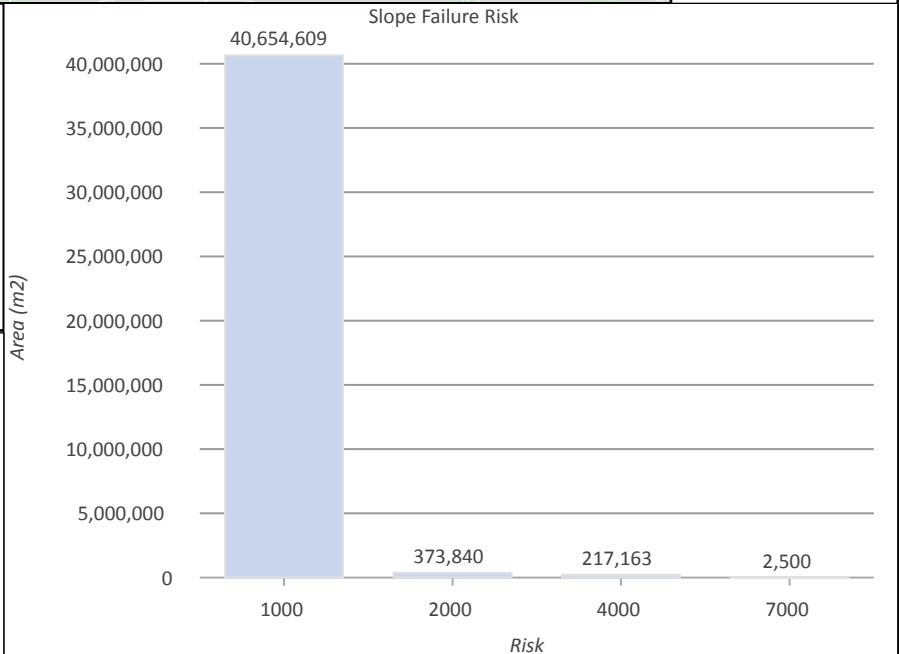
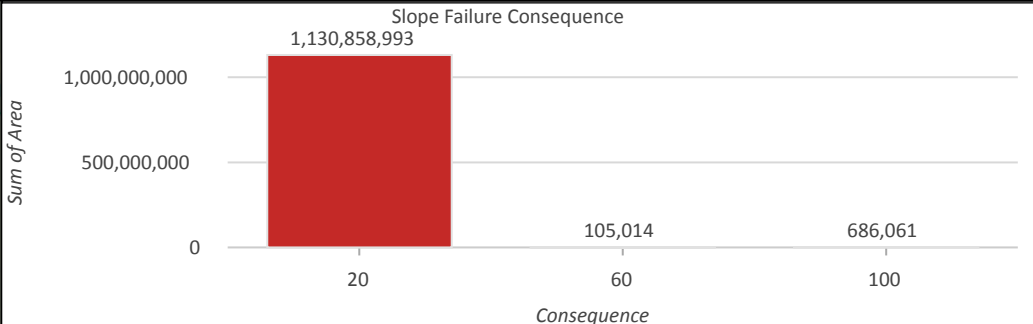
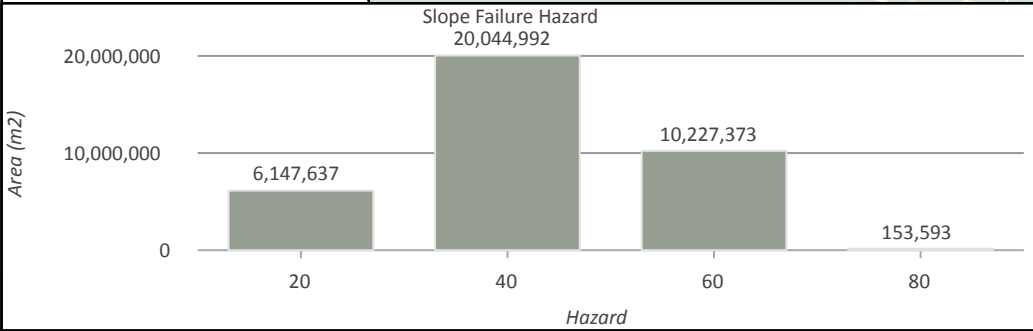


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

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Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
 ≤ 40
 ≤ 60
 ≤ 80
 ≤ 100

RISK

≤ 1000
 ≤ 2000
 ≤ 4000
 ≤ 7000
 ≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

NOTES:

1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.

REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Bonsall Creek Watershed



Slope Failure Risk Assessment - Bonsall Creek

BY: CJW

SCALE CONS: 1:73,550

DATE: 2019/01/07

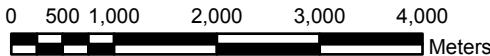
REF No:

REV: 0

CHK'D: DK

Proj Coord Sys: PCS Albers

651957-101-BONS

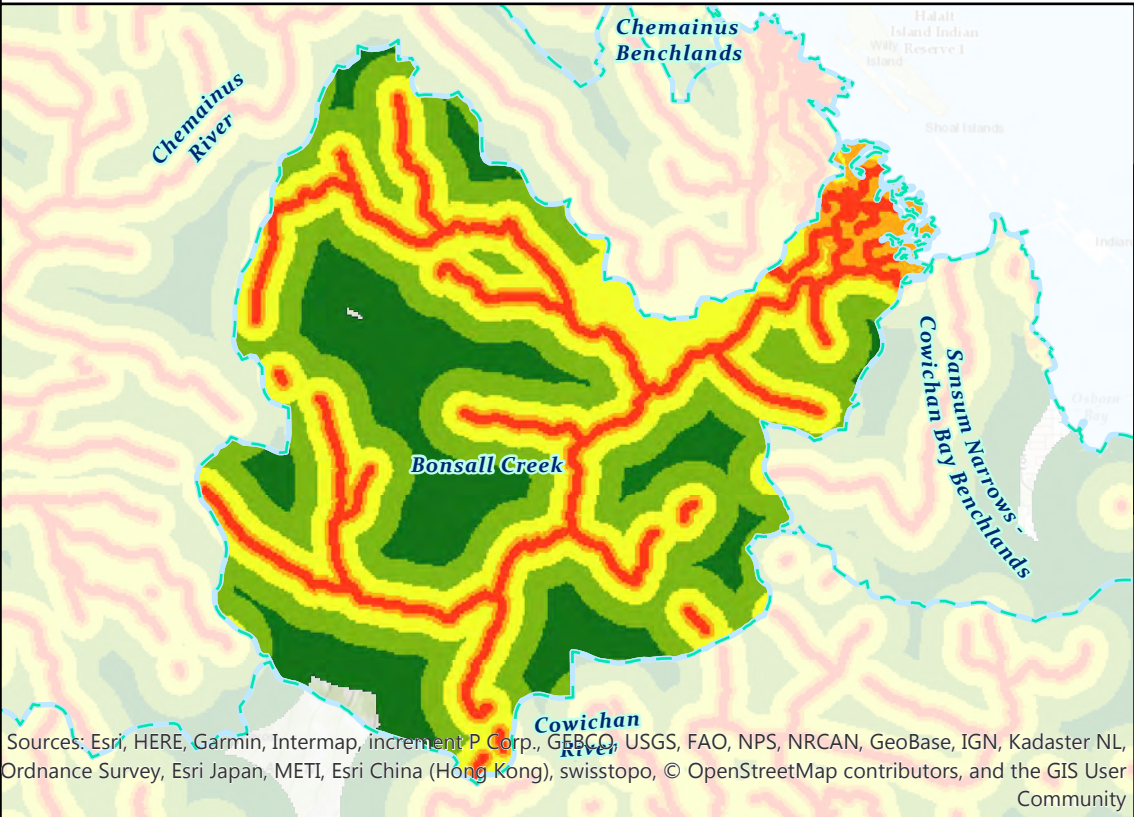


CONSEQUENCE



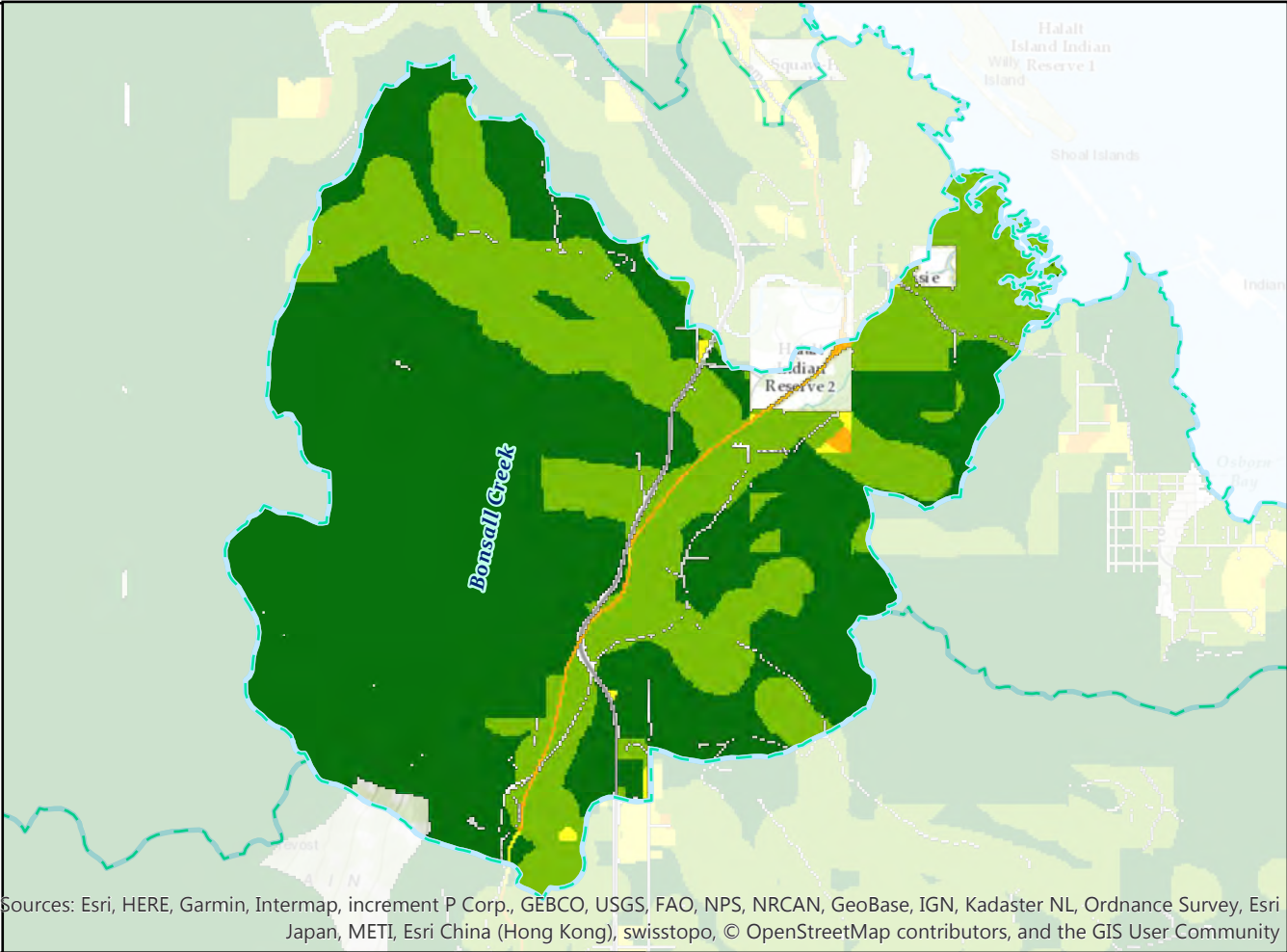
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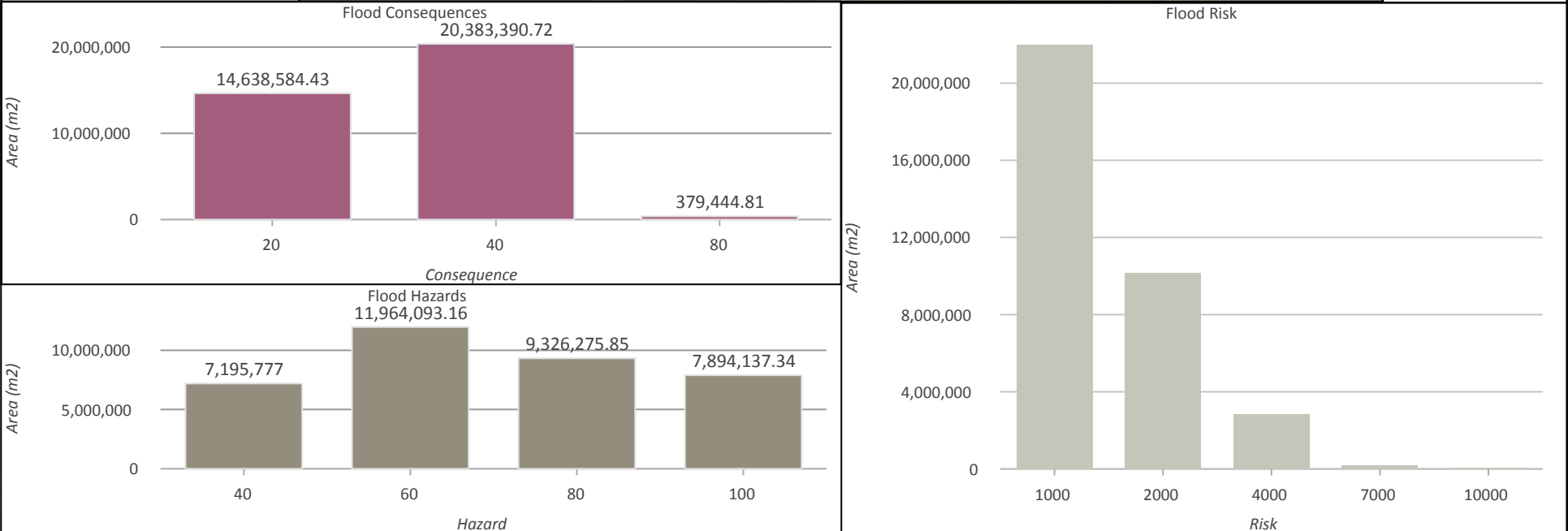


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0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Bonsall Creek Watershed

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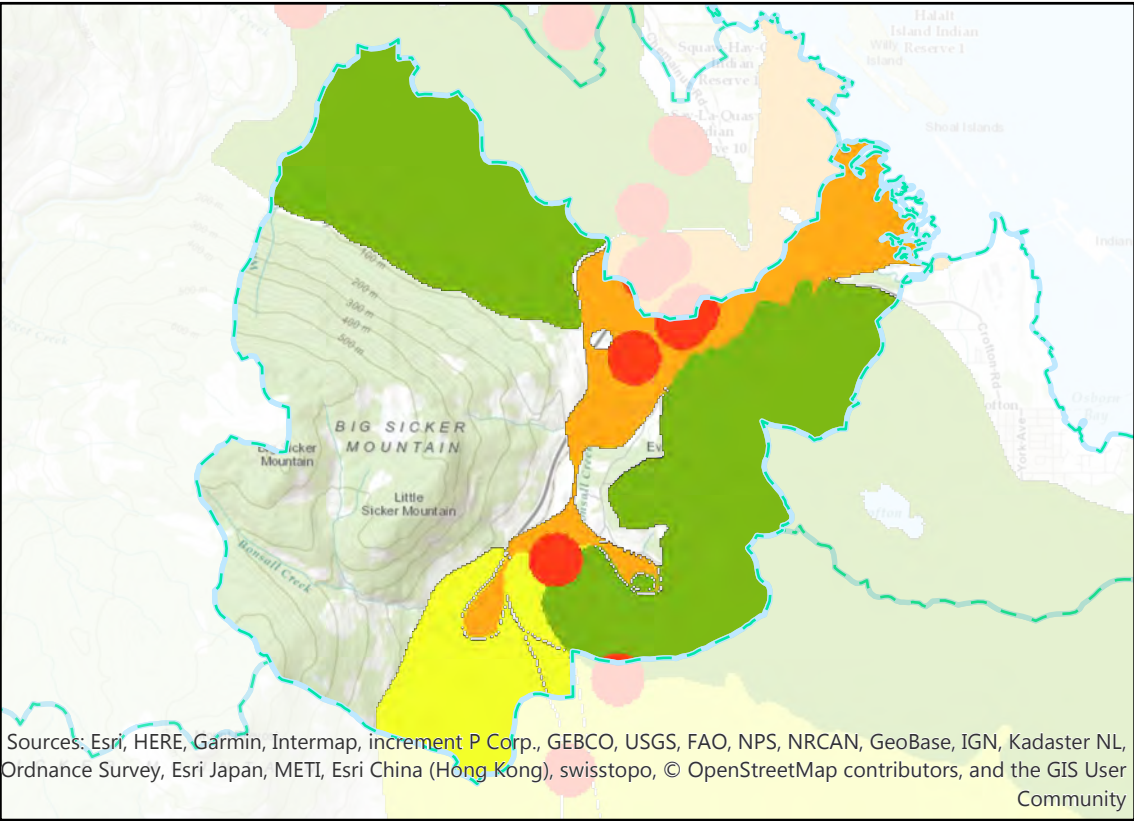
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BY: CJW SCALE CONS: 1:71,408 DATE: 2019/01/08 REF No: REV: 0

CHK'D: DK Proj Coord Sys: NAD 1983 UTM Zone 10N **651957-102-BONS**

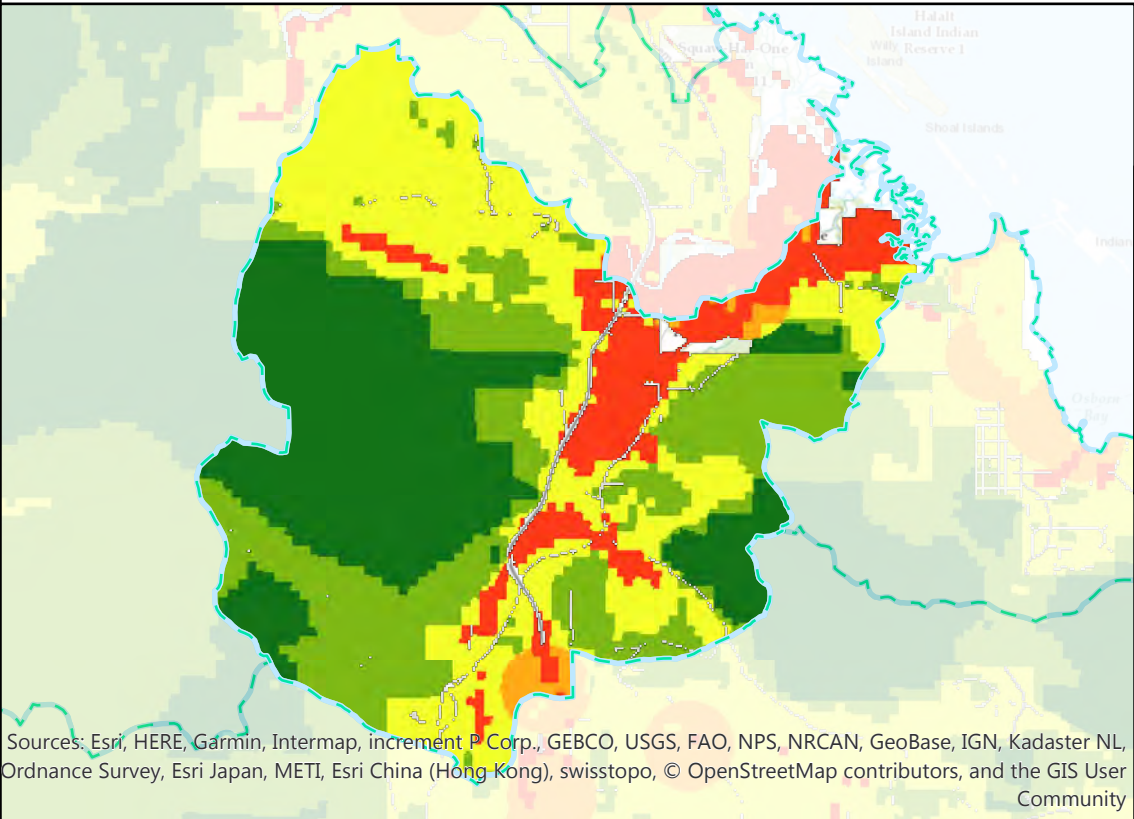
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CONSEQUENCE



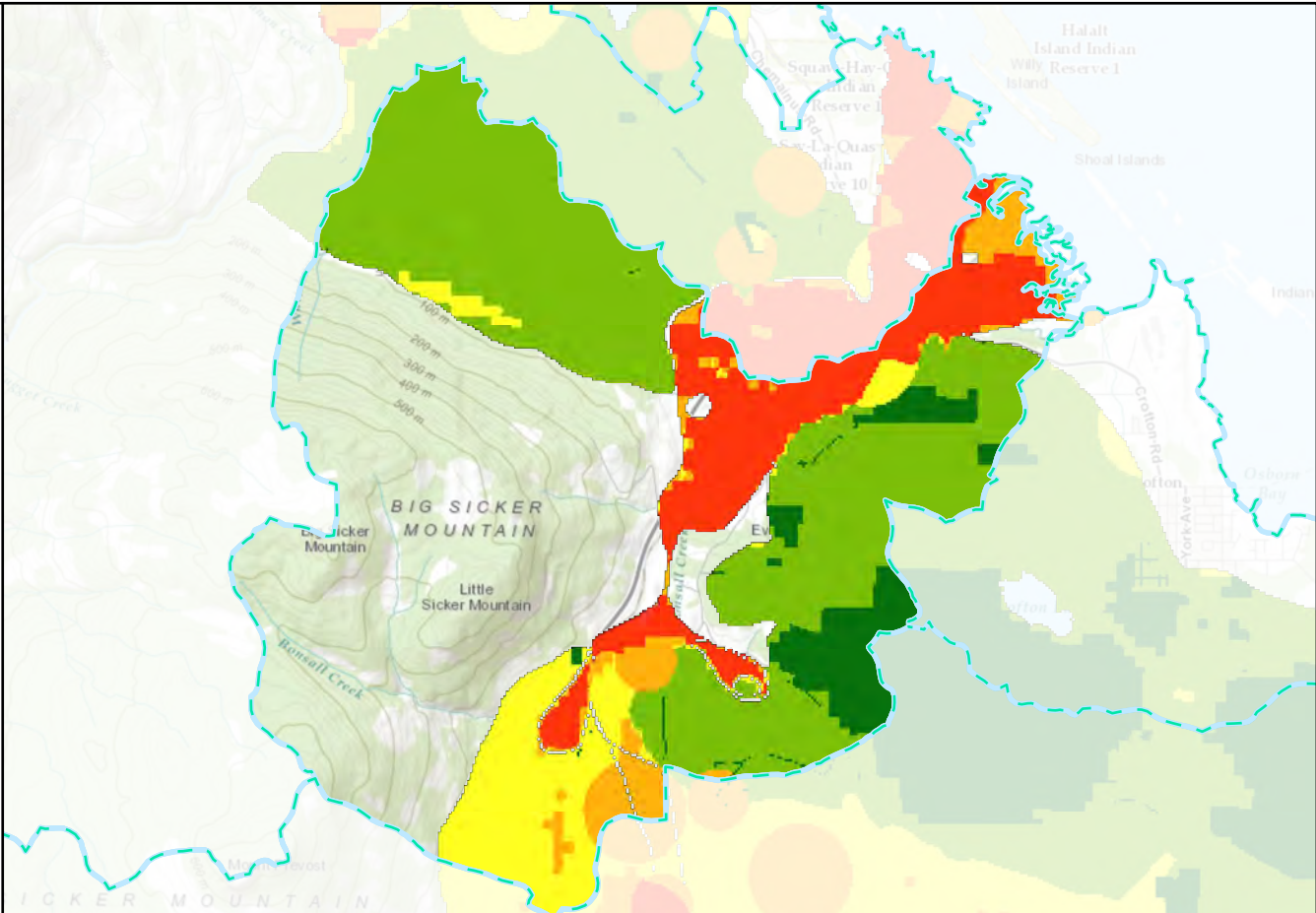
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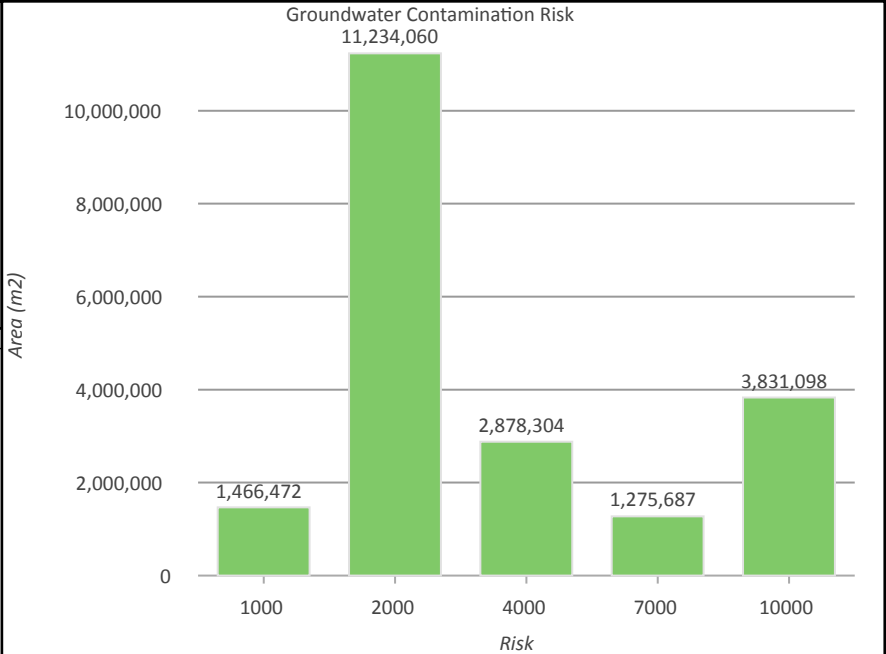
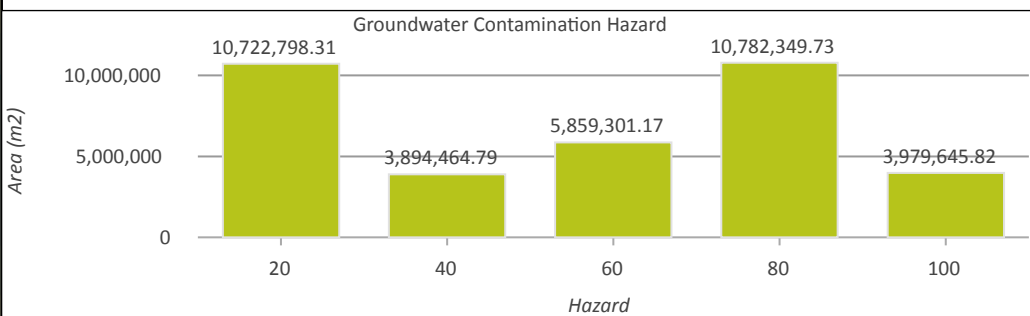
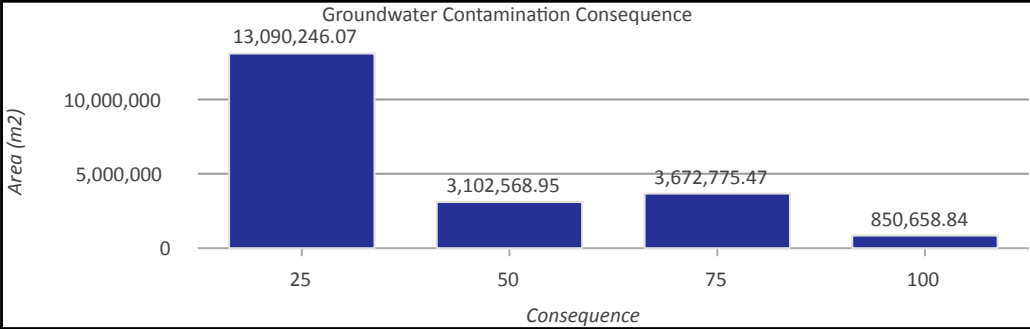


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

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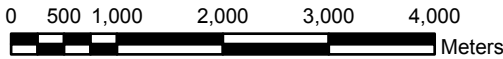
CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Bonsall Creek Watershed

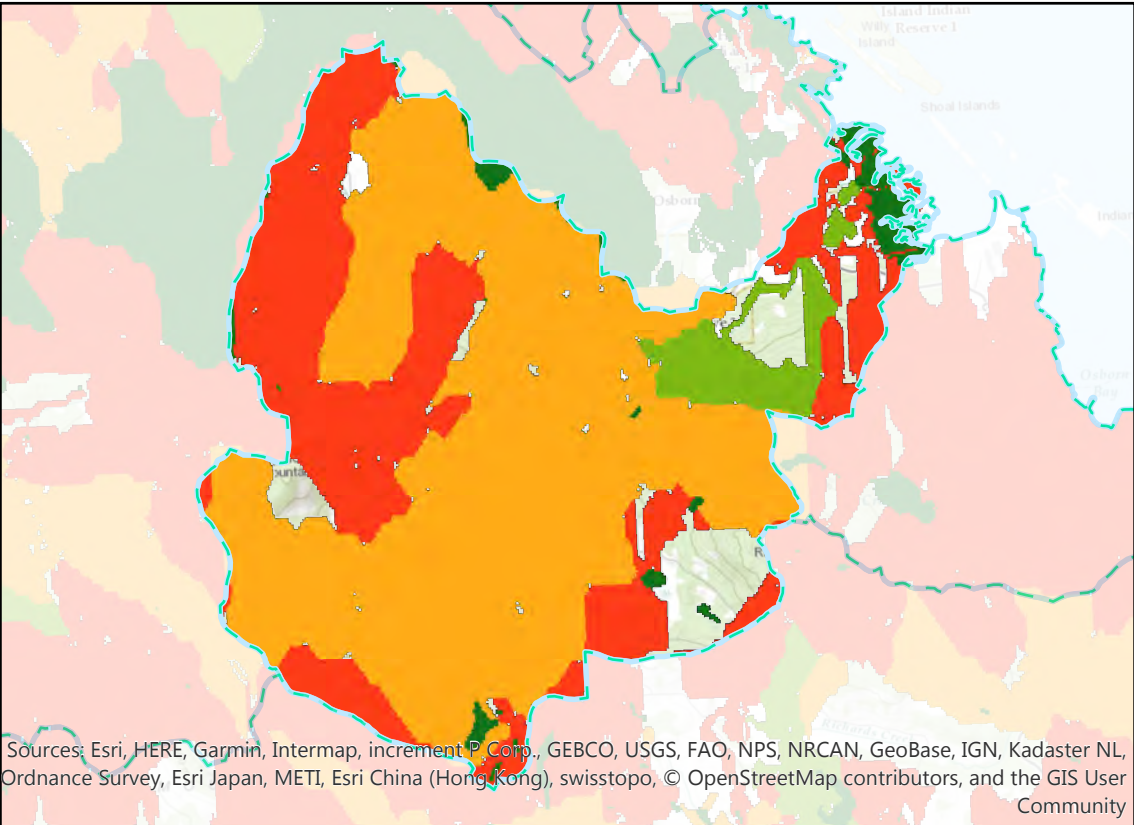
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Groundwater Contamination Risk Assessment - Bonsall Creek

BY: CJW	SCALE CONS: 1:71,408	DATE: 2019/01/08	REF No:	REV: 0
CHK'D: DK	Proj Coord Sys: NAD 1983 UTM Zone 10N		651957-103-BONS	

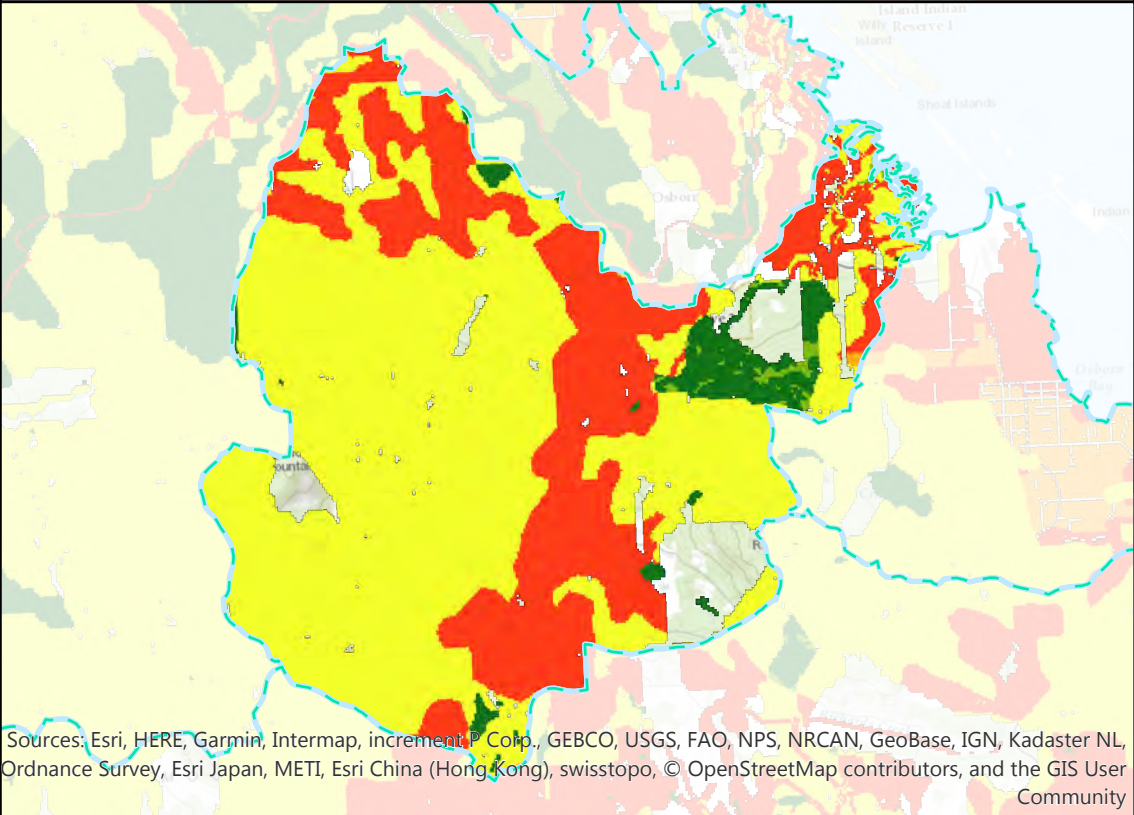


CONSEQUENCE



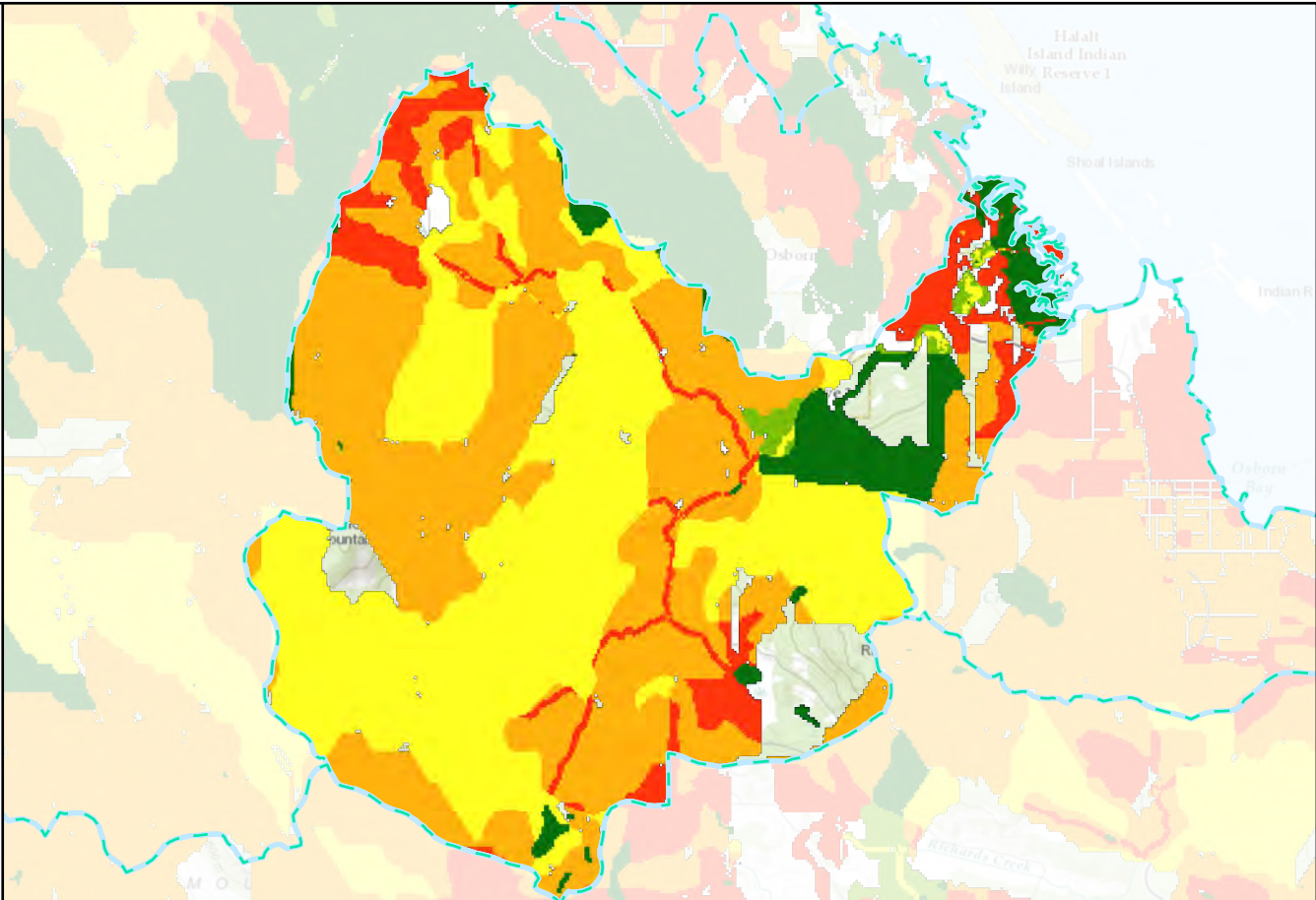
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

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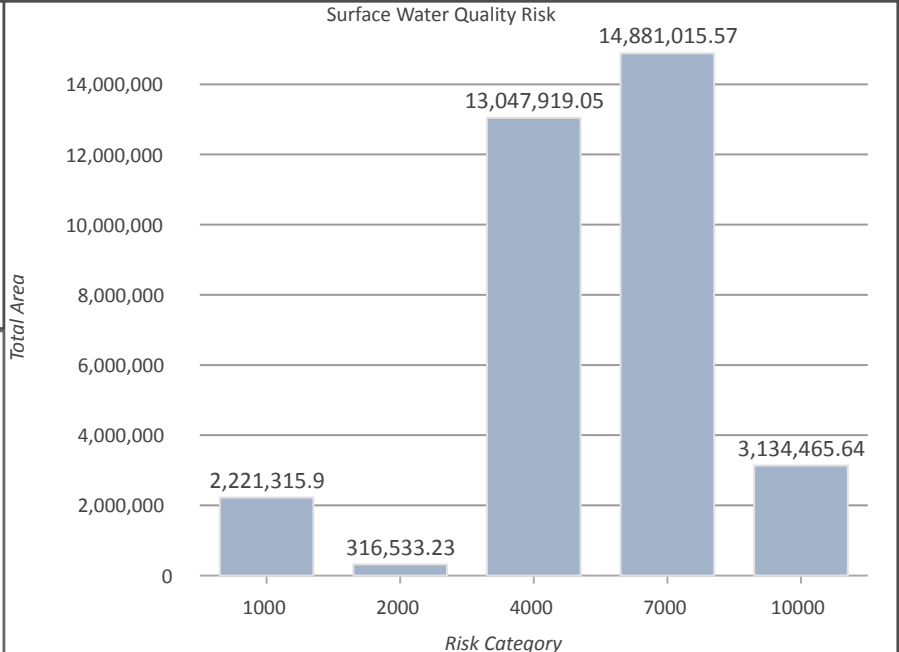
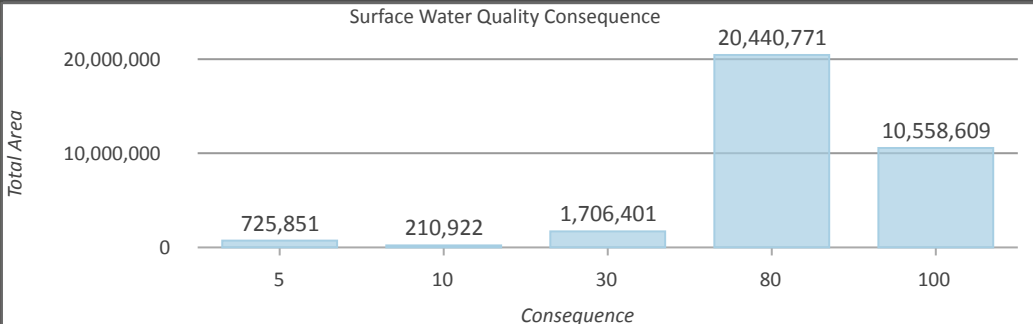
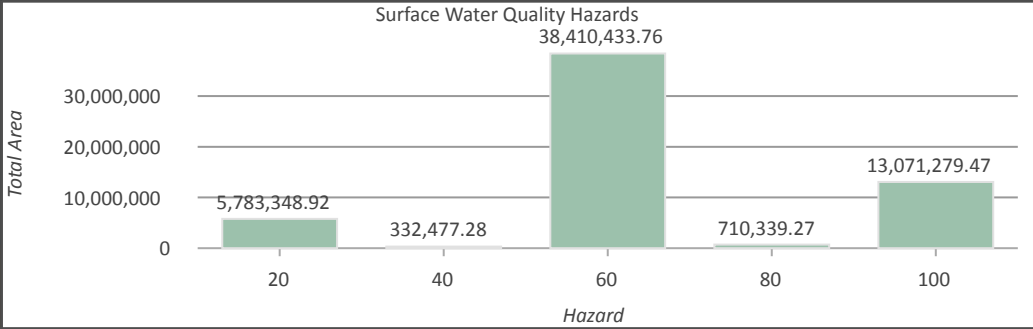


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

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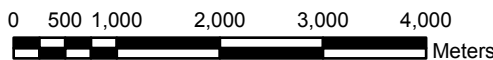
CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District Bonsall Creek Watershed



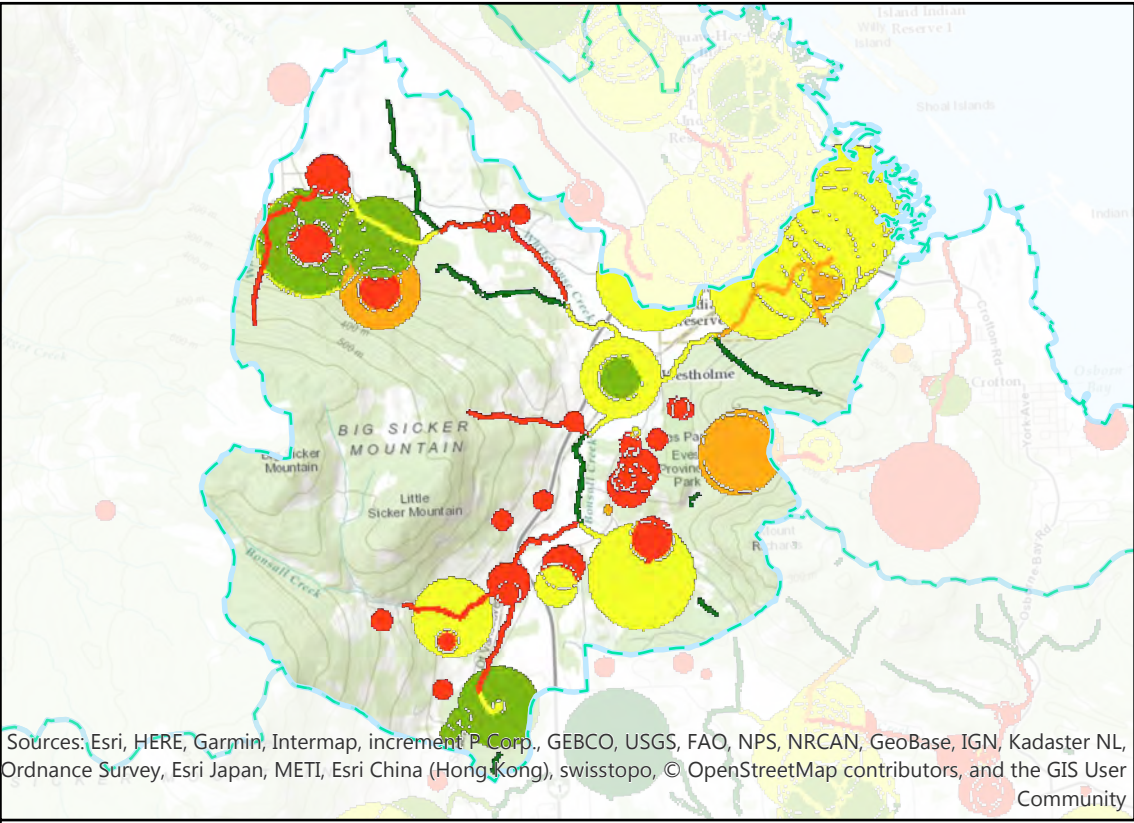
Surface Water Quality Risk Assessment - Bonsall Creek

BY: SCALE: 1:73,330 DATE: 2019/01/08 REF No: REV: 0
CHK'D: Proj Coord Sys: PCS Albers 651957-104-BONS



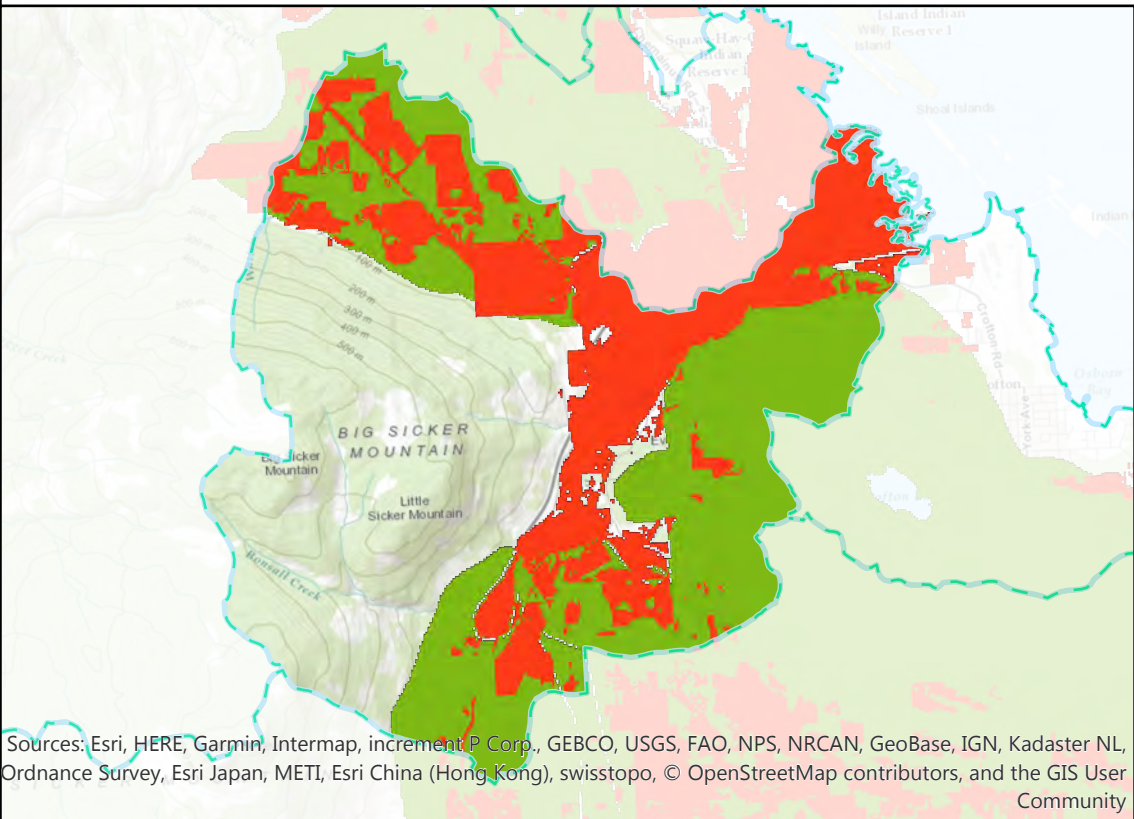
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CONSEQUENCE



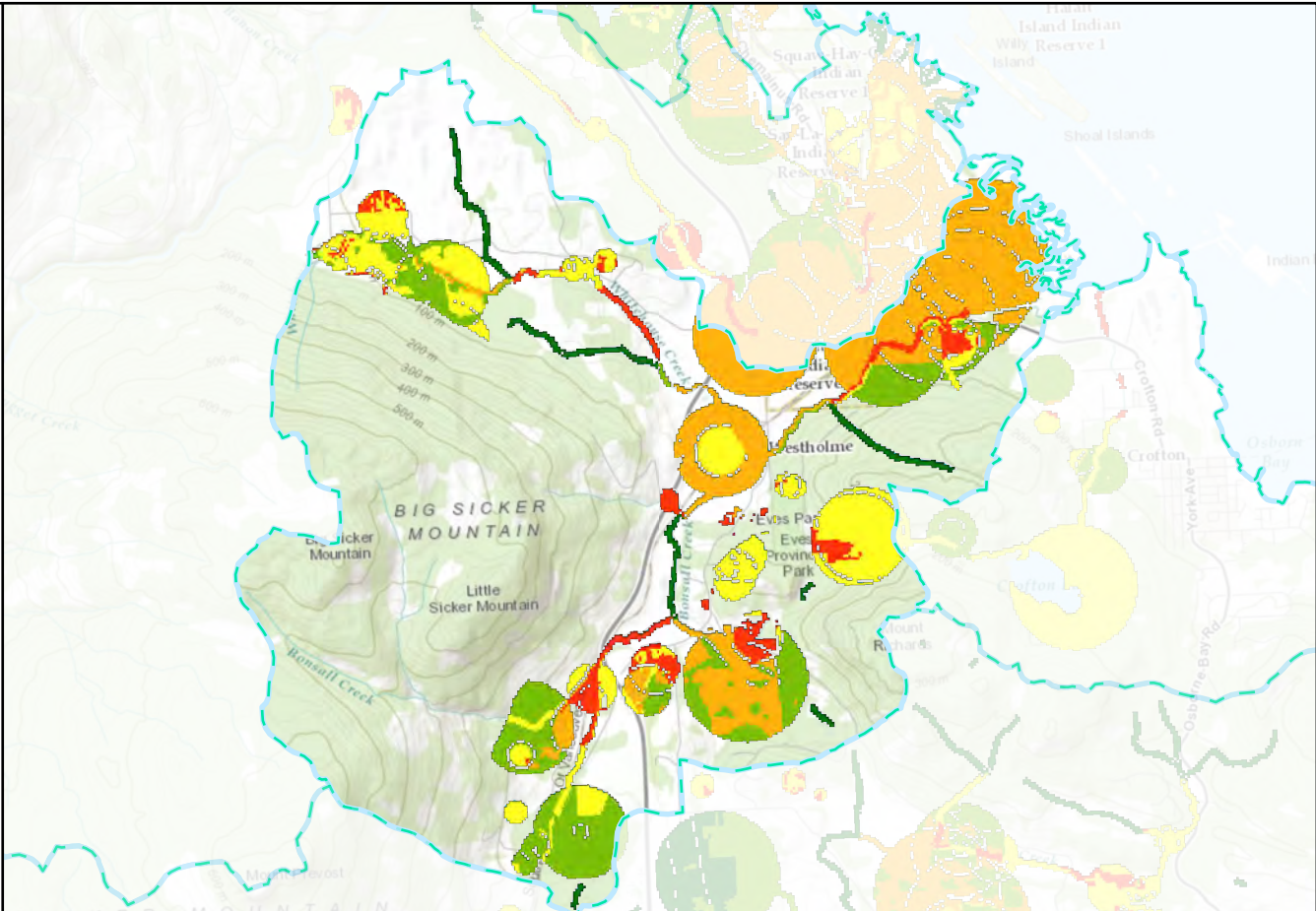
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

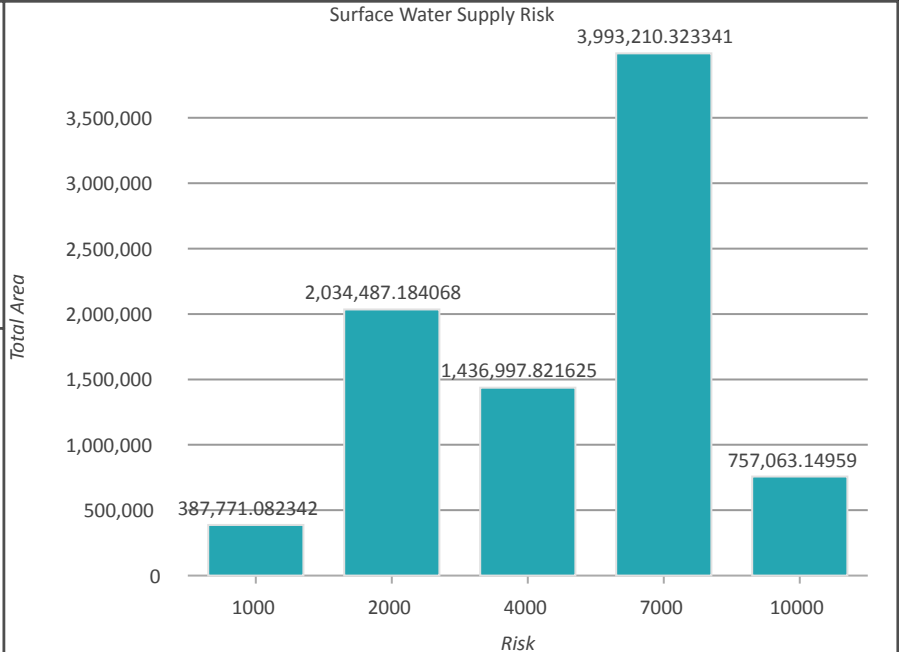
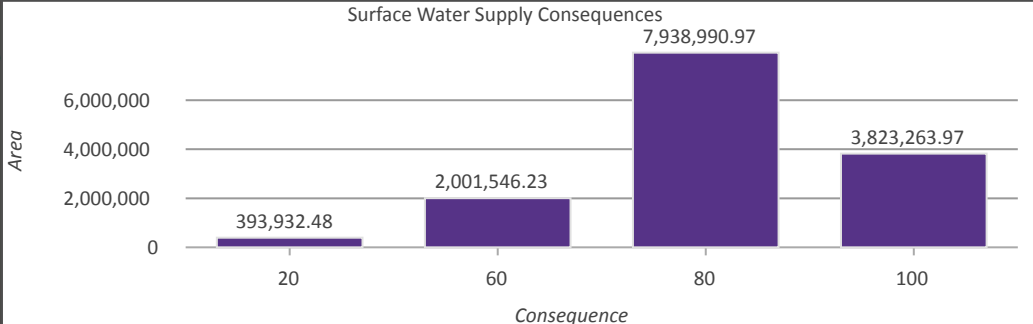
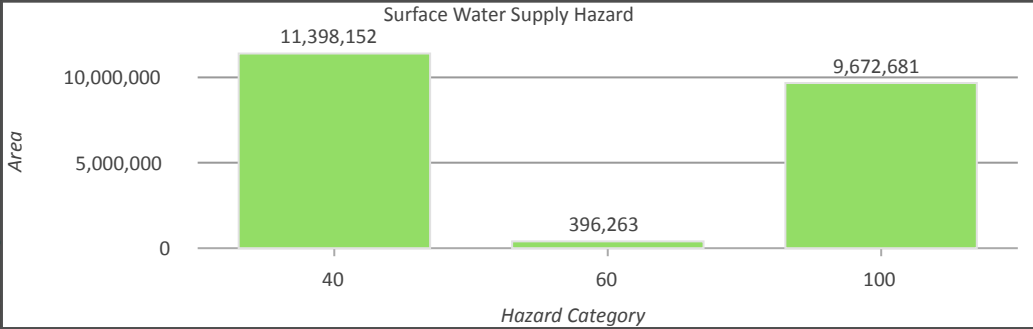


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

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REVISIONS:

0 - C-JW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

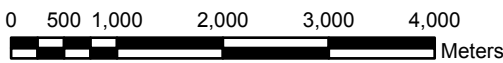
PROJECT LOCATION:
Cowichan Valley Regional District Bonsall Creek Watershed

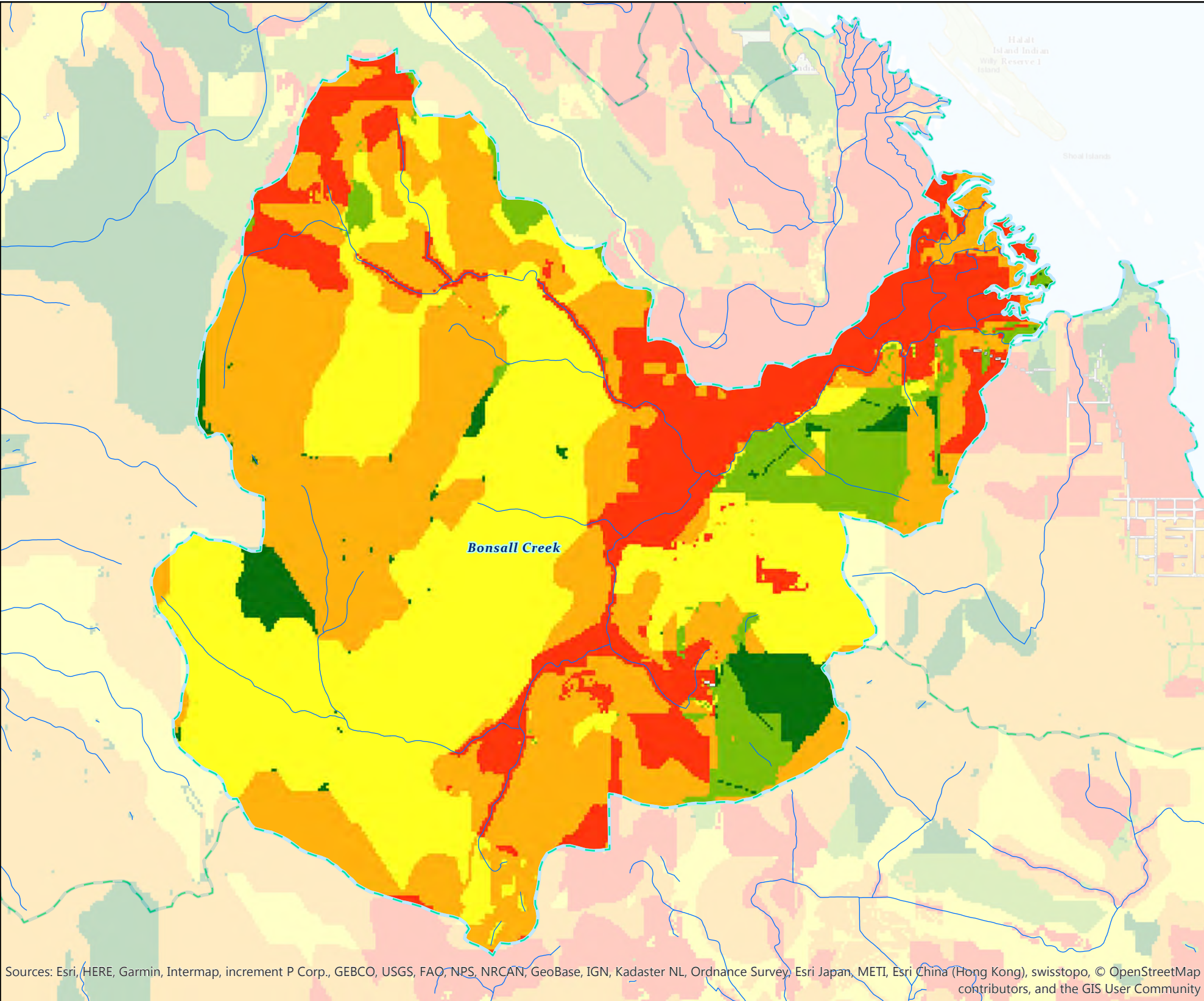


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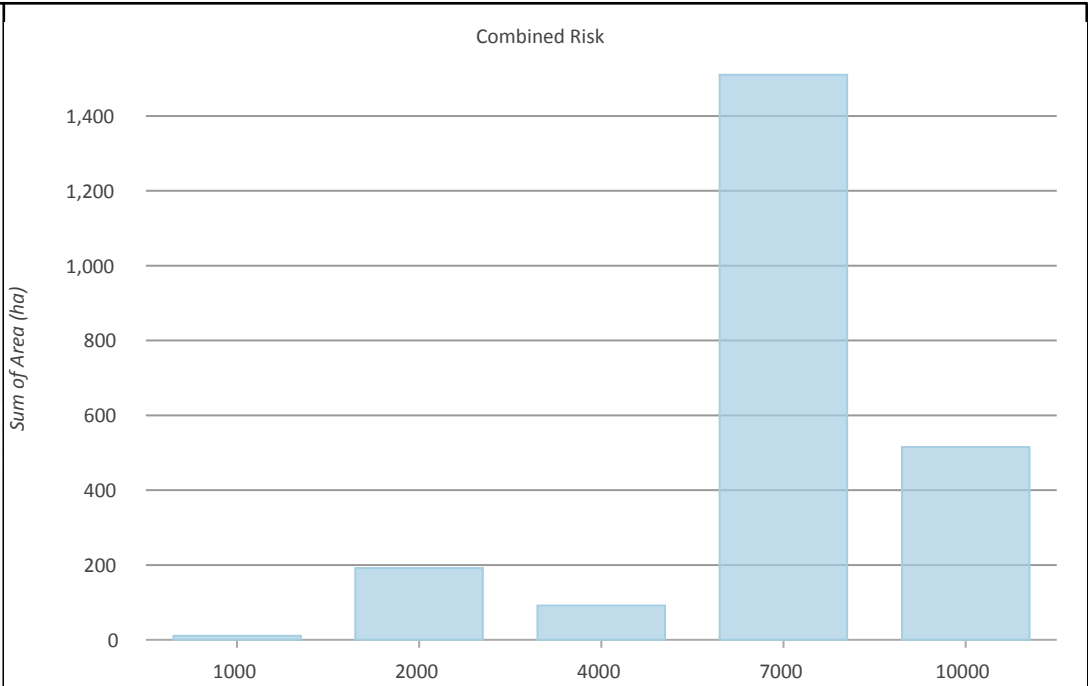
Surface Water Supply Risk Assessment - Bonsall Creek

BY:	SCALE: 1:71,408	DATE: 2019/01/08	REF No:	REV: 0
CHK'D:	Proj Coord Sys: PCS Albers		651957-105-BONS	





Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



NAME	Risk	POP ₂₀₂₁	POP ₂₀₂₆	POP ₂₀₃₁	POP ₂₀₃₆
SHAWNIGAN CREEK		10047	10760	11613	12598
BUSH CREEK		0	0	0	0
KOKSILAH RIVER		5463	5851	6315	6850
HOLLAND CREEK		1302	1368	1446	1537
BONSALL CREEK		934	974	1019	1073
CHEMAINUS RIVER		1490	1461	1439	1421
COWICHAN RIVER		36368	37905	39683	41766
YELLOW POINT BENCHLANDS		2239	2352	2487	2643
LADYSMITH - SALT AIR BENCHLANDS		8410	8834	9342	9929
STOCKING CREEK		1531	1608	1701	1807
CHEMAINUS BENCHLANDS		3663	3818	3997	4207
SATELLITE CHANNEL BENCHLANDS		4390	4701	5074	5504
SANSUM NARROWS - COWICHAN BAY BENCHLANDS		4941	5150	5391	5674
MALAHAT BENCHLANDS		2829	3030	3271	3548

NAME	POP ₂₀₀₁	POP ₂₀₀₆	POP ₂₀₁₁	POP ₂₀₁₆
SHAWNIGAN CREEK	6348	8439	8925	9484
BUSH CREEK	0			
KOKSILAH RIVER	4555	4808	4954	5157
HOLLAND CREEK	1611	1114	1169	1245
BONSALL CREEK	672	830	815	890
CHEMAINUS RIVER	1423	1395	1497	1514
COWICHAN RIVER	29779	32673	34075	34647
YELLOW POINT BENCHLANDS	1167	1958	2021	2141
LADYSMITH - SALT AIR BENCHLANDS	5275	7488	7541	8042
STOCKING CREEK	1332	1003	1354	1464
CHEMAINUS BENCHLANDS	3177	3129	3085	3490
SATELLITE CHANNEL BENCHLANDS	5425	3902	3989	4144
SANSUM NARROWS - COWICHAN BAY BENCHLANDS	5993	4221	4500	4707
MALAHAT BENCHLANDS	1673	2472	2548	2671

Legend

WATERSHED BOUNDARIES

RISK

≤ 1000

≤ 2000

≤ 4000

≤ 7000

≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

NOTES:

1. Original in colour.

2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.

3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.

REVISIONS:

0 - CJW - 2018-11-30 - Issued - DK

CLIENT:

Cowichan Valley Regional District

PROJECT LOCATION:

Cowichan Valley Regional District

Bonsall Creek Watershed

Combined Risk Assessment - Bonsall Creek

BY: CJW

SCALE CONS: 1:42,000

DATE: 2019/01/08

REF No: 651957-106-BONS

CHK'D: DK

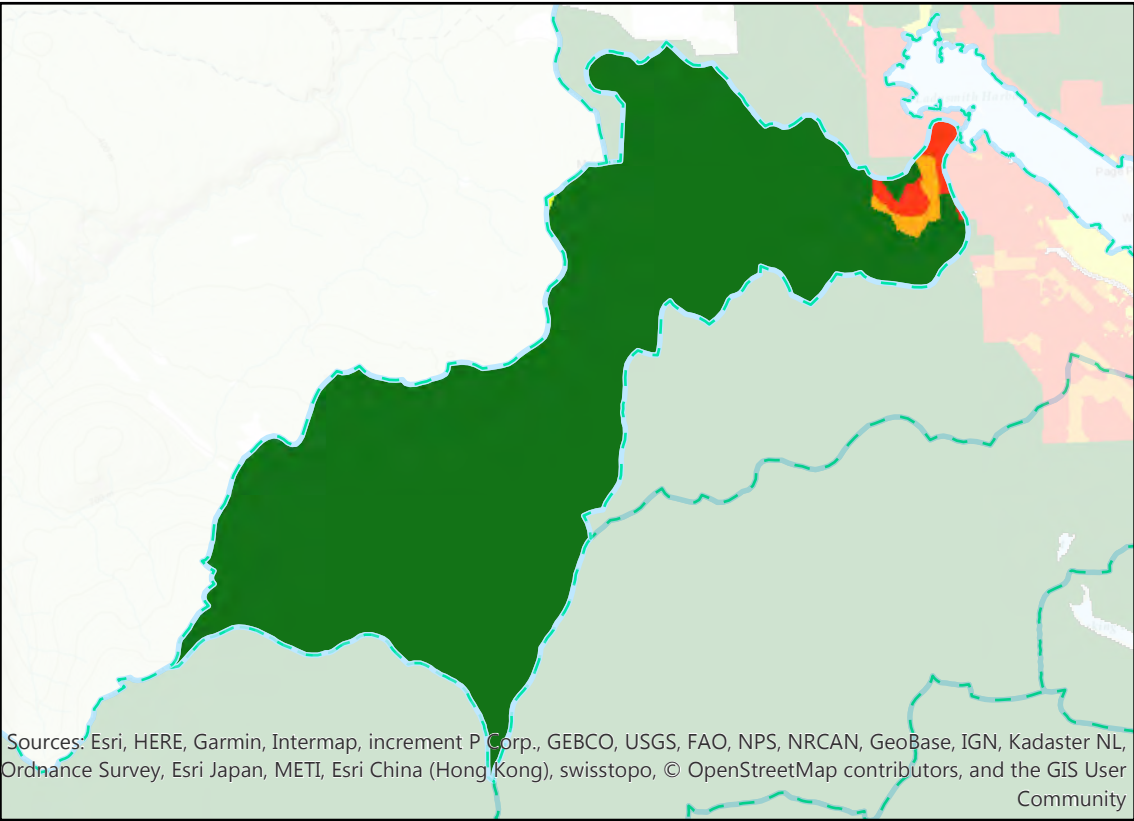
Proj Coord Sys: NAD 1983 UTM Zone 10N

REV: 0

Project Path: P:\Current Projects\CVRD\651957\ P: 1-6

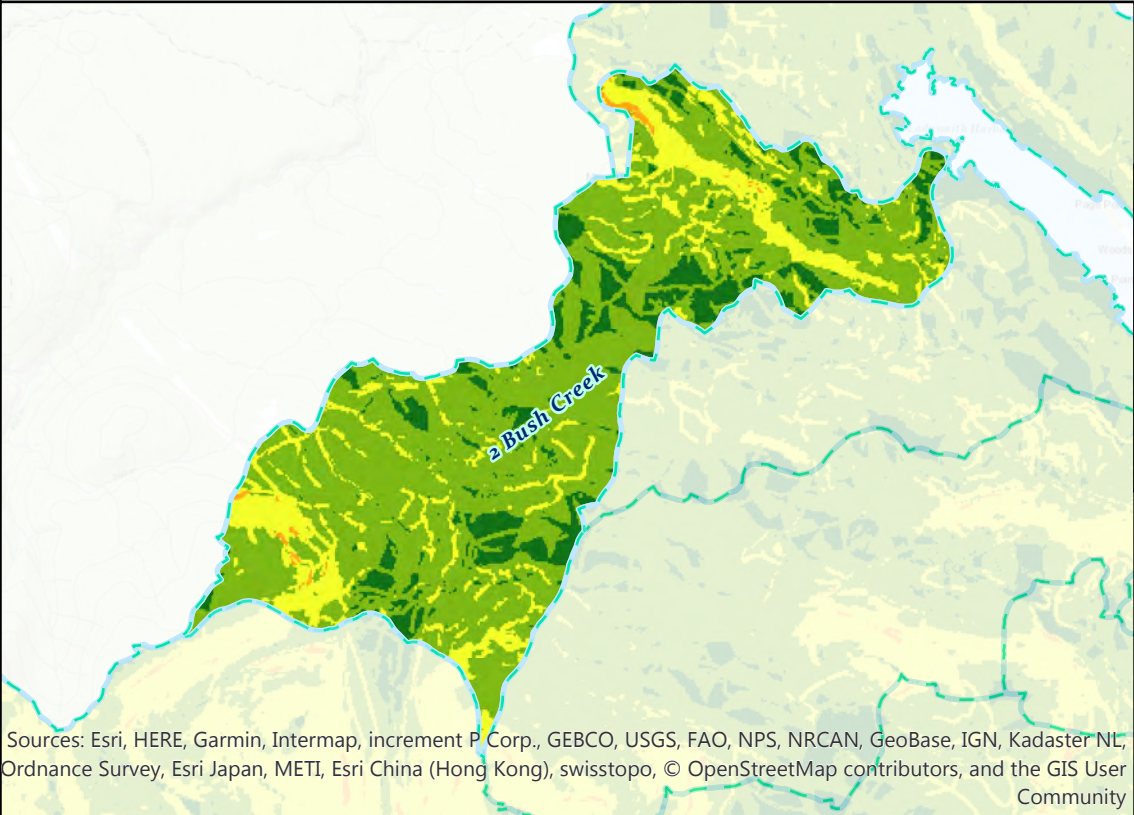
2. Bush Creek	
Topic	Discussion
Slope Failure	<p>Hazard was determined qualitatively at a high level to describe areas based on the degree to which they may be prone to landslides and other mass movements using terrain characteristics. Hazard classifications were generated to show relative comparisons between terrain units within the CVRD watershed study area. Risk ratings derived from this analysis are relative, and should be used to guide prioritization of further detailed studies.</p> <p>Hazard is generally low throughout the watershed due to low slope gradients. Some hazard exists where logging activities have occurred on slopes towards the western and northern edges of the watershed. Consequence is considered low for the majority of the watershed, with a small area of moderate to high consequence in the populated area near the outlet of Bush Creek. Risk is considered moderate in this populated area.</p>
Flooding	<p>There is considered to be some potential for flooding in the areas of the various rivers and streams. Consequence and risk are very low for the predominantly agricultural watershed with higher risk areas near several roadways and Highway 1 north of Ladysmith.</p>
Groundwater Contamination	<p>The high DRASTIC vulnerability value in the northeast area of the watershed and the presence of contaminated sites along highway 1 are the main drivers for the risk rating in this watershed. The consequence of groundwater contamination in this watershed is low to moderate due to the absence of municipal groundwater supply system and a low to moderate aquifer demand.</p>
Surface Water Quality	<p>Hazard is low for the watershed due to the lack of impervious land cover. Consequence is moderate since many of the tributaries of Bush Creek are lower order streams that have lower buffering capacity and therefore are more susceptible to water quality issues than larger streams. Risk is greatest for these lower order streams.</p>
Surface Water Supply	<p>Hazard is greatest in a zone across the lower reaches of the water northwest of Ladysmith. Consequence is considered low for the majority of the watershed, with a small area of moderate consequence near the outlet of Bush Creek. Risk is greatest in a small zone in the lower watershed, where points of diversion intersect the higher hazard area of the aquifer, occupying a very small proportion of the watershed's area. Population information indicates there are no residents of this watershed, and projected population change is not available for this watershed.</p>
General Data Notes	<p>Risk is focused in the northeast, with the exception of surface water supply / stream health. The population in this watershed is currently 0 and isn't projected to grow. Depending on the importance ecological and natural resource consequences might be developed to better understand impacts to natural resources.</p>

CONSEQUENCE



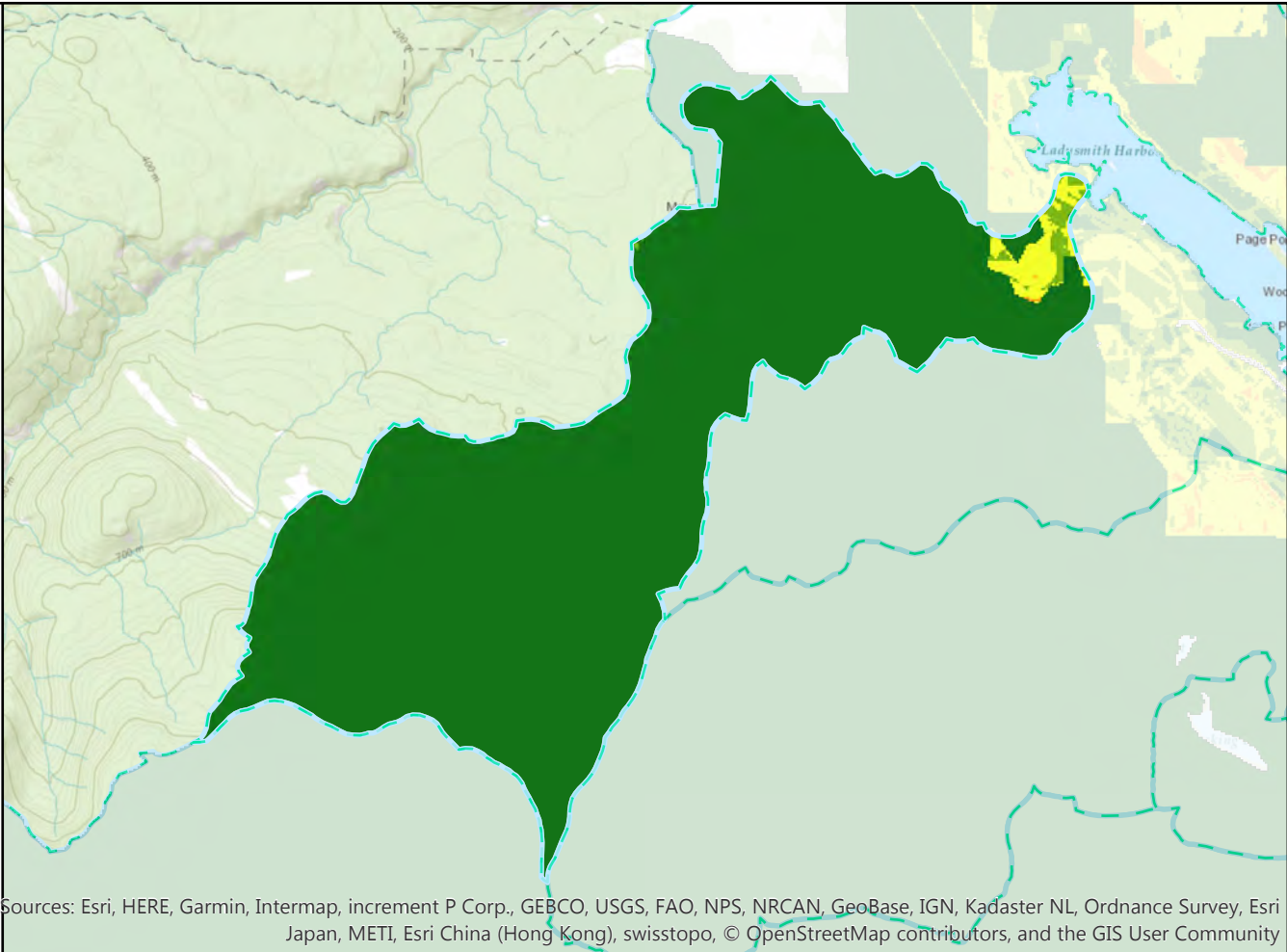
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

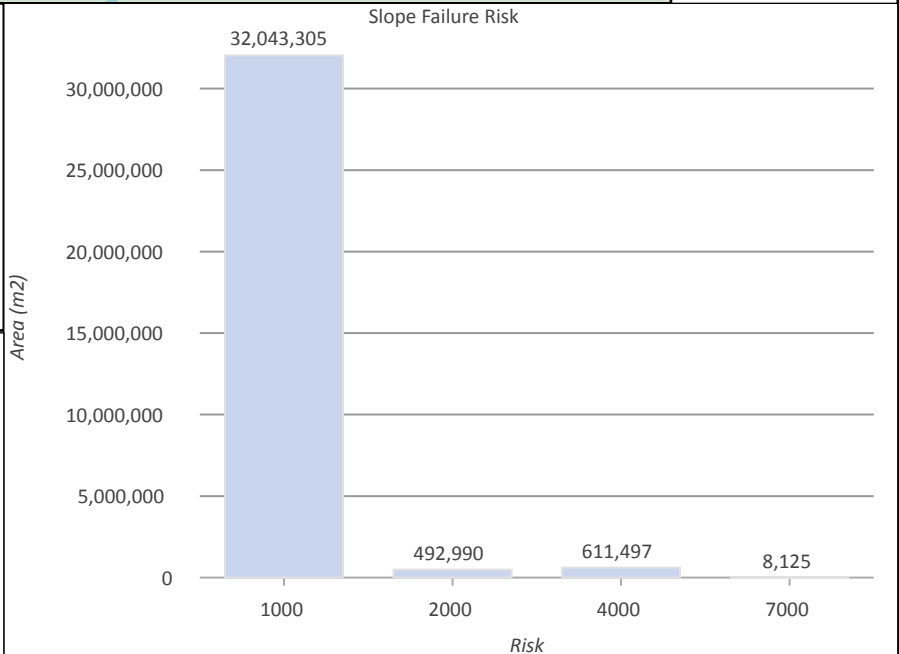
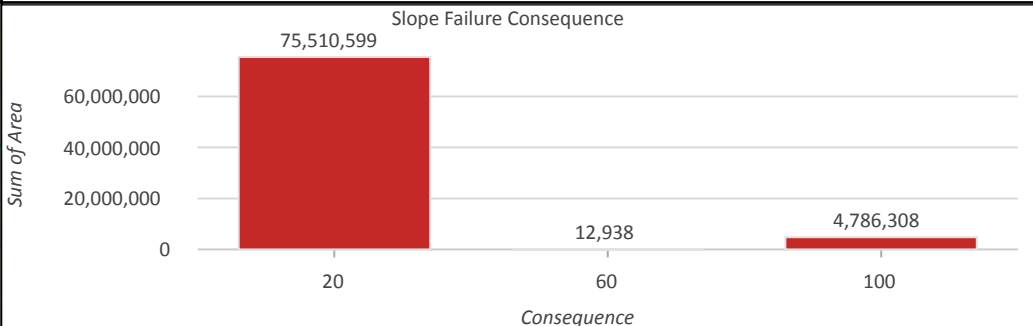
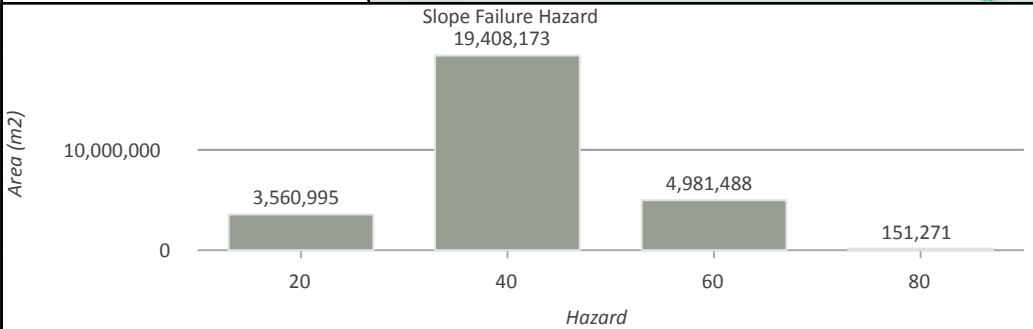


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



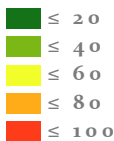
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS



RISK



REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Bush Creek Watershed



Slope Failure Risk Assessment - Bush Creek

BY: CJW

SCALE CONS: 1:82,275

DATE: 2019/01/07

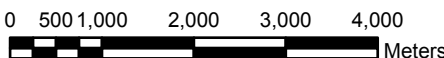
REF No:

REV: 0

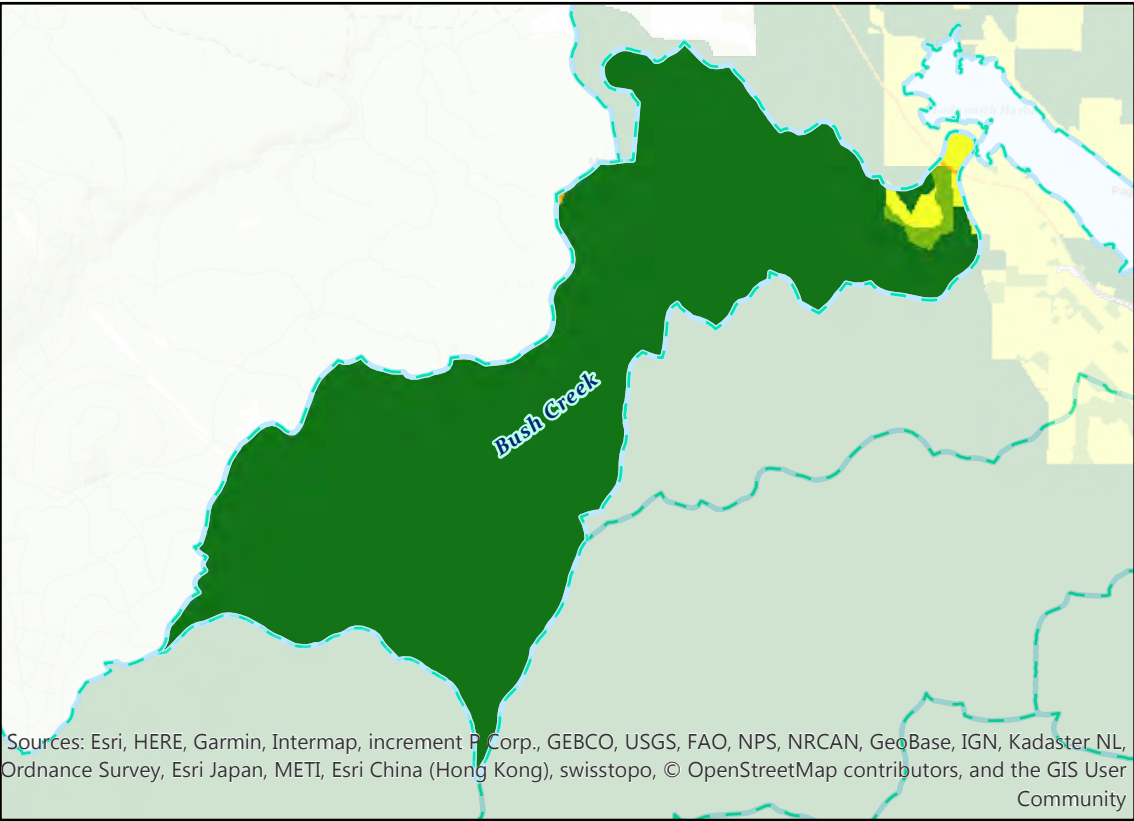
CHK'D: DK

Proj Coord Sys: PCS Albers

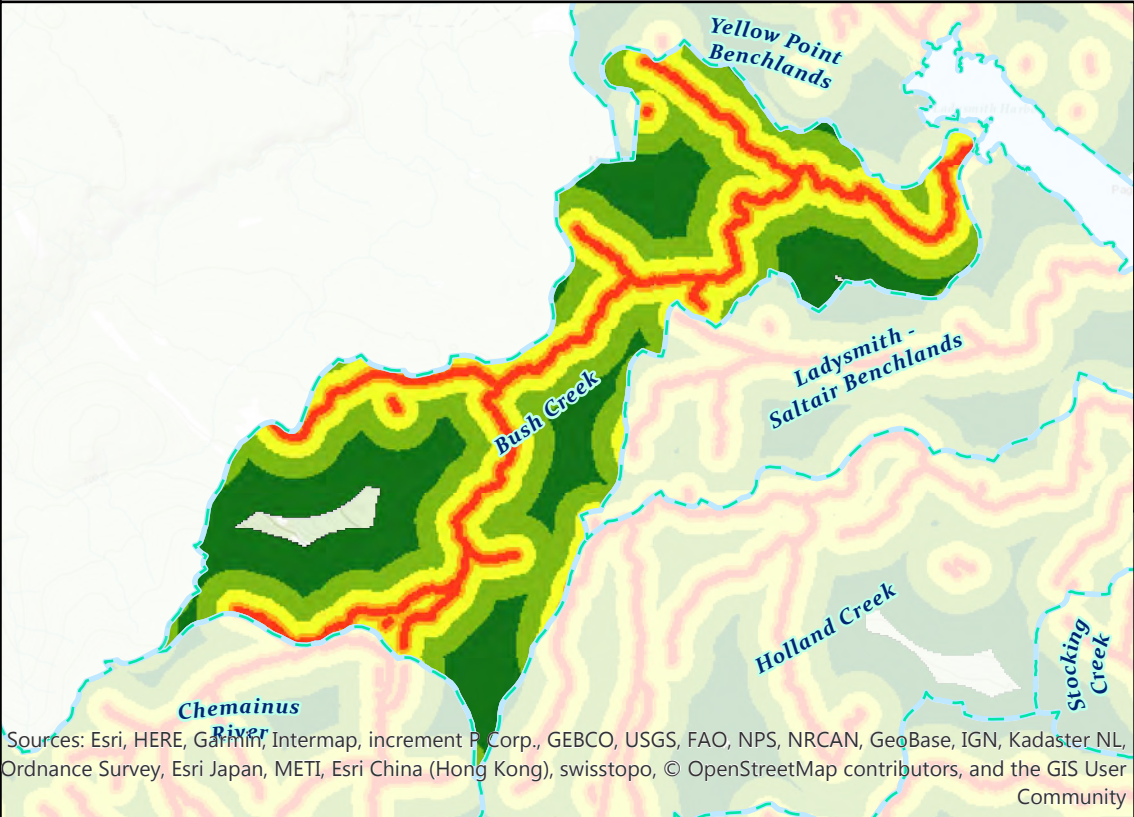
651957-101-BUSH



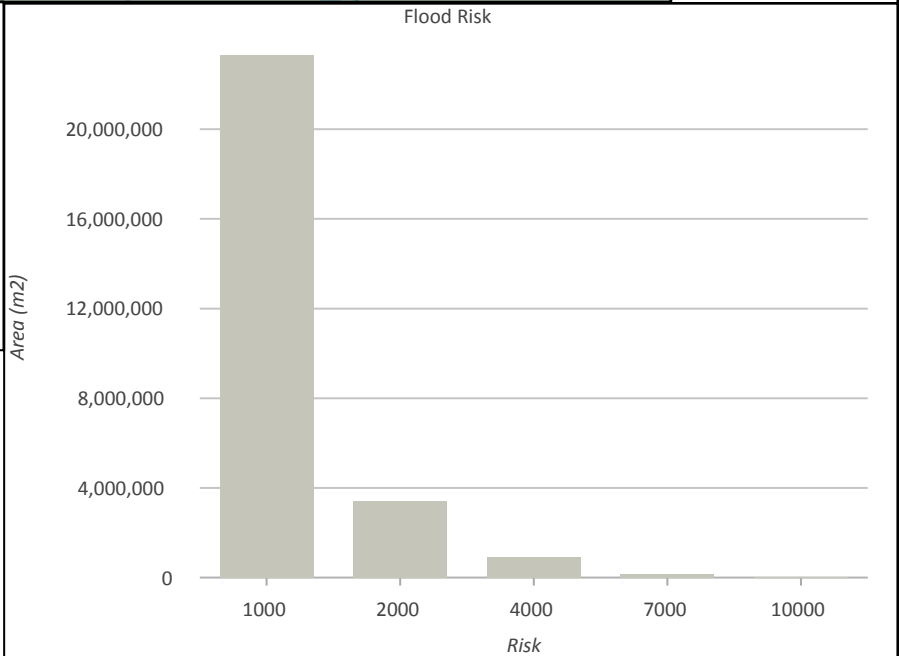
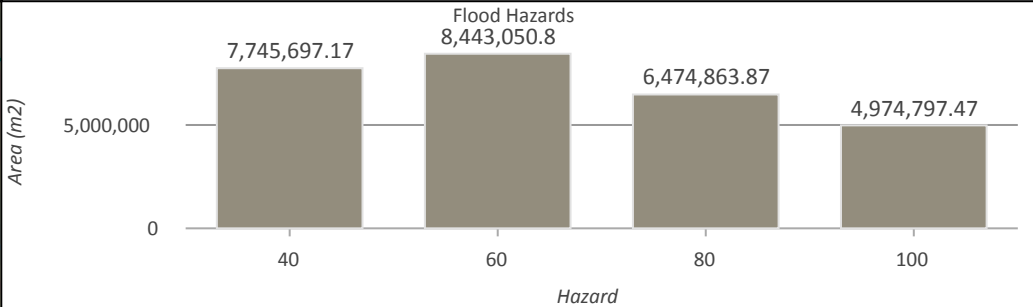
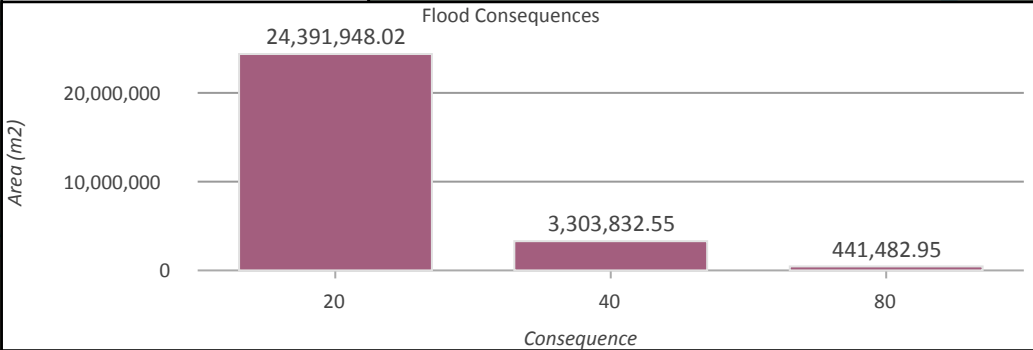
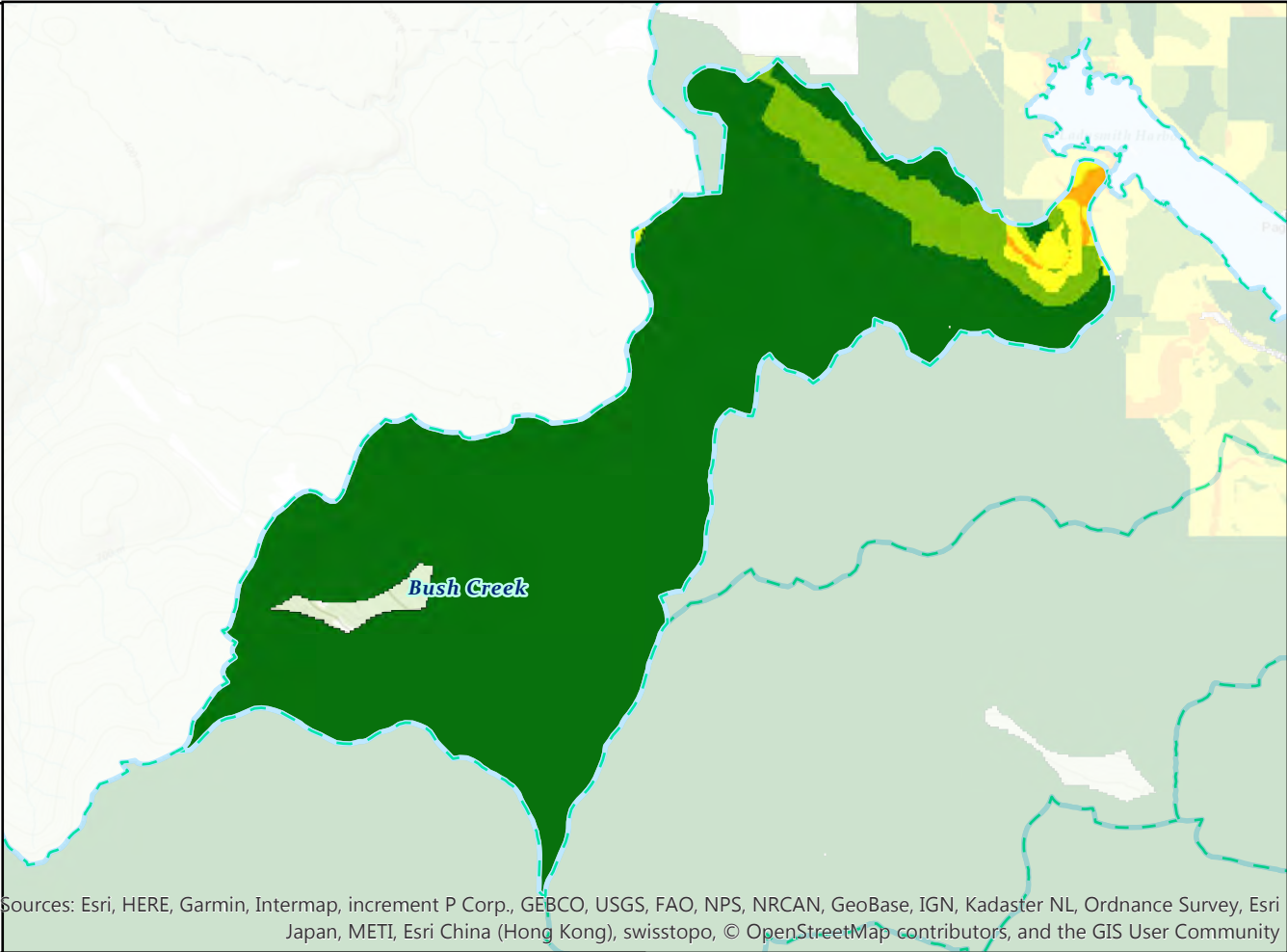
CONSEQUENCE



HAZARD



RISK



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

	≤ 20
	≤ 40
	≤ 60
	≤ 80
	≤ 100

RISK

	≤ 1000
	≤ 2000
	≤ 4000
	≤ 7000
	≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

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REVISIONS:

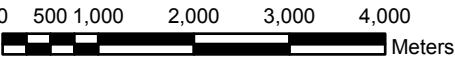
0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

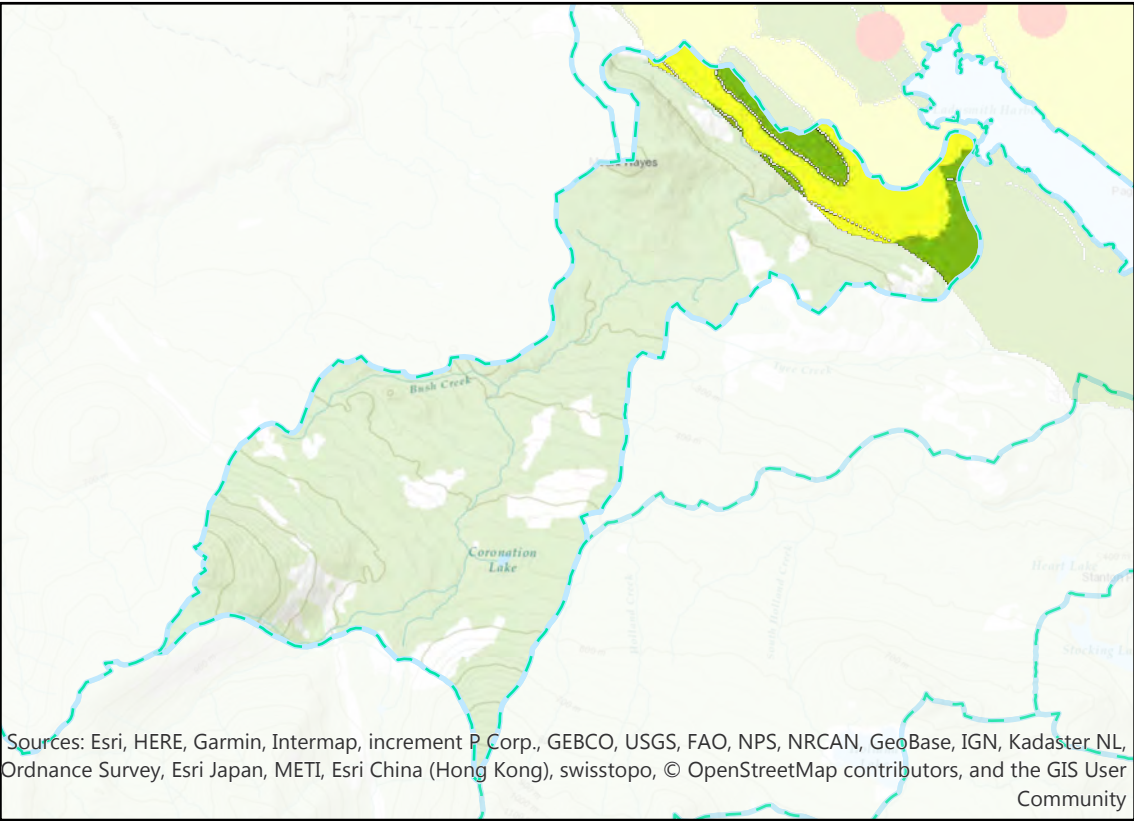
PROJECT LOCATION:
Cowichan Valley Regional District
Bush Creek Watershed

Flood Risk Assessment - Bush Creek

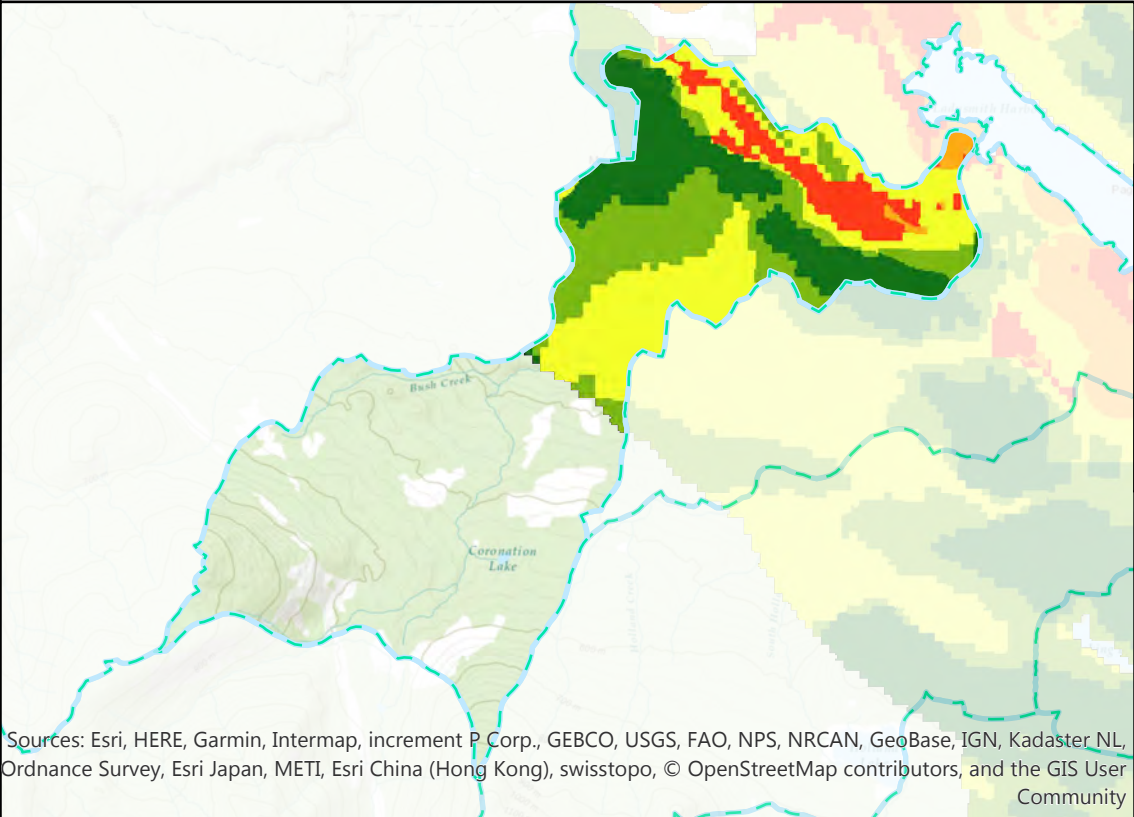
BY: CJW	SCALE CONS: 1:79,059	DATE: 2019/01/08	REF No:	REV: 0
CHK'D: DK	Proj Coord Sys: NAD 1983 UTM Zone 10N		651957-102-BUSH	



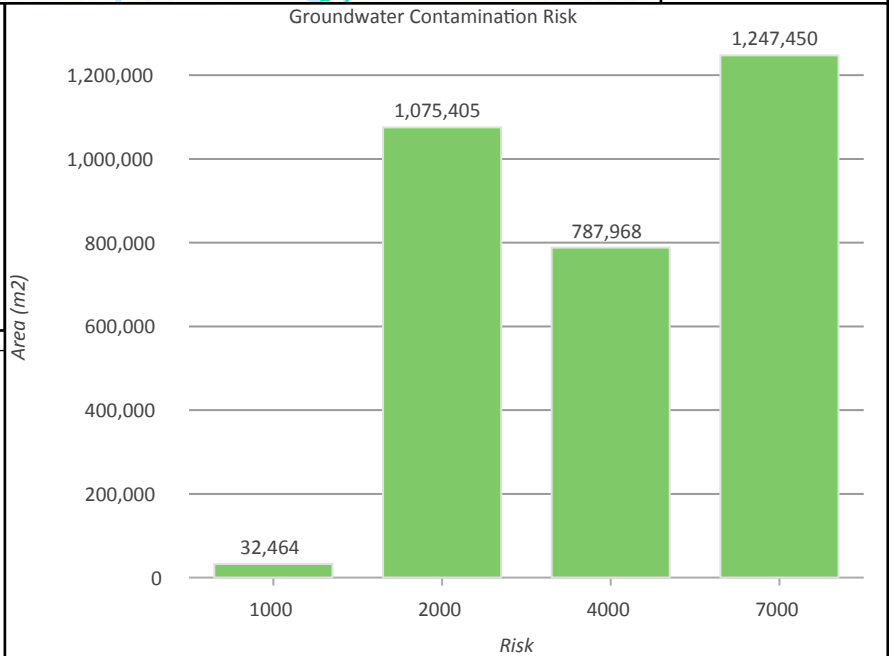
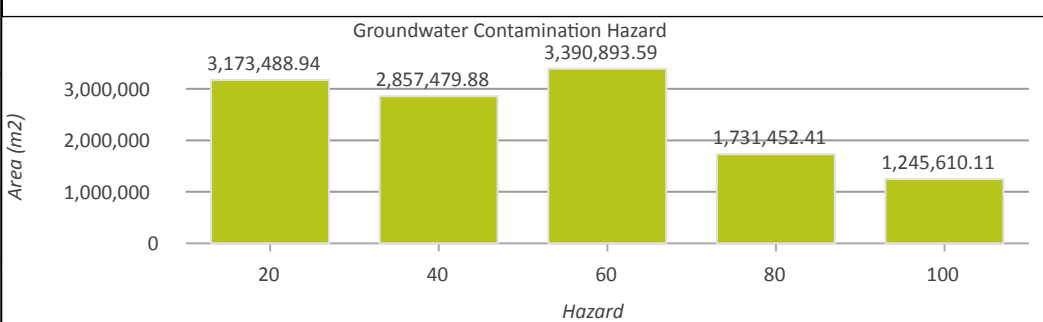
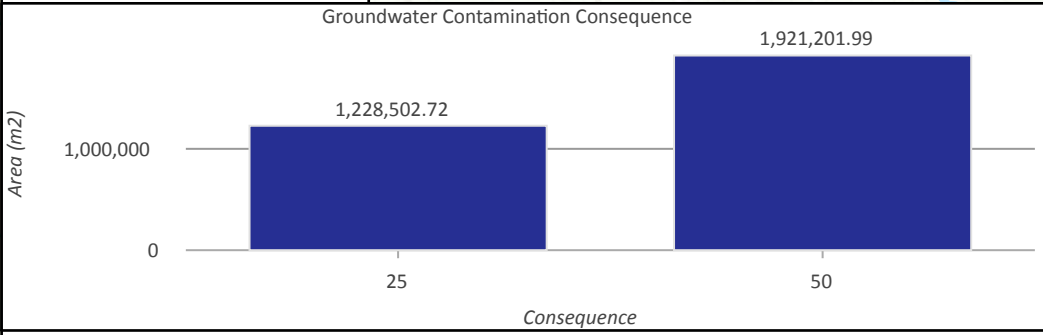
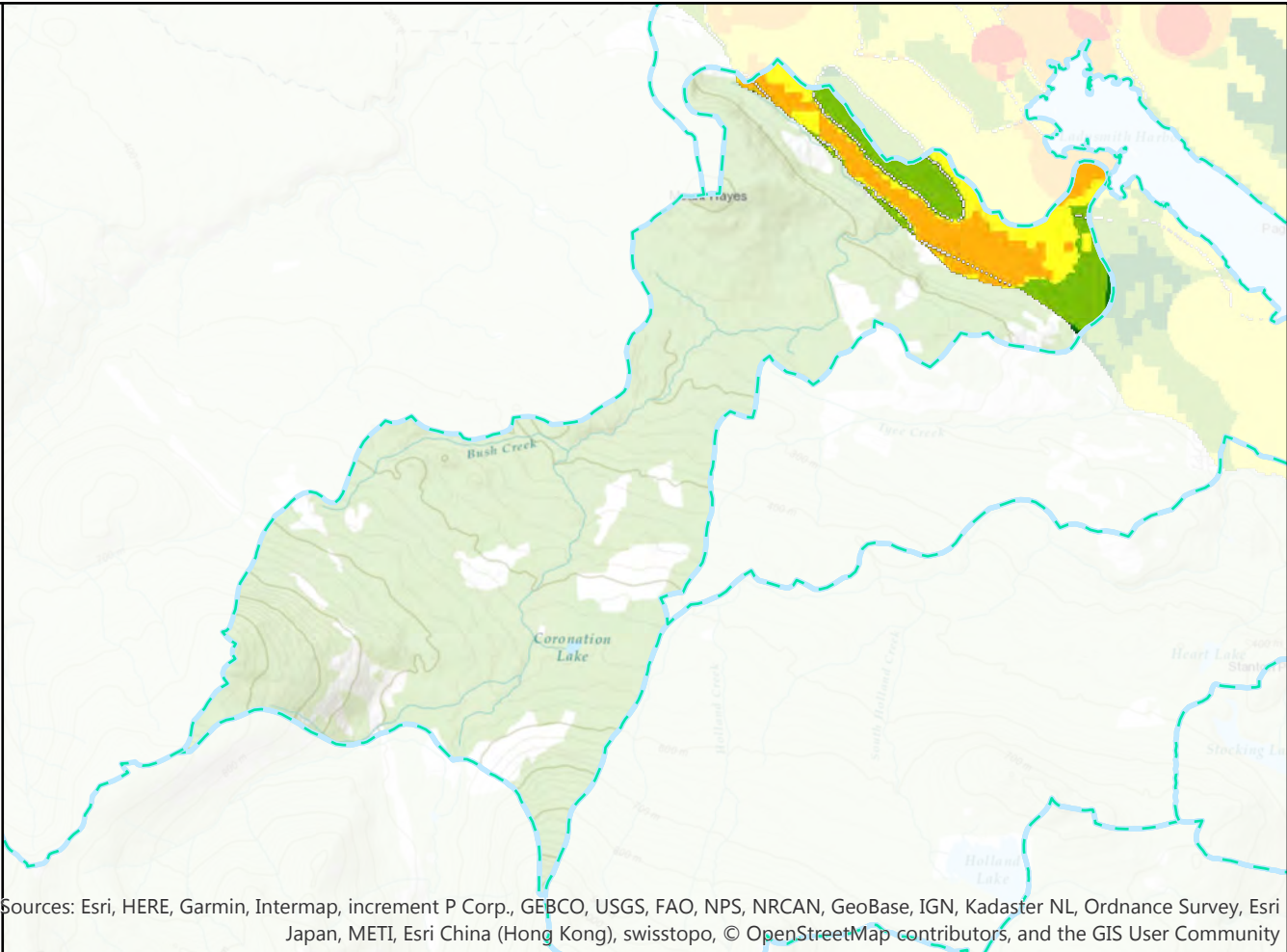
CONSEQUENCE



HAZARD



RISK



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

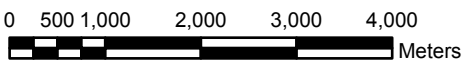
CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Bush Creek Watershed

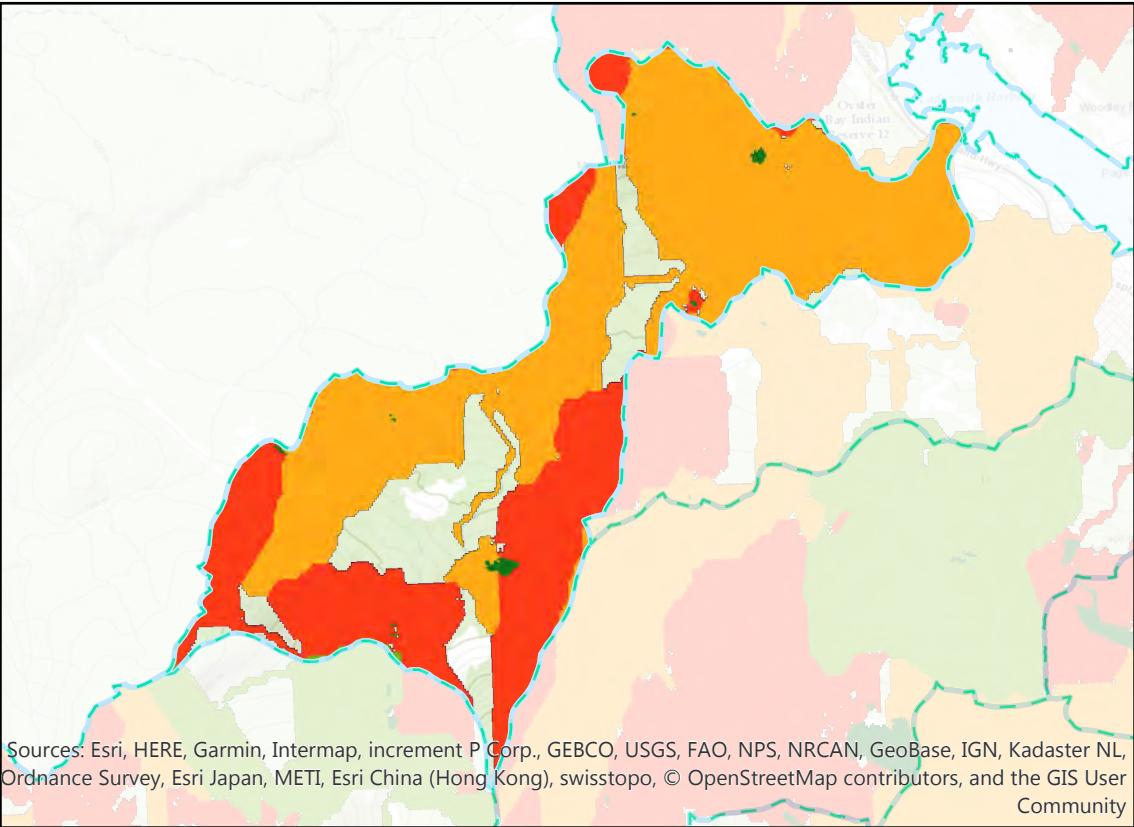


Groundwater Contamination Risk Assessment - Bush Creek

BY: CJW	SCALE CONS: 1:79,059	DATE: 2019/01/08	REF No:	REV: 0
CHK'D: DK	Proj Coord Sys: NAD 1983 UTM Zone 10N		651957-103-BUSH	

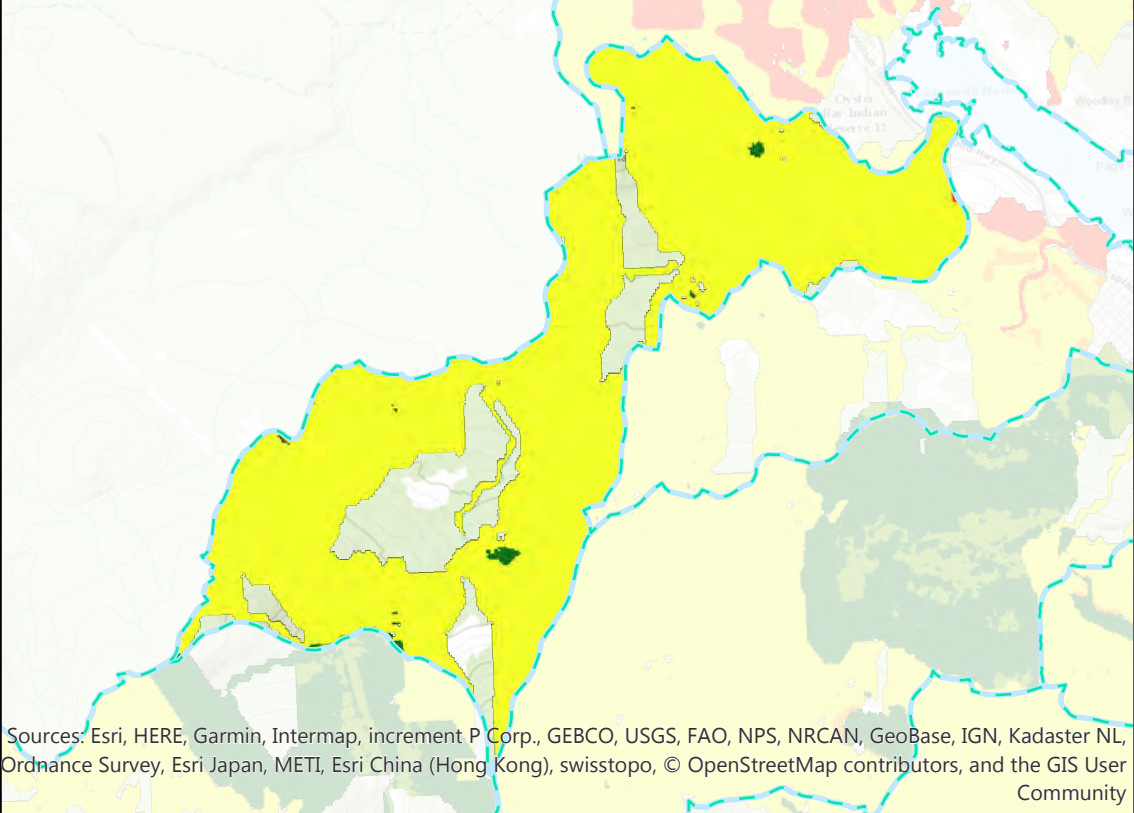


CONSEQUENCE



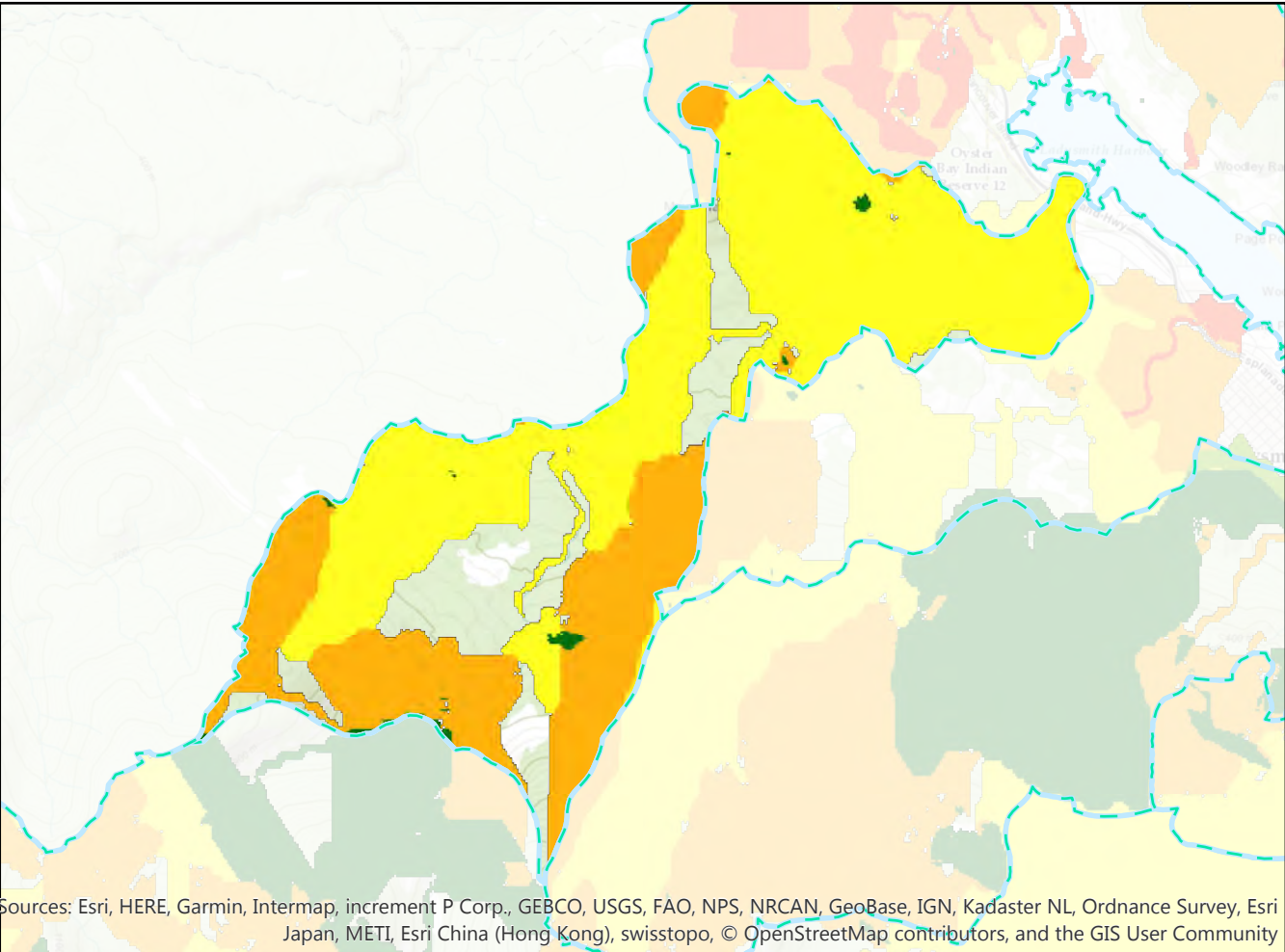
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

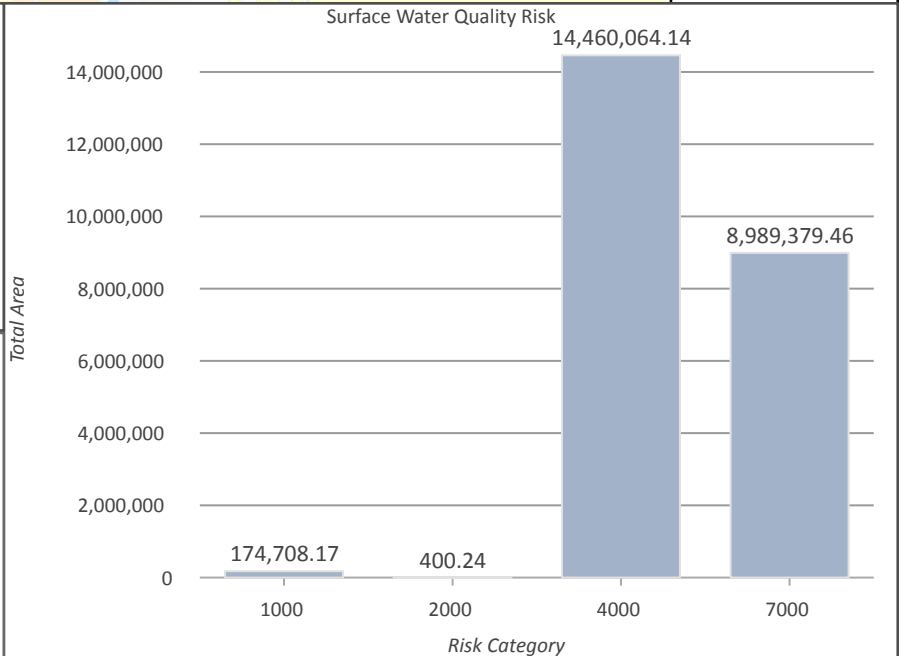
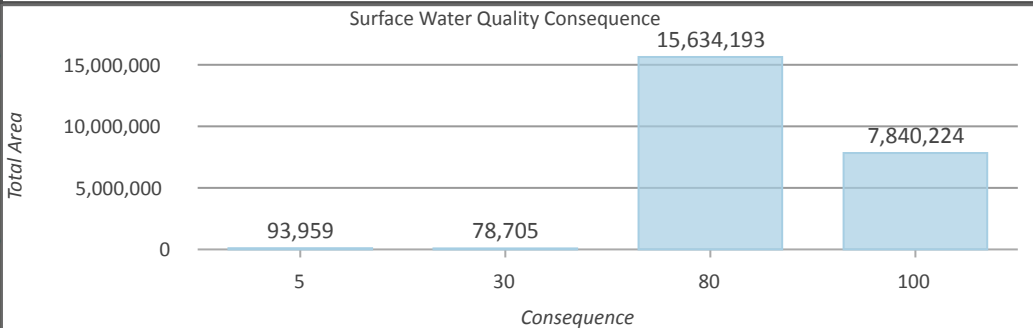
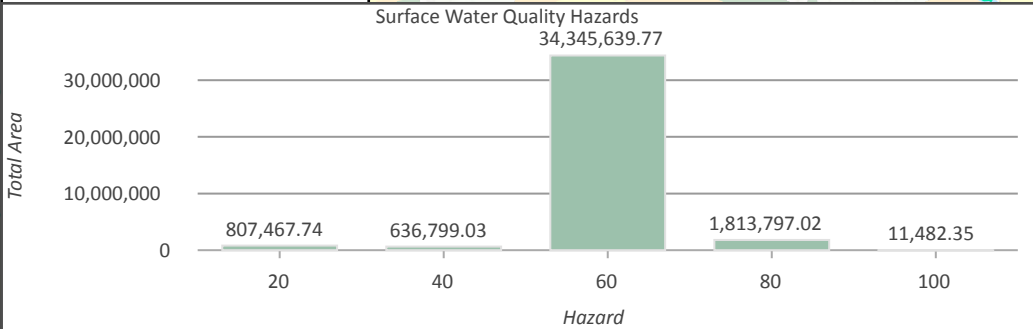


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



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Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

	≤ 20
	≤ 40
	≤ 60
	≤ 80
	≤ 100

RISK

	≤ 1000
	≤ 2000
	≤ 4000
	≤ 7000
	≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

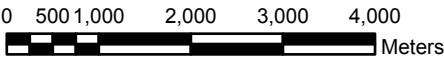
CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District Bush Creek Watershed



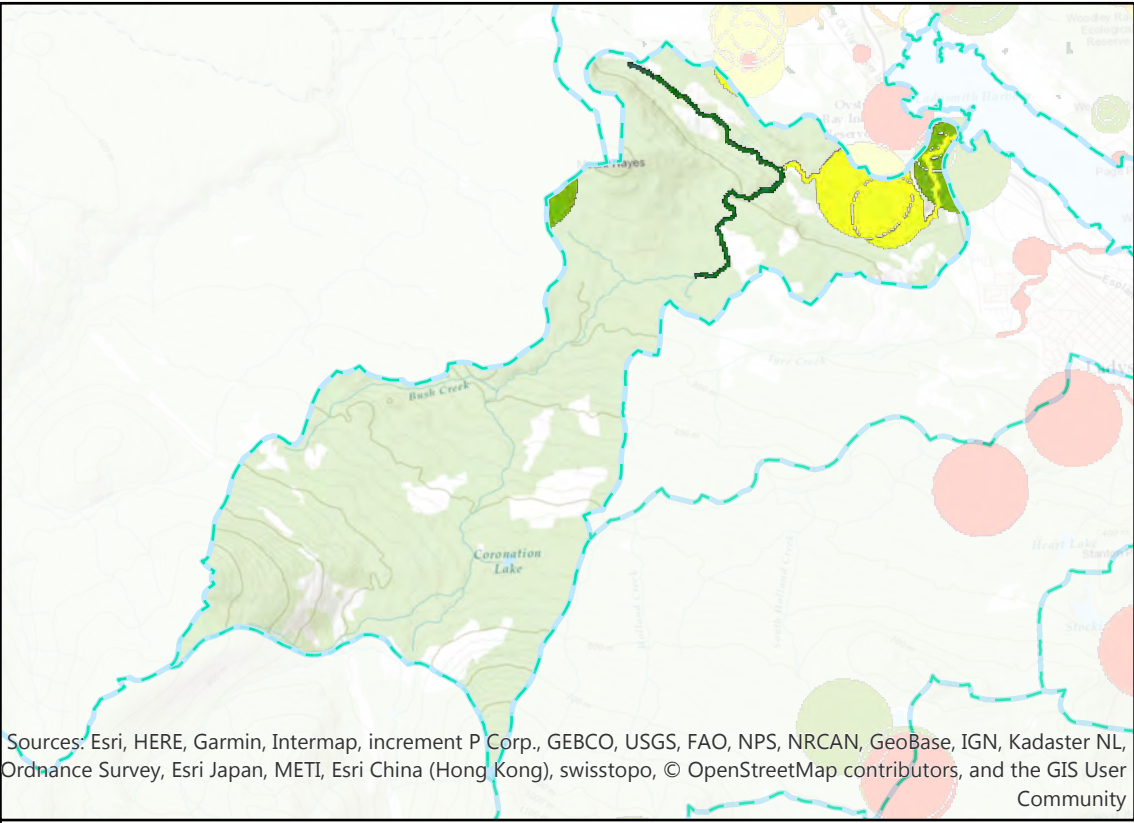
Surface Water Quality Risk Assessment - Bush Creek

BY:	SCALE: 1:82,135	DATE: 2019/01/08	REF No:	REV: 0
CHK'D:	Proj Coord Sys: PCS Albers		651957-104-BUSH	



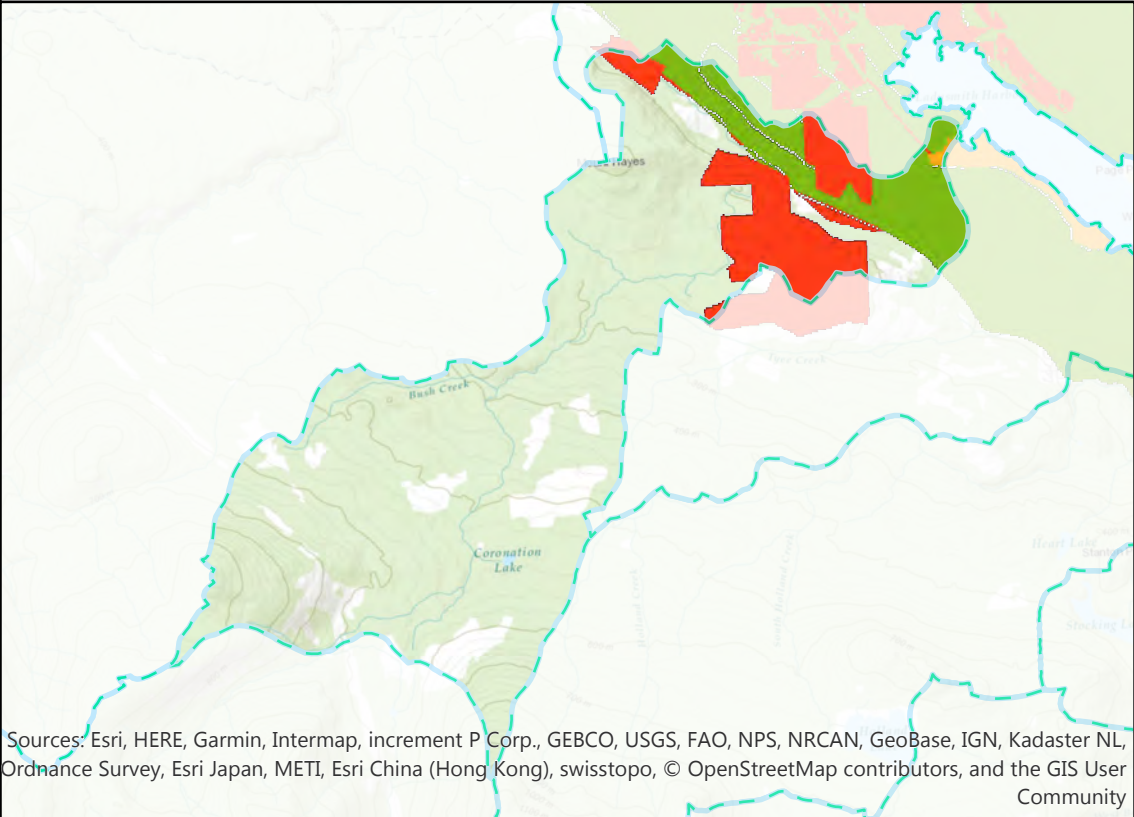
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CONSEQUENCE



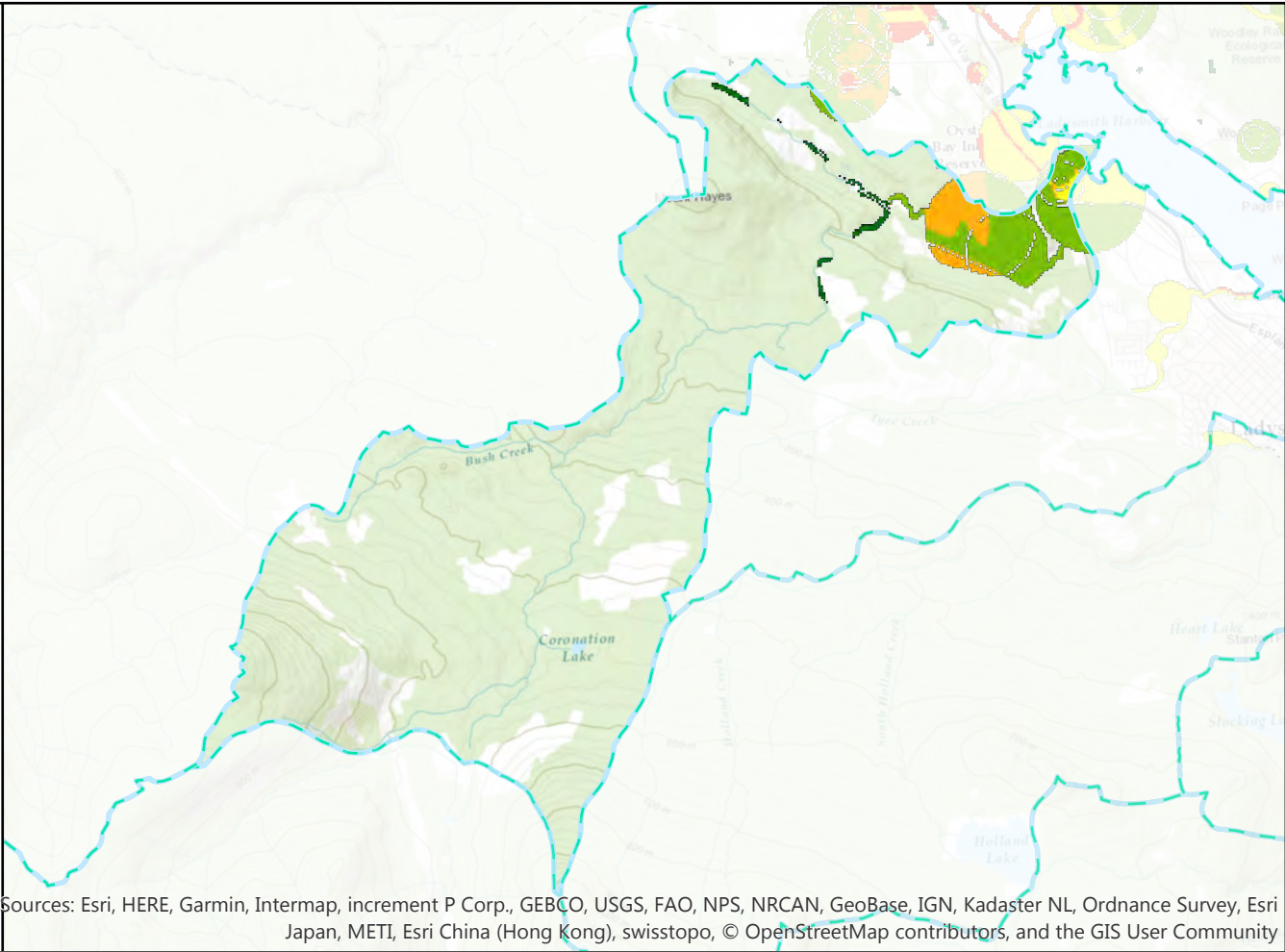
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

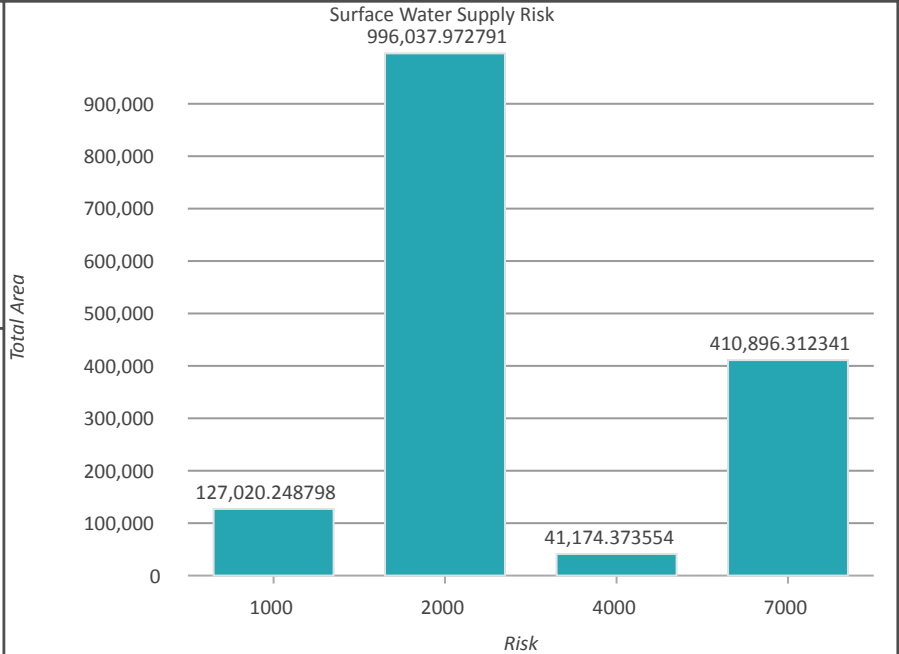
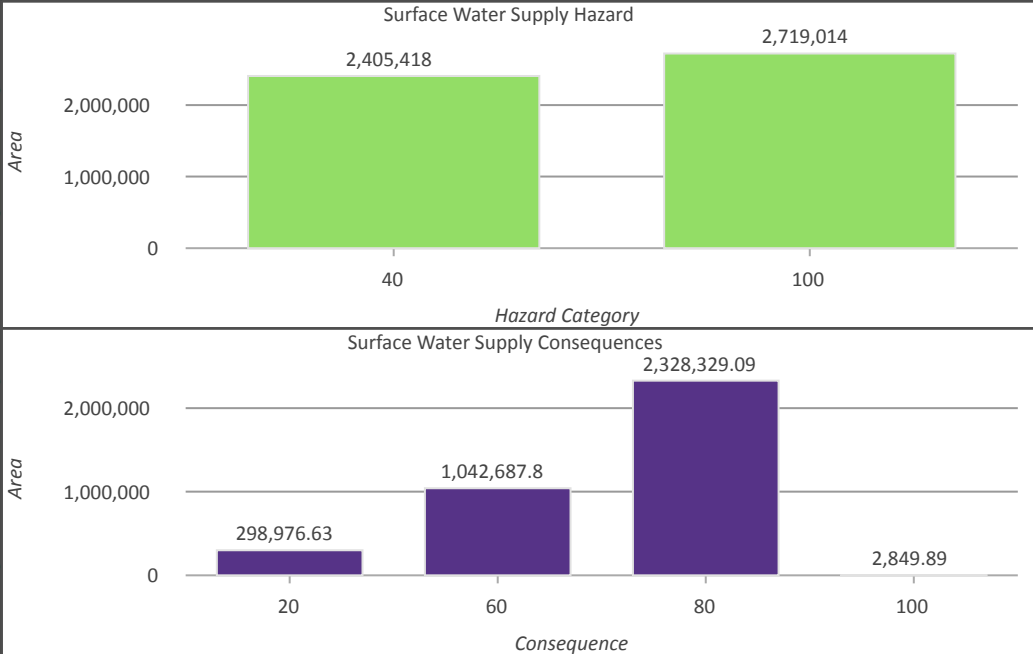


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

RISK

Consequences or Hazards	Risk
≤ 20	≤ 1000
≤ 40	≤ 2000
≤ 60	≤ 4000
≤ 80	≤ 7000
≤ 100	≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

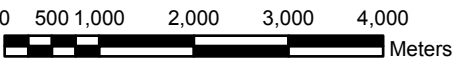
CLIENT:
Cowichan Valley Regional District

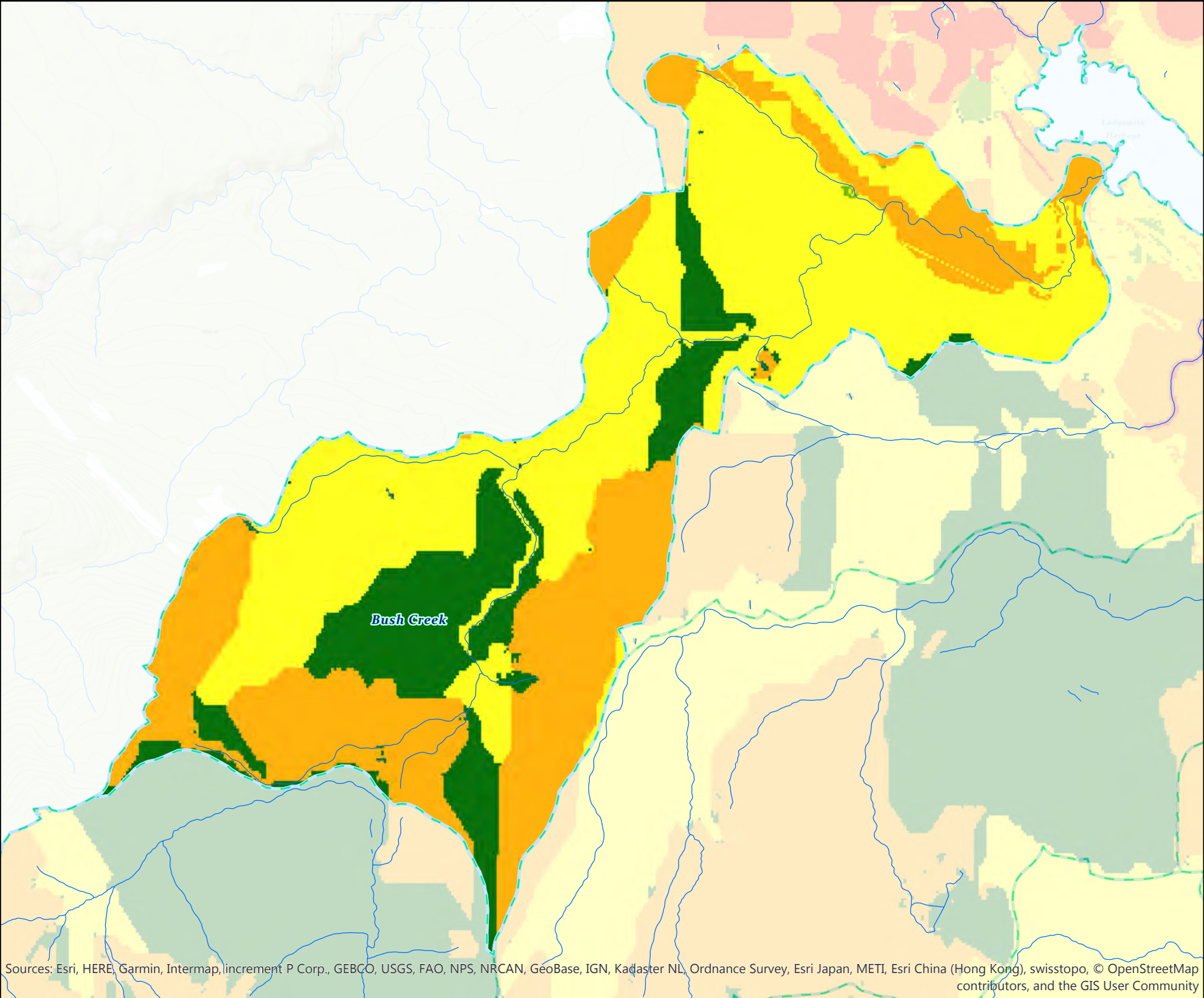
PROJECT LOCATION:
Cowichan Valley Regional District Bush Creek Watershed



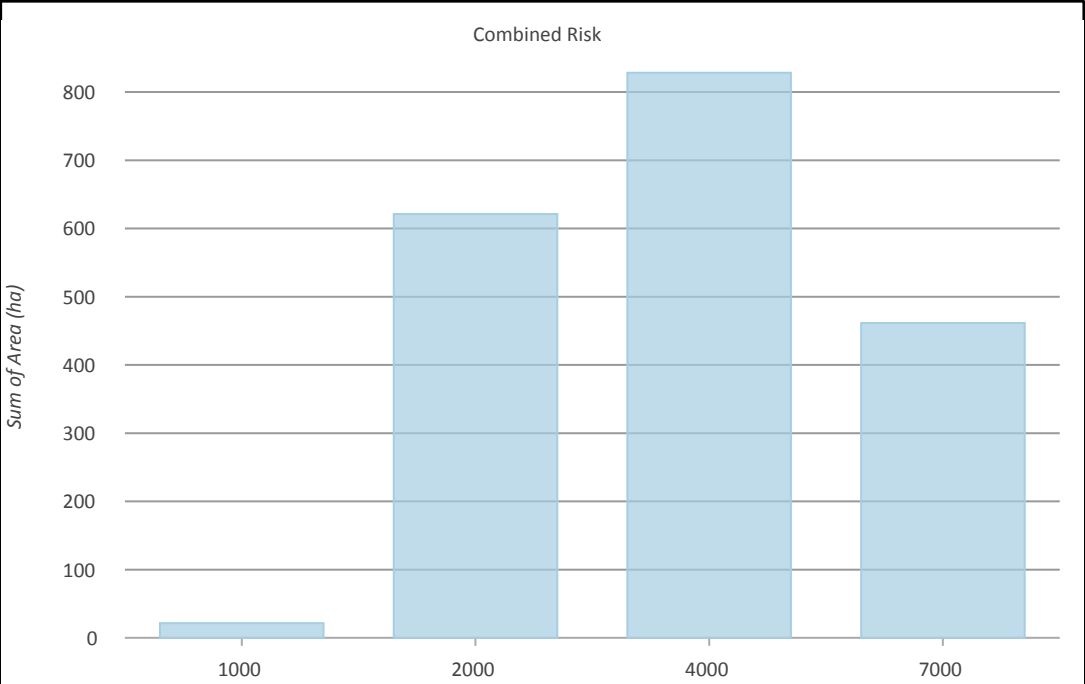
Surface Water Supply Risk Assessment - Bush Creek

BY:	SCALE: 1:79,909	DATE: 2019/01/08	REF No:	REV: 0
CHK'D:	Proj Coord Sys: PCS Albers		651957-105-BUSH	





Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



NAME	Risk			
SHAWNIGAN CREEK	10047	10760	11613	12598
BUSH CREEK	0	0	0	0
KOKSILAH RIVER	5463	5851	6315	6850
HOLLAND CREEK	1302	1368	1446	1537
BONSALL CREEK	934	974	1019	1073
CHEMAINUS RIVER	1490	1461	1439	1421
COWICHAN RIVER	36368	37905	39683	41766
YELLOW POINT BENCHLANDS	2239	2352	2487	2643
LADYSMITH - SALTAIR BENCHLANDS	8410	8834	9342	9929
STOCKING CREEK	1531	1608	1701	1807
CHEMAINUS BENCHLANDS	3663	3818	3997	4207
SATELLITE CHANNEL BENCHLANDS	4390	4701	5074	5504
SANSUM NARROWS - COWICHAN BAY BENCHLANDS	4941	5150	5391	5674
MALAHAT BENCHLANDS	2829	3030	3271	3548

NAME	POP2001	POP2006	POP2011	POP2016
SHAWNIGAN CREEK	6348	8439	8925	9484
BUSH CREEK	0			
KOKSILAH RIVER	4555	4808	4954	5157
HOLLAND CREEK	1611	1114	1169	1245
BONSALL CREEK	672	830	815	890
CHEMAINUS RIVER	1423	1395	1497	1514
COWICHAN RIVER	29779	32673	34075	34647
YELLOW POINT BENCHLANDS	1167	1958	2021	2141
LADYSMITH - SALTAIR BENCHLANDS	5275	7488	7541	8042
STOCKING CREEK	1332	1003	1354	1464
CHEMAINUS BENCHLANDS	3177	3129	3085	3490
SATELLITE CHANNEL BENCHLANDS	5425	3902	3989	4144
SANSUM NARROWS - COWICHAN BAY BENCHLANDS	5993	4221	4500	4707
MALAHAT BENCHLANDS	1673	2472	2548	2671

Legend

WATERSHED BOUNDARIES

RISK

≤ 1000

≤ 2000

≤ 4000

≤ 7000

≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-30 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Bush Creek Watershed

SNC • LAVALIN

Combined Risk Assessment - Bush Creek

BY: CJW

CHK'D: DK

SCALE CONS: 1:46,000

Proj Coord Sys: NAD 1983 UTM Zone 10N

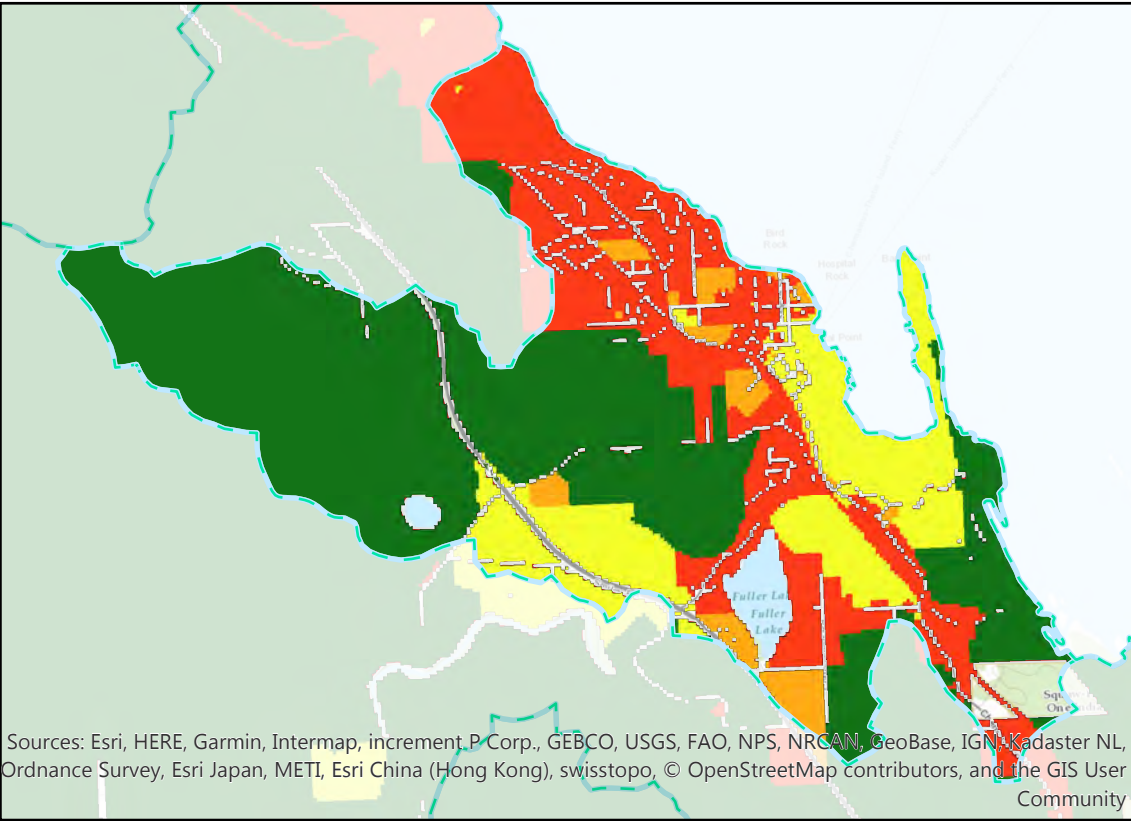
DATE: 2019/01/08

REF No: 651957-106-BUSH

REV: 0

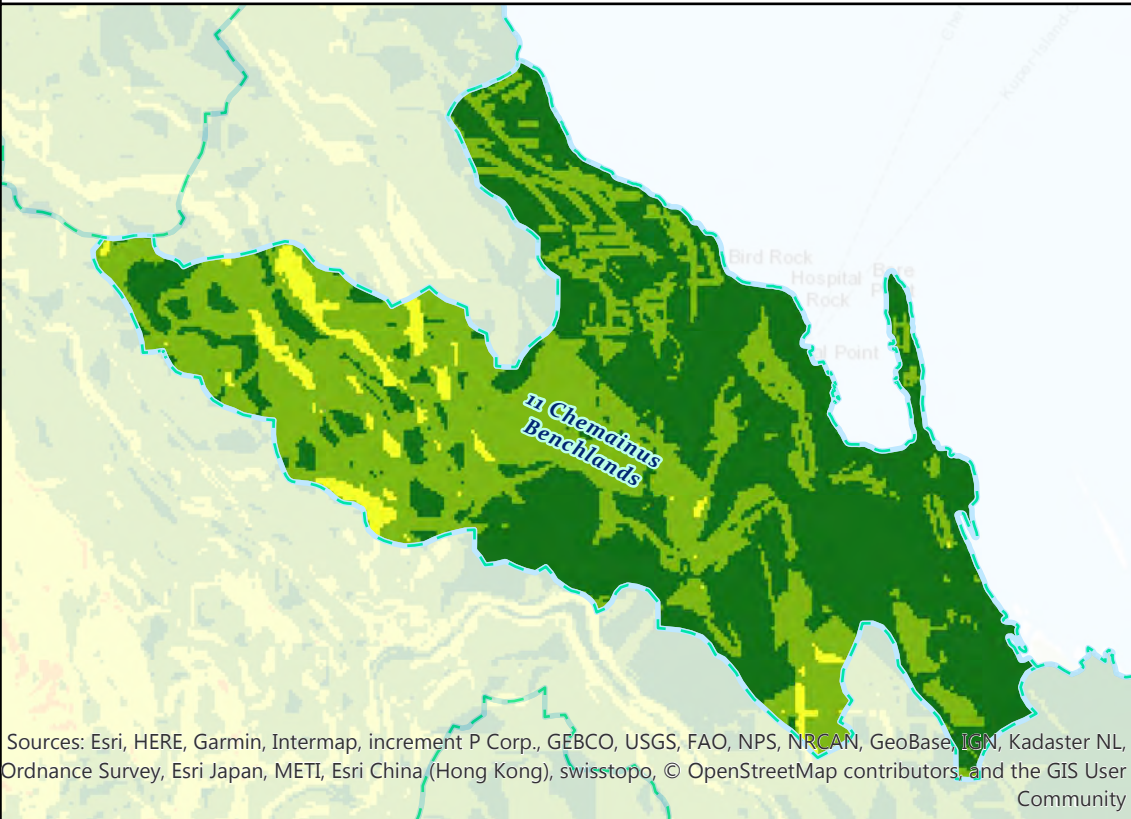
3. Chemainus Benchlands	
Topic	Discussion
Slope Failure	<p>Hazard was determined qualitatively at a high level to describe areas based on the degree to which they may be prone to landslides and other mass movements using terrain characteristics. Hazard classifications were generated to show relative comparisons between terrain units within the CVRD watershed study area. Risk ratings derived from this analysis are relative, and should be used to guide prioritization of further detailed studies.</p> <p>Hazard is generally low throughout the watershed due to the gentle slopes. Consequence is considered moderate to high through the populated areas in and around Chemainus. Risk is generally considered low throughout the watershed.</p>
Flooding	<p>A few creeks span the watershed but consequence and risk are relatively limited to the residential and industrial zones that are accessed from Highway 1. Consequence is greatest along Highway 1.</p>
Groundwater Contamination	<p>Hazard is relatively high due to the populated area of Chemainus within a small watershed. Consequence and risk levels are relatively low throughout the watershed but are enhanced in isolated areas such as the area southwest of Fuller Lake that spans to nearly the southern boundary of the watershed where a municipal water supply is located and areas northwest in the watershed that overlaps an aquifer of high demand and moderate productivity.</p>
Surface Water Quality	<p>Hazard varies greatly across the watershed. Also the zones of different hazard classes are scattered throughout the watershed. Hazard is generally greatest east of Fuller Lake, in portions of Chemainus, and in the industrial lot between Chemainus Lake and Fuller Lake. Consequence is considered high for much of the watershed due to the presence of lower order streams. Risk is generally greatest east of Fuller Lake and surrounding Chemainus Road south of Chemainus, in portions of Chemainus, and in the industrial lot between Chemainus Lake and Fuller Lake. Projected population growth may add greater pressure on surface water supply / stream health by either expanding the area of high risk zones or by enhancing moderate risk zones to high risk zones. A small proportion of the watershed's area is currently considered relatively low risk.</p>
Surface Water Supply	<p>Hazard is greatest through the central part of the watershed, at the southeast end, and small isolated zones of greater hazard also in the north end of the watershed. Consequence is greatest in the stream draining to the coast from Fuller Lake and at isolated locations near Chemainus. Consequence is moderate across the central region of the watershed, through agricultural and industrial corridors. Risk is greatest near the center of the watershed north of Fuller Lake, and in sections of the stream draining from Fuller Lake. Projected population increase for the watershed is moderate and could add pressures on groundwater sources in the north and west sections of the watershed, which may increase the level of hazard and risk.</p>
General Data Notes	<p>Risk in the Chemainus Benchlands watershed is largely driven by surface water quality, especially in the area around Fuller Lake. Flood risk, and some small areas of high surface water supply risk are also contributors. Slope risk is exaggerated due to the presences of roads, and groundwater contamination is a substantial contributor to overall risk due to a potentially contaminated site, industrial areas, and potential septic field usage.</p>

CONSEQUENCE



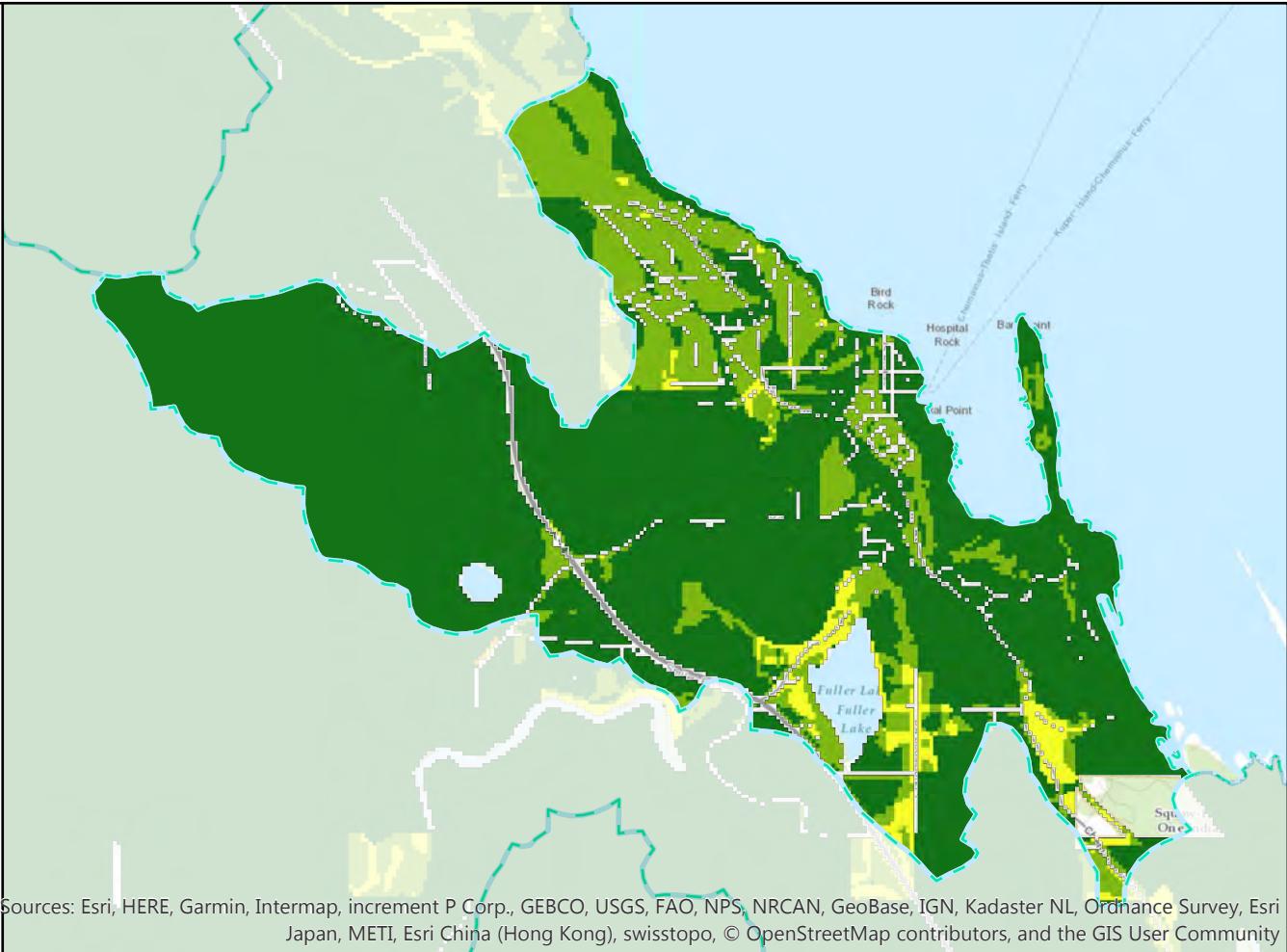
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

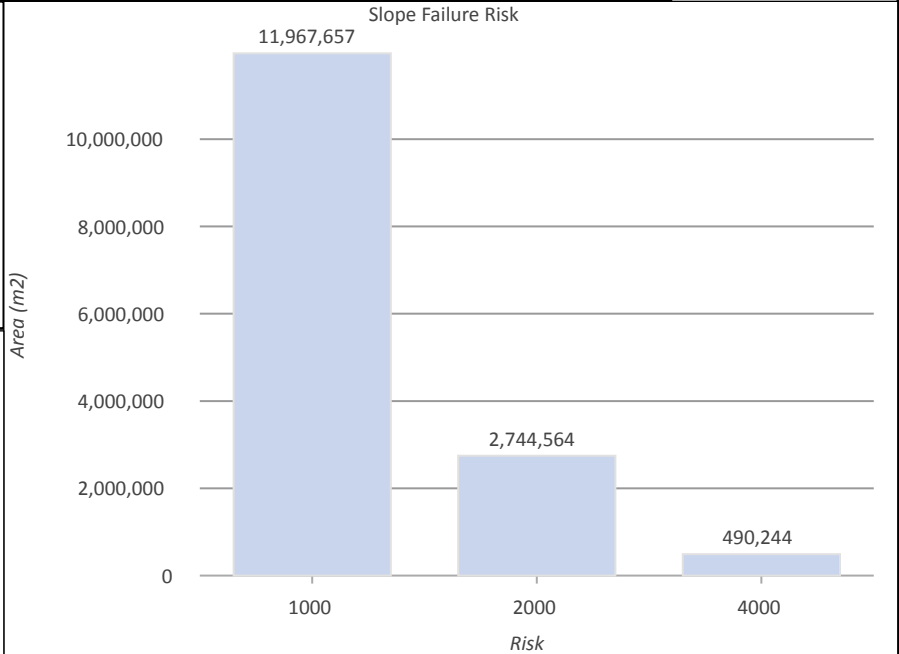
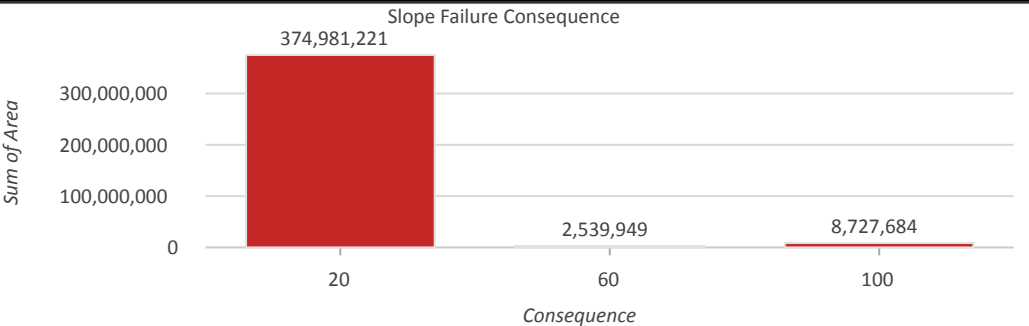
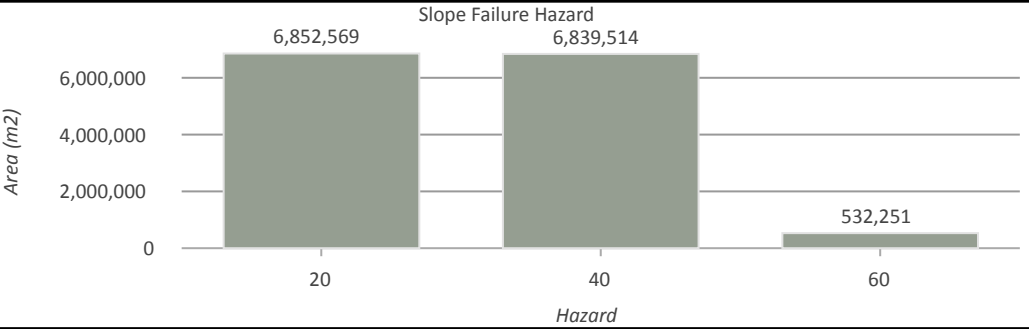


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

NOTES:

1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.

REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Chemainus Benchlands Watershed

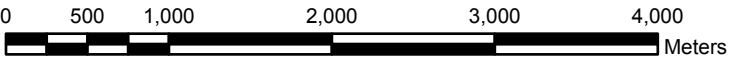
BY: CJW
CHK'D: DK

SCALE CONS: 1:46,402
Proj Coord Sys: PCS Albers

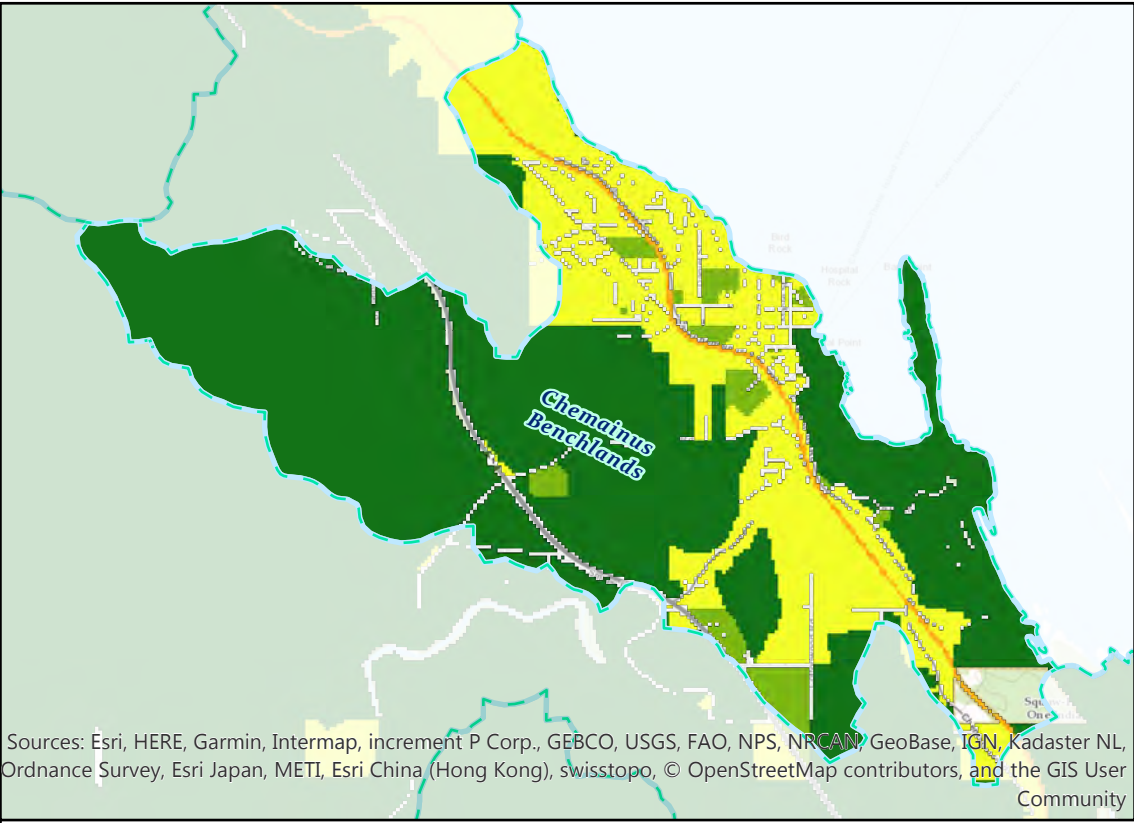
SNC • LAVALIN

Slope Failure Risk Assessment - Chemainus

REF No: 651957-101-CHBL
REV: 0

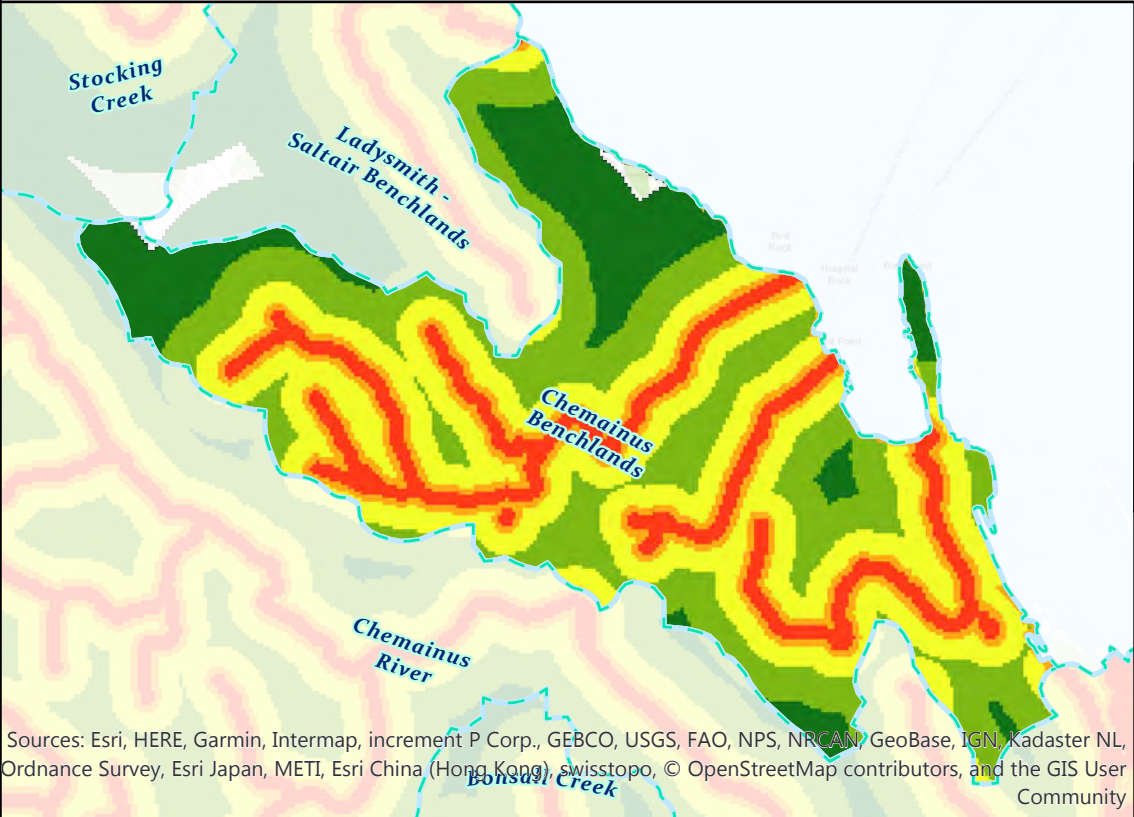


CONSEQUENCE



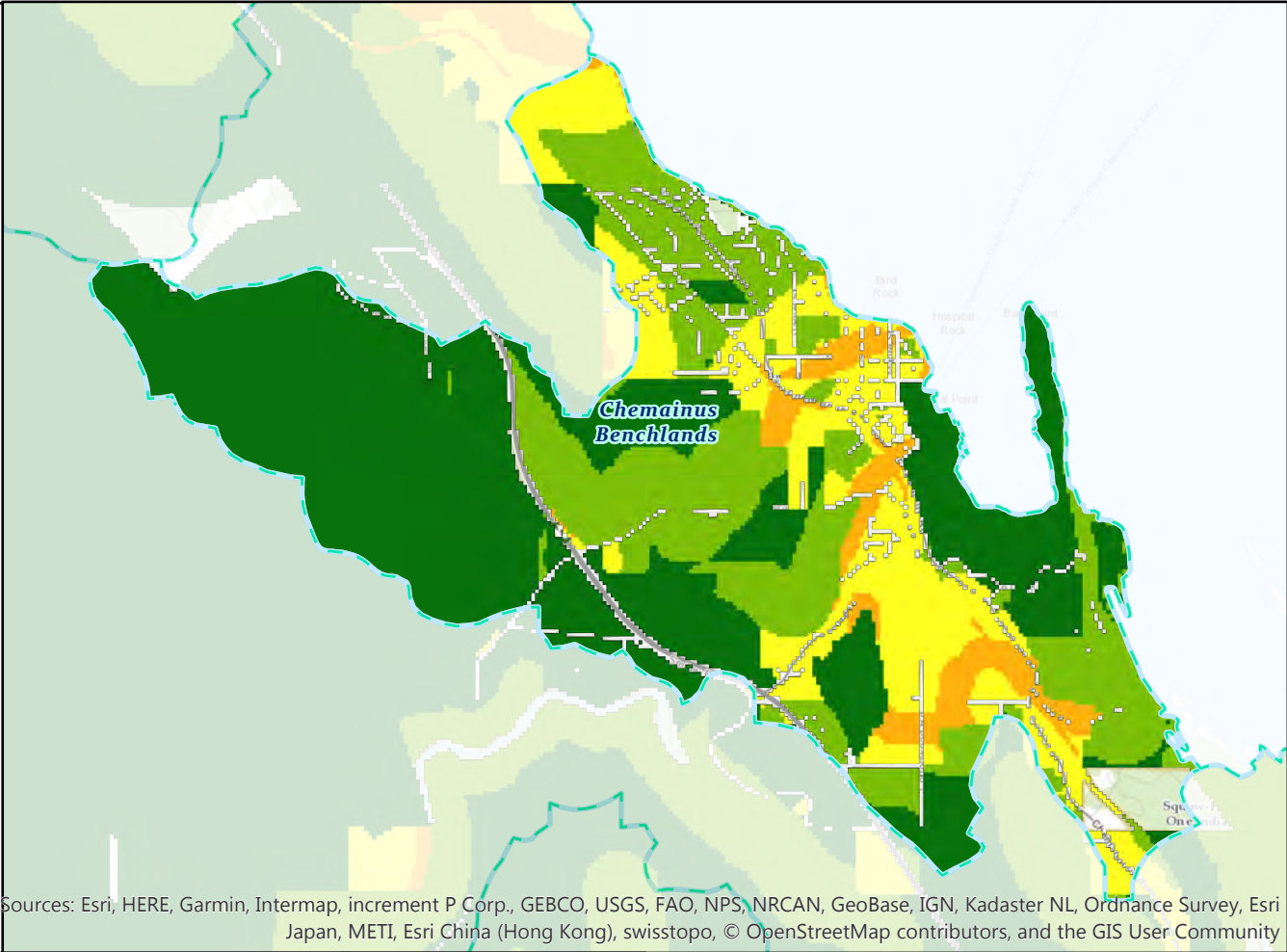
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

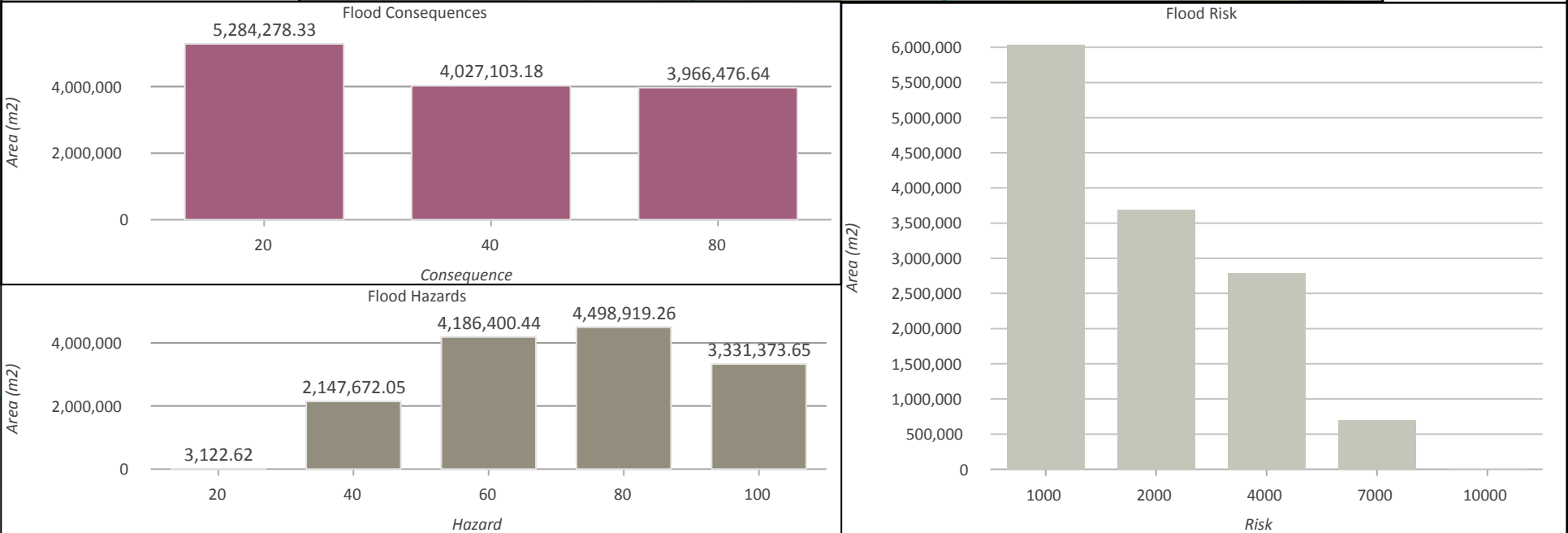


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

	≤ 20
	≤ 40
	≤ 60
	≤ 80
	≤ 100

RISK

	≤ 1000
	≤ 2000
	≤ 4000
	≤ 7000
	≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

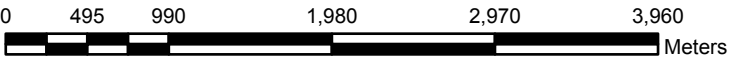
CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Chemainus Benchlands Watershed

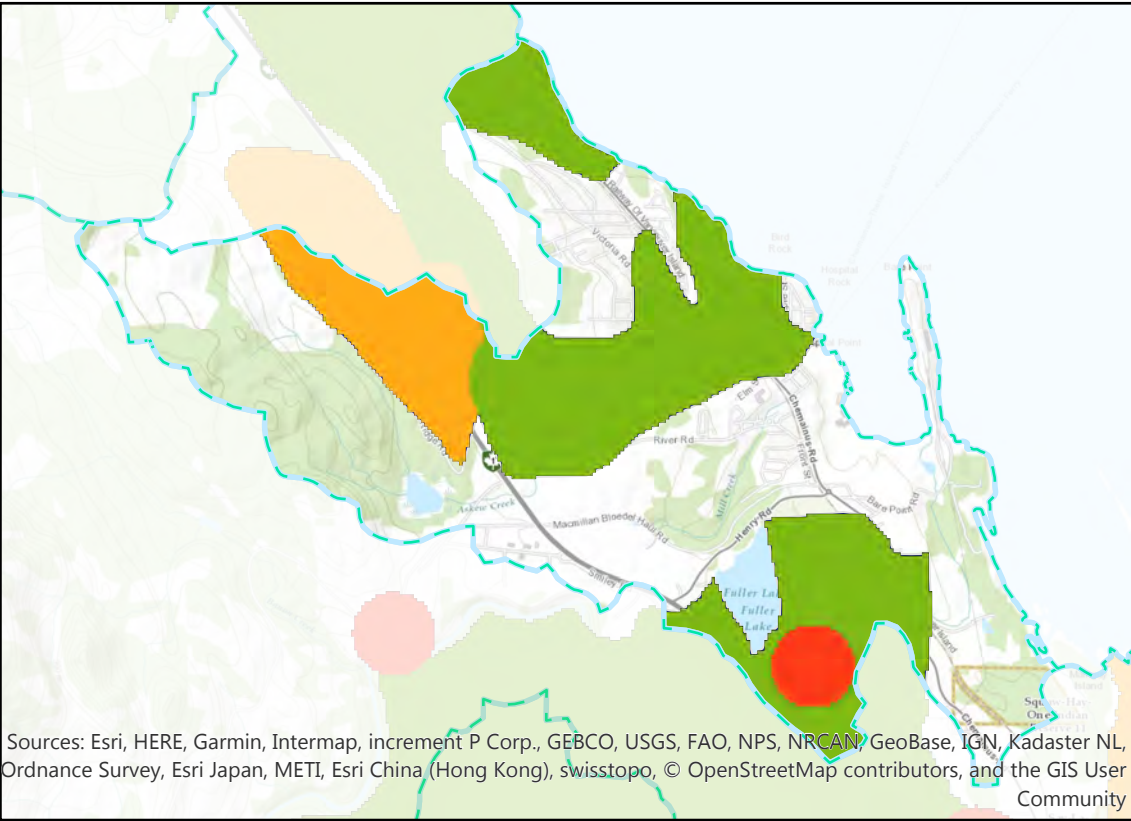
SNC • LAVALIN

Flood Risk Assessment - Chemainus Benchlands

BY: CJW	SCALE CONS: 1:45,905	DATE: 2019/01/08	REF No:	REV: 0
CHK'D: DK	Proj Coord Sys: NAD 1983 UTM Zone 10N		651957-102-CHBL	

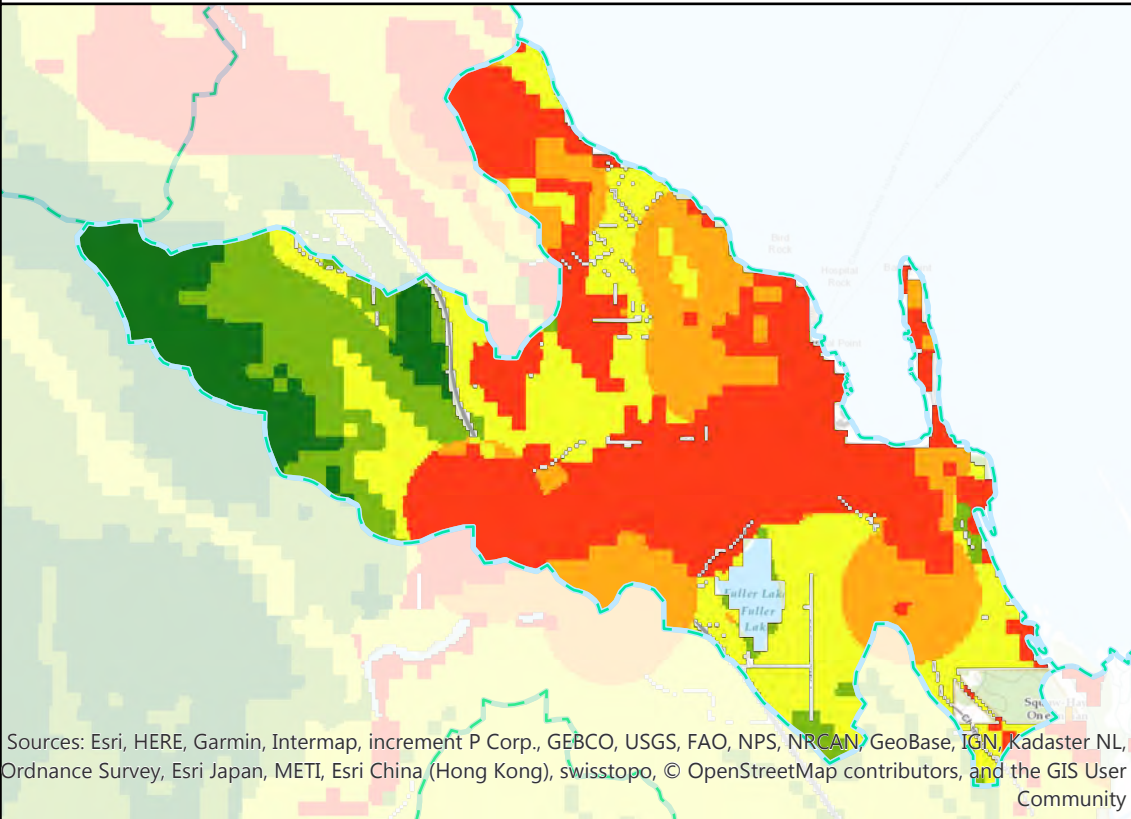


CONSEQUENCE



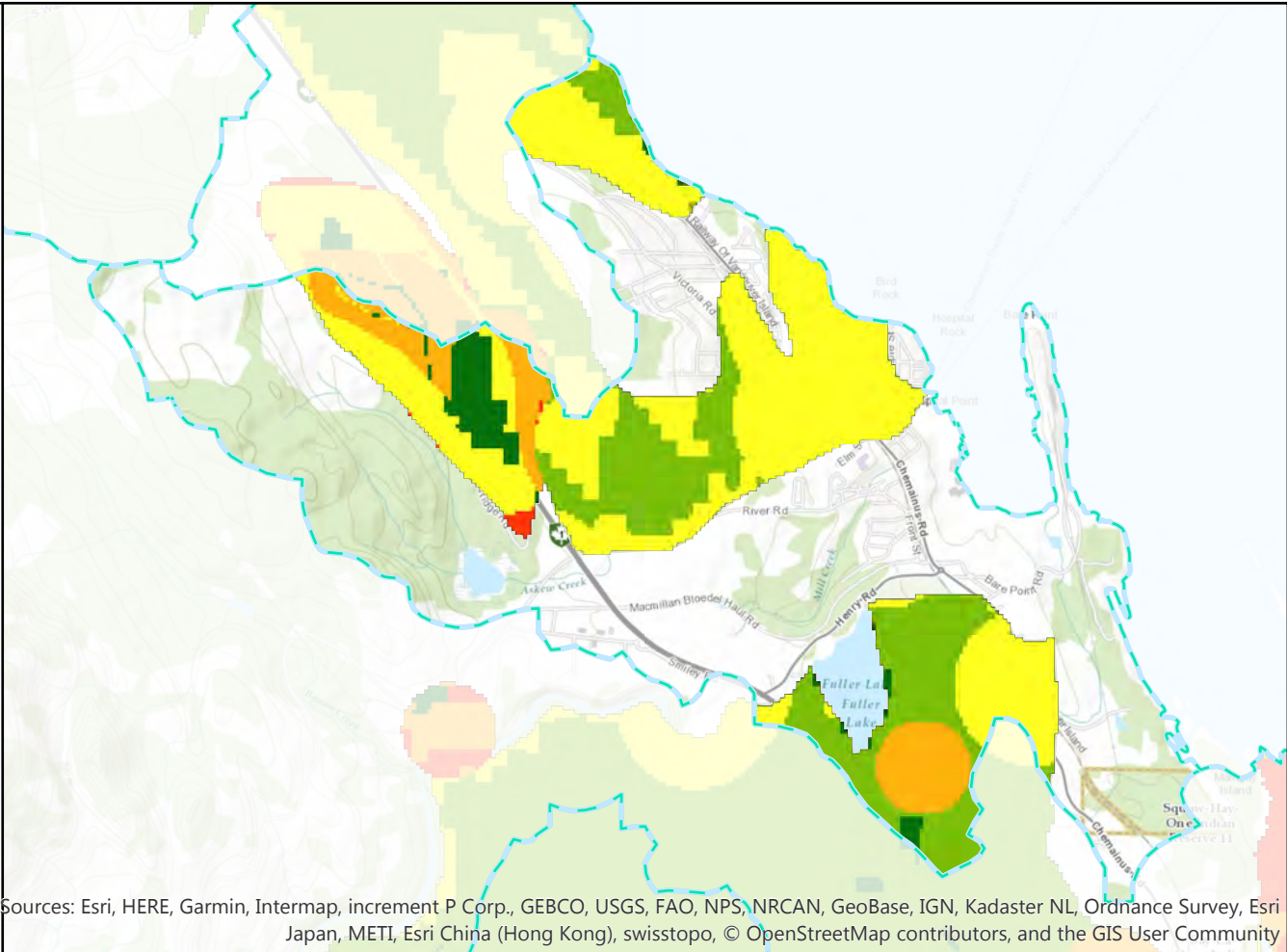
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HAZARD

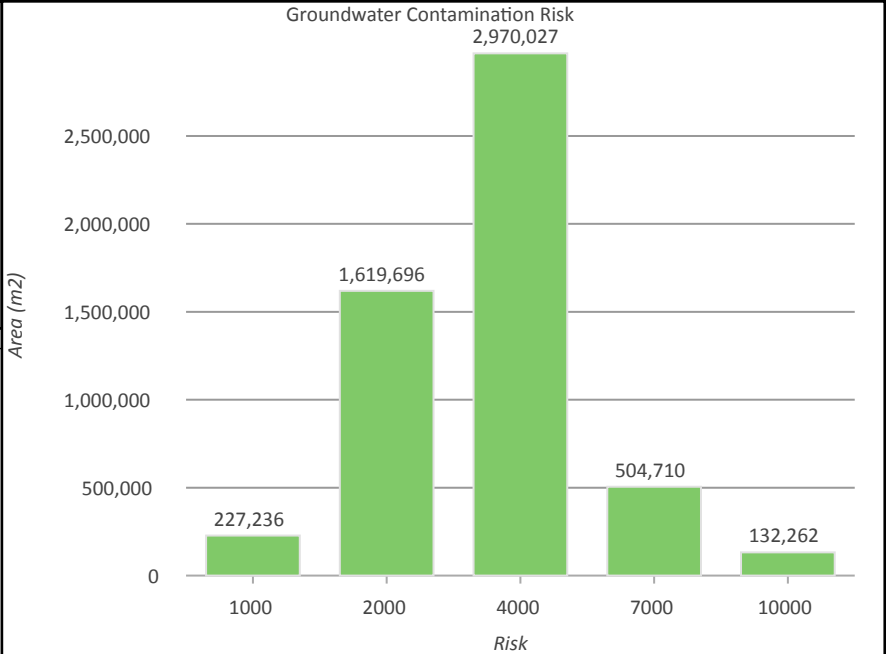
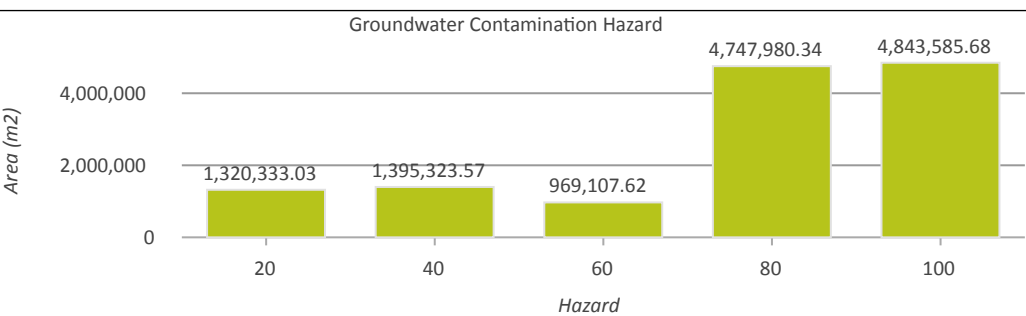
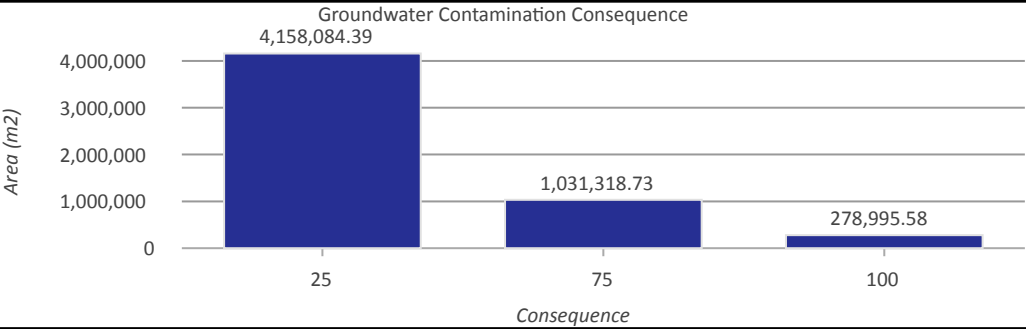


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Chemainus Benchlands Watershed



Groundwater Contamination Risk Assessment - Chemainus

BY: CJW

SCALE CONS: 1:45,905

DATE: 2019/01/08

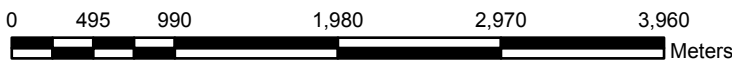
REF No:

REV: 0

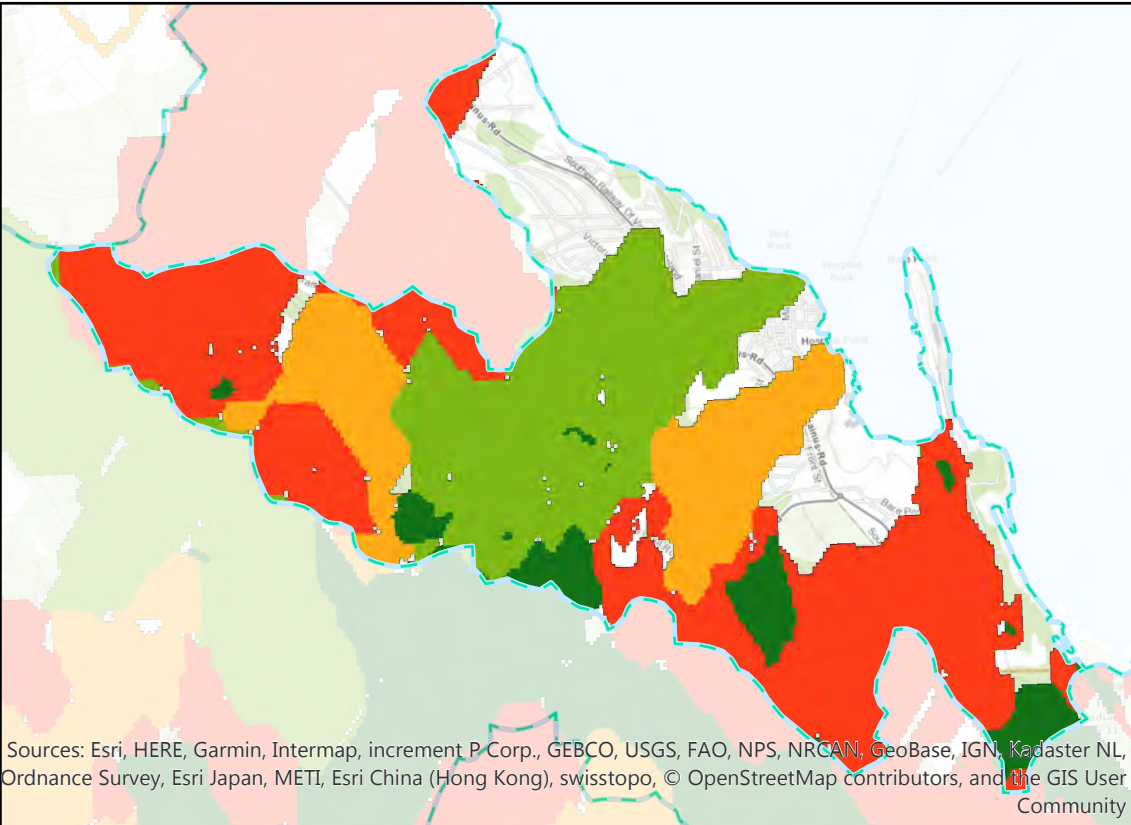
CHK'D: DK

Proj Coord Sys: NAD 1983 UTM Zone 10N

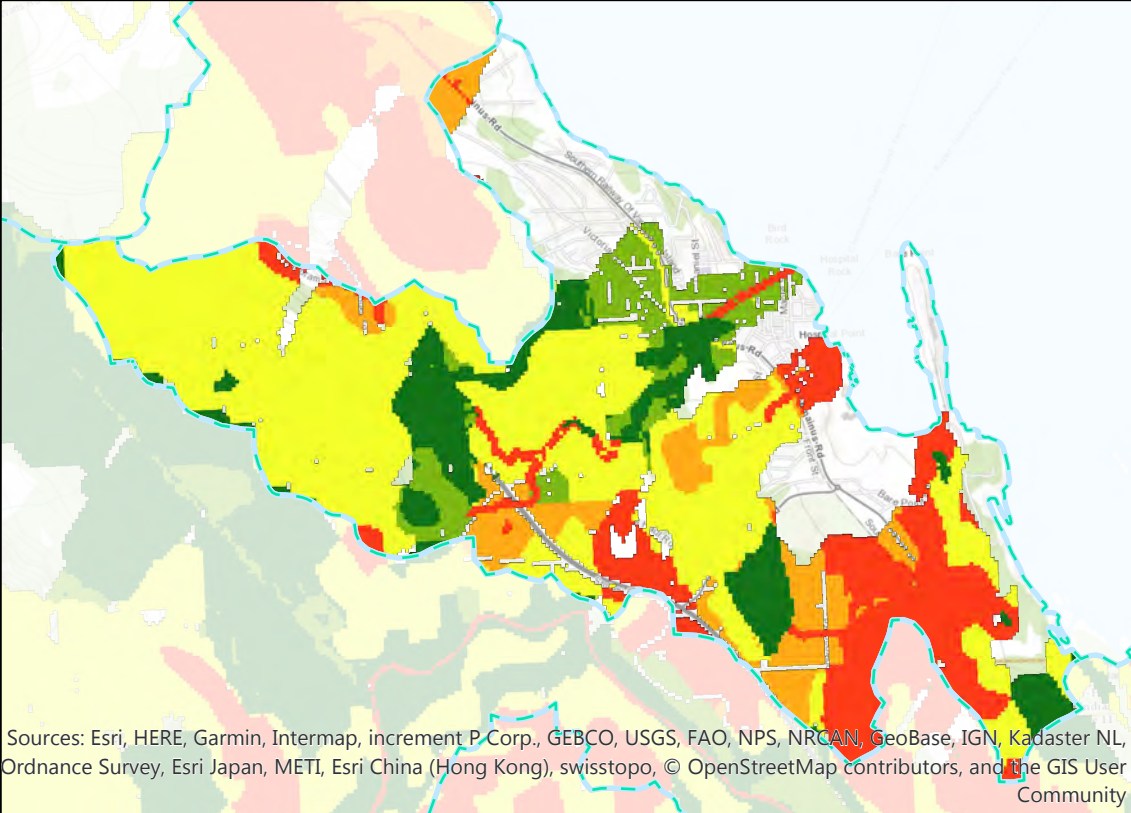
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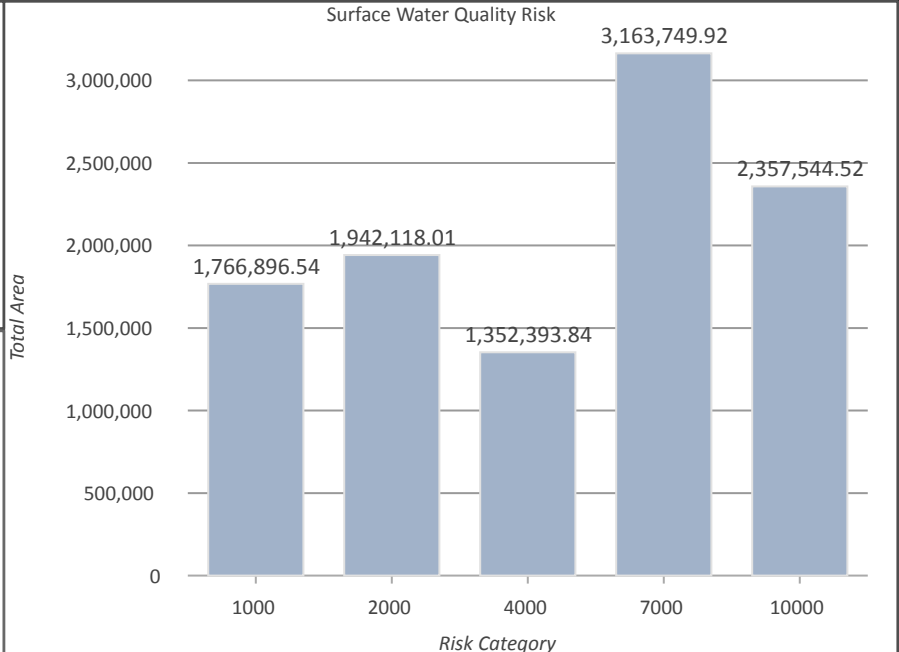
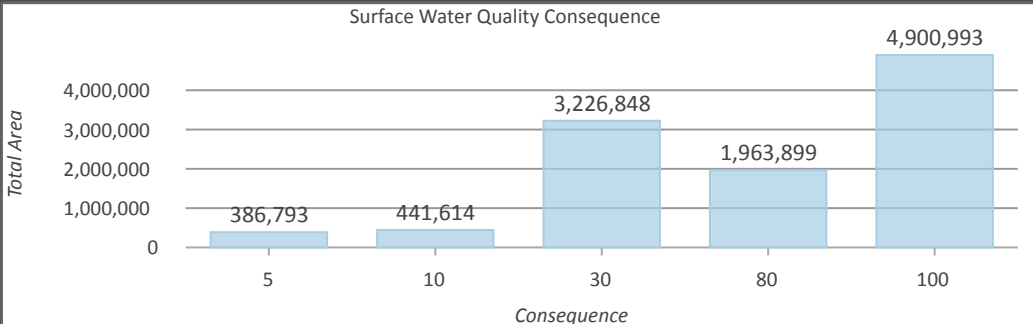
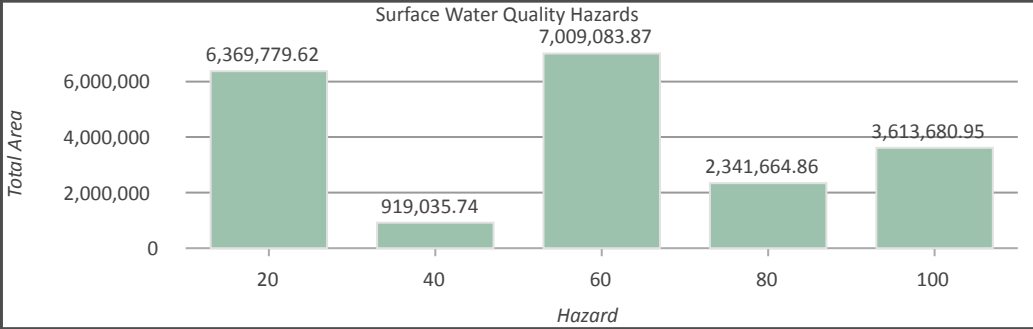
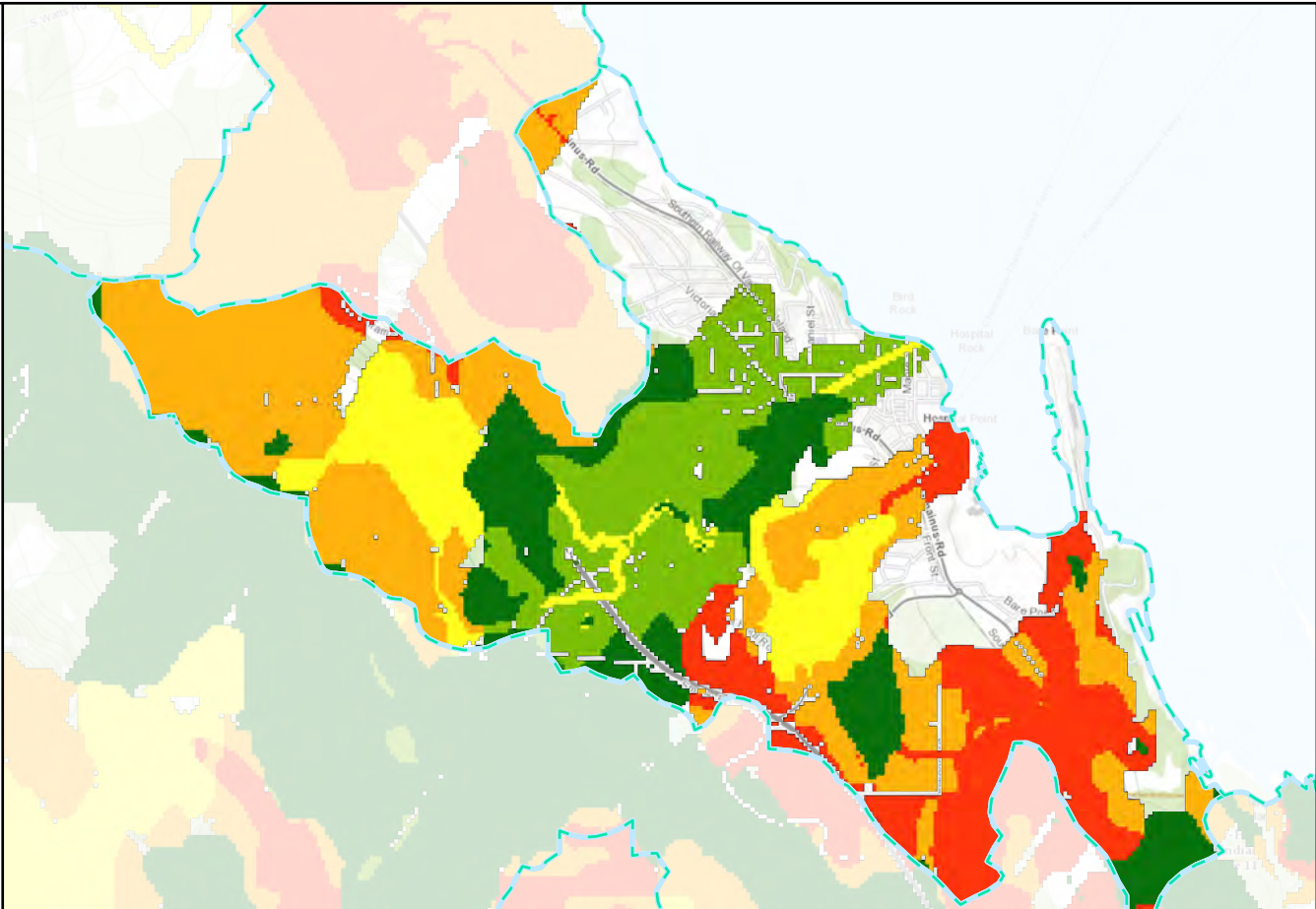
CONSEQUENCE



HAZARD



RISK



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

- ≤ 20
- ≤ 40
- ≤ 60
- ≤ 80
- ≤ 100

RISK

- ≤ 1000
- ≤ 2000
- ≤ 4000
- ≤ 7000
- ≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

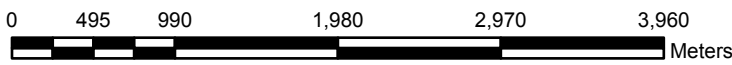
CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District Chemainus
Benchlands Watershed



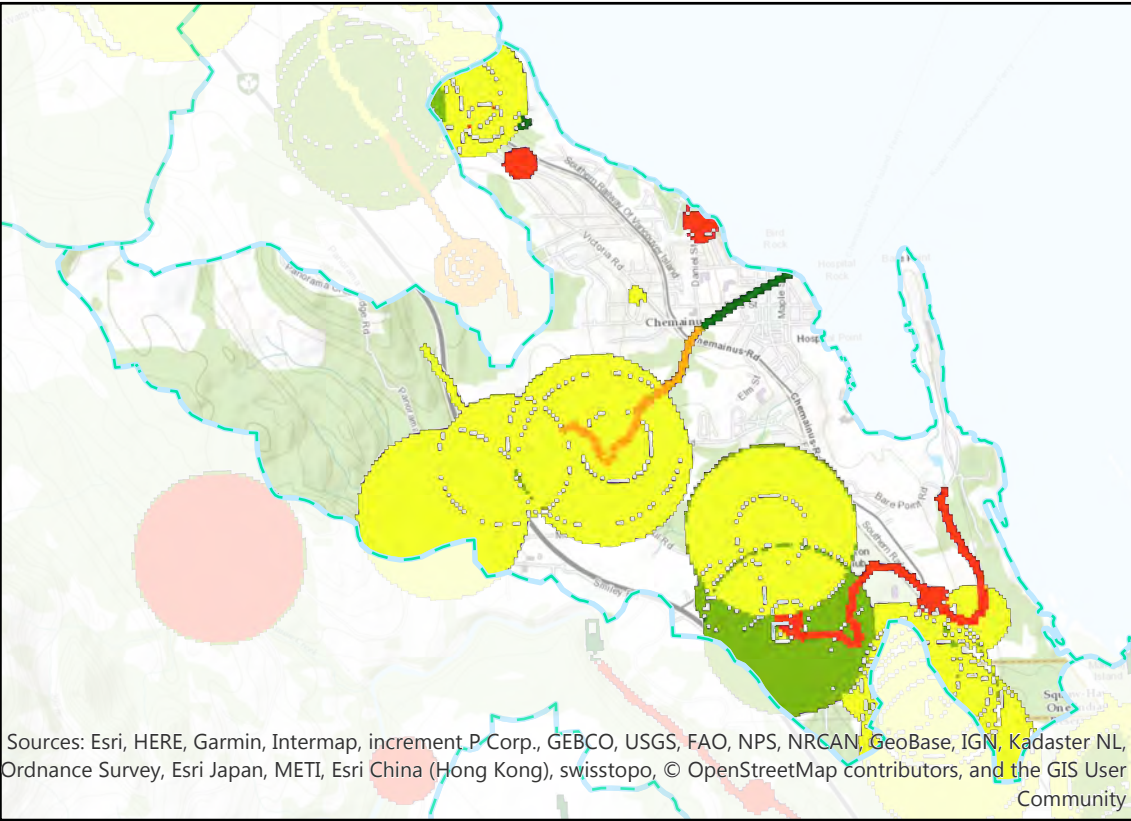
Surface Water Quality Risk Assessment - Chemainus

BY:	SCALE: 1:45,938	DATE: 2019/01/08	REF No:	REV: 0
CHK'D:	Proj Coord Sys: PCS Albers		651957-104-CHBL	



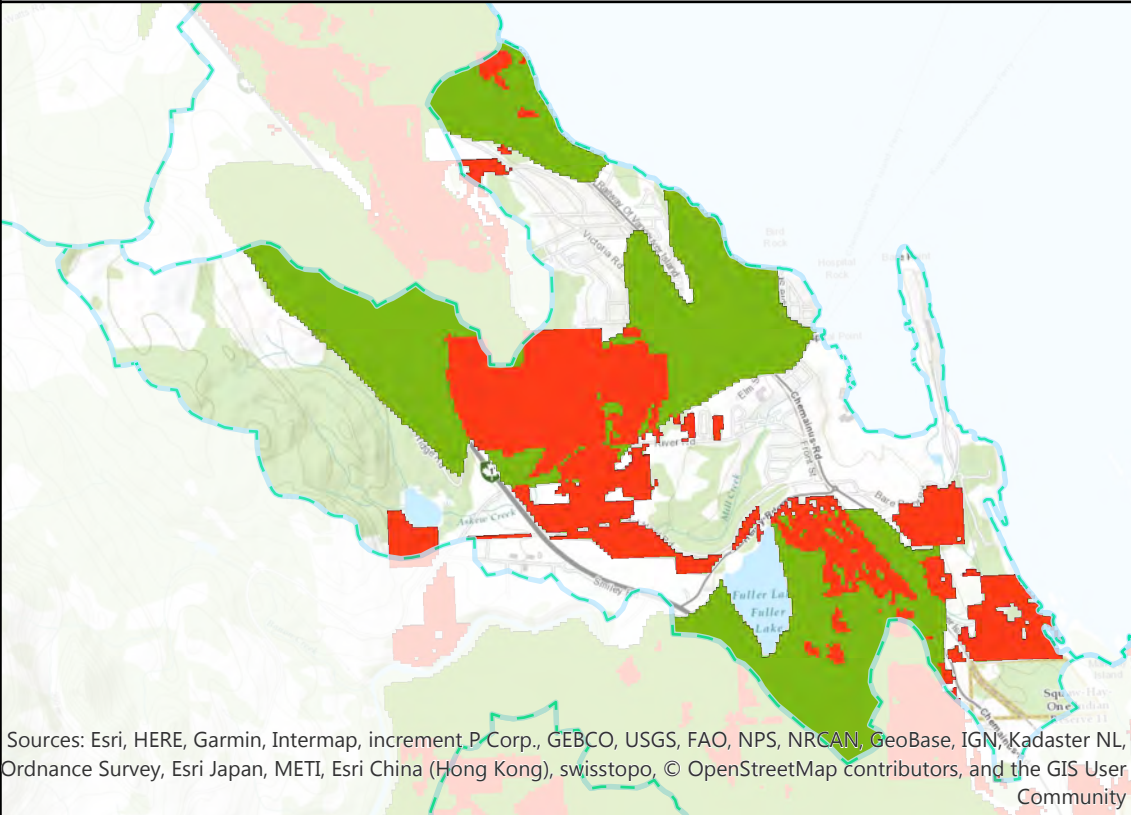
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CONSEQUENCE



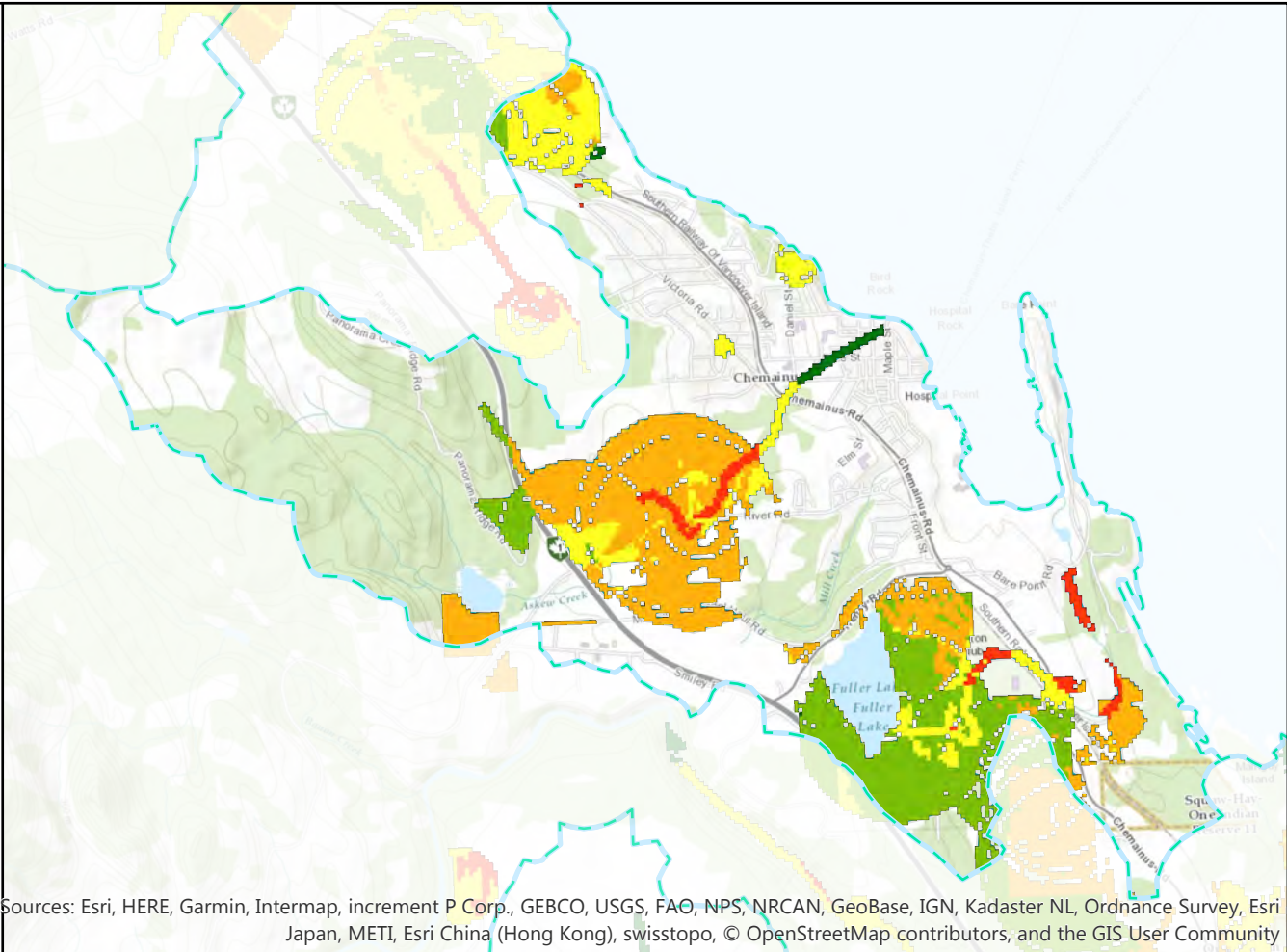
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

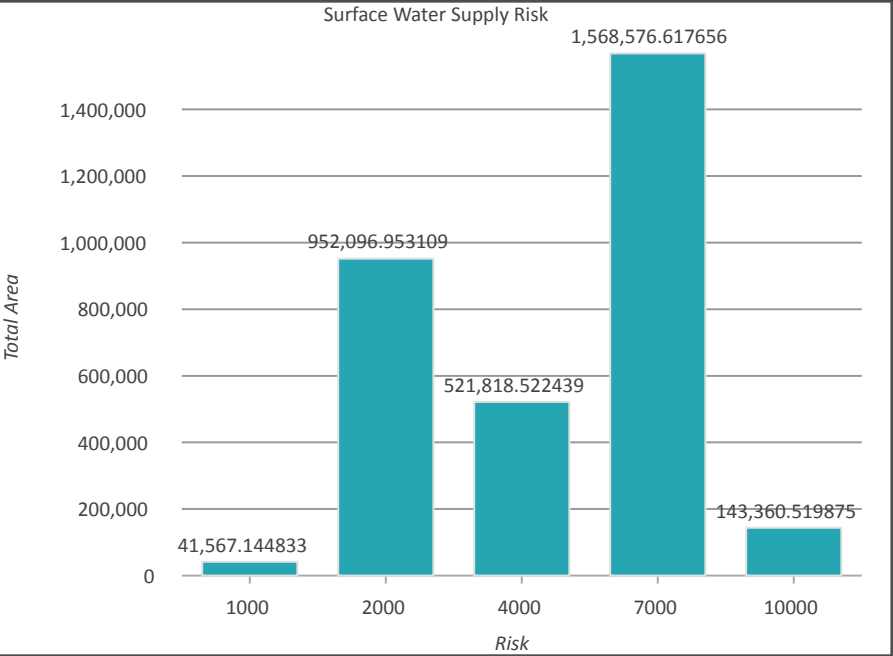
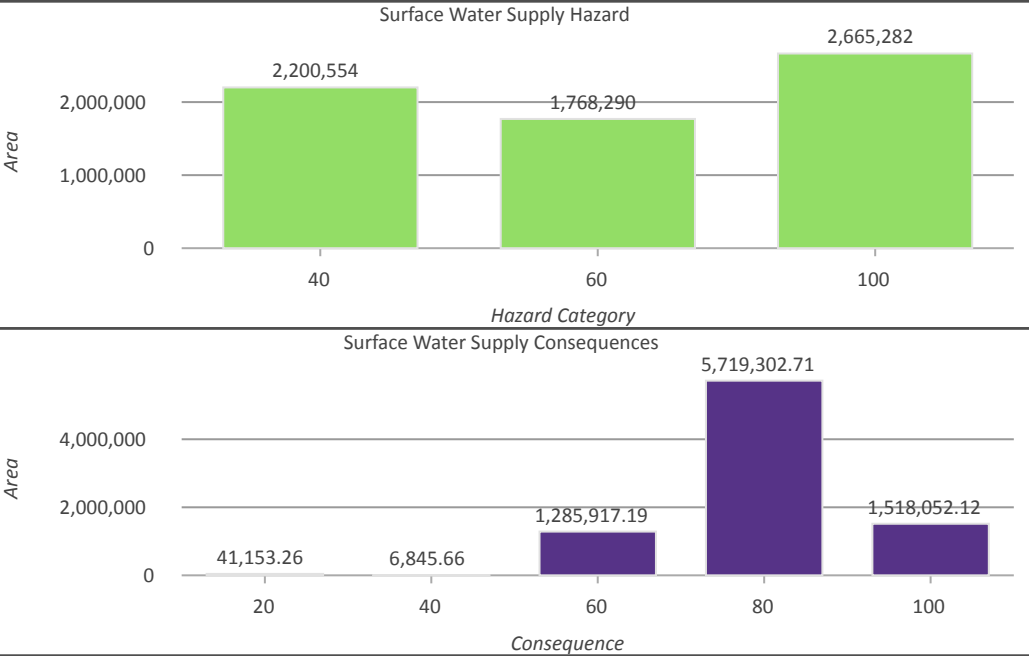


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

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REVISIONS:

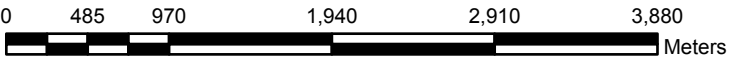
0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District Chemainus
Benchlands Watershed

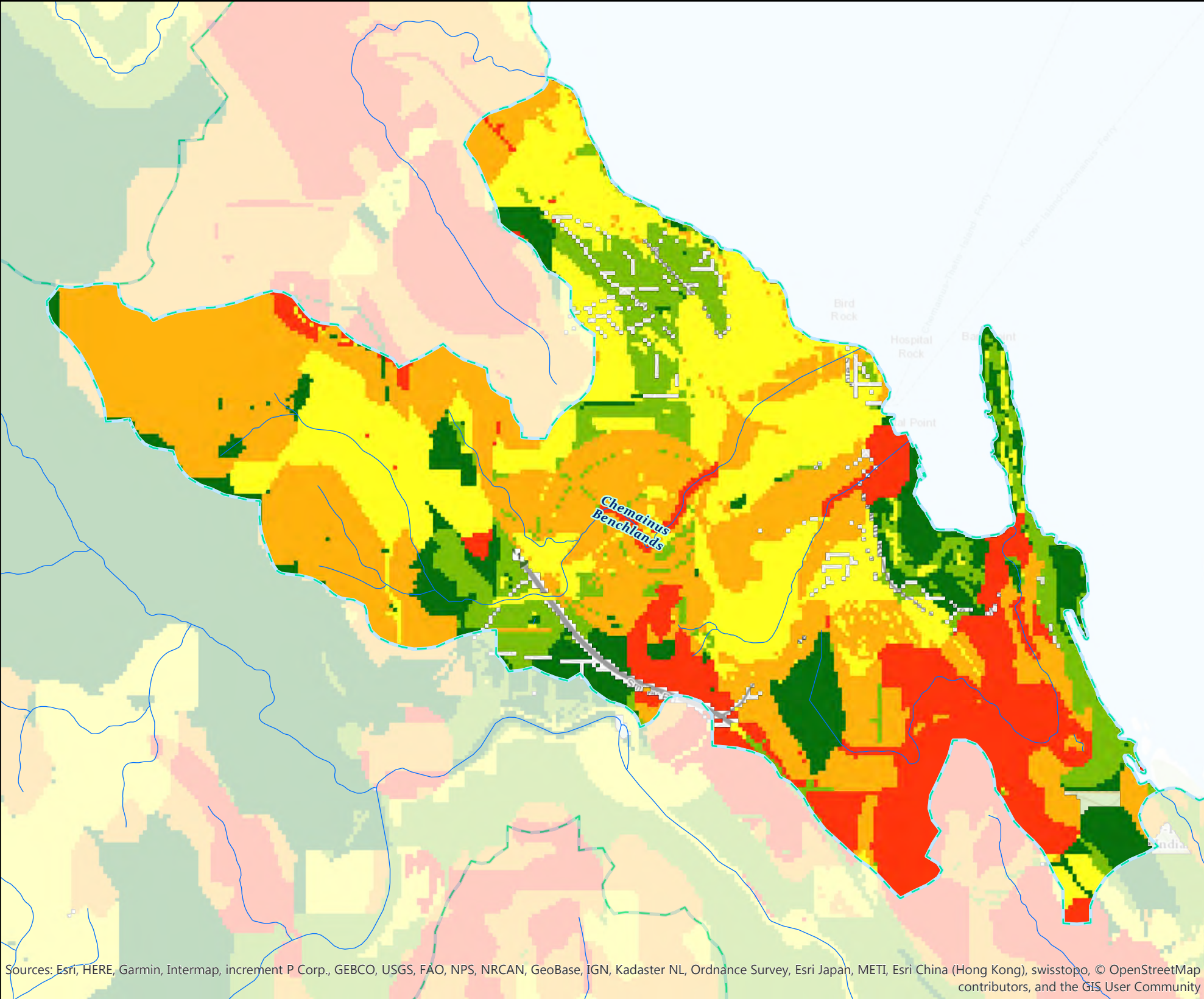


Surface Water Supply Risk Assessment - Chemainus

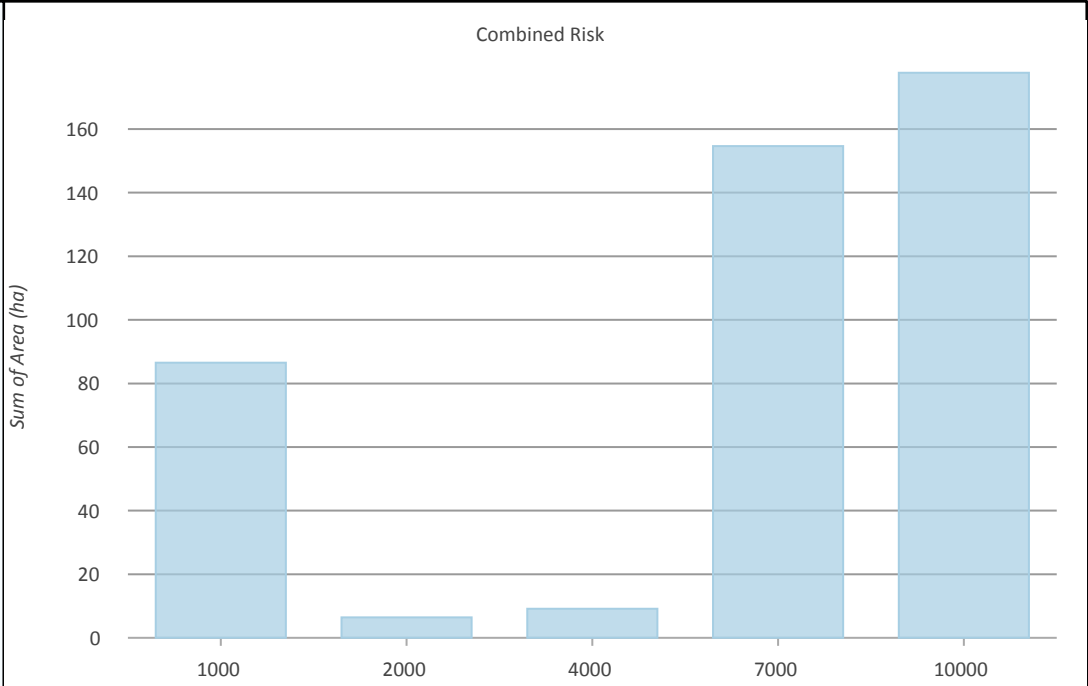


BY: SCALE: 1:45,055 DATE: 2019/01/08 REF No: REV: 0

CHK'D: Proj Coord Sys: PCS Albers 651957-105-CHBL



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



NAME	Risk	POP ₂₀₂₁	POP ₂₀₂₆	POP ₂₀₃₁	POP ₂₀₃₆
SHAWNIGAN CREEK		10047	10760	11613	12598
BUSH CREEK		0	0	0	0
KOKSILAH RIVER		5463	5851	6315	6850
HOLLAND CREEK		1302	1368	1446	1537
BONSALL CREEK		934	974	1019	1073
CHEMAINUS RIVER		1490	1461	1439	1421
COWICHAN RIVER		36368	37905	39683	41766
YELLOW POINT BENCHLANDS		2239	2352	2487	2643
LADYSMITH - SALT AIR BENCHLANDS		8410	8834	9342	9929
STOCKING CREEK		1531	1608	1701	1807
CHEMAINUS BENCHLANDS		3663	3818	3997	4207
SATELLITE CHANNEL BENCHLANDS		4390	4701	5074	5504
SANSUM NARROWS - COWICHAN BAY BENCHLANDS		4941	5150	5391	5674
MALAHAT BENCHLANDS		2829	3030	3271	3548

NAME	POP ₂₀₀₁	POP ₂₀₀₆	POP ₂₀₁₁	POP ₂₀₁₆
SHAWNIGAN CREEK	6348	8439	8925	9484
BUSH CREEK	0			
KOKSILAH RIVER	4555	4808	4954	5157
HOLLAND CREEK	1611	1114	1169	1245
BONSALL CREEK	672	830	815	890
CHEMAINUS RIVER	1423	1395	1497	1514
COWICHAN RIVER	29779	32673	34075	34647
YELLOW POINT BENCHLANDS	1167	1958	2021	2141
LADYSMITH - SALT AIR BENCHLANDS	5275	7488	7541	8042
STOCKING CREEK	1332	1003	1354	1464
CHEMAINUS BENCHLANDS	3177	3129	3085	3490
SATELLITE CHANNEL BENCHLANDS	5425	3902	3989	4144
SANSUM NARROWS - COWICHAN BAY BENCHLANDS	5993	4221	4500	4707
MALAHAT BENCHLANDS	1673	2472	2548	2671

Legend

WATERSHED BOUNDARIES

RISK

≤ 1000

≤ 2000

≤ 4000

≤ 7000

≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

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REVISIONS:

0 - CJW - 2018-11-30 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Chemainus Benchlands Watershed

SNC • LAVALIN

Combined Risk Assessment - Chemainus Benchlands

BY: CJW

CHK'D: DK

SCALE CONS: 1:29,000

Proj Coord Sys: NAD 1983 UTM Zone 10N

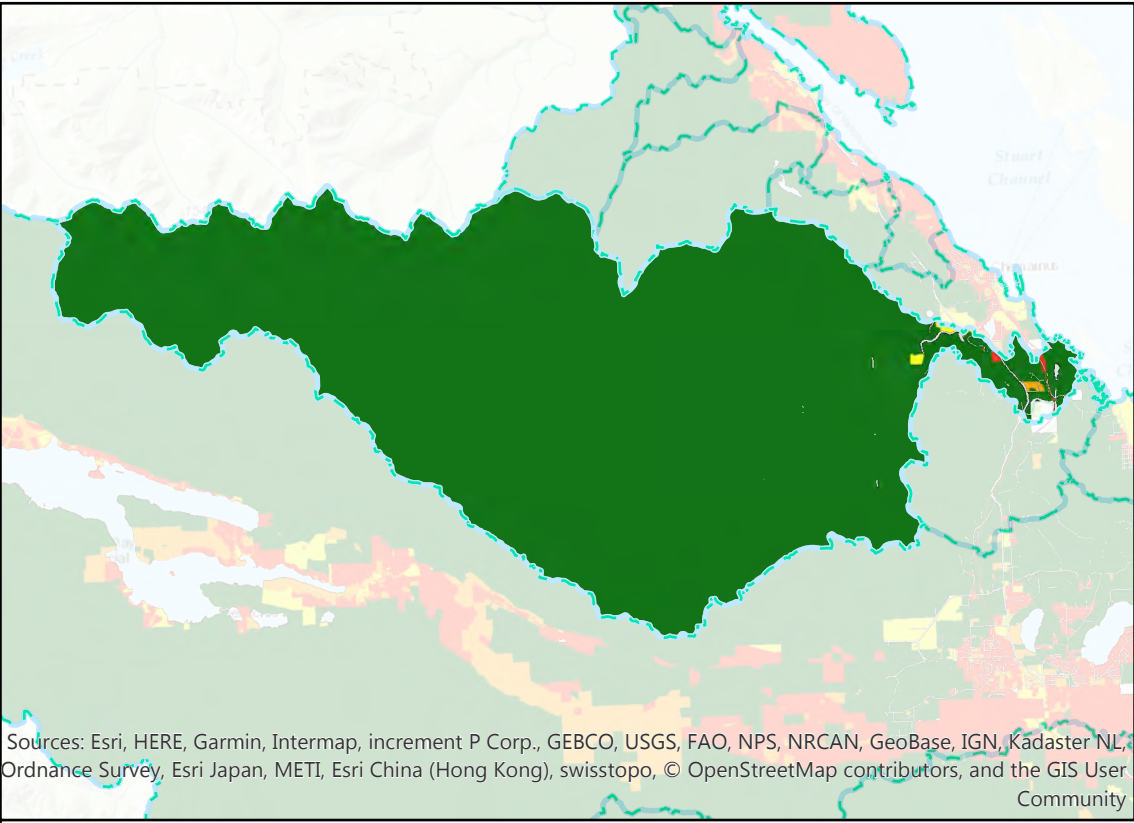
DATE: 2019/01/08

REF No: **651957-106-CHBL**

REV: **0**

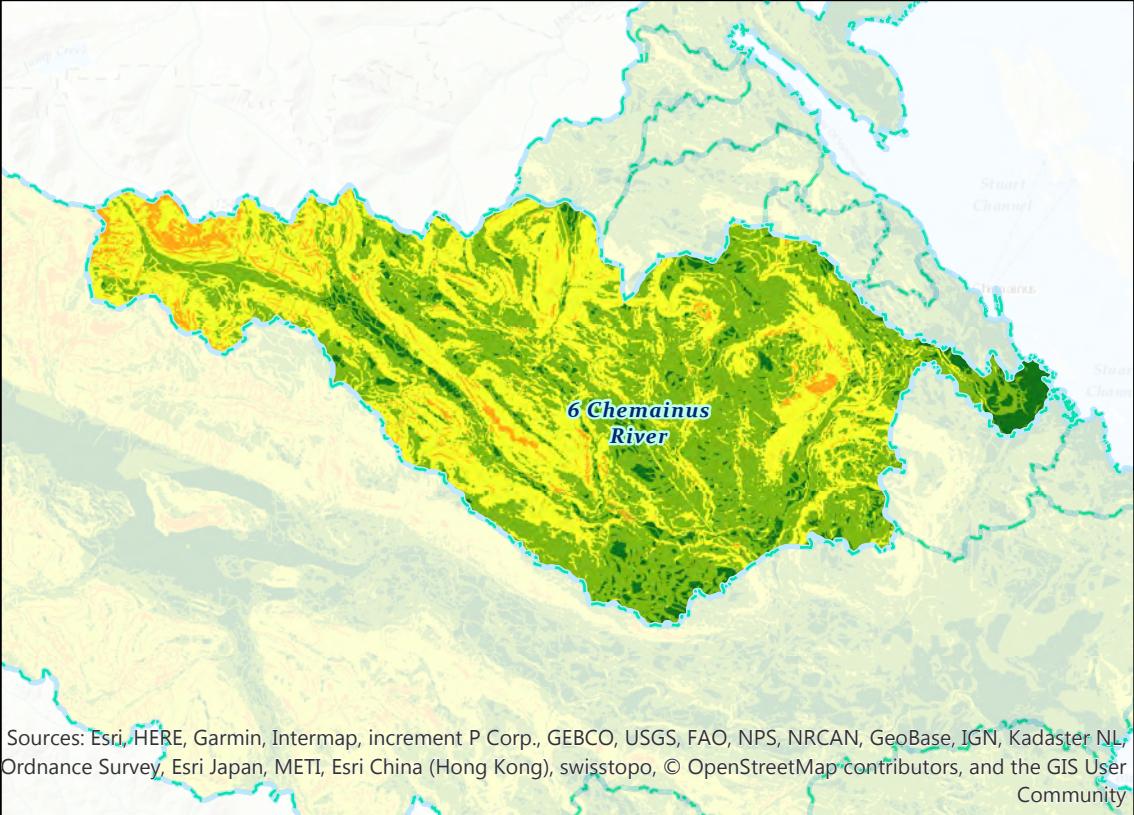
4. Chemainus River	
Topic	Discussion
Slope Failure	<p>Hazard was determined qualitatively at a high level to describe areas based on the degree to which they may be prone to landslides and other mass movements using terrain characteristics. Hazard classifications were generated to show relative comparisons between terrain units within the CVRD watershed study area. Risk ratings derived from this analysis are relative, and should be used to guide prioritization of further detailed studies.</p> <p>The Chemainus River watershed is dissected by a dense network of creeks with relatively steep valley slopes. Hazard varies locally, but is generally moderate throughout the watershed due to this dense slope network. Hazard is relatively low toward the river outlet. Consequence is considered low for the majority of the watershed, with a small area of moderate to high consequence in the populated areas near Chemainus. Risk is considered low throughout the watershed.</p>
Flooding	A relatively dense network of creeks span the watershed but consequence and risk are very low throughout, with the exceptions of the eastern coast south of Chemainus and the nearby areas along Chemainus Road and Highway 1 as well as the adjacent industrial area.
Groundwater Contamination	Likelihood is low for the vast majority of the watershed but are enhanced in the areas where the vulnerability is high immediately north of the Bonsall Creek watershed in the vicinity of Highway 1 and Chemainus Road. The highest consequence and risk are generally in the same areas.
Surface Water Quality	Hazard is low for the vast majority of the watershed's area and is higher in small zones depending on land use type and impervious surface areas. Levels of higher likelihood are situated in the industrial area along Highway 1 south of Chemainus and the developed areas surrounding Chemainus Road in the eastern end of the watershed. The watershed contains many smaller order streams and therefore consequence is greatest at these streams. Risk is greatest in portions of the eastern end of the watershed. Population for the watershed is projected to minimally reduce, placing slightly less pressure on surface water quality but dependent upon changes in land use and extent of impervious surfaces.
Surface Water Supply	Hazard is greatest in small isolated zones near the outlet of the Chemainus River. Consequence considered variable around surface water points of diversion in the watershed, with isolated points of greater consequence in the central watershed, and a zone of greater consequences along the stream and around concentrated near the outlet of the Chemainus River at the coast. Population projections for the watershed suggest the population will remain stable, and therefore groundwater pressures from residential use is not expected to increase the level of hazard or risk.
General Data Notes	The projected population decrease of the Chemainus river is potentially incorrect, and is primarily due to the majority of the watershed being in the Western region of the LAM study. With the majority of the populated area being in the relatively small and flatter section near the ocean, slope failure isn't considered to be a primary contributor to overall risk. The Chemainus river flood plain is considered to be the biggest contributor to risk, with surface water quality, surface water supply, and groundwater contamination all contributing.

CONSEQUENCE



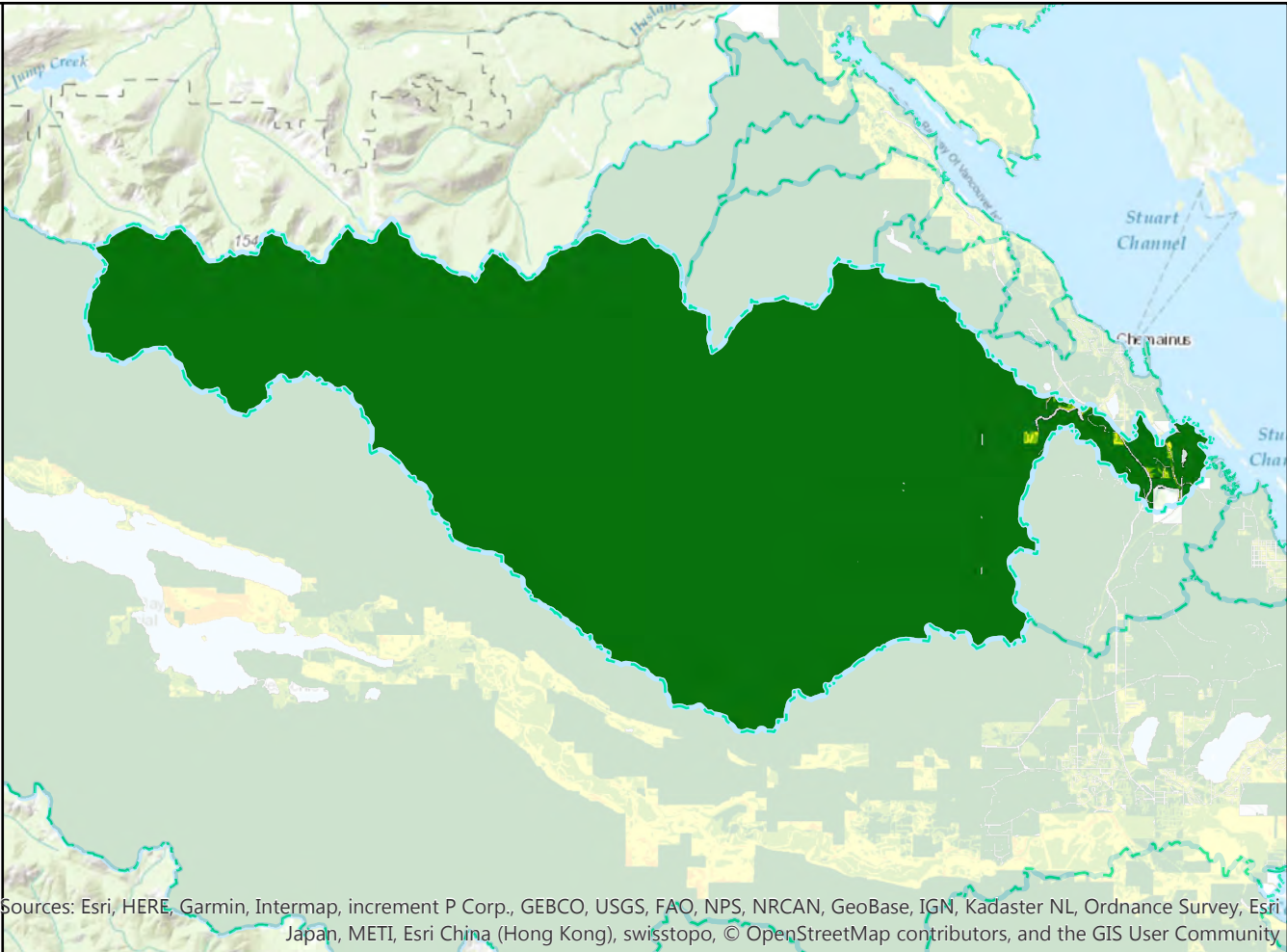
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

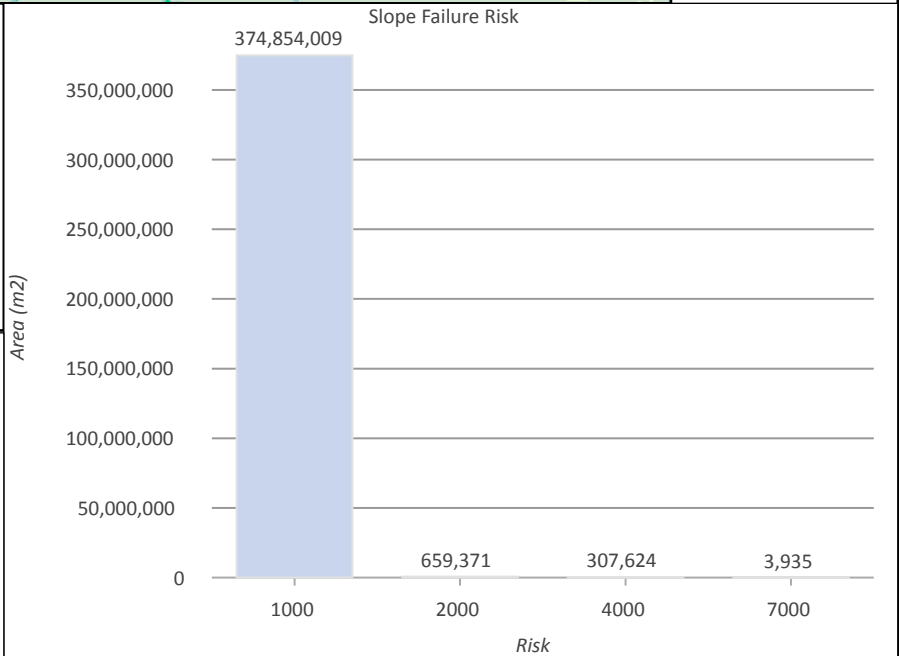
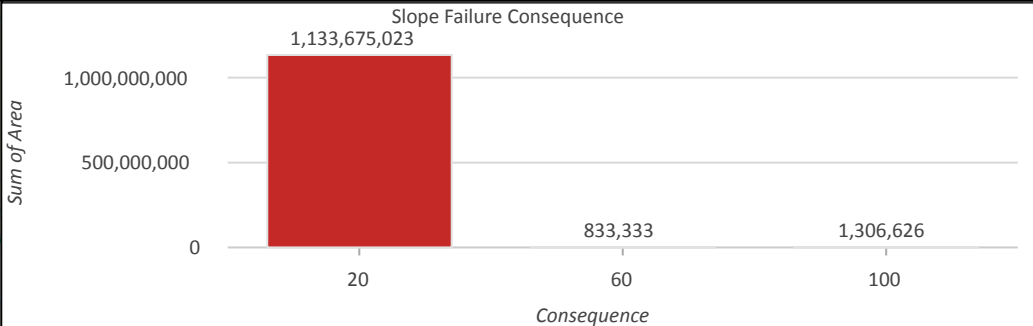
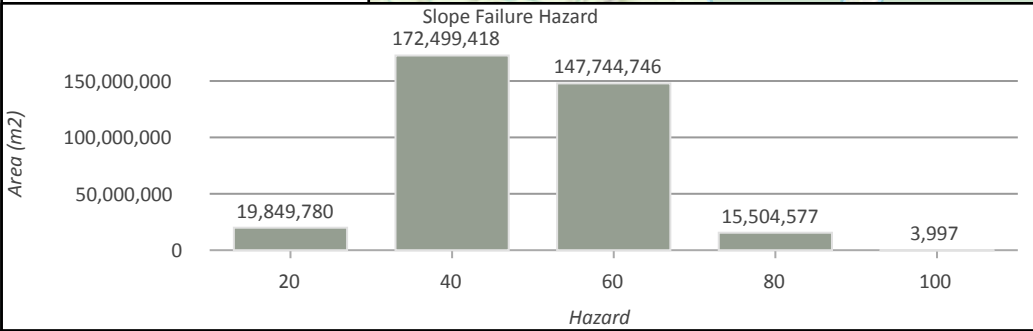


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

NOTES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Chemainus River Watershed

Slope Failure Risk Assessment - Chemainus River

BY: CJW SCALE CONS: 1:259,975 DATE: 2019/01/07 REF No: REV: 0

CHK'D: DK Proj Coord Sys: PCS Albers **651957-101-CHEM**

SNC • LAVALIN

0 2,500 5,000 10,000 15,000 20,000 Meters

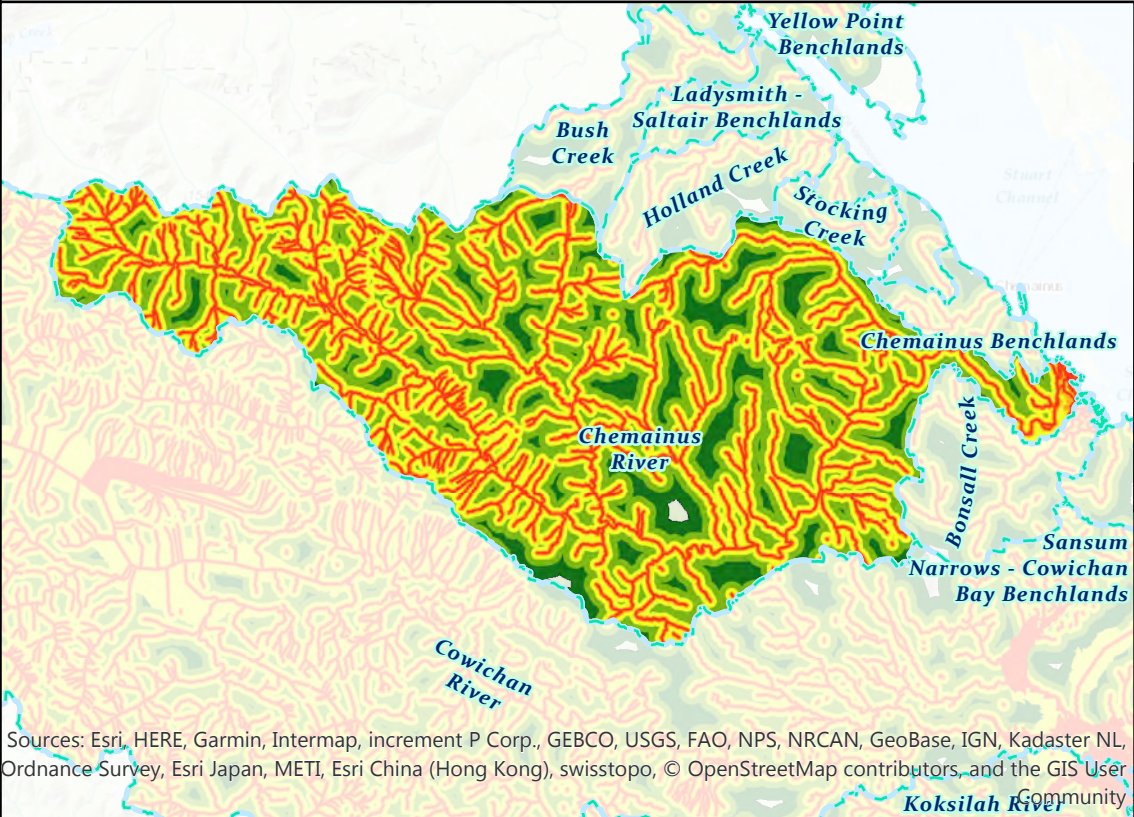
Project Path: P:\Current Projects\CVRD\651957\ P: 4-1

CONSEQUENCE



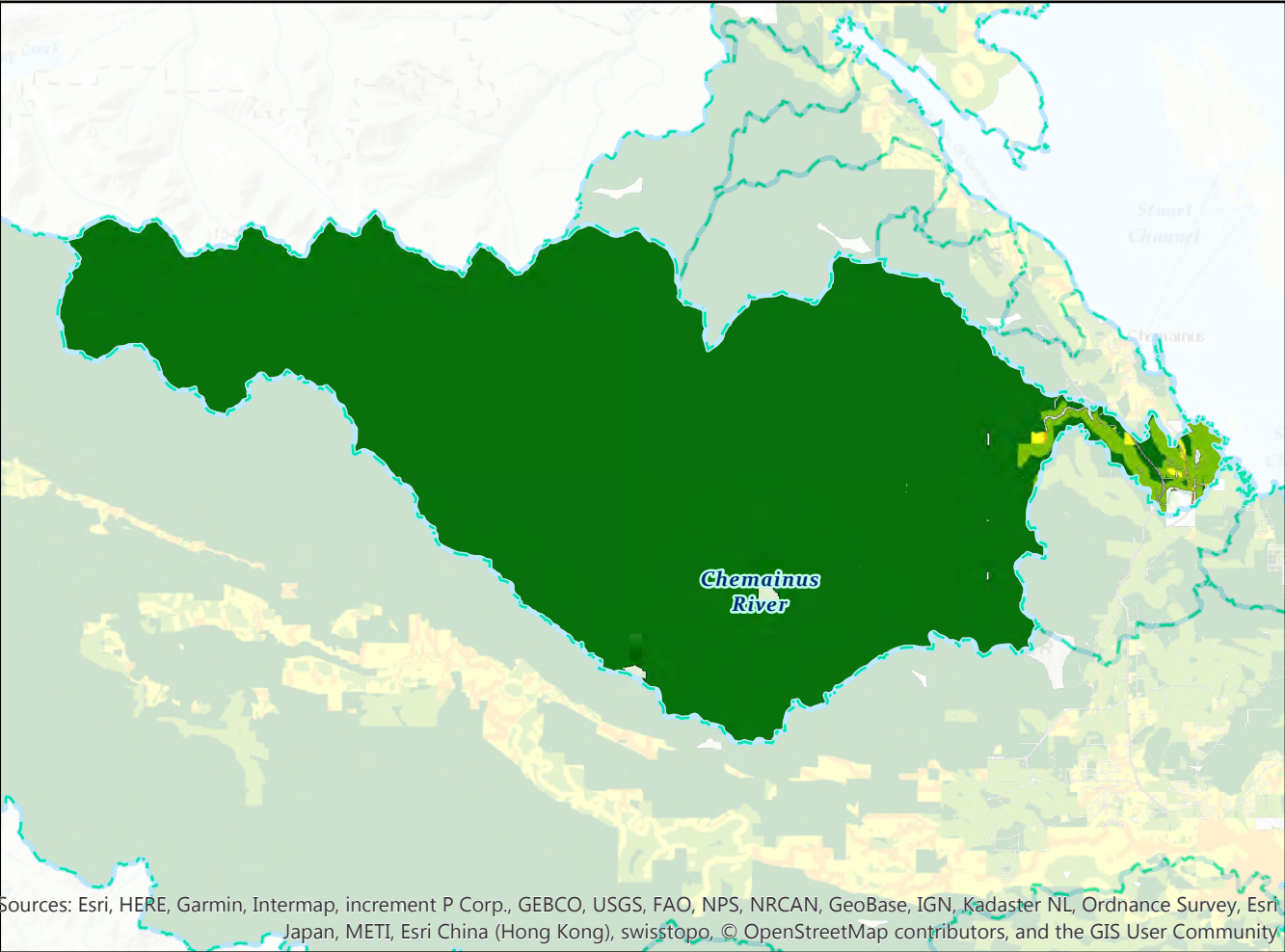
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

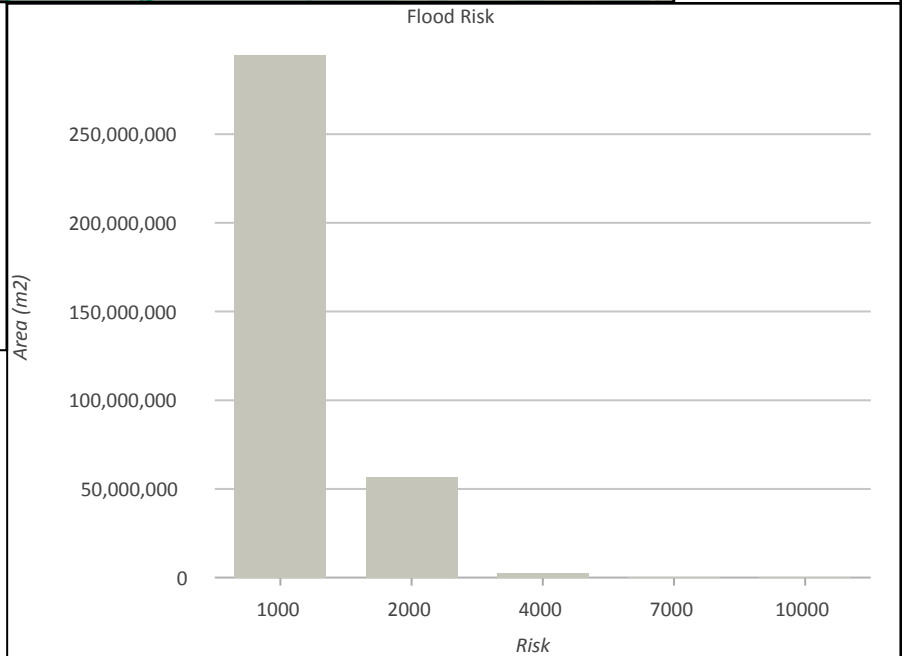
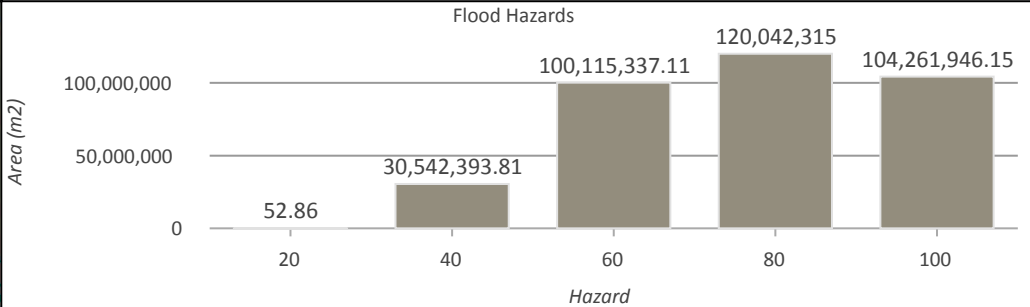
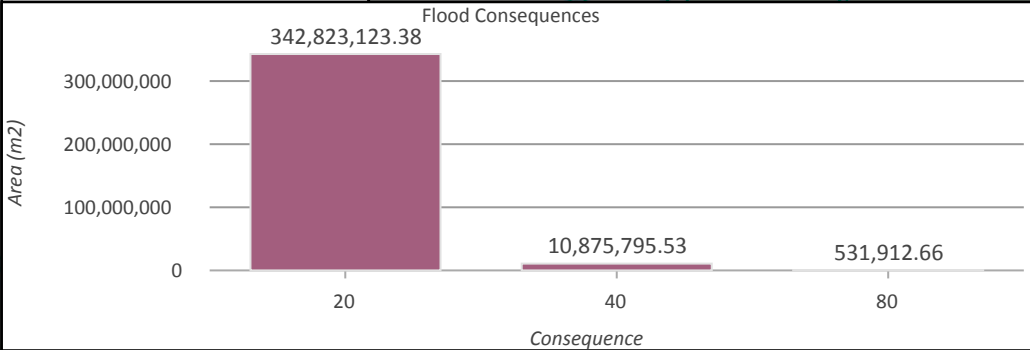


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

RISK

≤ 20	≤ 1000
≤ 40	≤ 2000
≤ 60	≤ 4000
≤ 80	≤ 7000
≤ 100	≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:

Cowichan Valley Regional District

PROJECT LOCATION:

Cowichan Valley Regional District

Chemainus River Watershed



Flood Risk Assessment - Chemainus River

BY: CJW

SCALE CONS: 1:250,779

DATE: 2019/01/08

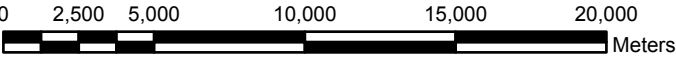
REF No:

REV: 0

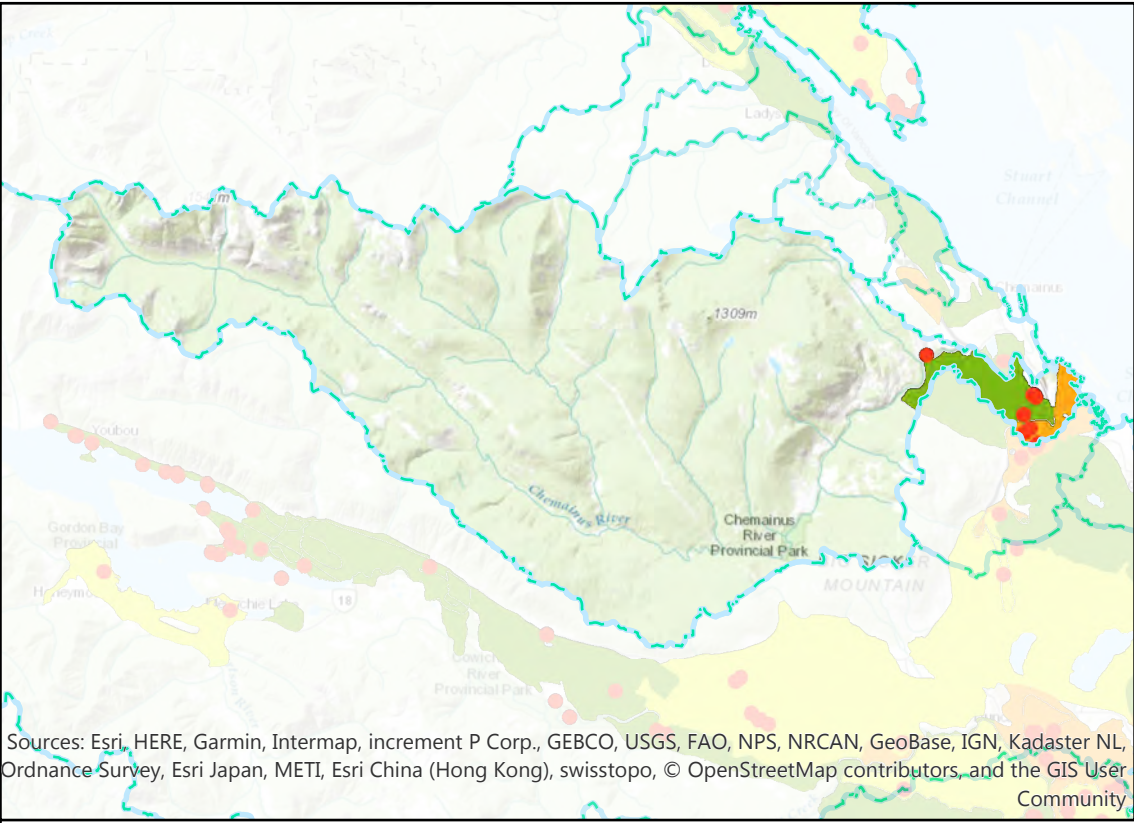
CHK'D: DK

Proj Coord Sys: NAD 1983 UTM Zone 10N

651957-102-CHEM

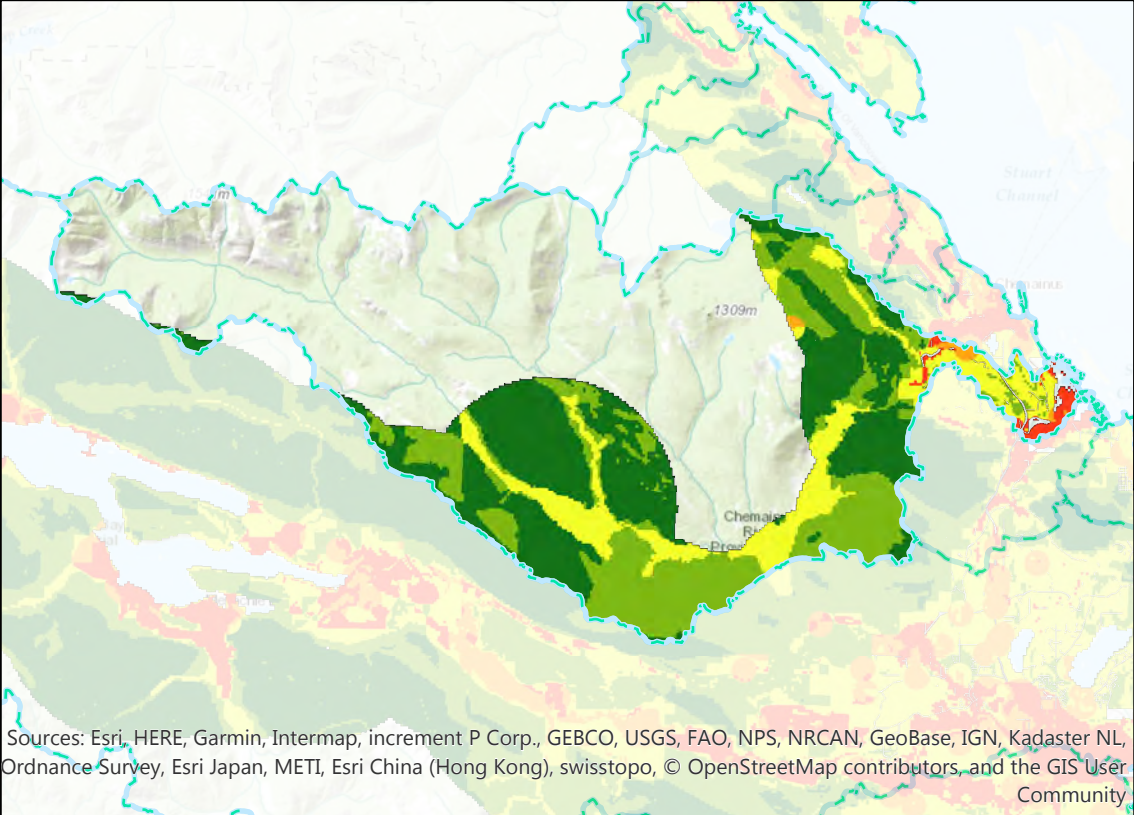


CONSEQUENCE



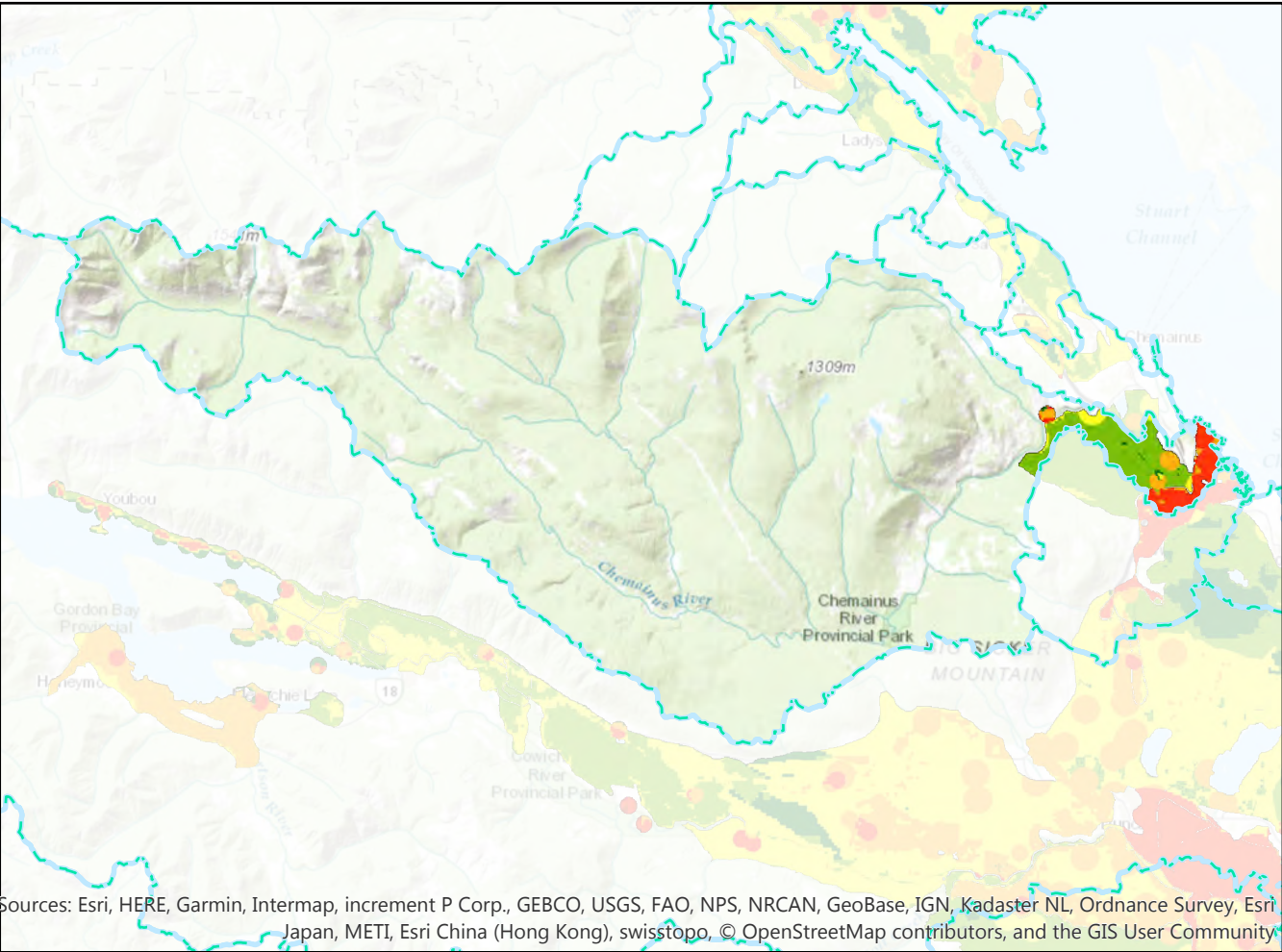
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HAZARD

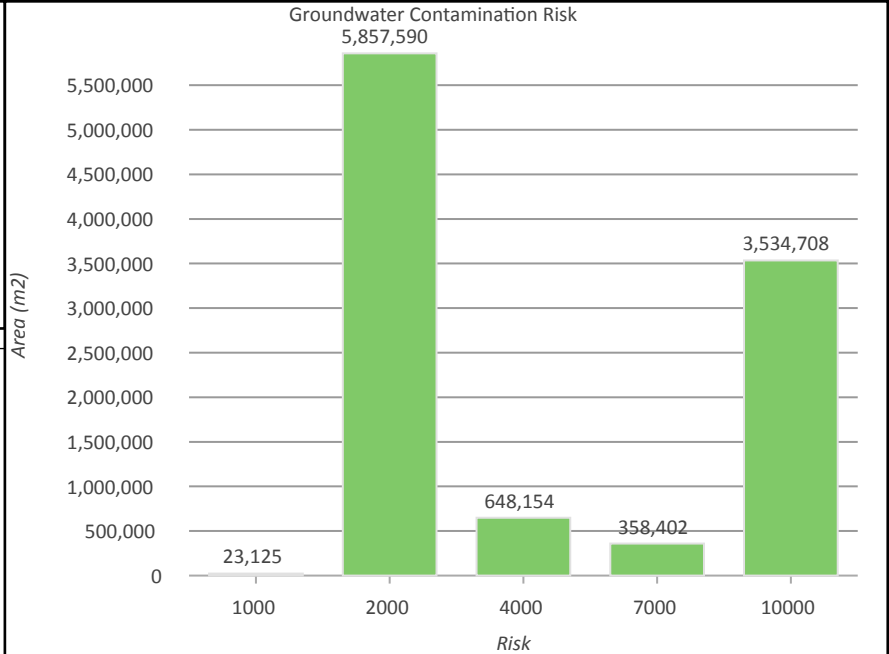
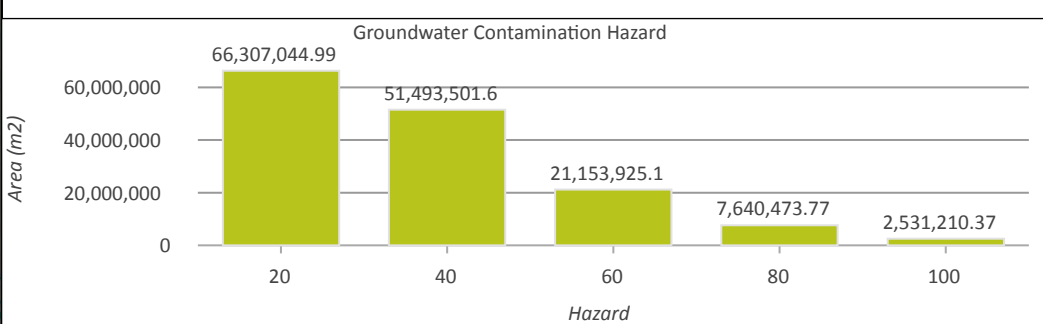
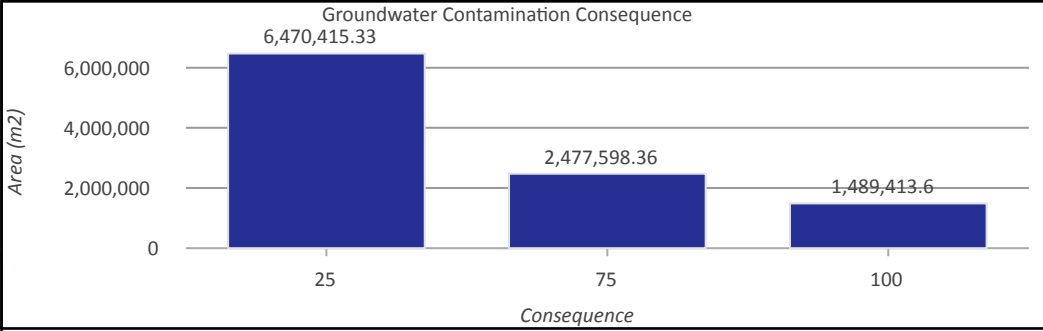


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



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Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

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RISK

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REVISIONS:

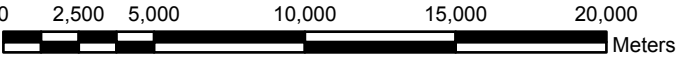
0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

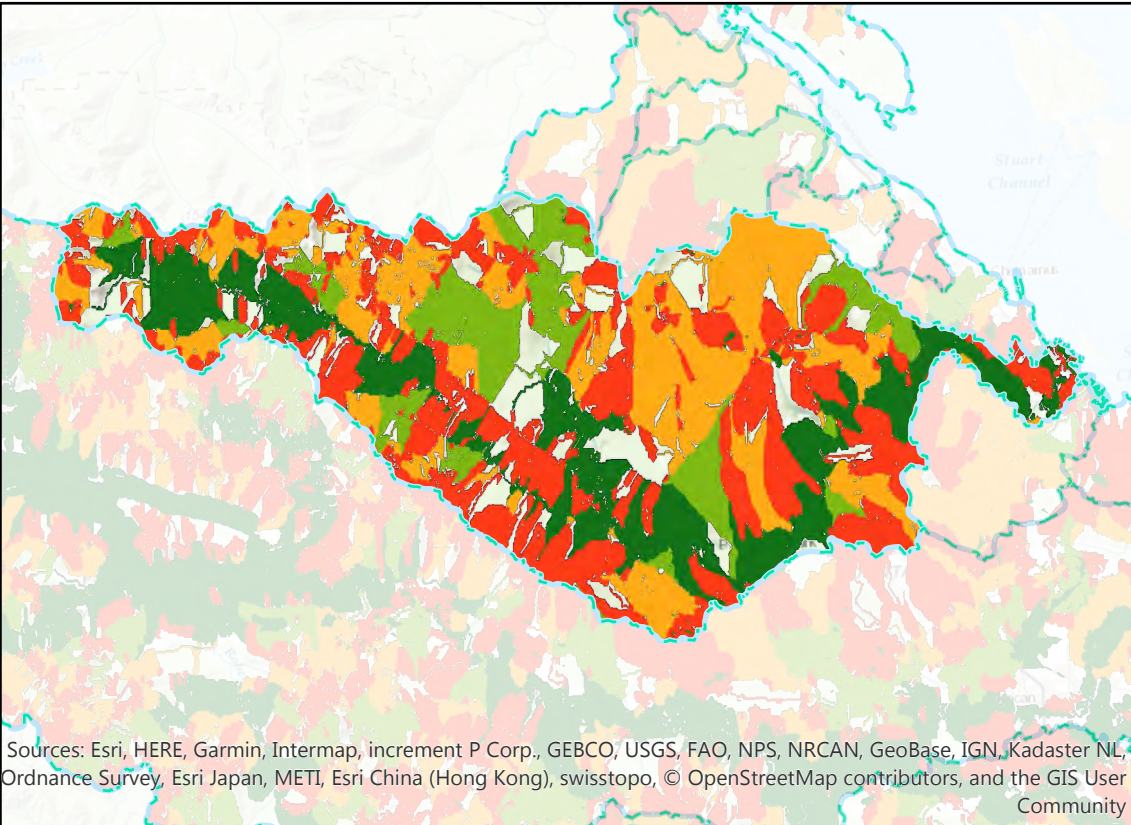
PROJECT LOCATION:
Cowichan Valley Regional District
Chemainus River Watershed

Groundwater Contamination Risk Assessment - Chemainus River

BY: CJW	SCALE CONS: 1:250,779	DATE: 2019/01/08	REF No:	REV: 0
CHK'D: DK	Proj Coord Sys: NAD 1983 UTM Zone 10N		651957-103-CHEM	

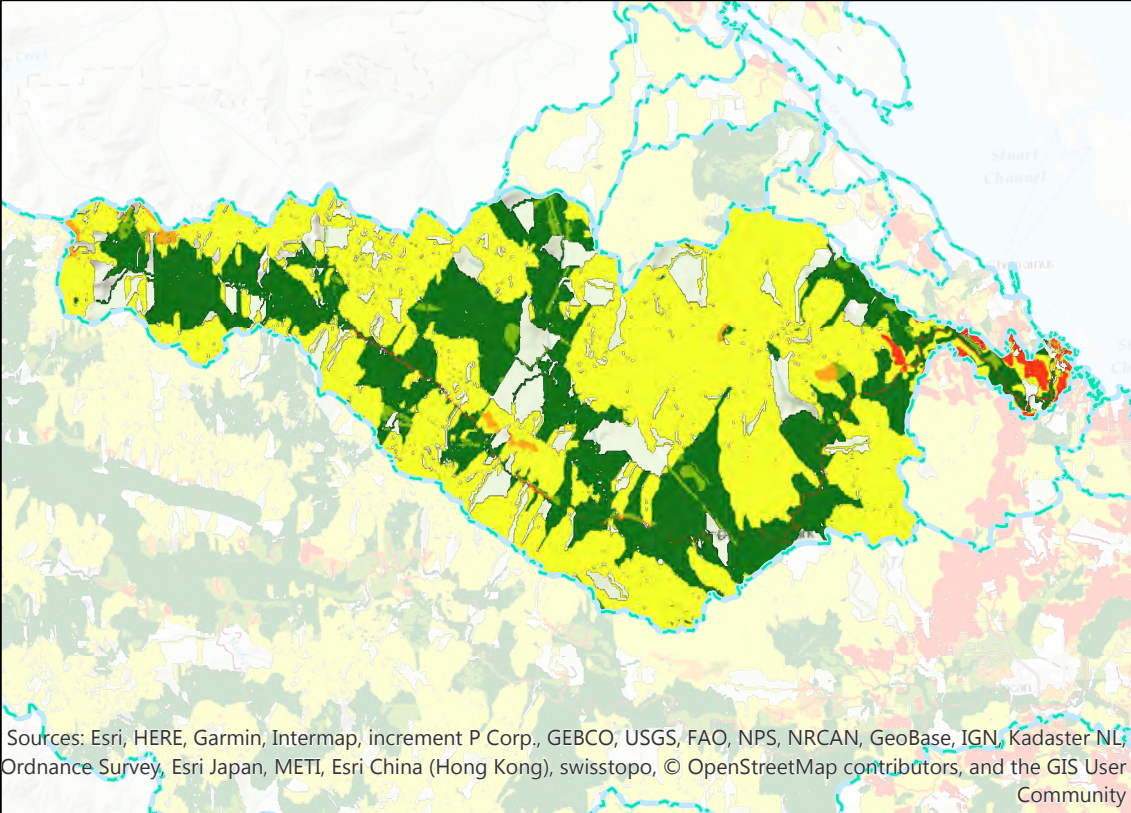


CONSEQUENCE



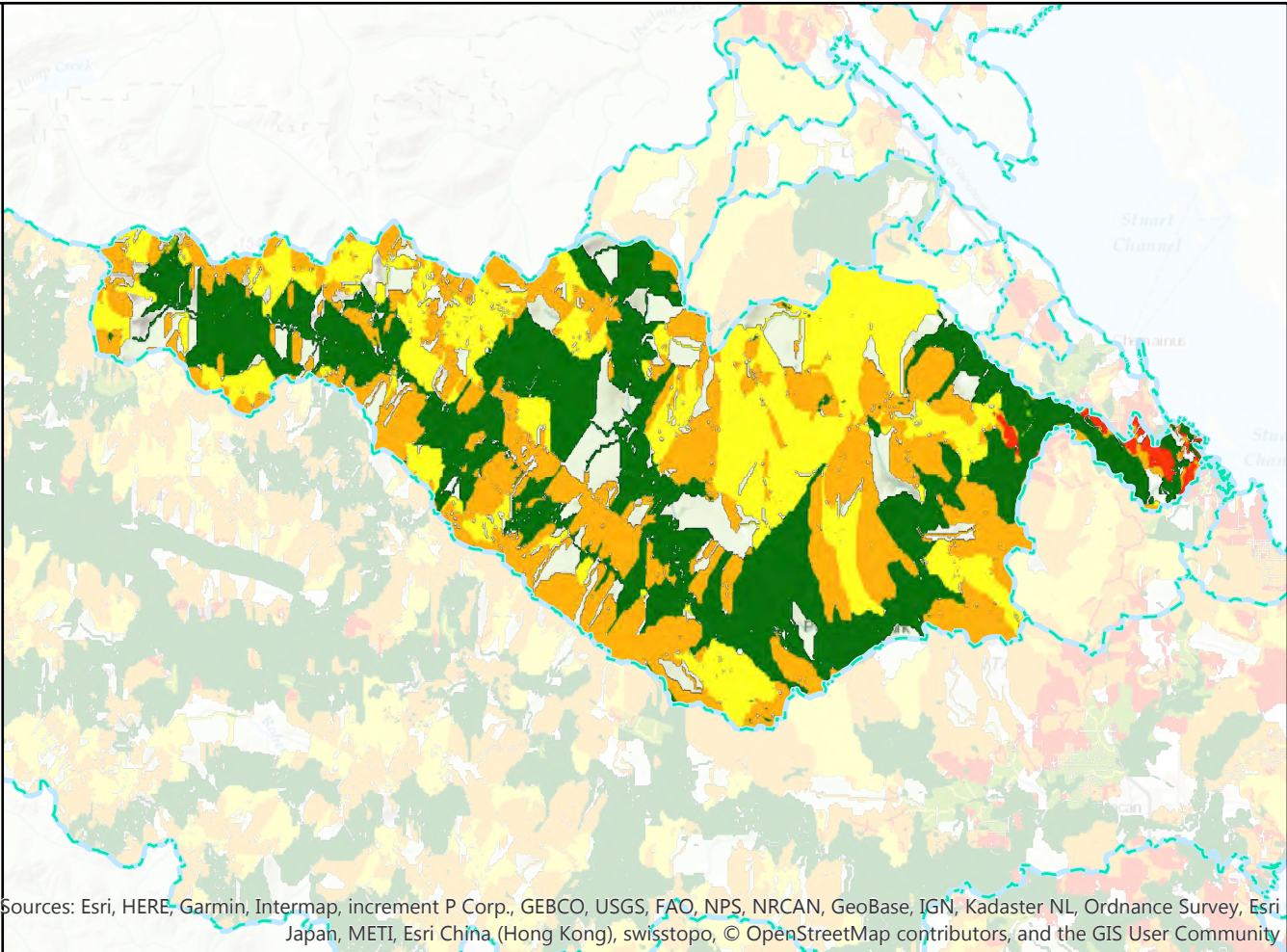
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

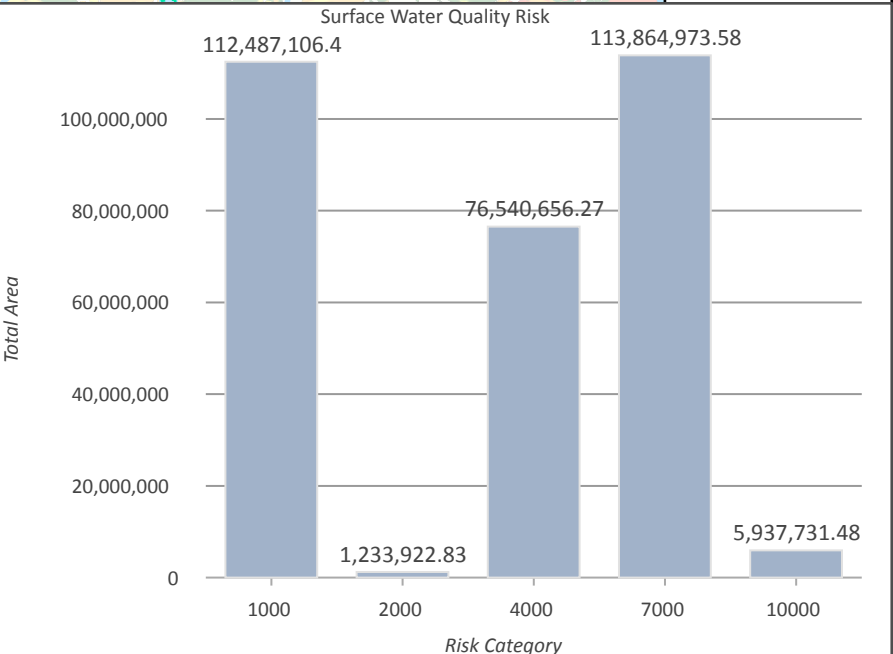
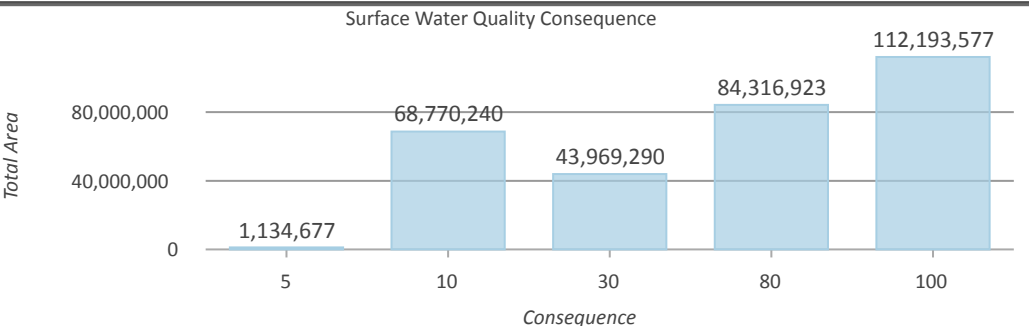
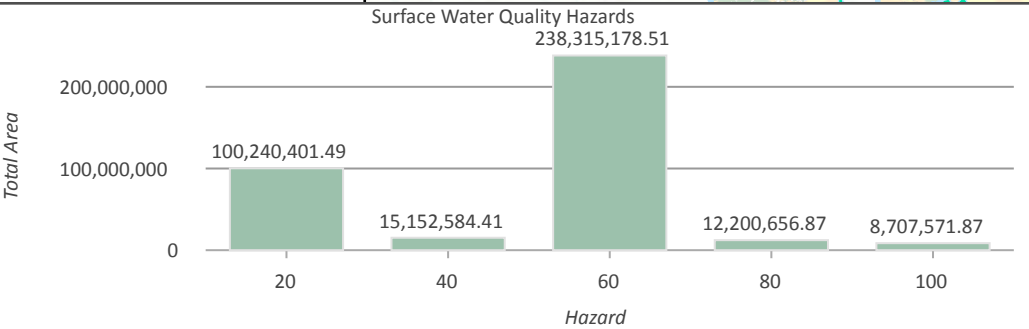


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



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Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
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REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District Chemainus River Watershed



SNC • LAVALIN

Surface Water Quality Risk Assessment - Chemainus River

BY:

SCALE: 1:262,323

DATE: 2019/01/08

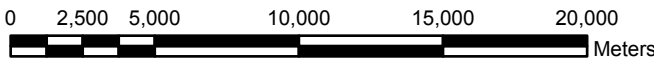
REF No:

REV: 0

CHK'D:

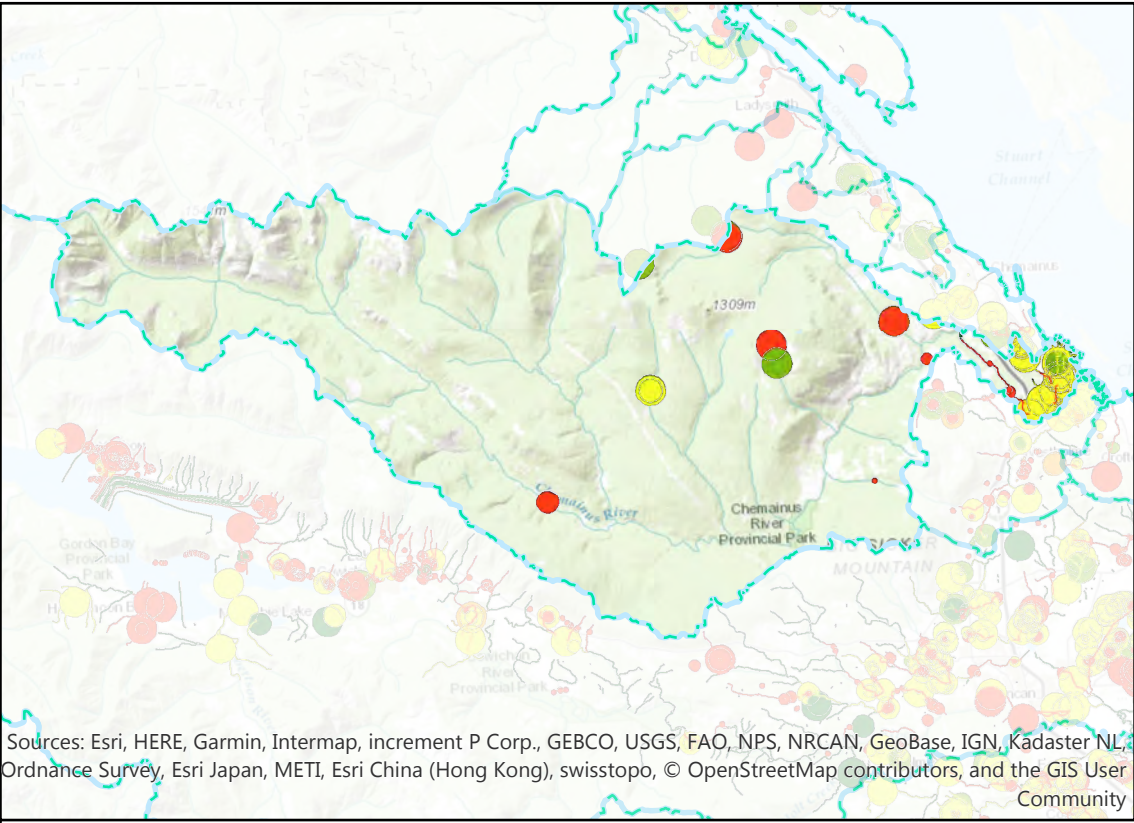
Proj Coord Sys: PCS Albers

651957-104-CHEM



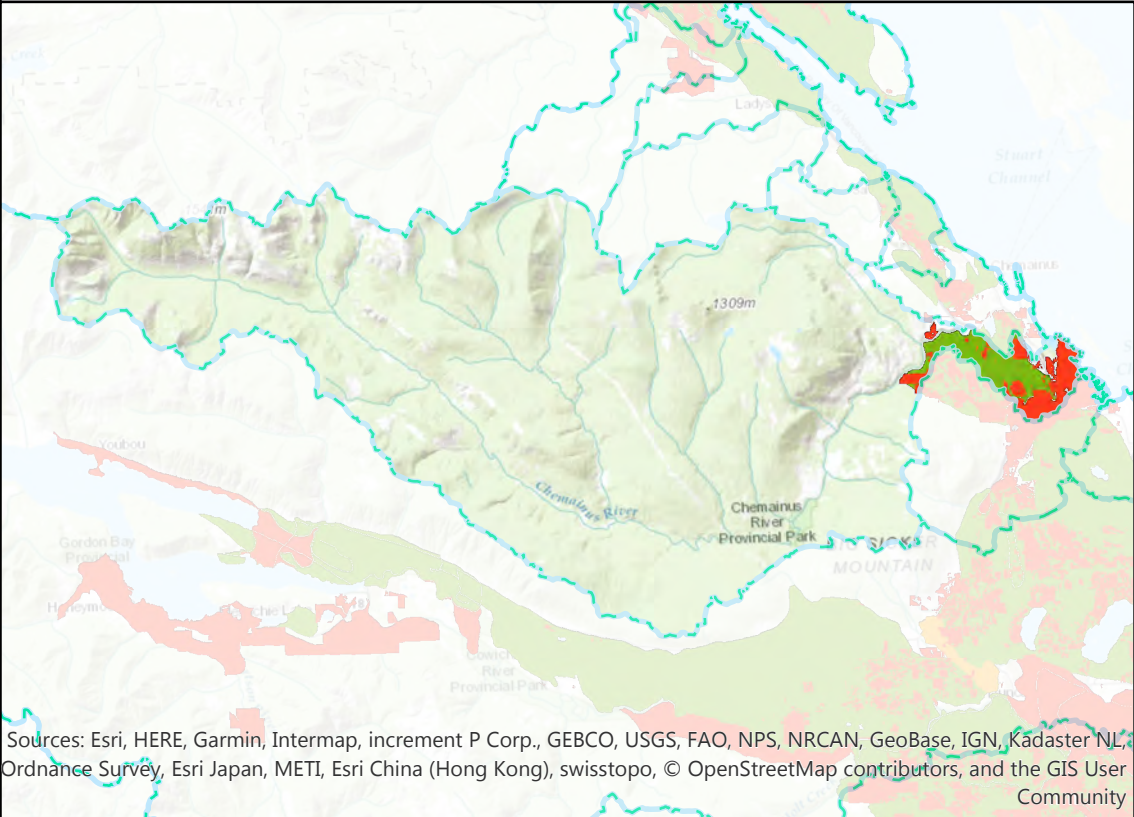
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CONSEQUENCE



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

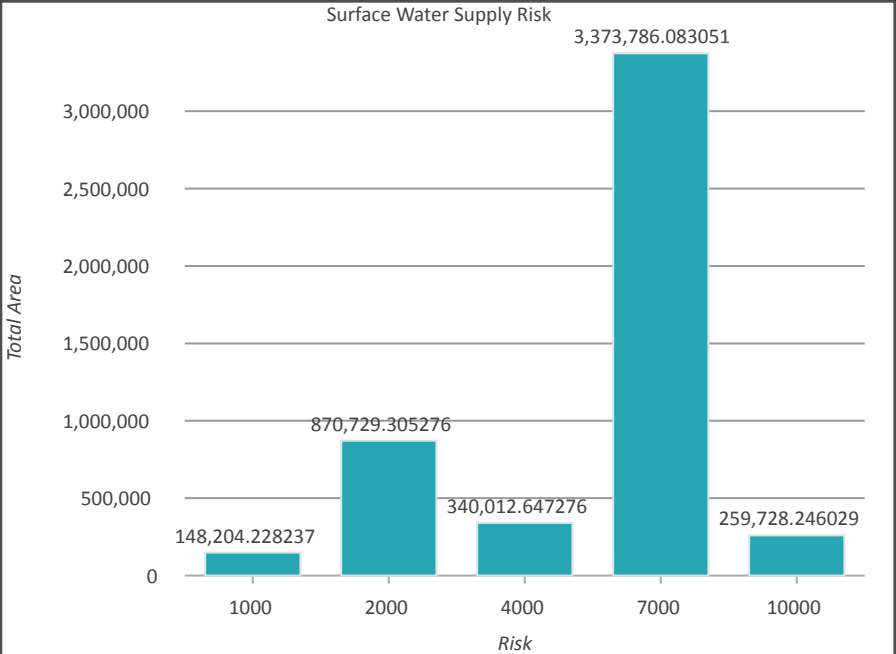
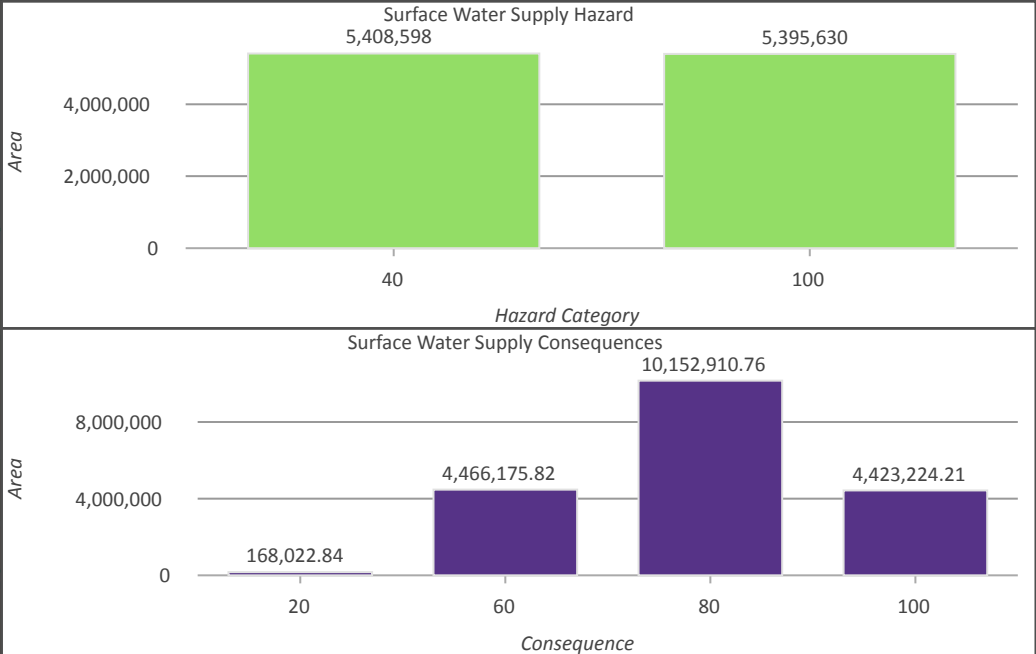


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

	≤ 20
	≤ 40
	≤ 60
	≤ 80
	≤ 100

RISK

	≤ 1000
	≤ 2000
	≤ 4000
	≤ 7000
	≤ 10000

REFERENCES:
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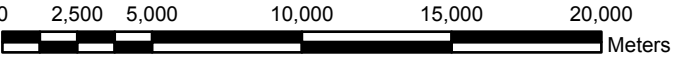
REVISIONS:
0 - CJW - 2018-11-29 - Issued - DK

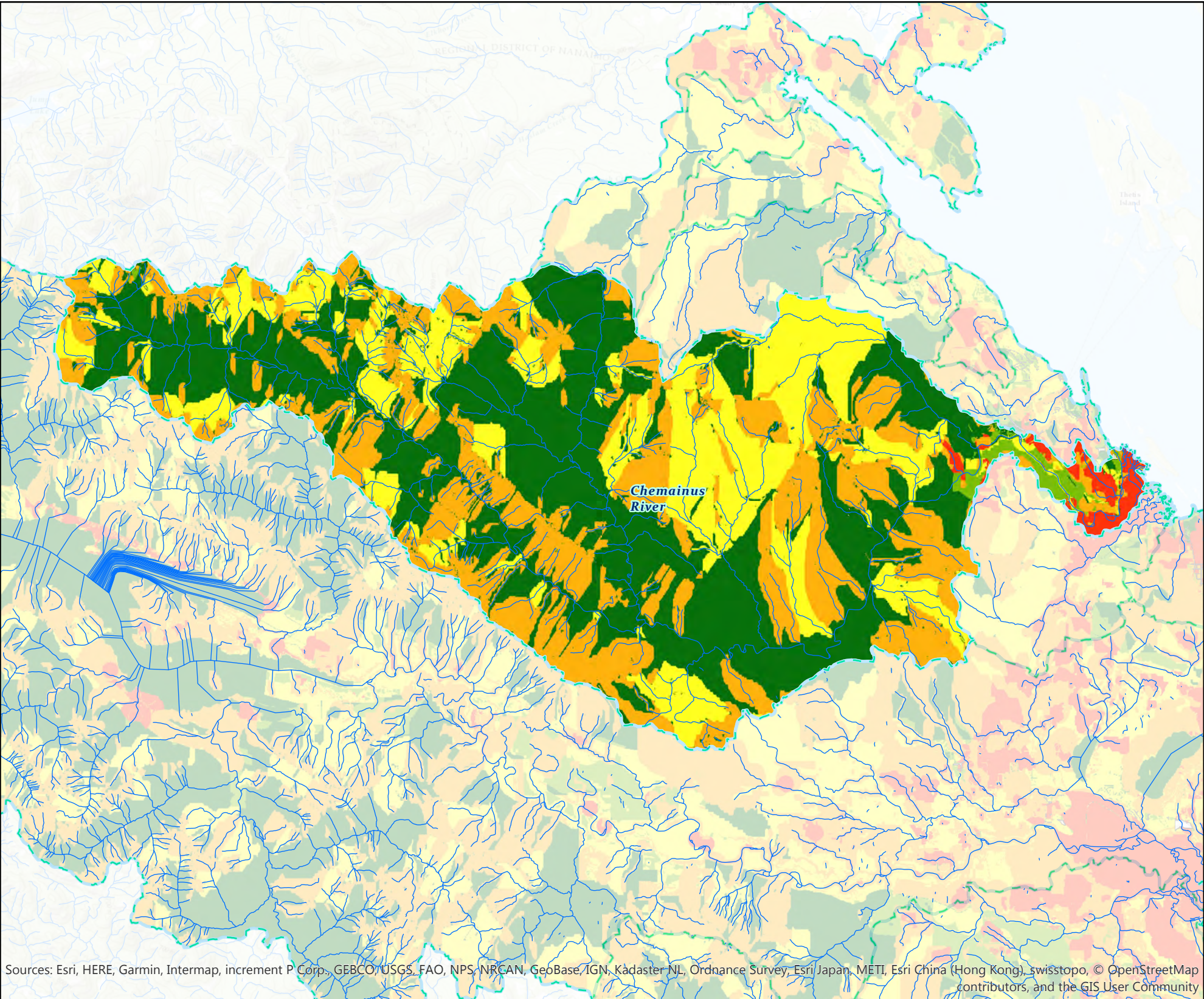
CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District Chemainus River Watershed

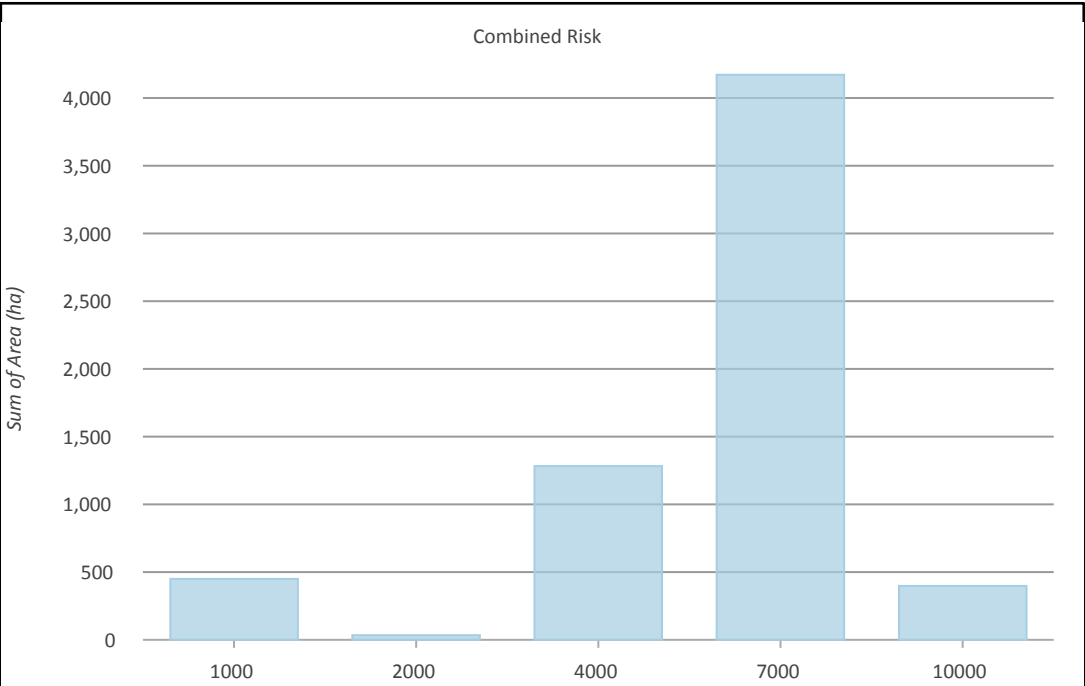
Surface Water Supply Risk Assessment - Chemainus River

BY:	SCALE: 1:252,479	DATE: 2019/01/08	REF No:	REV: 0
CHK'D:	Proj Coord Sys: PCS Albers			651957-105-CHEM





Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



NAME	Risk	POP ₂₀₂₁	POP ₂₀₂₆	POP ₂₀₃₁	POP ₂₀₃₆
SHAWNIGAN CREEK		10047	10760	11613	12598
BUSH CREEK		0	0	0	0
KOKSILAH RIVER		5463	5851	6315	6850
HOLLAND CREEK		1302	1368	1446	1537
BONSALL CREEK		934	974	1019	1073
CHEMAINUS RIVER		1490	1461	1439	1421
COWICHAN RIVER		36368	37905	39683	41766
YELLOW POINT BENCHLANDS		2239	2352	2487	2643
LADYSMITH - SALT AIR BENCHLANDS		8410	8834	9342	9929
STOCKING CREEK		1531	1608	1701	1807
CHEMAINUS BENCHLANDS		3663	3818	3997	4207
SATELLITE CHANNEL BENCHLANDS		4390	4701	5074	5504
SANSUM NARROWS - COWICHAN BAY BENCHLANDS		4941	5150	5391	5674
MALAHAT BENCHLANDS		2829	3030	3271	3548

NAME	POP ₂₀₀₁	POP ₂₀₀₆	POP ₂₀₁₁	POP ₂₀₁₆
SHAWNIGAN CREEK	6348	8439	8925	9484
BUSH CREEK	0			
KOKSILAH RIVER	4555	4808	4954	5157
HOLLAND CREEK	1611	1114	1169	1245
BONSALL CREEK	672	830	815	890
CHEMAINUS RIVER	1423	1395	1497	1514
COWICHAN RIVER	29779	32673	34075	34647
YELLOW POINT BENCHLANDS	1167	1958	2021	2141
LADYSMITH - SALT AIR BENCHLANDS	5275	7488	7541	8042
STOCKING CREEK	1332	1003	1354	1464
CHEMAINUS BENCHLANDS	3177	3129	3085	3490
SATELLITE CHANNEL BENCHLANDS	5425	3902	3989	4144
SANSUM NARROWS - COWICHAN BAY BENCHLANDS	5993	4221	4500	4707
MALAHAT BENCHLANDS	1673	2472	2548	2671

Legend

WATERSHED BOUNDARIES

RISK

	≤ 1000
	≤ 2000
	≤ 4000
	≤ 7000
	≤ 10000

REFERENCES:

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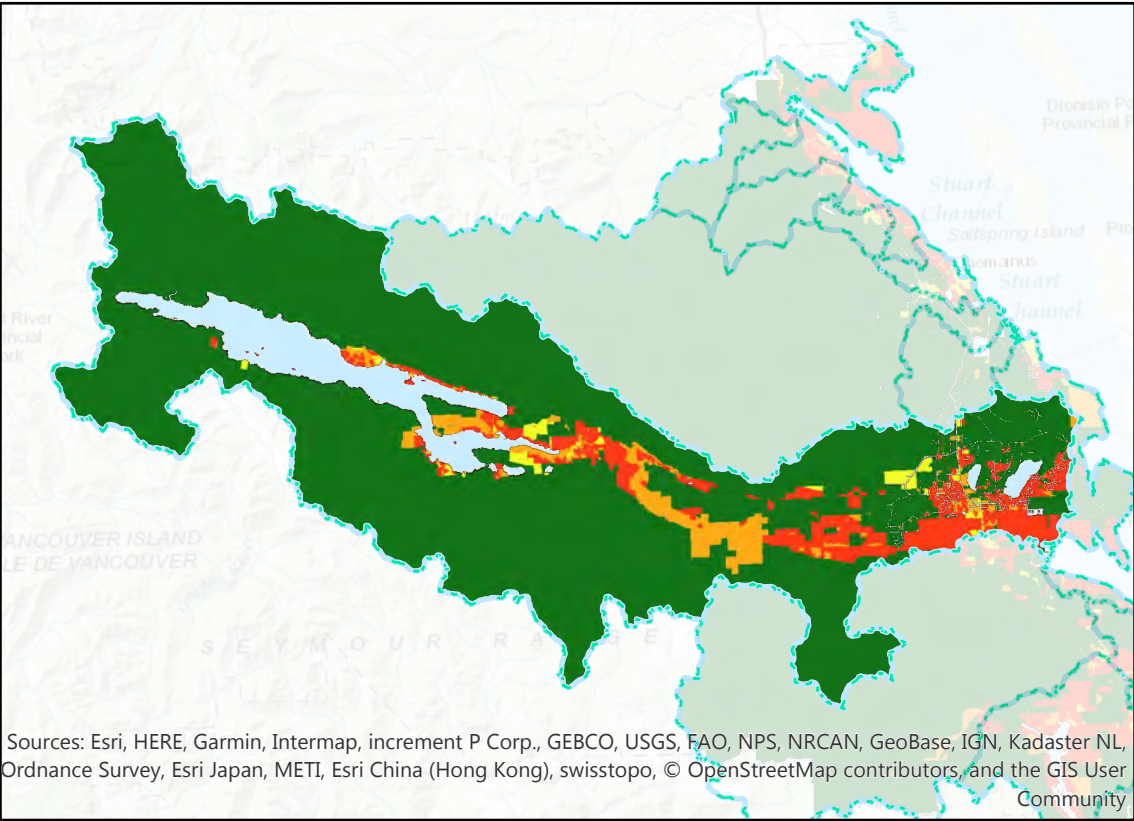
REVISIONS:

0 - CJW - 2018-11-30 - Issued - DK

CLIENT: Cowichan Valley Regional District	
PROJECT LOCATION: Cowichan Valley Regional District Chemainus River Watershed	
Combined Risk Assessment - Chemainus River	
BY: CJW	SCALE CONS: 1:169,000
CHK'D: DK	Proj Coord Sys: NAD 1983 UTM Zone 10N
DATE: 2019/01/08	
REF No: 651957-106-CHEM	
REV: 0	

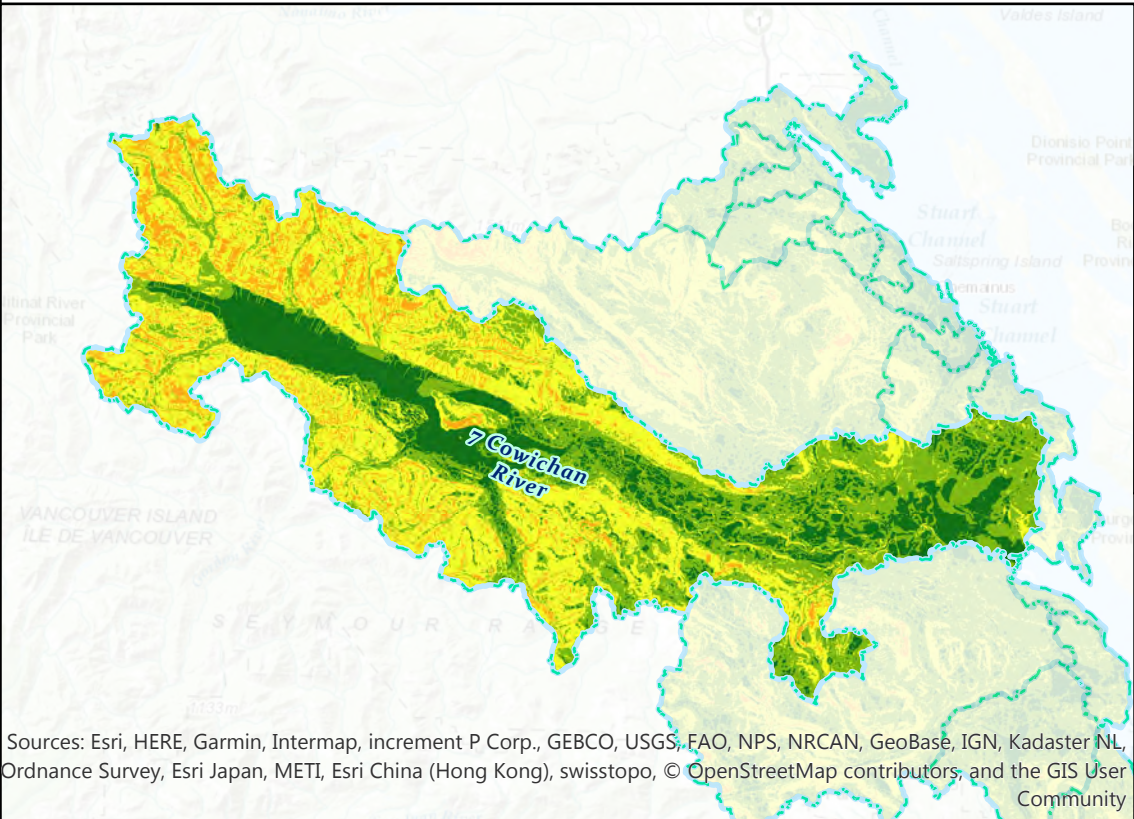
5. Cowichan River	
Topic	Discussion
Slope Failure	<p>Hazard was determined qualitatively at a high level to describe areas based on the degree to which they may be prone to landslides and other mass movements using terrain characteristics. Hazard classifications were generated to show relative comparisons between terrain units within the CVRD watershed study area. Risk ratings derived from this analysis are relative, and should be used to guide prioritization of further detailed studies.</p> <p>Hazard is greatest around Lake Cowichan due to the relatively steep slopes and logging activity. Hazard decreases towards Duncan as the topography becomes gentler. Consequence is considered moderate to high through the populated areas spanning the central watershed area between Lake Cowichan and Duncan. Risk is considered moderate in these populated areas and is highest where slopes encroach on populated areas near Lake Cowichan.</p>
Flooding	<p>Numerous rivers and creeks span the large watershed. Consequence and risk are greatest near Duncan, along the Cowichan River between Duncan and Lake Cowichan, and surrounding portions of Lake Cowichan.</p>
Groundwater Contamination	<p>Likelihood of groundwater contamination varies greatly throughout the watershed and is greatest in isolated small zones surrounding Lake Cowichan and along its draining tributaries that convey flows to the east. Some of these isolated zones are reflected in the areas of higher risk. Other higher risk areas are located within the south-east corner of the watershed in the vicinity of Highway 1 and where municipal supply wells are located.</p>
Surface Water Quality	<p>Hazard is greatest in the developed areas of Lake Cowichan and Duncan. Consequence varies considerably, with higher consequence zones scattered throughout the watershed where lower order streams are present. Unsurprisingly, due to the large area of the watershed, risk also varies considerably throughout the watershed. Risk is generally greatest at Lake Cowichan and Duncan. These areas are projected to expand with increased populations that may increase the areas where risk is considered greatest.</p>
Surface Water Supply	<p>Hazard is greatest in areas around the lower end of Lake Cowichan, east and west of Duncan, and in isolated zones between Maple Bay and Somenos. Consequence were identified in the watershed from Lake Cowichan down the river valley toward Genoa Bay. Consequences were moderate to high in most of those areas, with the greatest concentration of consequences in the lower part of the watershed and in smaller tributary drainages adjacent to the Cowichan River. Risk is greatest in small zones around Lake Cowichan, and around Duncan. Population projections indicate a growing population for the Cowichan River watershed, and therefore pressures on groundwater supplies for residential are expected to increase the level of hazard or risk.</p>
General Data Notes	<p>Further work to understand Surface Water Supply risk could include consideration of timing volumes of water use for agricultural, commercial and industrial purposes both from surface water and groundwater, and climate change projections. Additional factors for consequence that could be expanded for this watershed include ecosystem service, and ecological impacts. As the biggest of the watersheds (in terms of total area) the Cowichan watershed has some of the most densely populated areas, and more focused studies than any other watershed. Risk is concentrated along the Cowichan River corridor between Cowichan Lake and the ocean, with the exception of Surface Water Quality.</p>

CONSEQUENCE



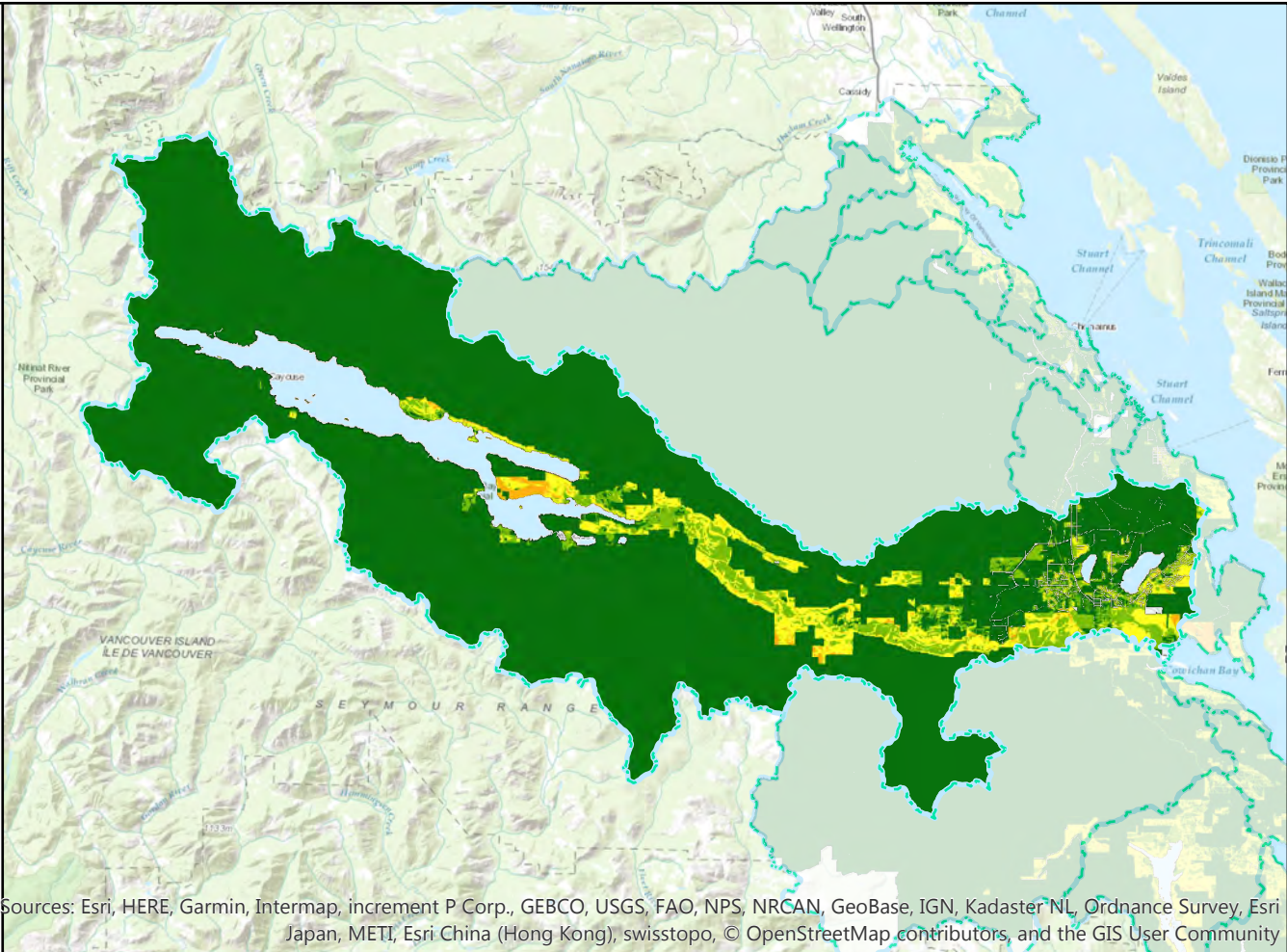
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

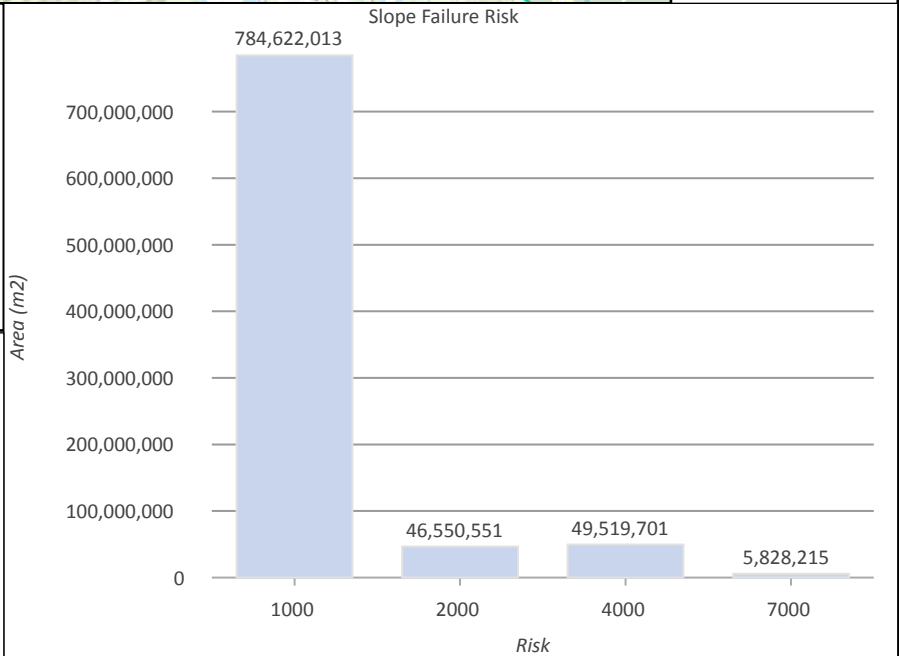
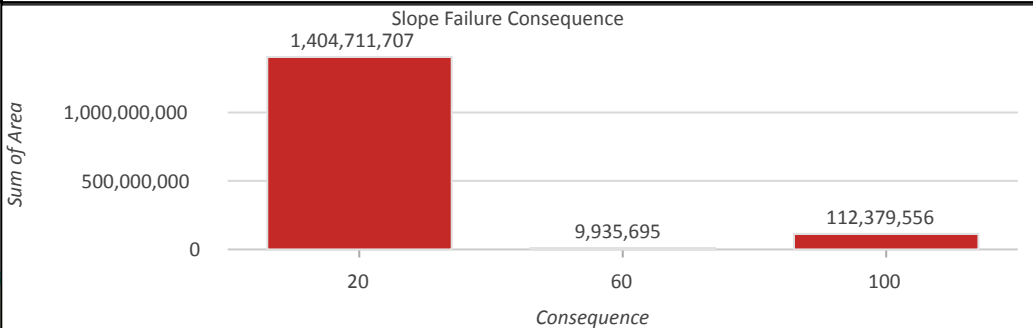
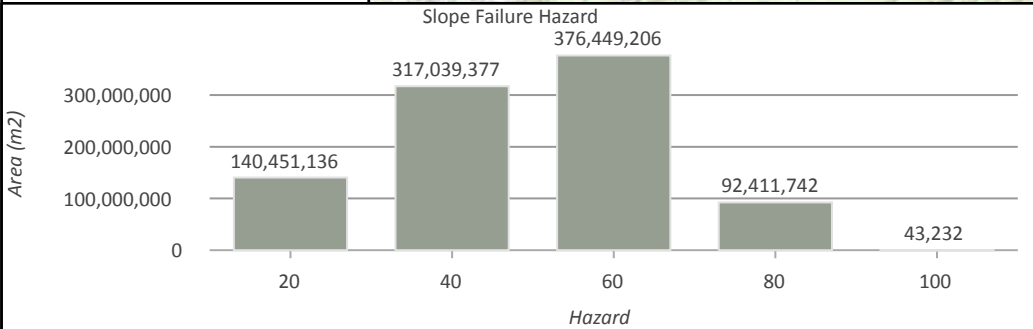


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

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	≤ 60
	≤ 80
	≤ 100

RISK

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

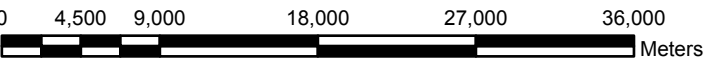
CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Cowichan River Watershed

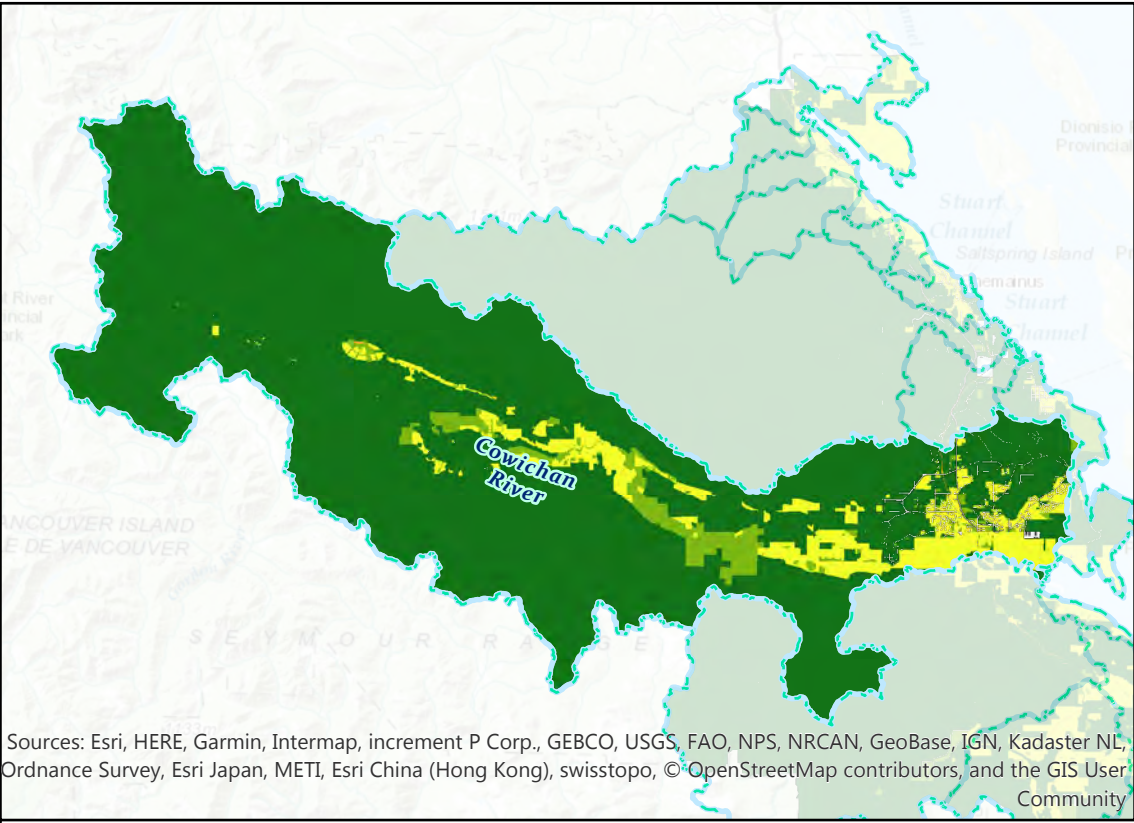


Slope Failure Risk Assessment - Cowichan River

BY: CJW	SCALE CONS: 1:430,632	DATE: 2019/01/07	REF No:	REV: 0
CHK'D: DK	Proj Coord Sys: PCS Albers	651957-101-COWI		

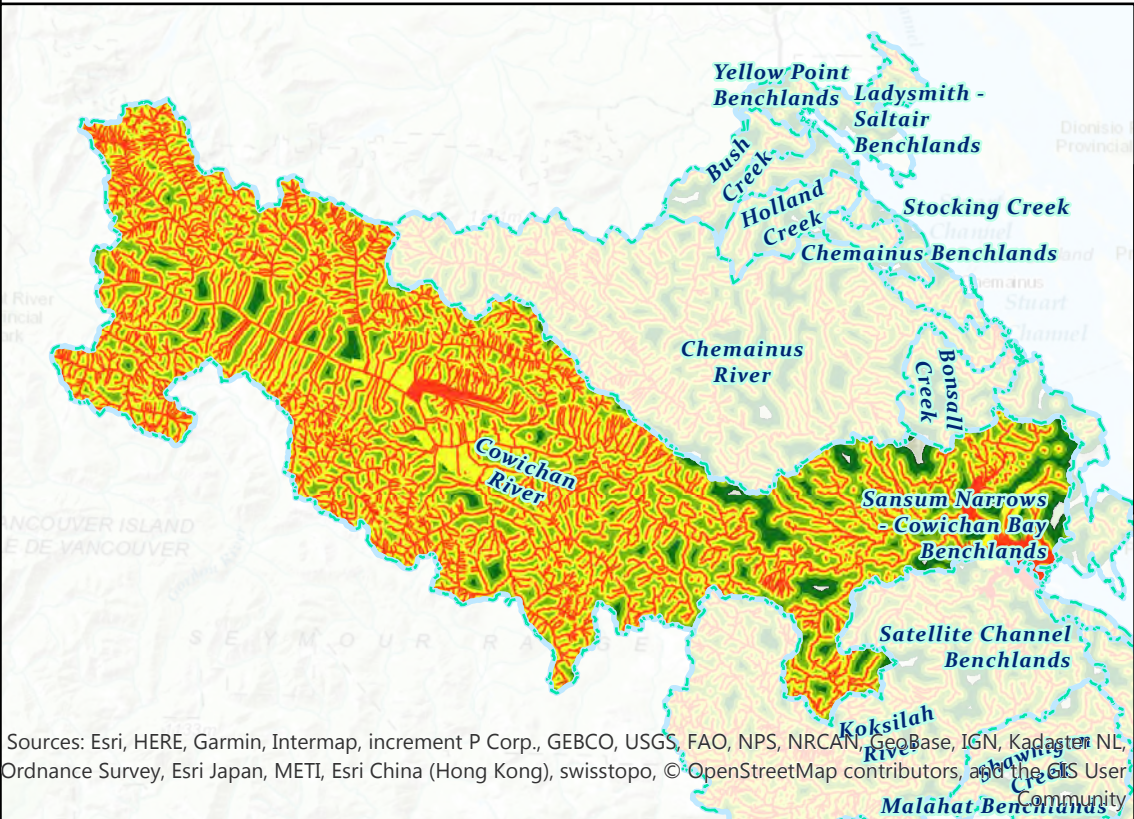


CONSEQUENCE



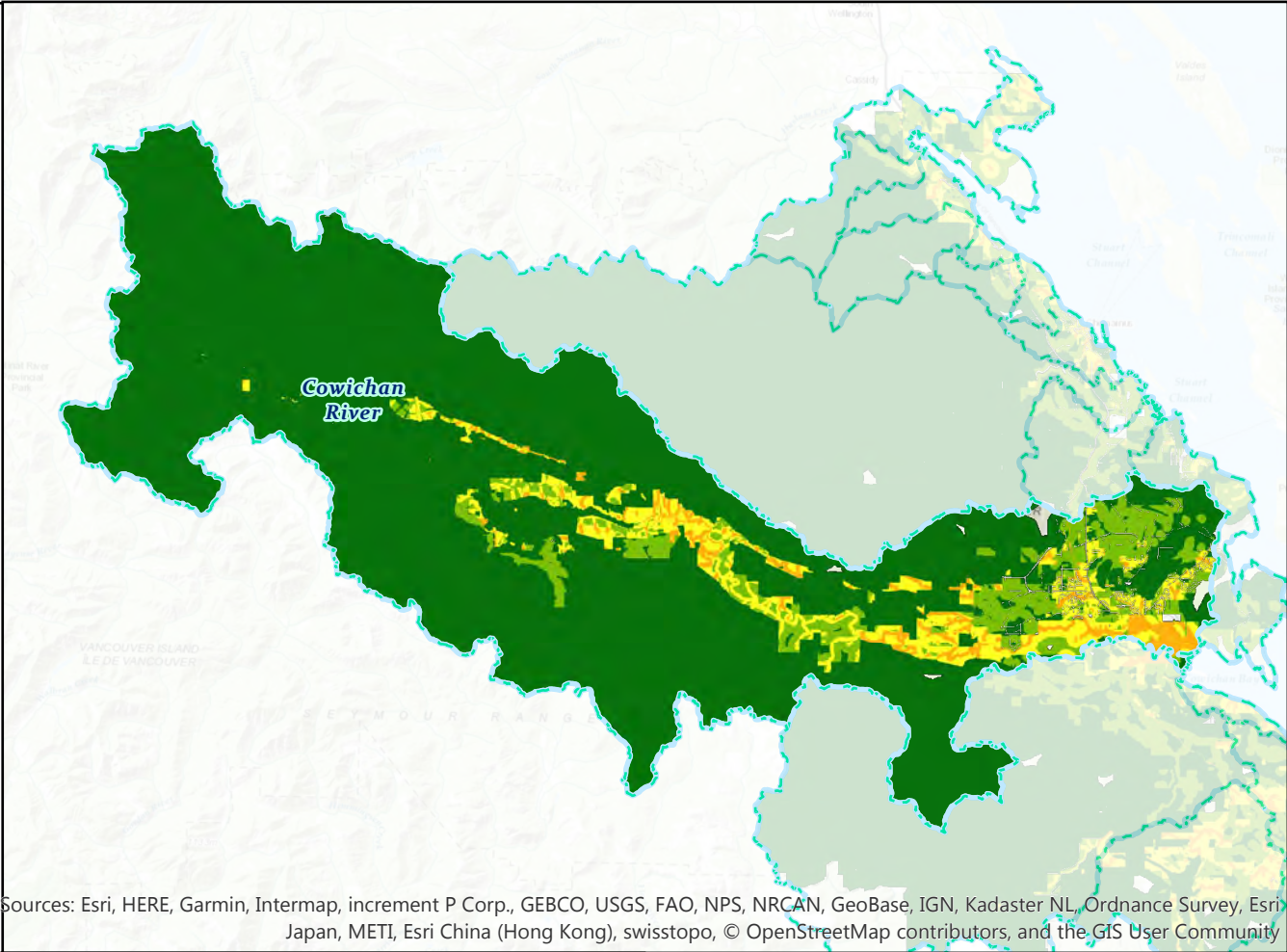
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

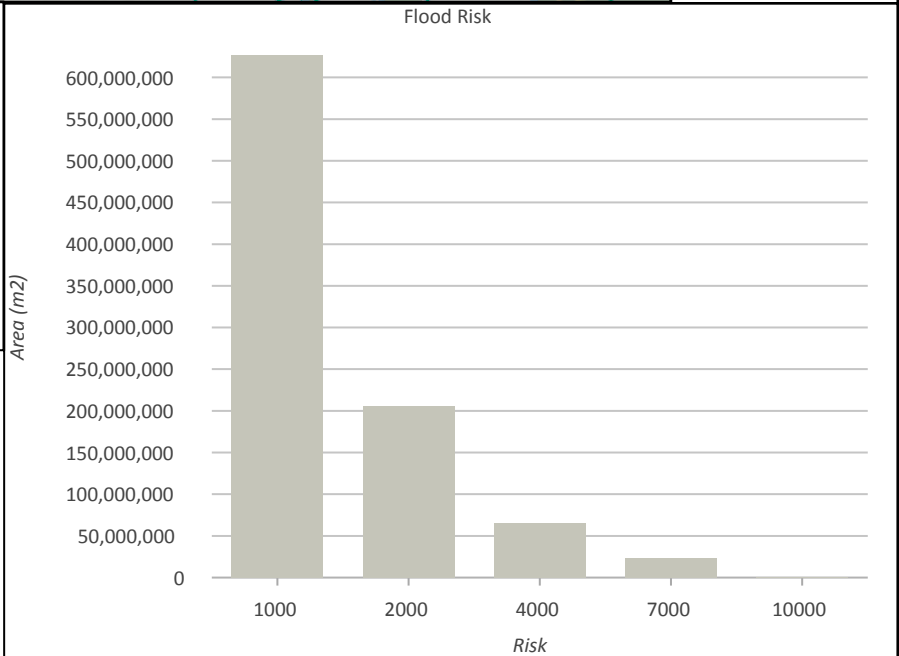
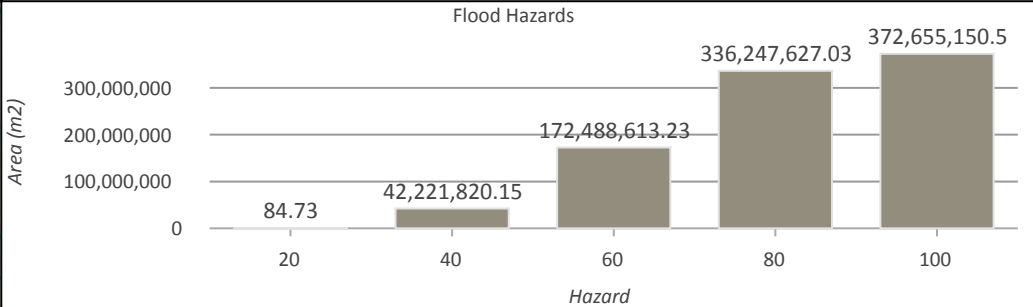
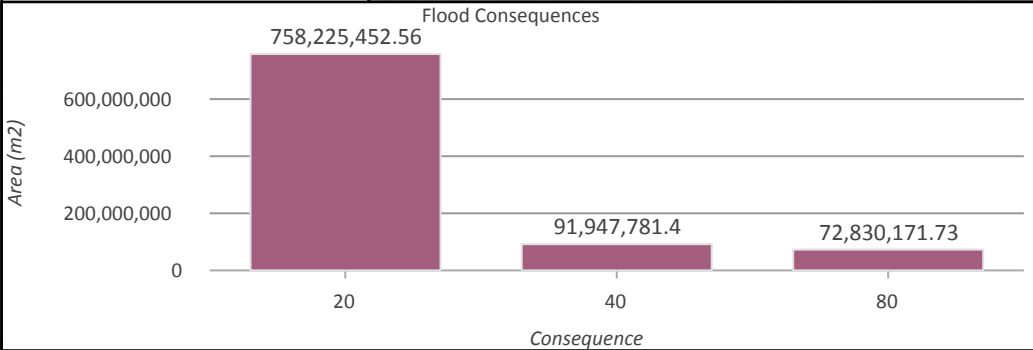


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

RISK

≤ 20	≤ 1000
≤ 40	≤ 2000
≤ 60	≤ 4000
≤ 80	≤ 7000
≤ 100	≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

NOTES:

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3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.

REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

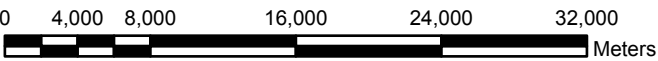
CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Cowichan River Watershed

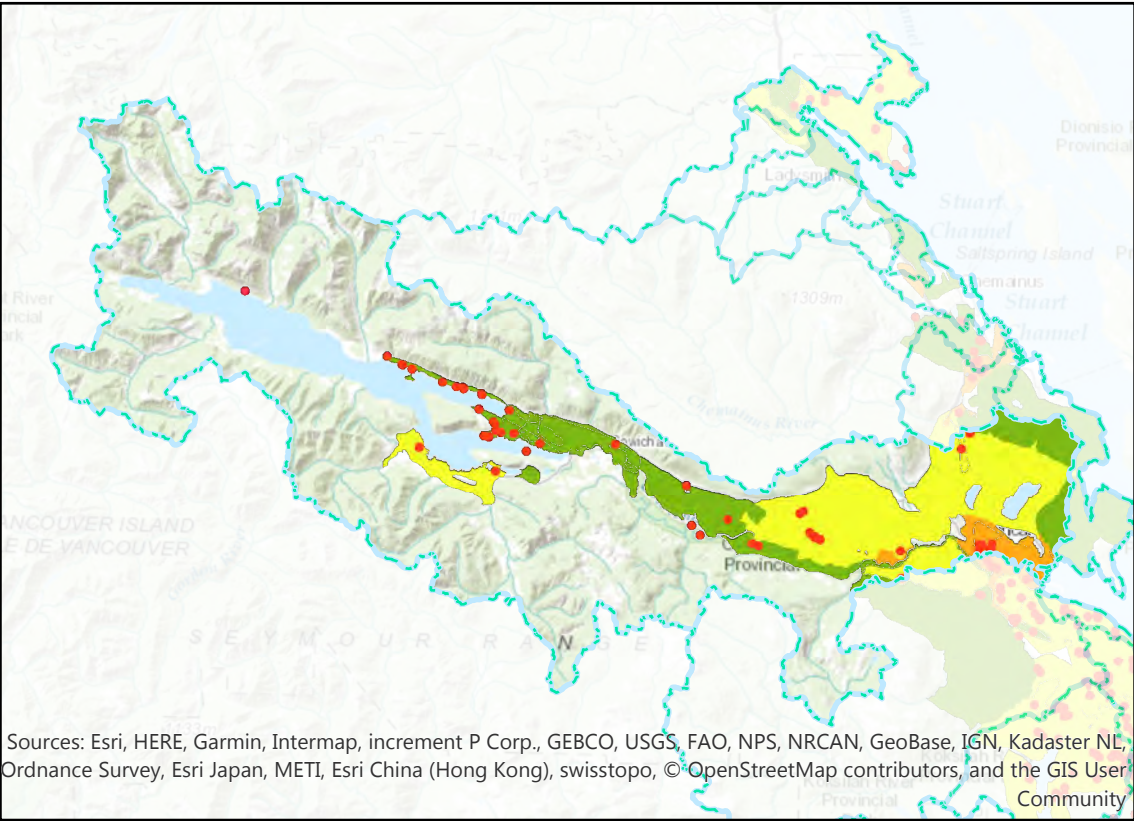


Flood Risk Assessment - Cowichan River

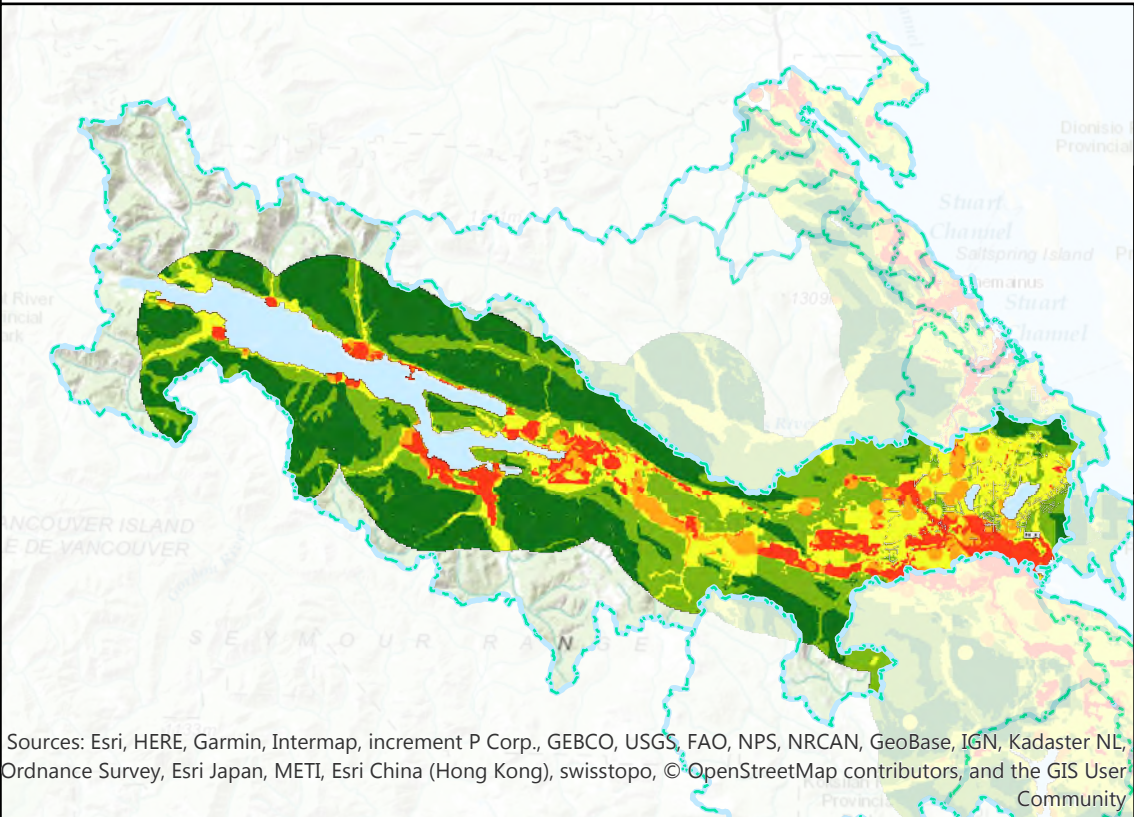
BY: CJW	SCALE CONS: 1:415,698	DATE: 2019/01/08	REF No:	REV: 0
CHK'D: DK	Proj Coord Sys: NAD 1983 UTM Zone 10N	651957-102-COWI		



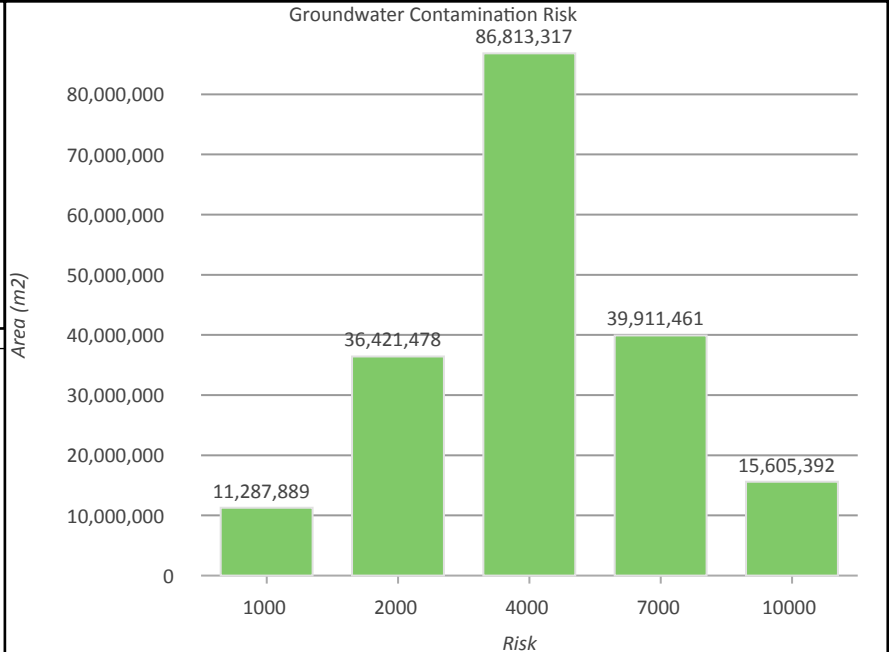
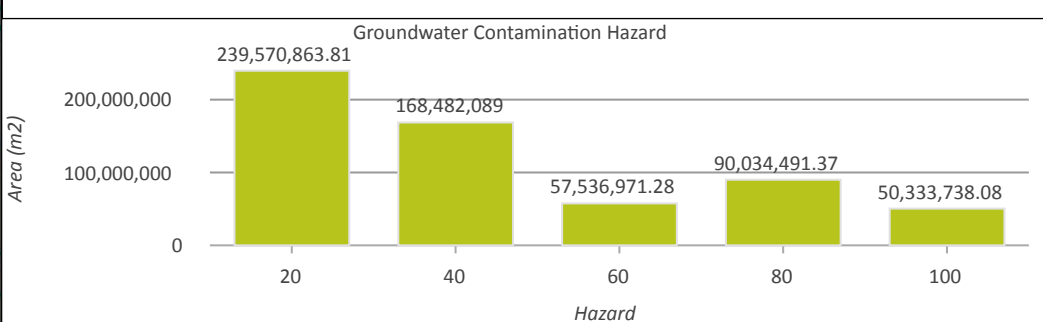
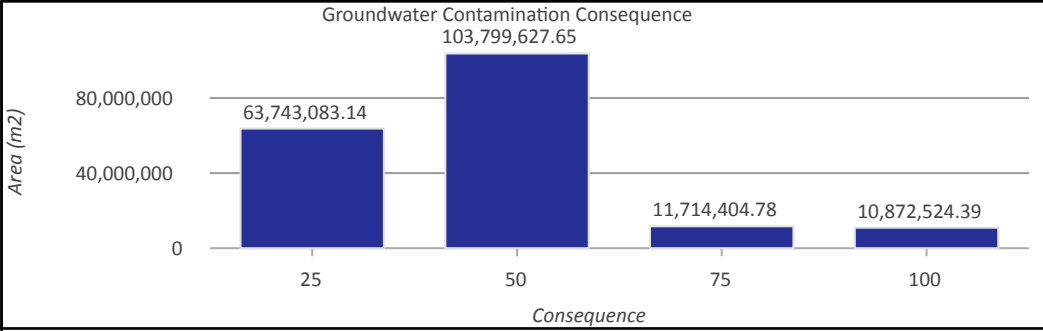
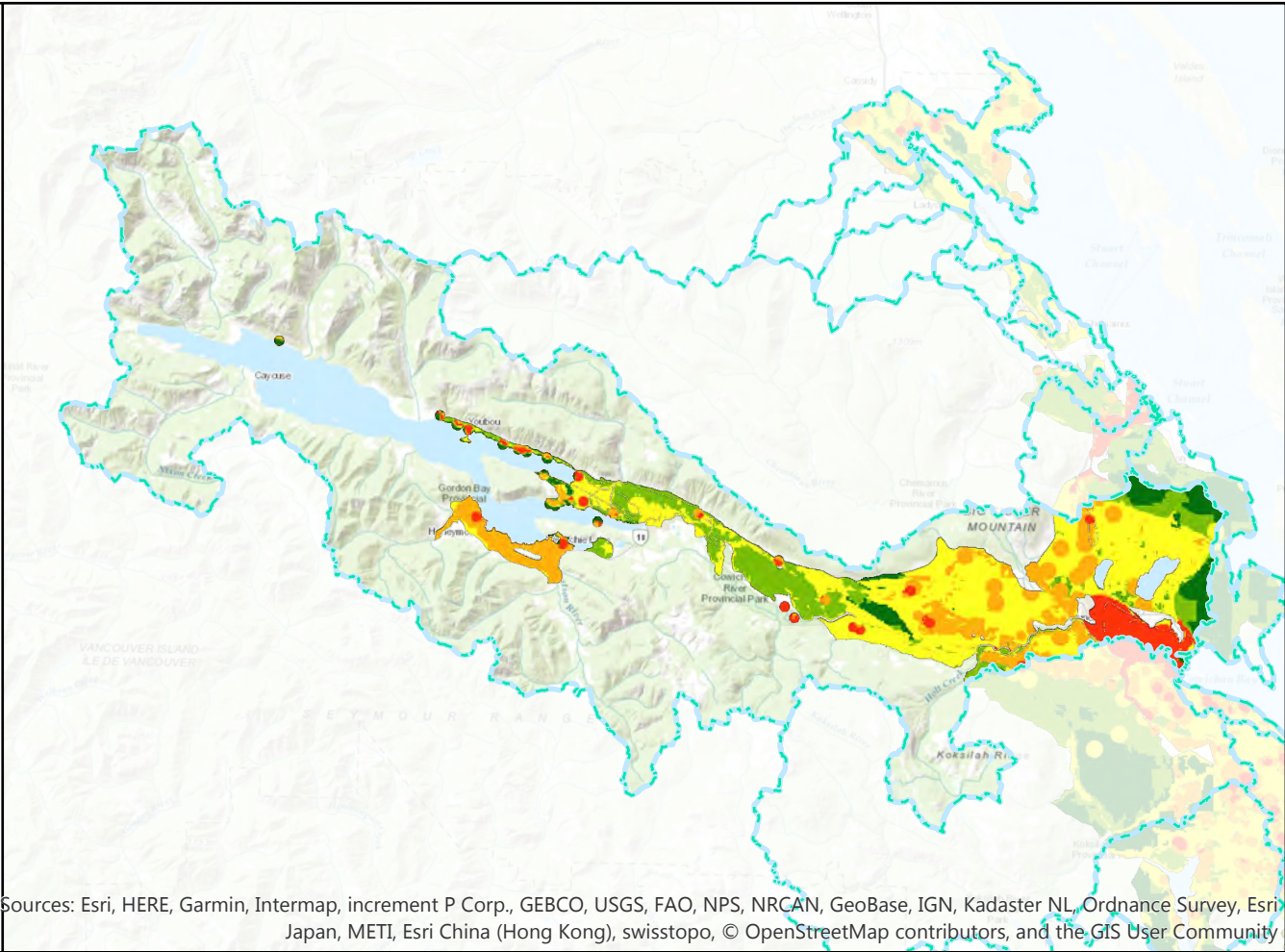
CONSEQUENCE



HAZARD



RISK



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Cowichan River Watershed



Groundwater Contamination Risk Assessment - Cowichan River

BY: CJW

SCALE CONS: 1:415,698

DATE: 2019/01/08

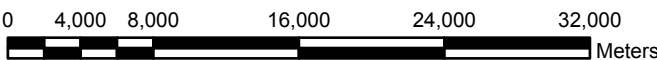
REF No:

REV: 0

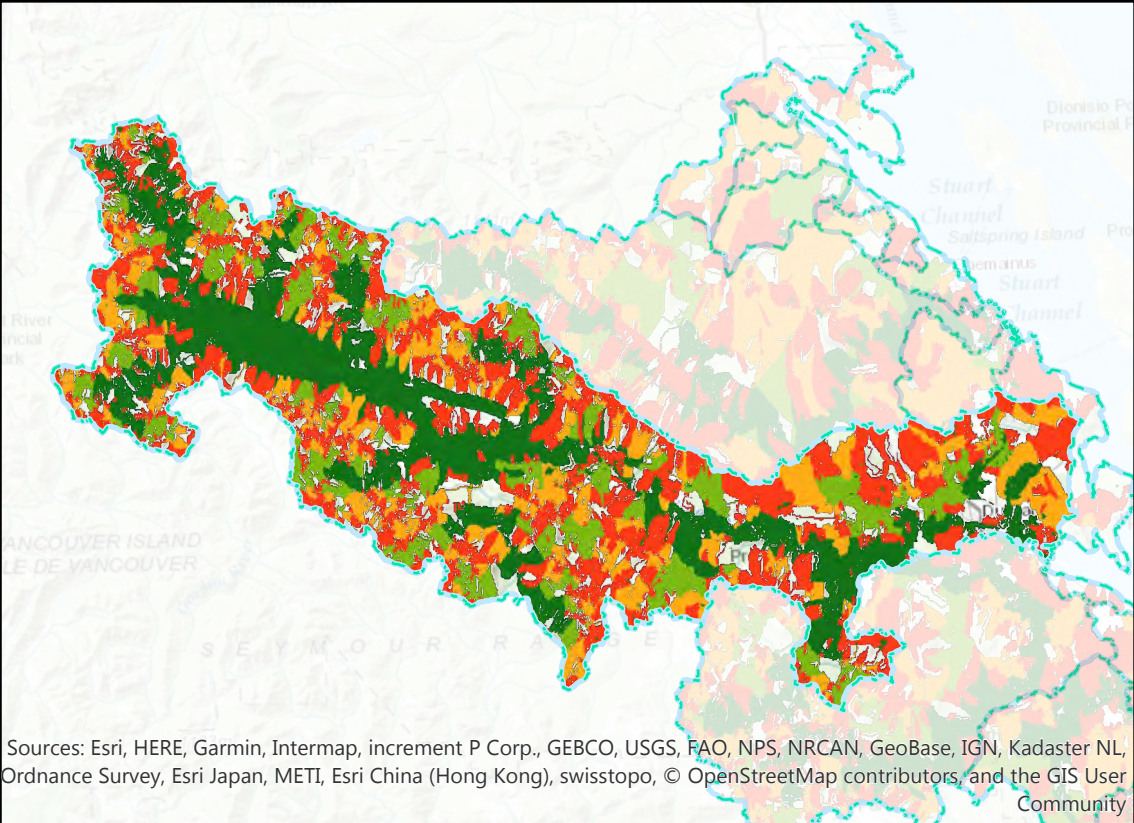
CHK'D: DK

Proj Coord Sys: NAD 1983 UTM Zone 10N

651957-103-COWI

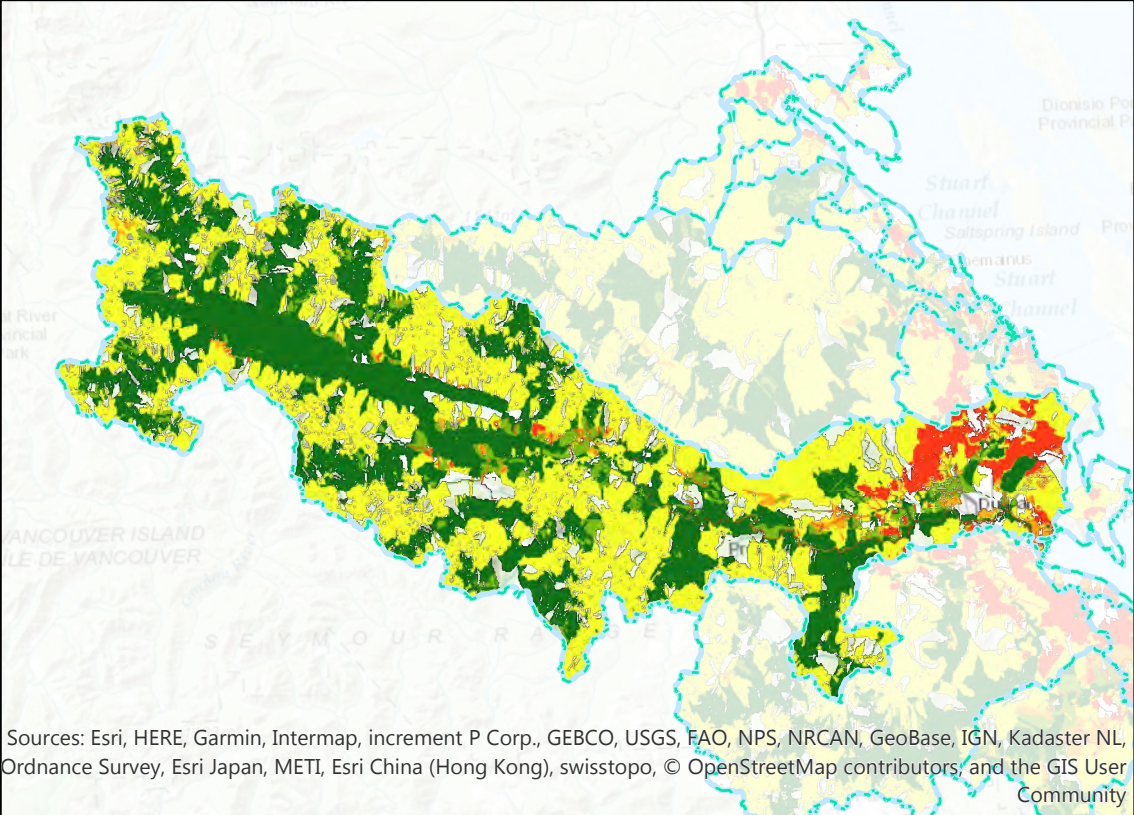


CONSEQUENCE



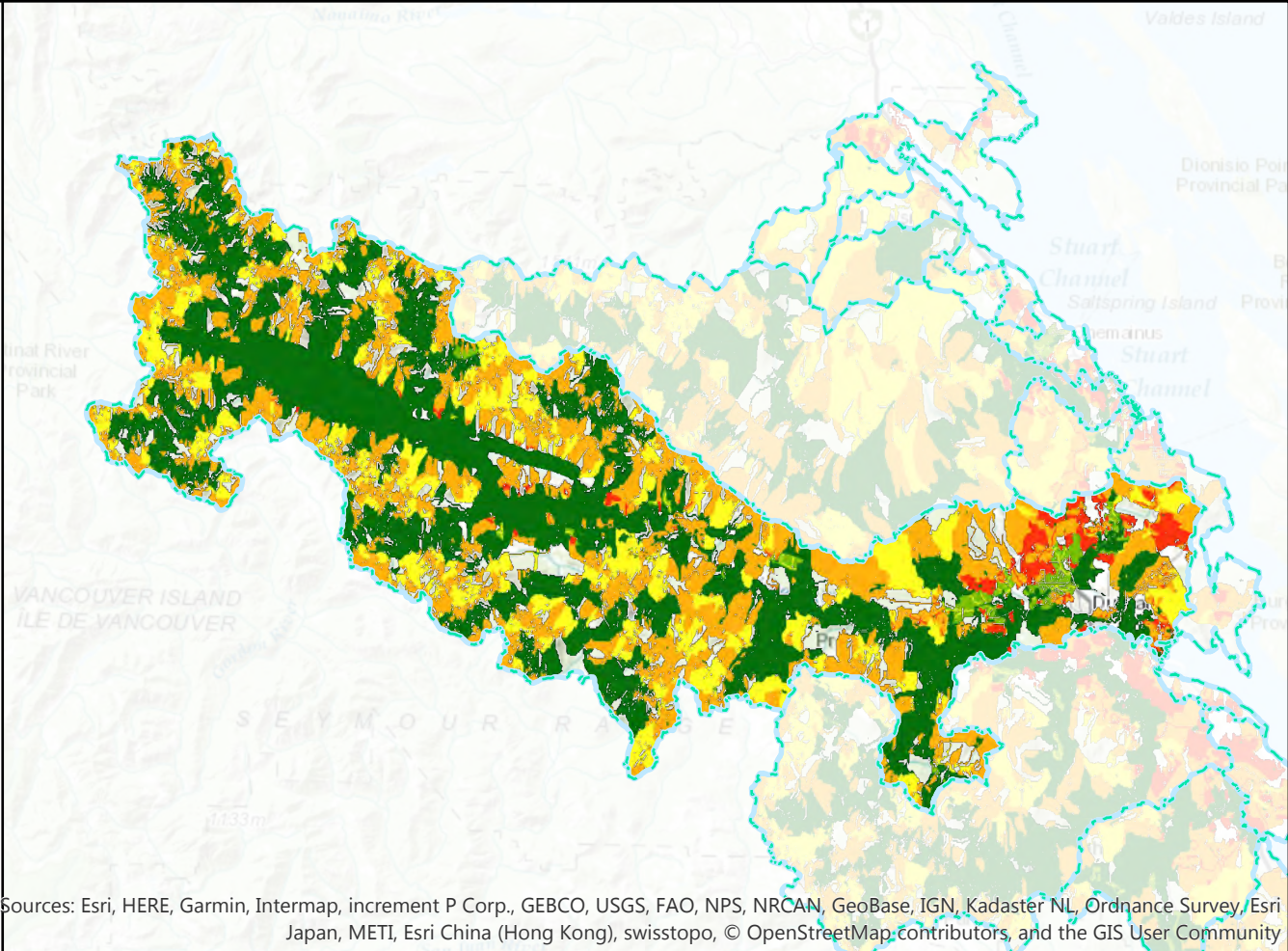
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

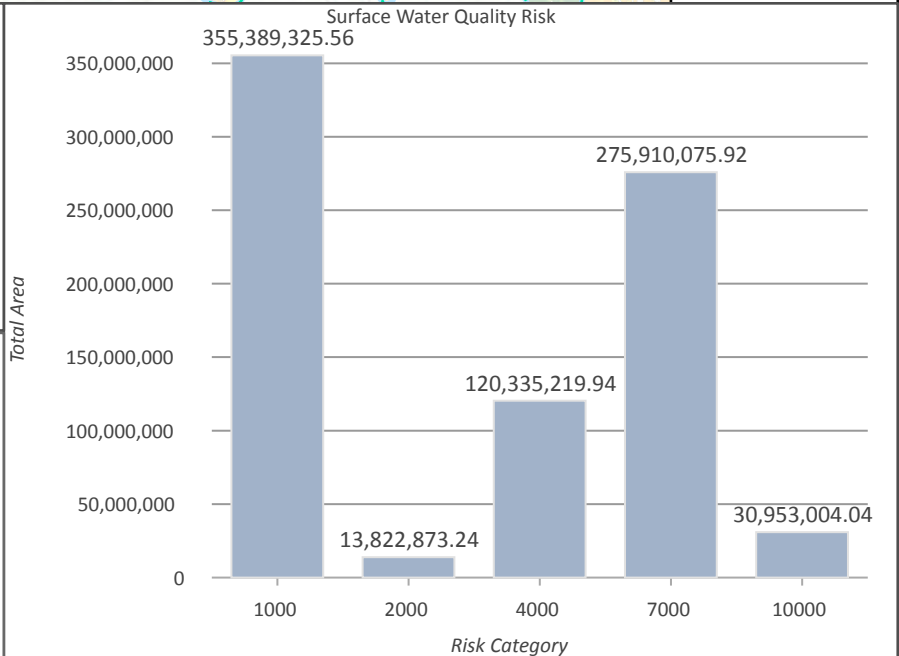
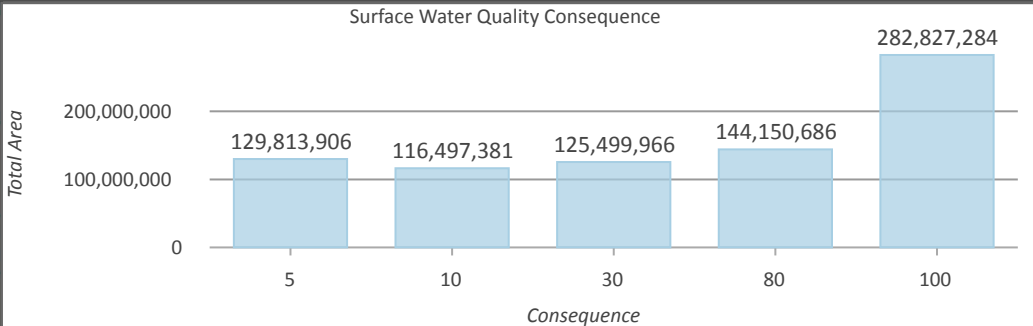
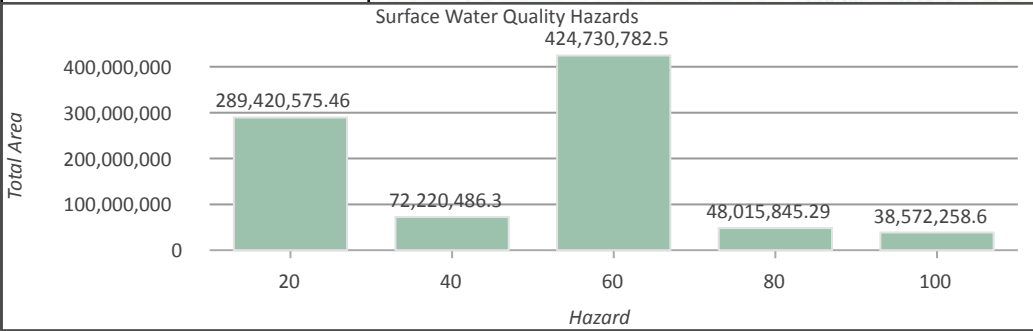


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

RISK

≤ 20	≤ 1000
≤ 40	≤ 2000
≤ 60	≤ 4000
≤ 80	≤ 7000
≤ 100	≤ 10000

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REVISIONS:

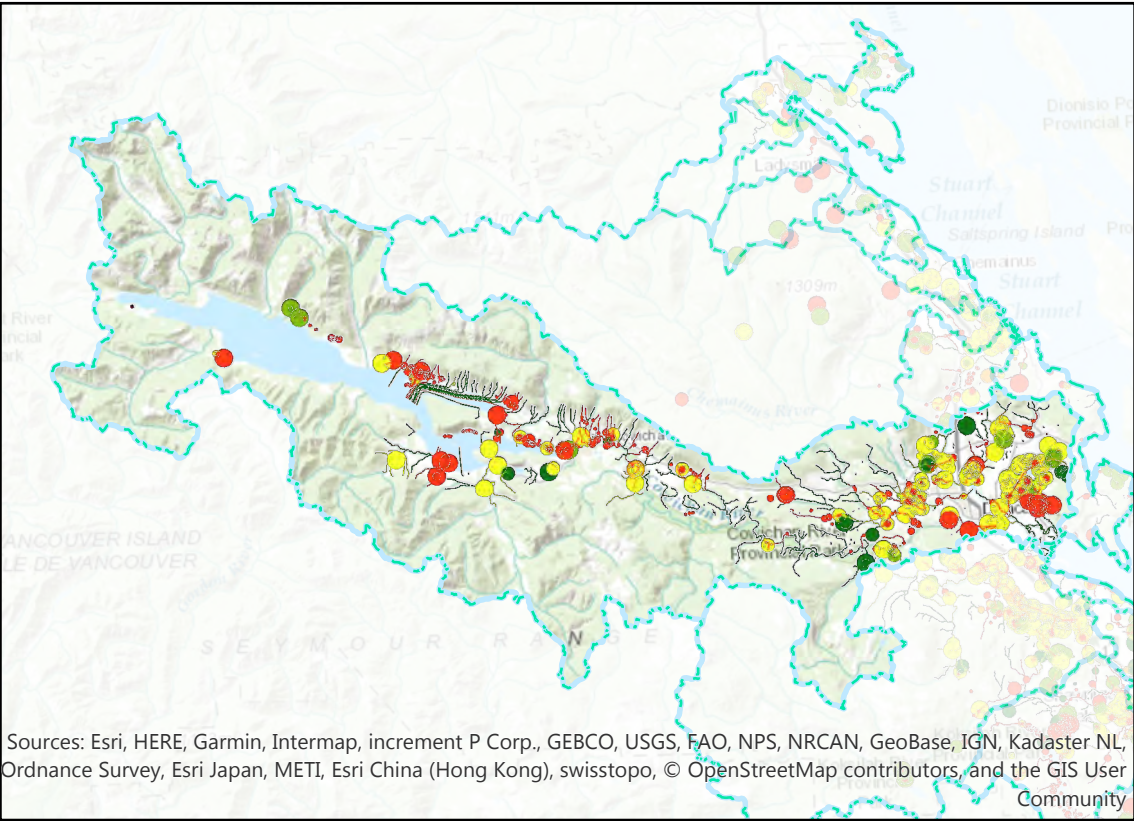
0 - CJW - 2018-11-29 - Issued - DK

CLIENT: Cowichan Valley Regional District			
PROJECT LOCATION: Cowichan Valley Regional District Cowichan River Watershed			
Surface Water Quality Risk Assessment - Cowichan River			
BY:	SCALE: 1:434,522	DATE: 2019/01/08	REF No:
CHK'D:	Proj Coord Sys: PCS Albers		REV: 0
			651957-104-COWI



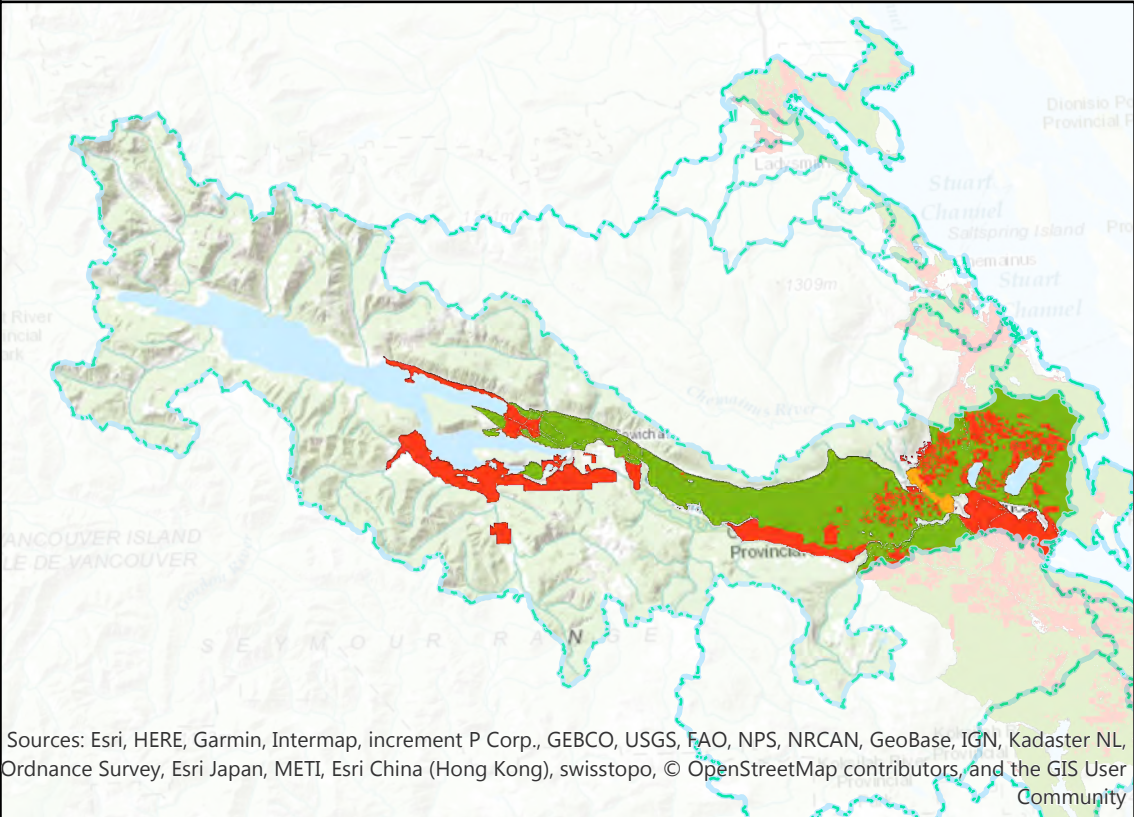
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CONSEQUENCE



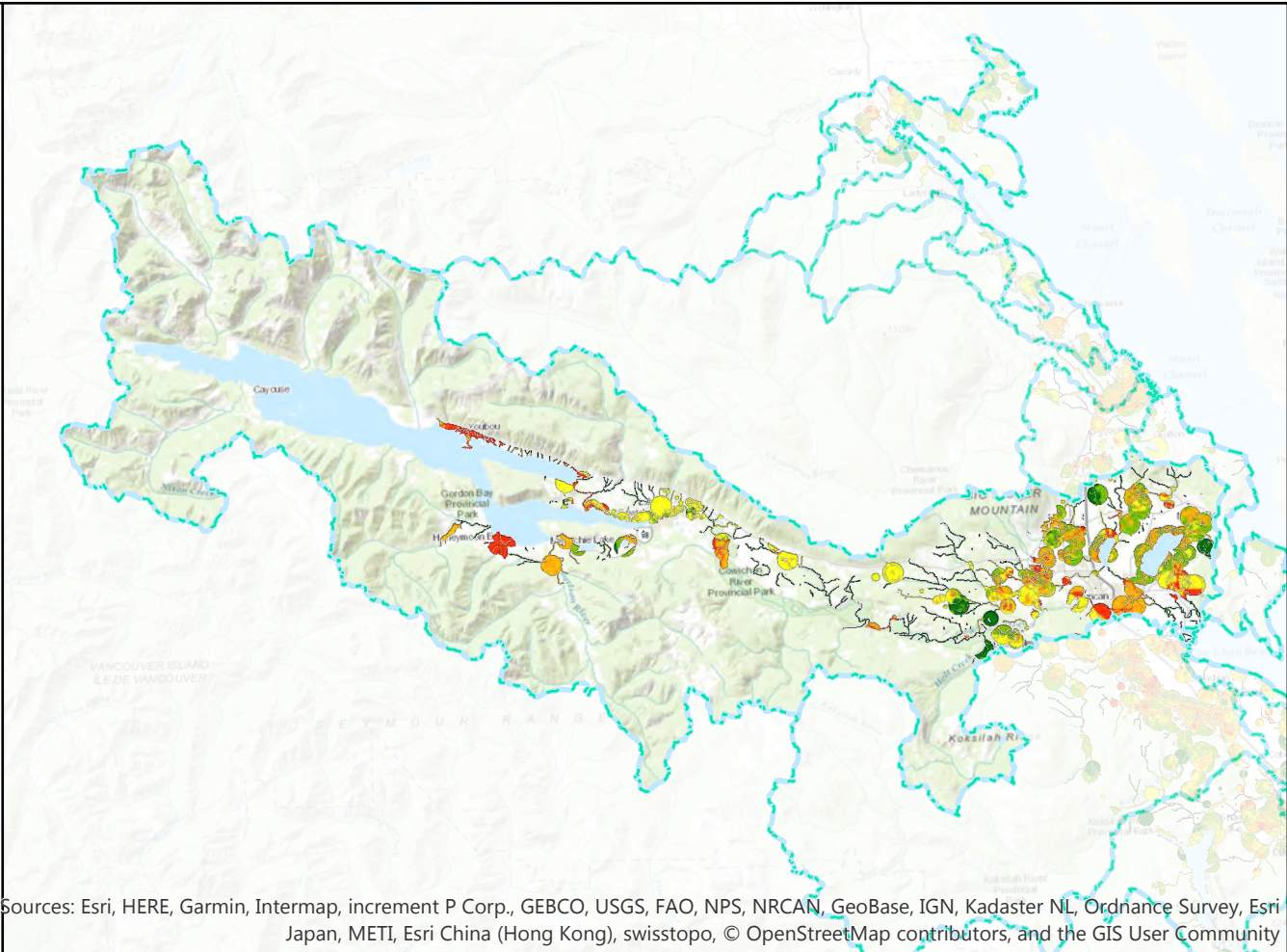
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

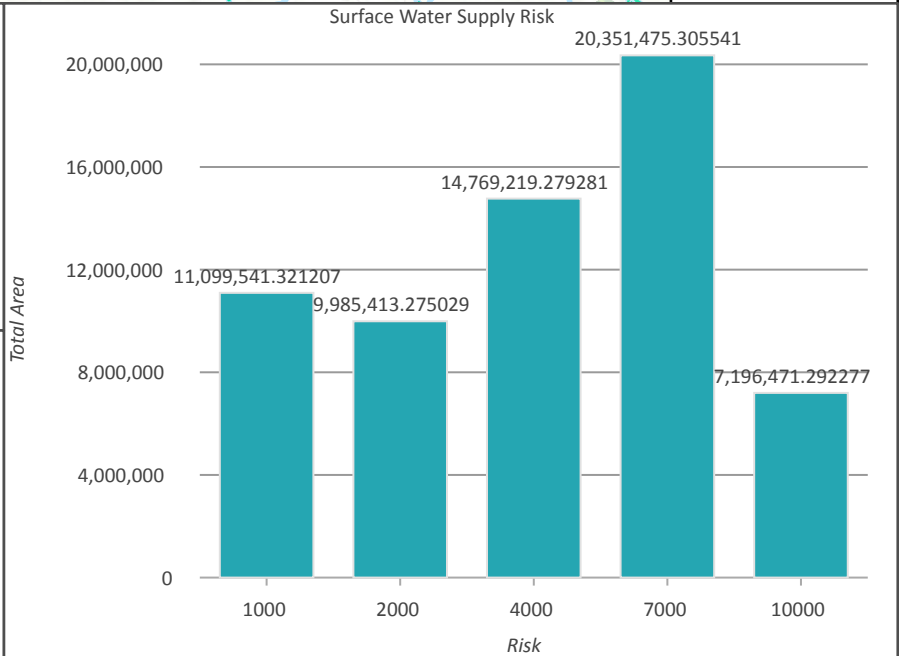
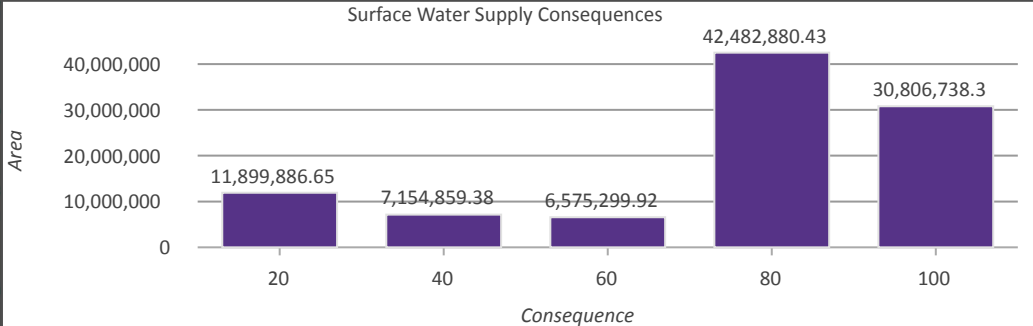
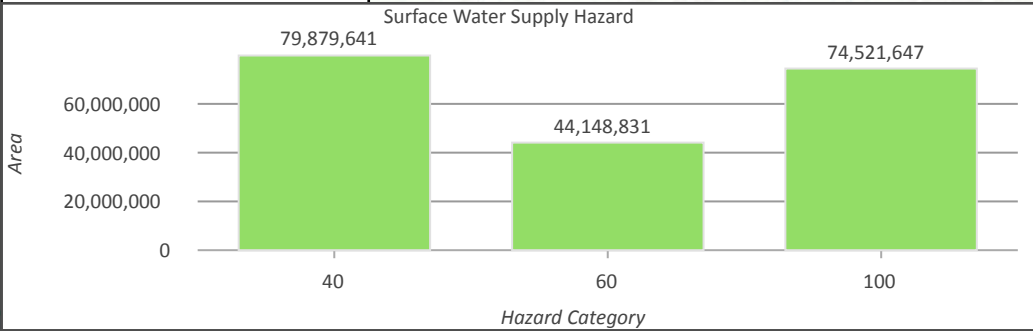


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

	≤ 20
	≤ 40
	≤ 60
	≤ 80
	≤ 100

RISK

	≤ 1000
	≤ 2000
	≤ 4000
	≤ 7000
	≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

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REVISIONS:

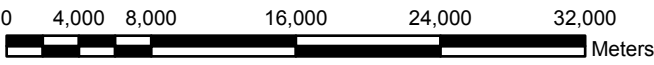
0 - CJW - 2018-11-29 - Issued - DK

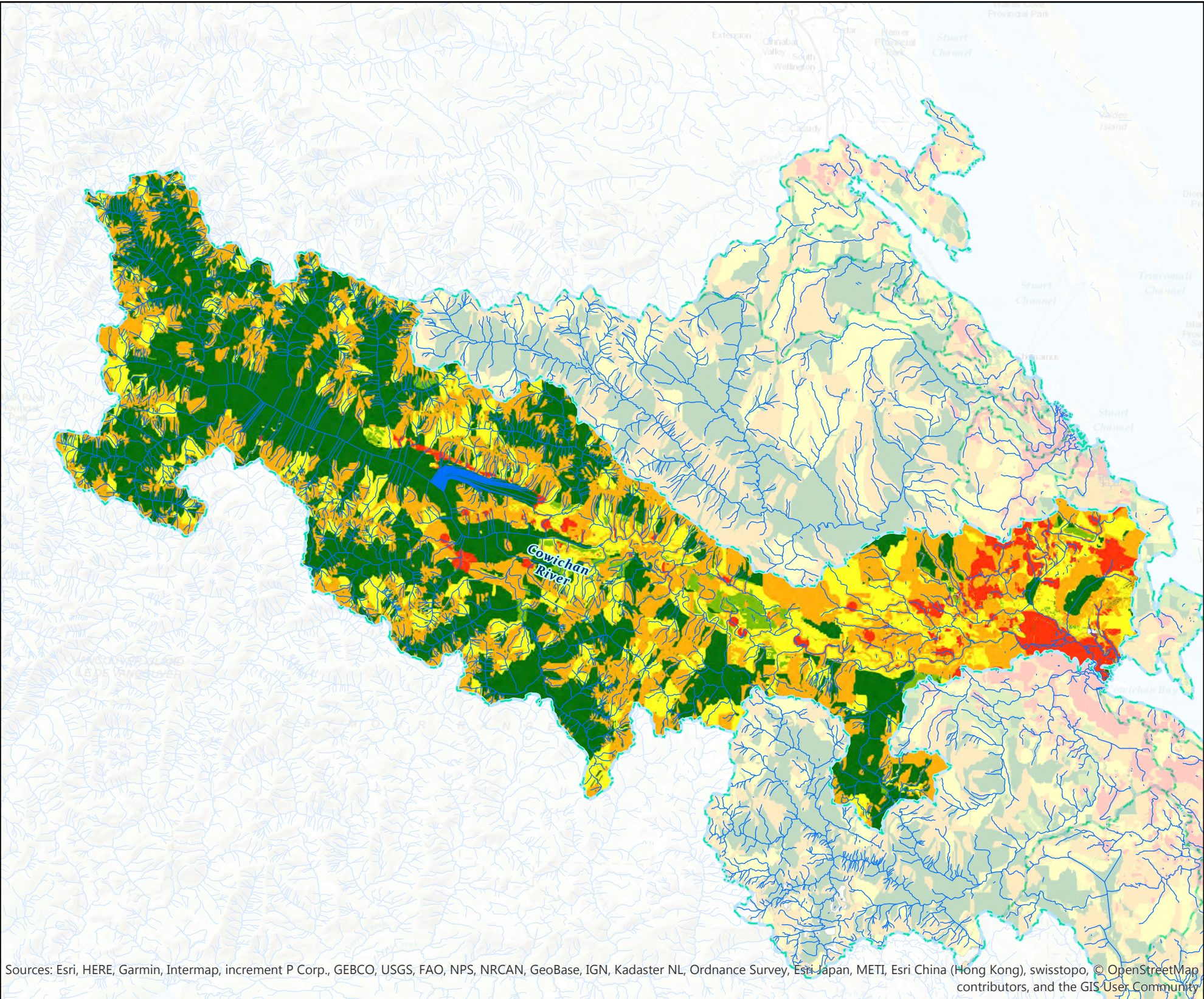
CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Cowichan River Watershed

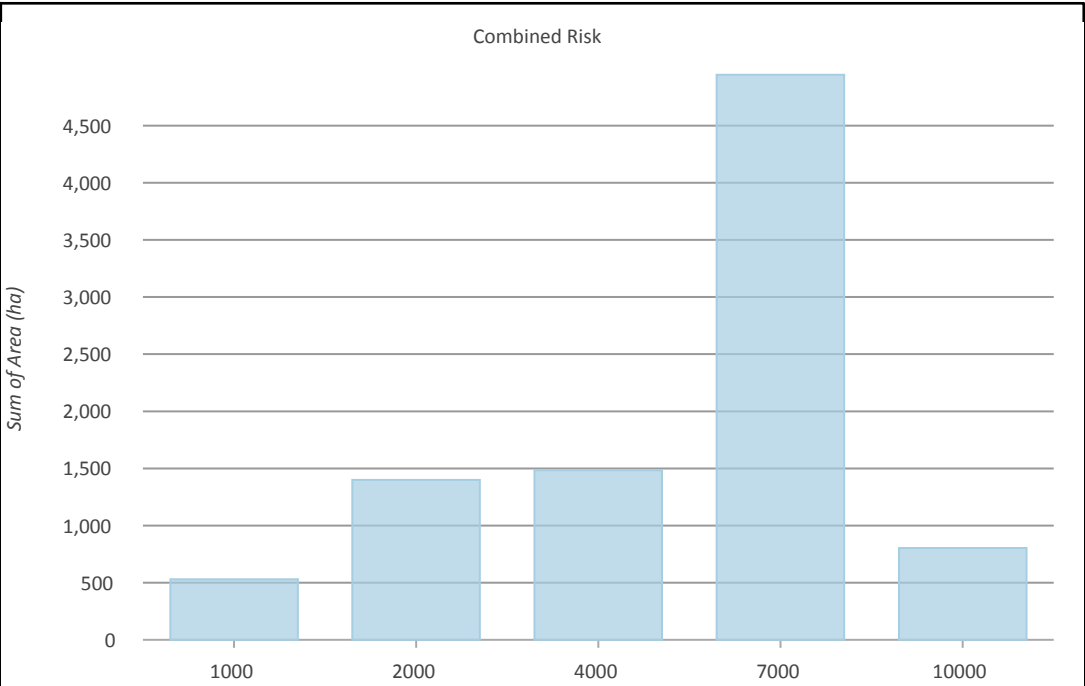
Surface Water Supply Risk Assessment - Cowichan River

BY:	SCALE: 1:418,248	DATE: 2019/01/08	REF No:	REV: 0
CHK'D:	Proj Coord Sys: PCS Albers		651957-105-COWI	





Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



NAME	Risk	POP ₂₀₂₁	POP ₂₀₂₆	POP ₂₀₃₁	POP ₂₀₃₆
SHAWNIGAN CREEK		10047	10760	11613	12598
BUSH CREEK		0	0	0	0
KOKSILAH RIVER		5463	5851	6315	6850
HOLLAND CREEK		1302	1368	1446	1537
BONSALL CREEK		934	974	1019	1073
CHEMAINUS RIVER		1490	1461	1439	1421
COWICHAN RIVER		36368	37905	39683	41766
YELLOW POINT BENCHLANDS		2239	2352	2487	2643
LADYSMITH - SALTAIR BENCHLANDS		8410	8834	9342	9929
STOCKING CREEK		1531	1608	1701	1807
CHEMAINUS BENCHLANDS		3663	3818	3997	4207
SATELLITE CHANNEL BENCHLANDS		4390	4701	5074	5504
SANSUM NARROWS - COWICHAN BAY BENCHLANDS		4941	5150	5391	5674
MALAHAT BENCHLANDS		2829	3030	3271	3548

NAME	POP ₂₀₀₁	POP ₂₀₀₆	POP ₂₀₁₁	POP ₂₀₁₆
SHAWNIGAN CREEK	6348	8439	8925	9484
BUSH CREEK	0			
KOKSILAH RIVER	4555	4808	4954	5157
HOLLAND CREEK	1611	1114	1169	1245
BONSALL CREEK	672	830	815	890
CHEMAINUS RIVER	1423	1395	1497	1514
COWICHAN RIVER	29779	32673	34075	34647
YELLOW POINT BENCHLANDS	1167	1958	2021	2141
LADYSMITH - SALTAIR BENCHLANDS	5275	7488	7541	8042
STOCKING CREEK	1332	1003	1354	1464
CHEMAINUS BENCHLANDS	3177	3129	3085	3490
SATELLITE CHANNEL BENCHLANDS	5425	3902	3989	4144
SANSUM NARROWS - COWICHAN BAY BENCHLANDS	5993	4221	4500	4707
MALAHAT BENCHLANDS	1673	2472	2548	2671

Legend

WATERSHED BOUNDARIES

RISK

- ≤ 1000
- ≤ 2000
- ≤ 4000
- ≤ 7000
- ≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

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REVISIONS:

0 - CJW - 2018-11-30 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Cowichan River Watershed

Combined Risk Assessment - Cowichan River

BY: CJW

CHK'D: DK

SCALE CONS: 1:280,000

Proj Coord Sys: NAD 1983 UTM Zone 10N

DATE: 2019/01/08

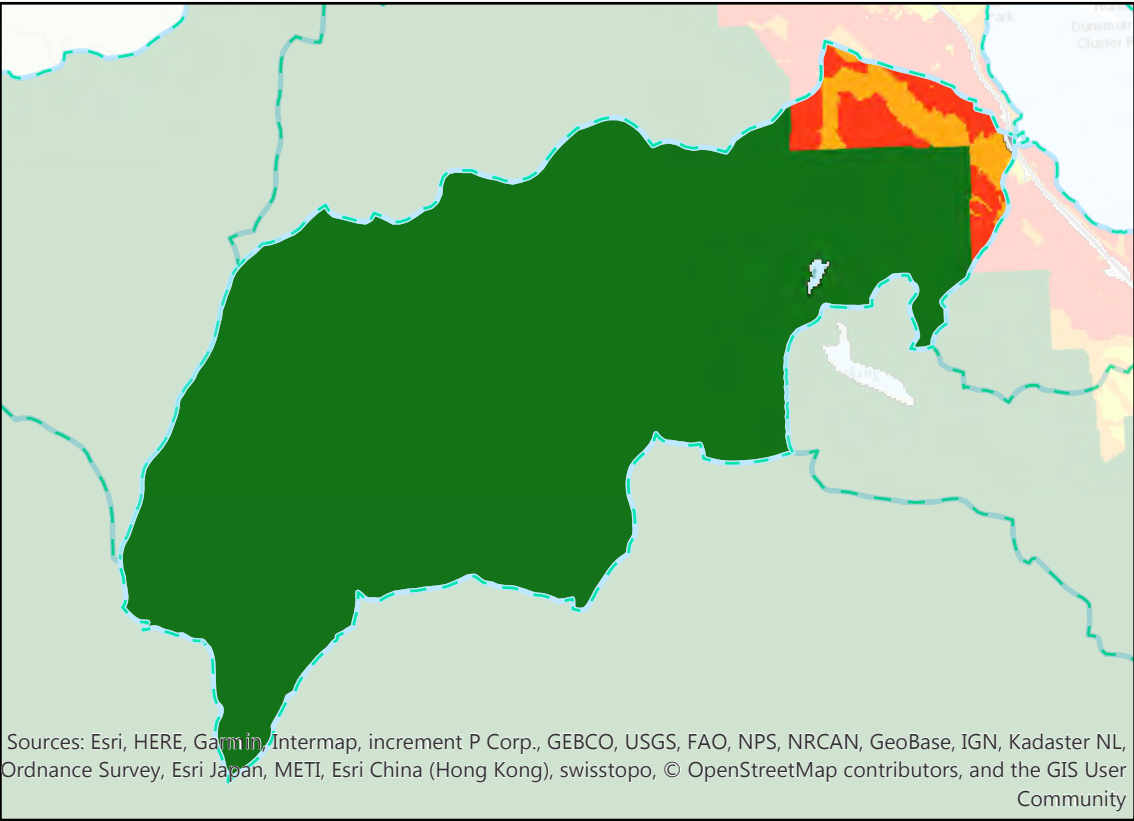
REF No: **651957-106-COWI**

REV: **0**

Project Path: P:\Current Projects\CVRD\651957\ P: 5-6

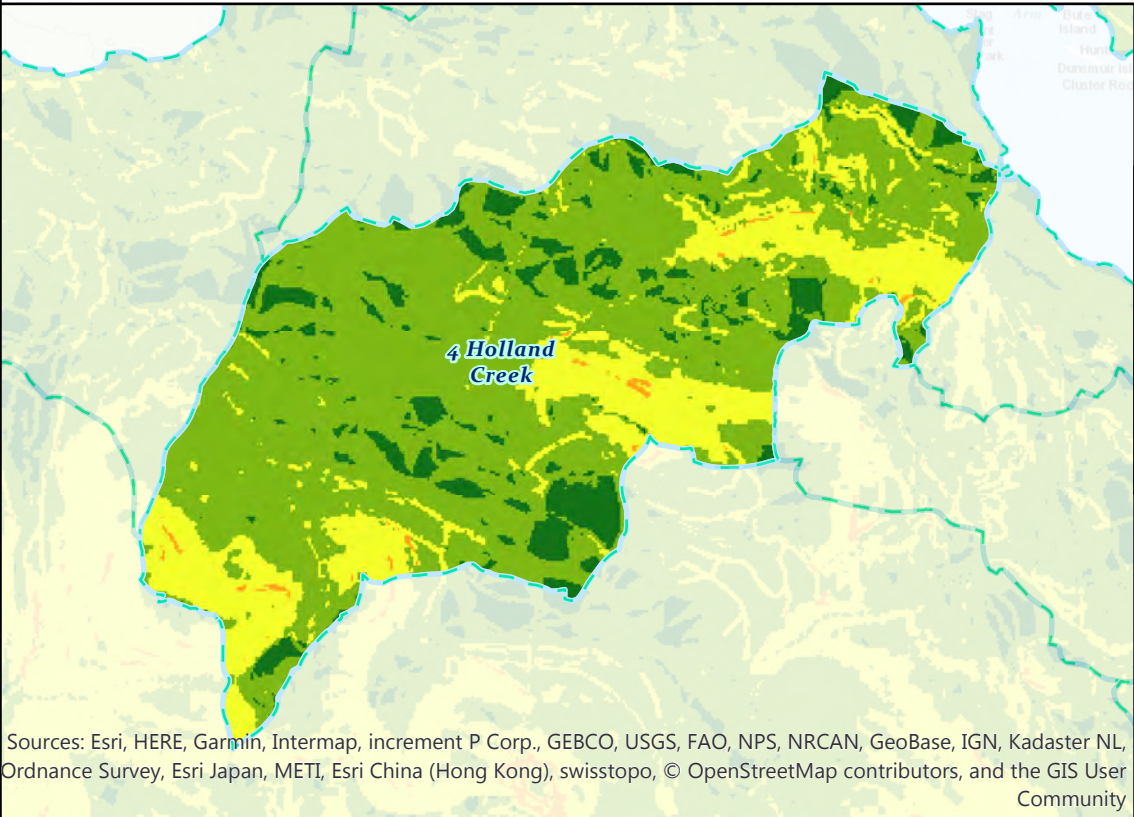
6. Holland Creek	
Topic	Discussion
Slope Failure	<p>Hazard was determined qualitatively at a high level to describe areas based on the degree to which they may be prone to landslides and other mass movements using terrain characteristics. Hazard classifications were generated to show relative comparisons between terrain units within the CVRD watershed study area. Risk ratings derived from this analysis are relative, and should be used to guide prioritization of further detailed studies.</p> <p>Hazard is generally low throughout the watershed due to low slope gradients. Some hazard exists where logging activities have occurred on slopes. Consequence is considered low for the majority of the watershed, with a small area of moderate to high consequence in the populated area near the outlet of Holland Creek. Risk is considered moderate in this populated area.</p>
Flooding	<p>There is considered to be some potential for flooding in the areas of Holland Creek and its tributaries. Consequence and risk are very low for the predominantly forested watershed with moderate risk areas near roadways and Highway 1 South of Ladysmith.</p>
Groundwater Contamination	<p>The high DRASTIC vulnerability value in the northeast area of the watershed and the presence of contaminated sites along Highway 1 are the main drivers for the risk rating in this watershed. The consequence of groundwater contamination in this watershed is low to moderate due to the absence of municipal groundwater supply system and a low to moderate aquifer demand.</p>
Surface Water Quality	<p>Hazard is low to moderate for the watershed due to the predominance of forested land cover with logging activities increasing hazard rating. Consequence is moderate since many of the tributaries of Bush Creek are lower order streams that have lower buffering capacity and therefore are more susceptible to water quality issues than larger streams. Risk is greatest for these lower order streams.</p>
Surface Water Supply	<p>Consequence is greatest in select locations around supply wells and a small area around Highway 1 on the southern outskirts of Ladysmith and negligible elsewhere in this predominantly forested catchment. Hazard is considered low for the majority of the watershed, with a small areas of low consequence near the outlet of Holland Creek. Risk is greatest in a small zone in the lower watershed, where points of diversion intersect the higher hazard area of the aquifer, occupying a very small proportion of the watershed's area.</p>
General Data Notes	<p>Risk is focused broadly across the catchment where low order streams and forestry affect surface water supply / stream health. There is moderate risk focused around the developed portions around highway One and the outlet of Holland Creek. The population in this watershed is projected to grow with population pressure from Ladysmith and the Saltair Benchlands.</p>

CONSEQUENCE



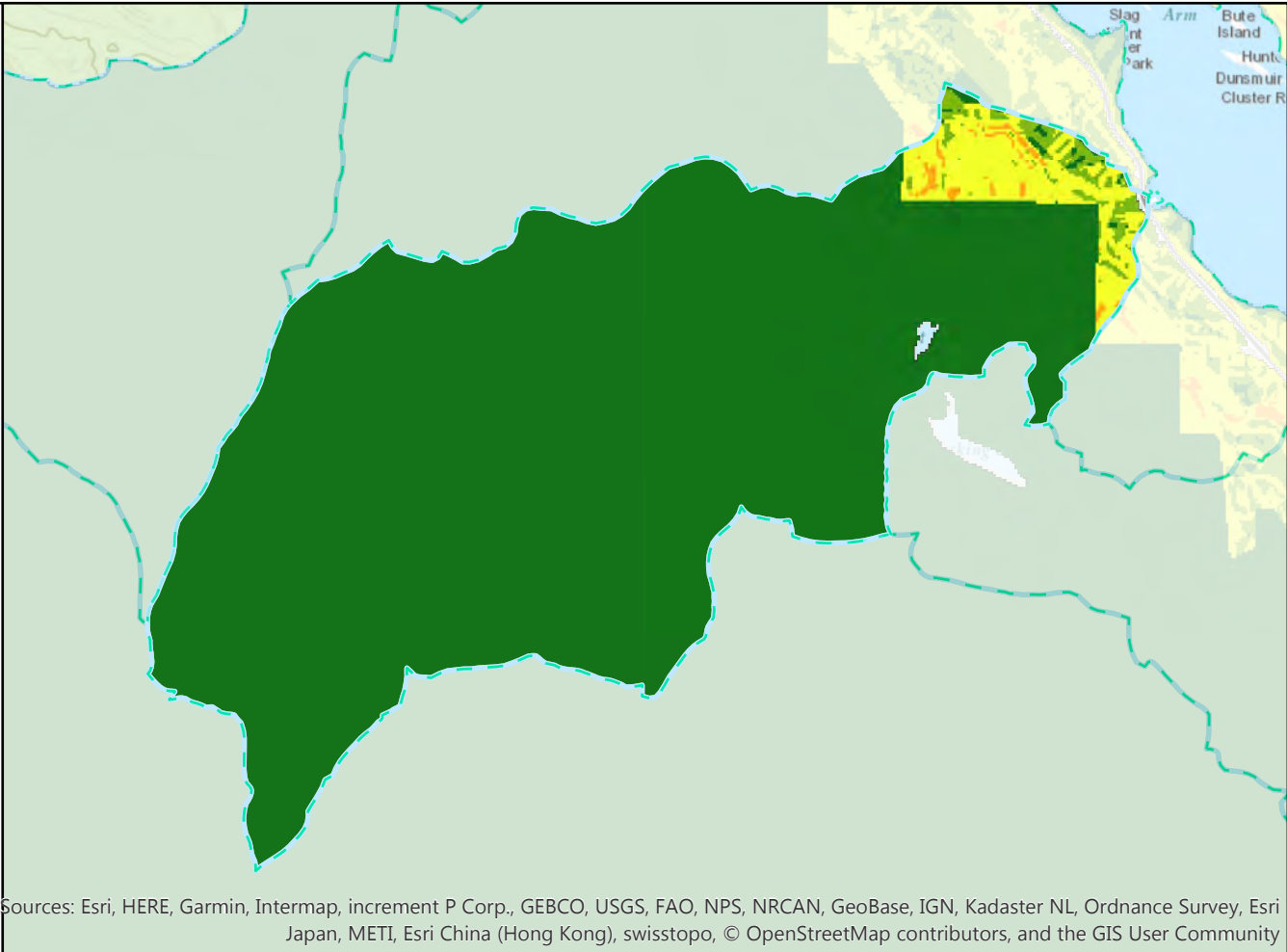
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

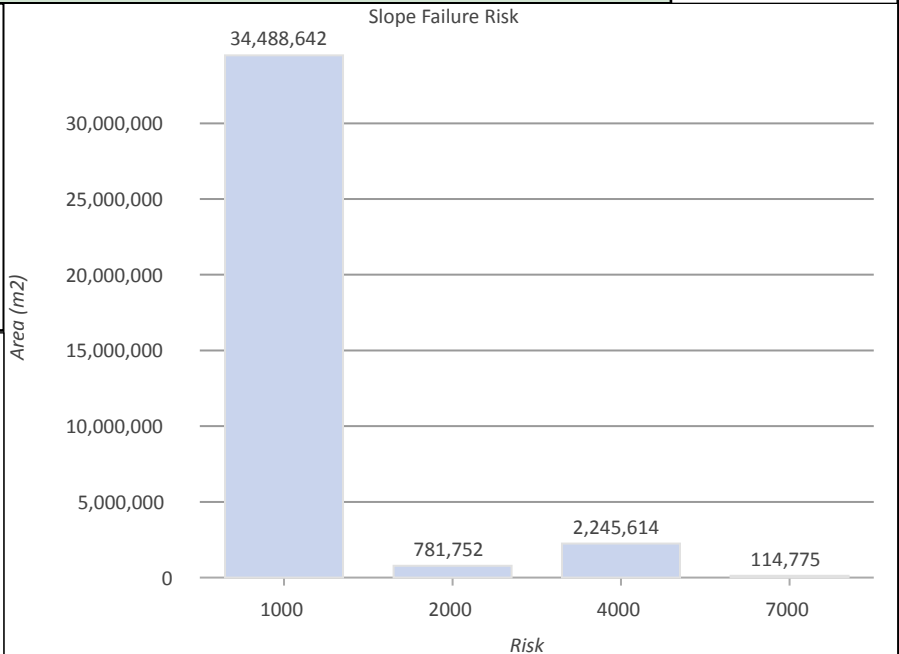
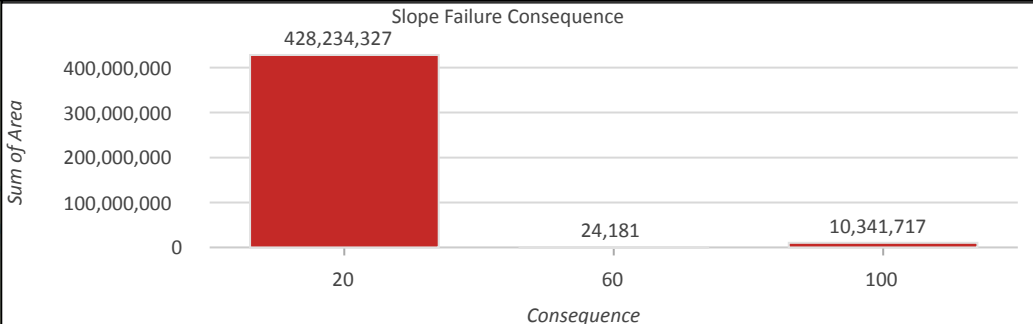
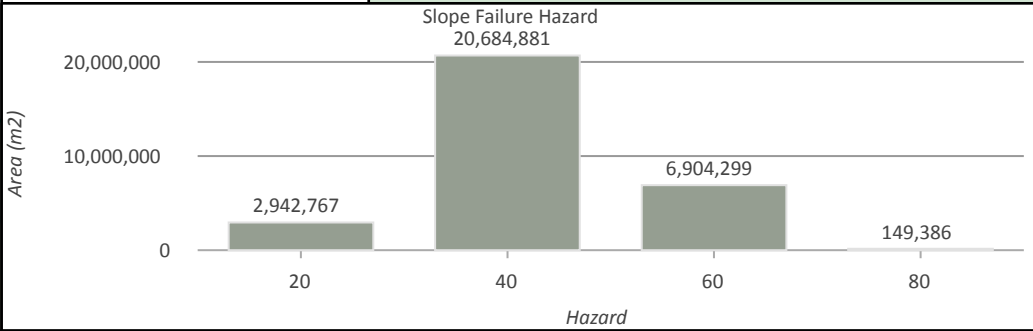


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Holland Creek Watershed



SNC • LAVALIN

Slope Failure Risk Assessment - Holland Creek

BY: CJW

SCALE CONS: 1:67,401

DATE: 2019/01/07

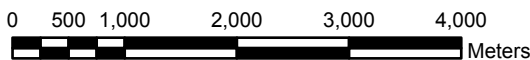
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REV: 0

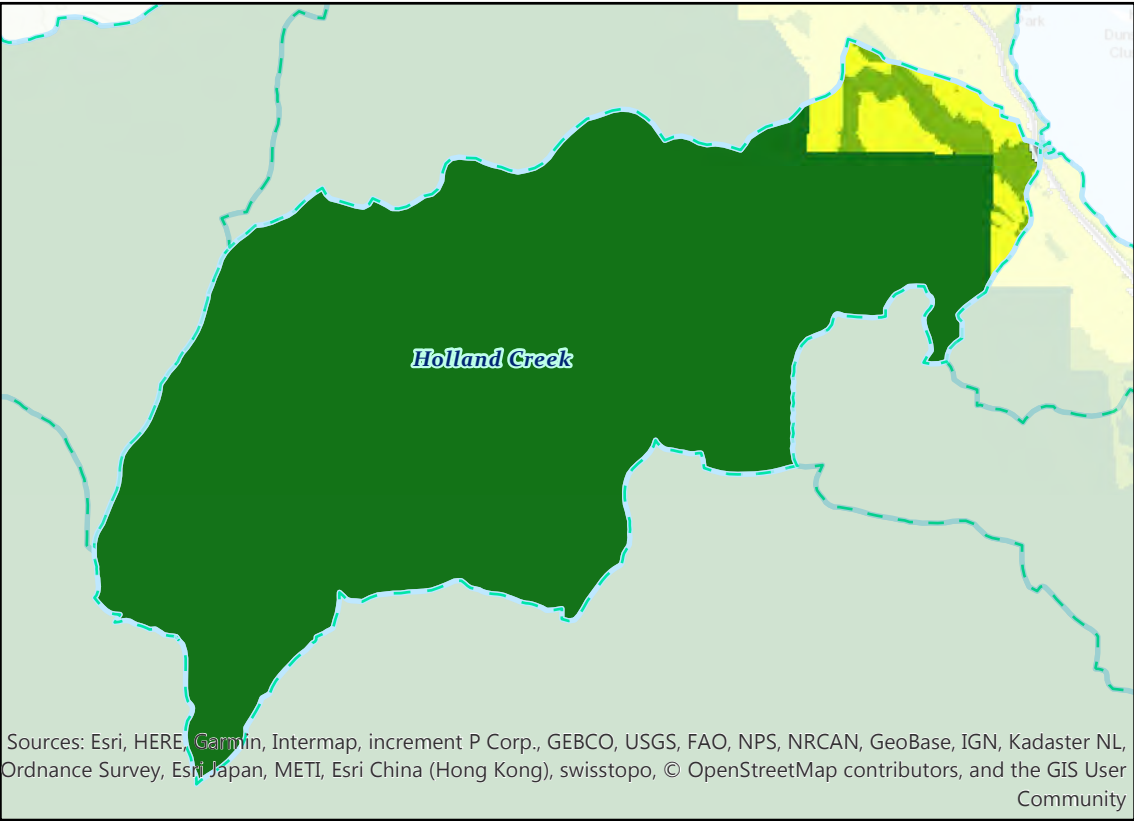
CHK'D: DK

Proj Coord Sys: PCS Albers

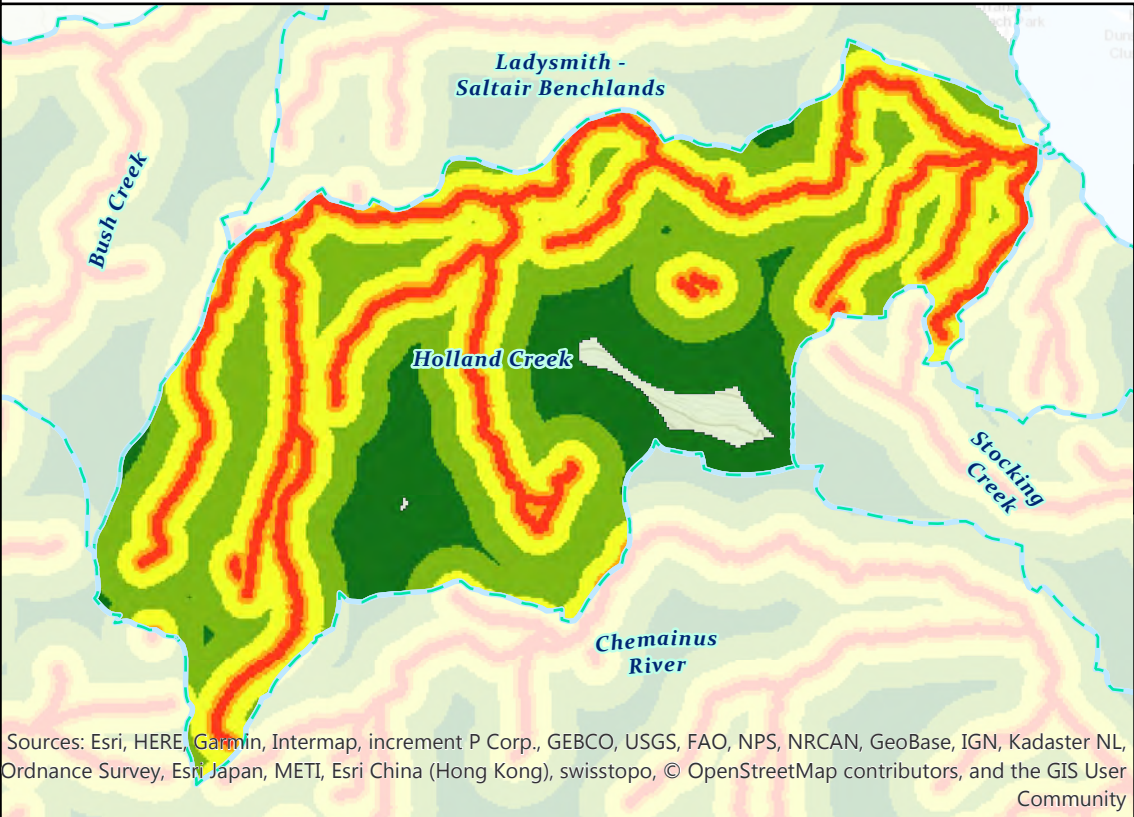
651957-101-HOLL



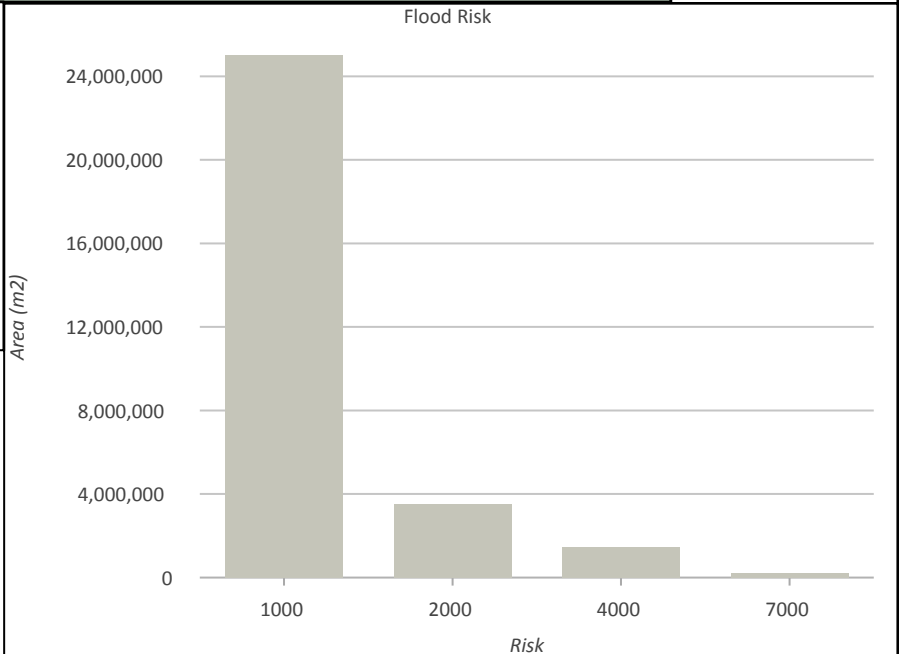
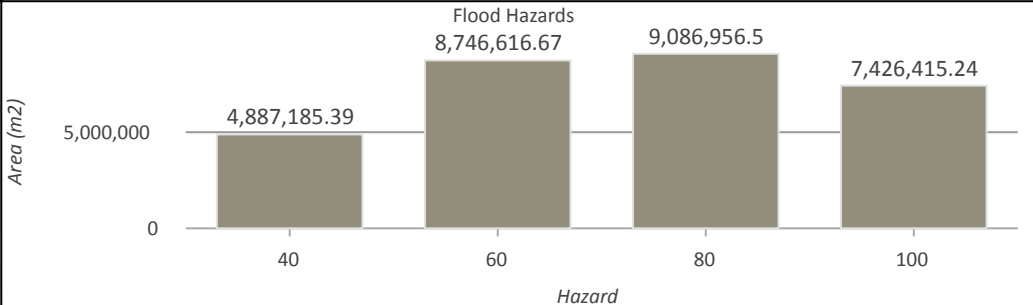
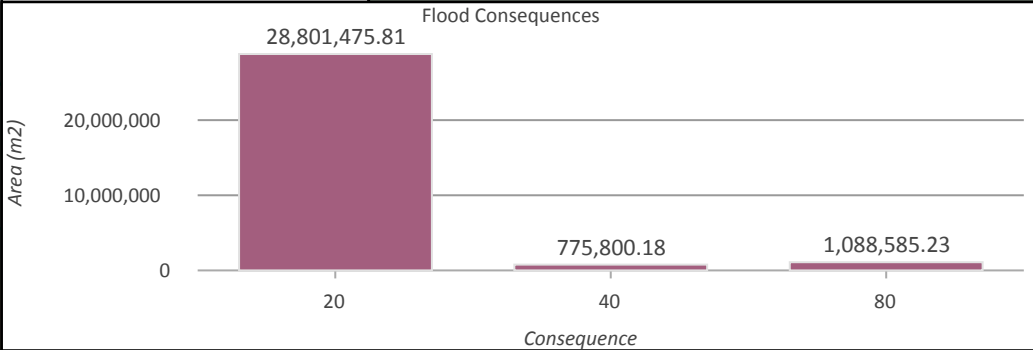
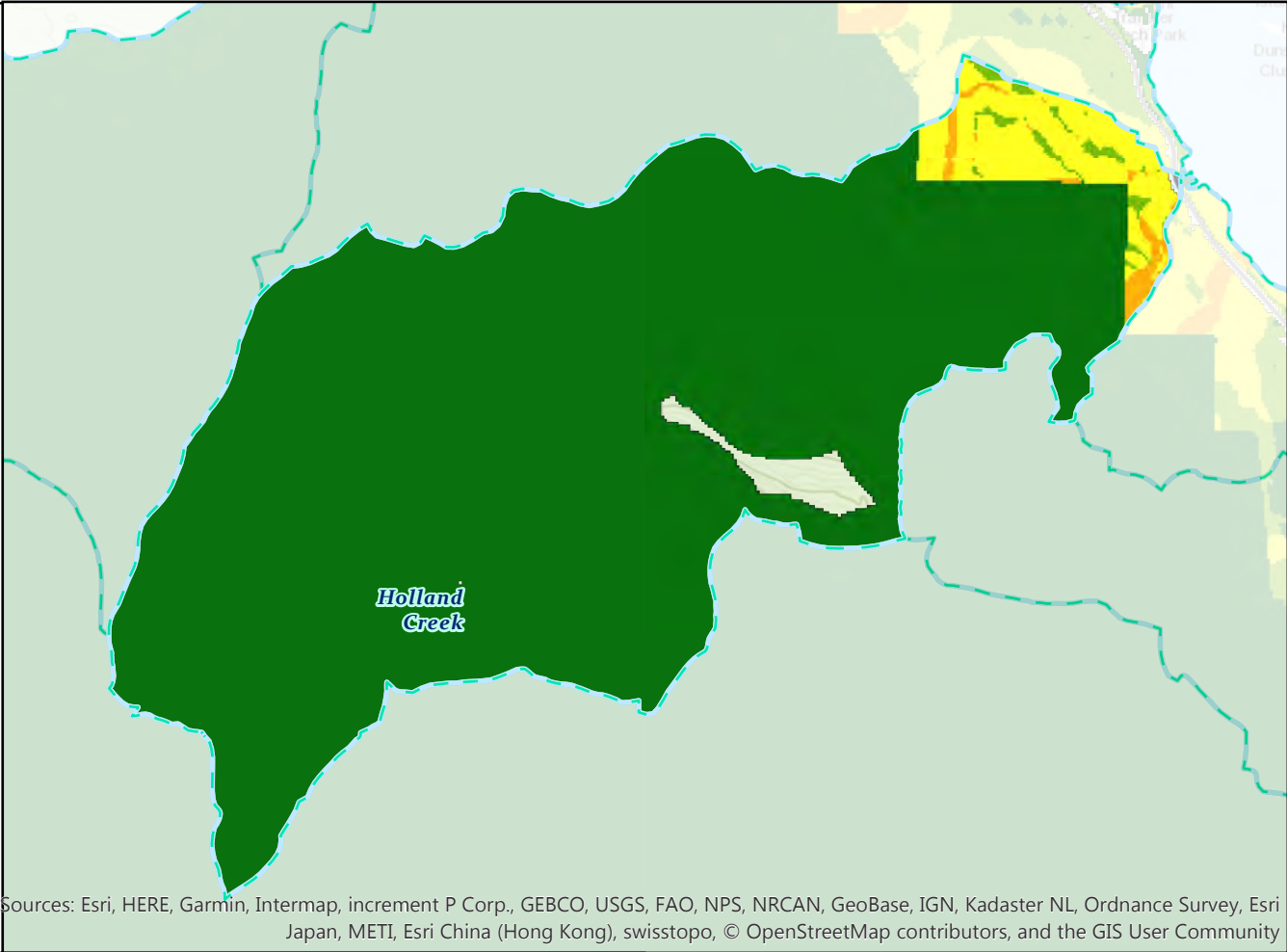
CONSEQUENCE



HAZARD



RISK



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

	≤ 20
	≤ 40
	≤ 60
	≤ 80
	≤ 100

RISK

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	≤ 2000
	≤ 4000
	≤ 7000
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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Holland Creek Watershed

SNC • LAVALIN

Flood Risk Assessment - Holland Creek

BY: CJW

CHK'D: DK

SCALE CONS: 1:62,907

Proj Coord Sys: NAD 1983 UTM Zone 10N

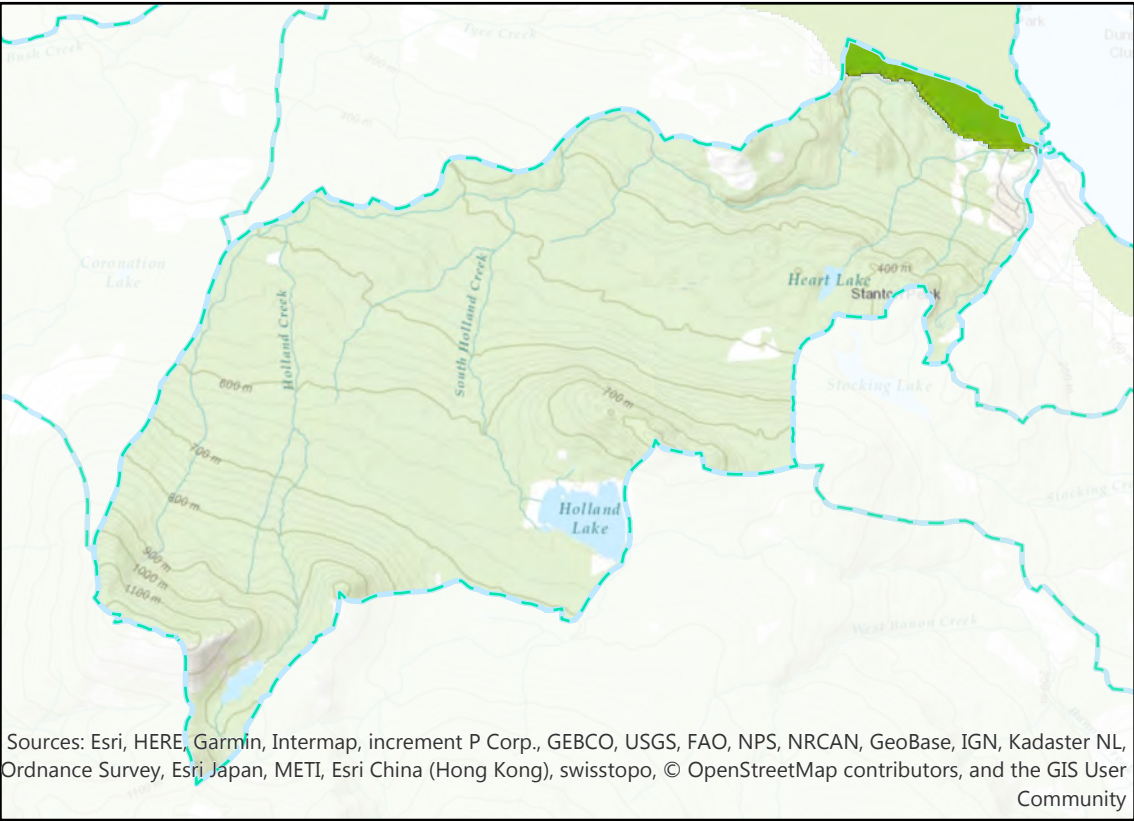
DATE: 2019/01/08

REF No: 651957-102-HOLL

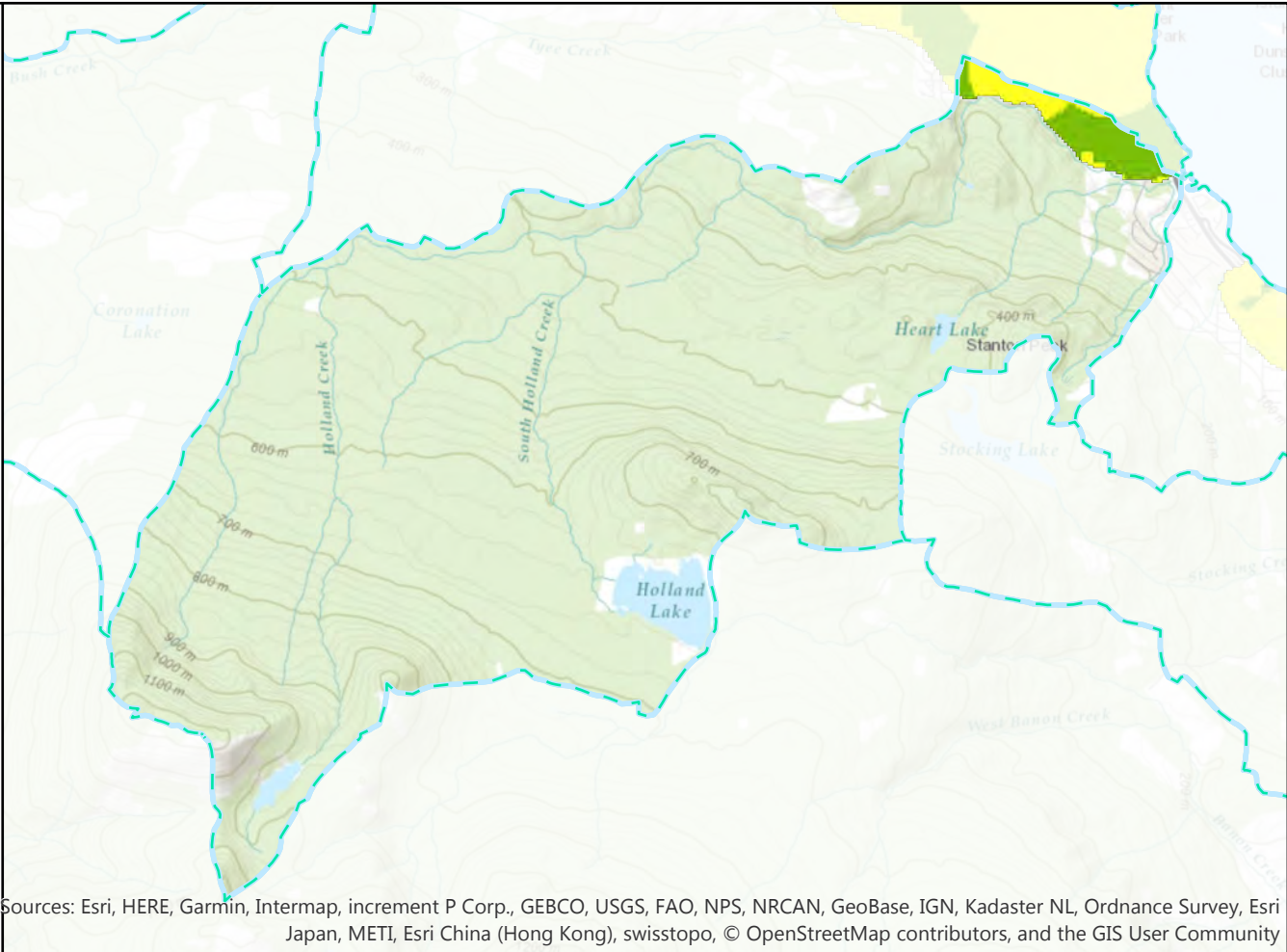
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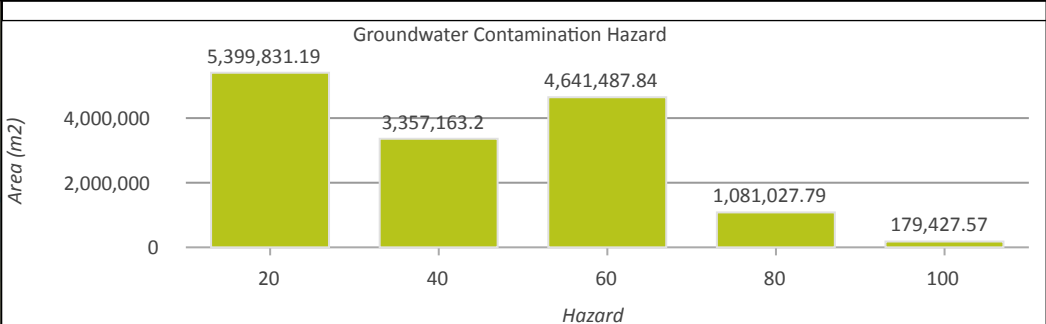
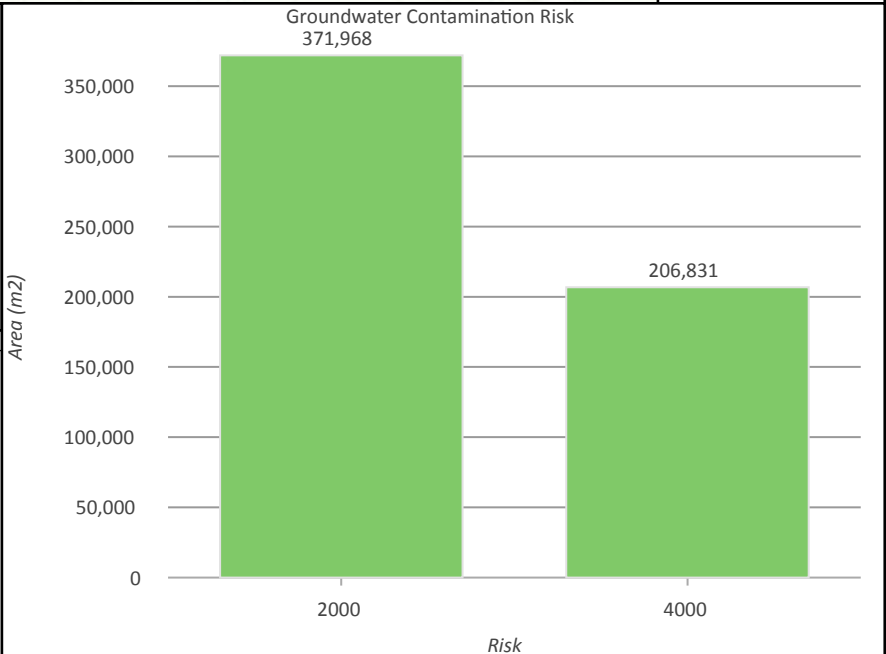
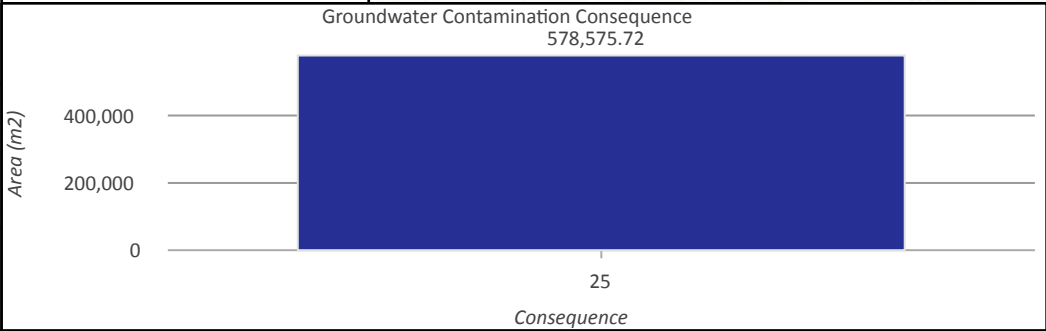
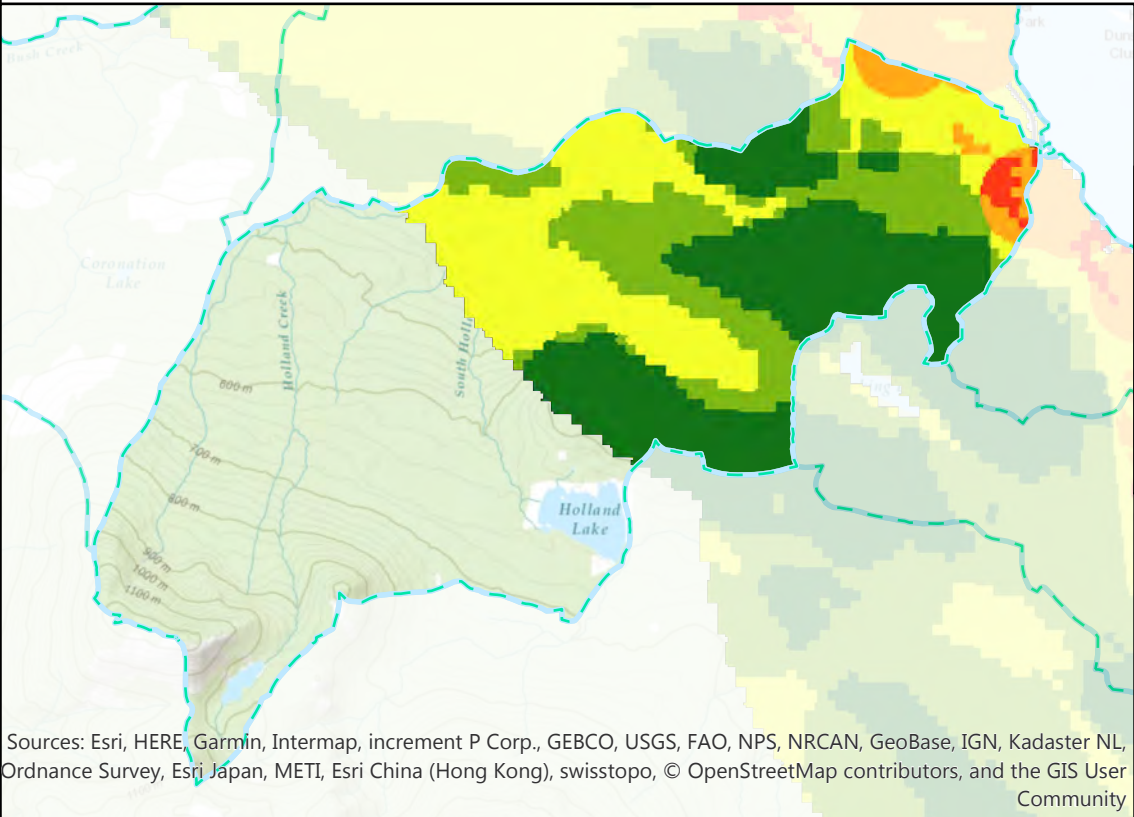
CONSEQUENCE



RISK



HAZARD



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

- ≤ 20
- ≤ 40
- ≤ 60
- ≤ 80
- ≤ 100

RISK

- ≤ 1000
- ≤ 2000
- ≤ 4000
- ≤ 7000
- ≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

NOTES:

1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.

REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Holland Creek Watershed



Groundwater Contamination Risk Assessment - Holland Creek

BY: CJW

SCALE CONS: 1:62,907

DATE: 2019/01/08

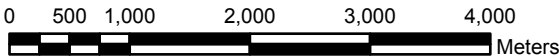
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REV: 0

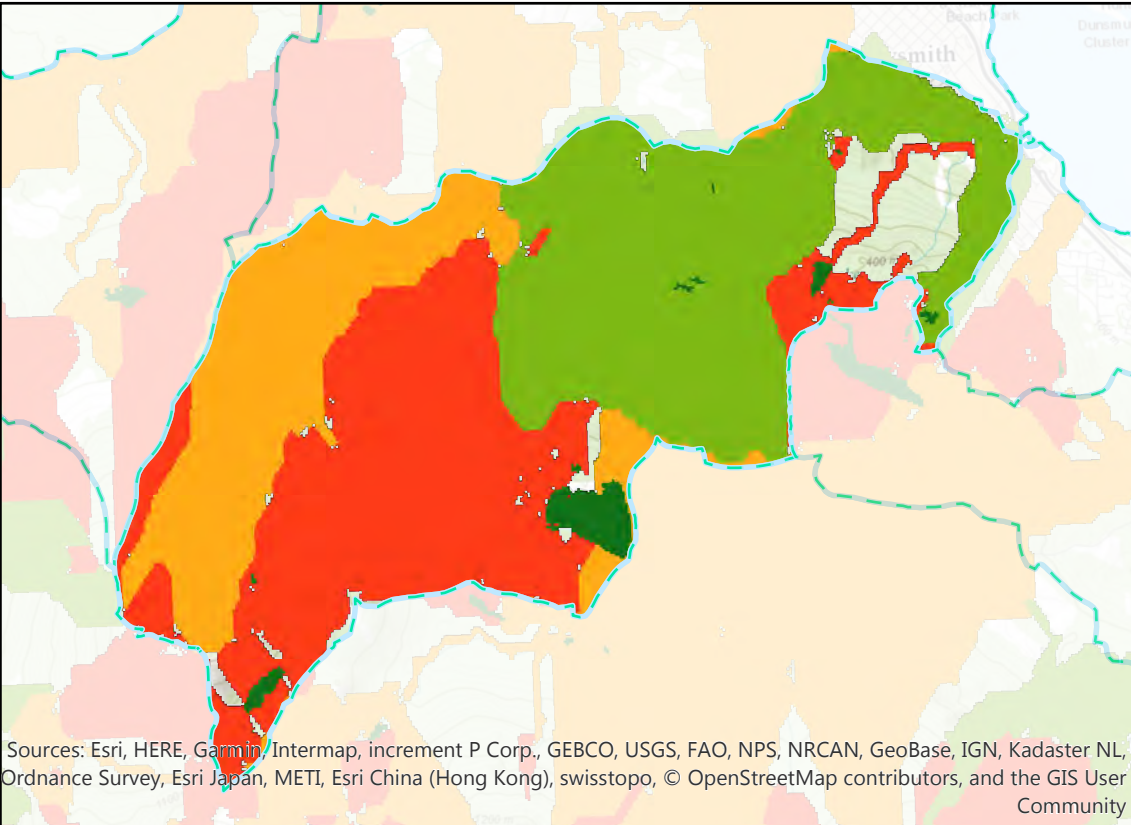
CHK'D: DK

Proj Coord Sys: NAD 1983 UTM Zone 10N

651957-103-HOLL

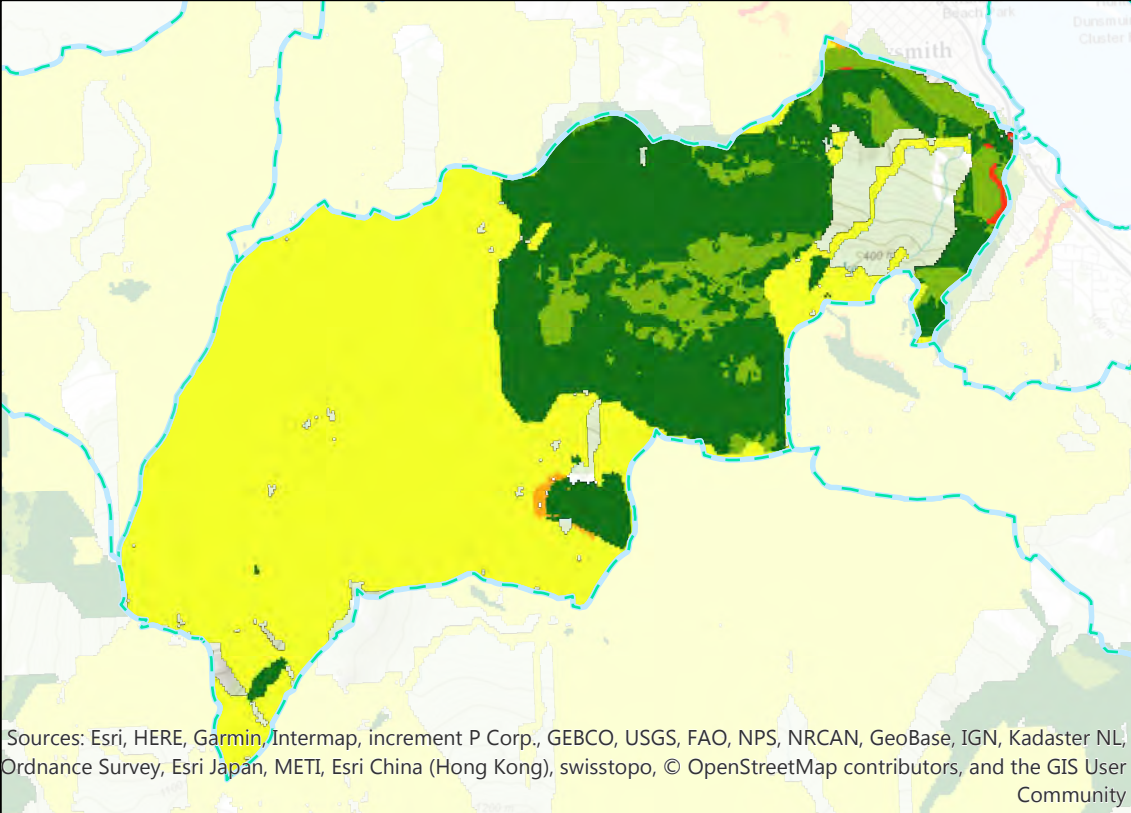


CONSEQUENCE



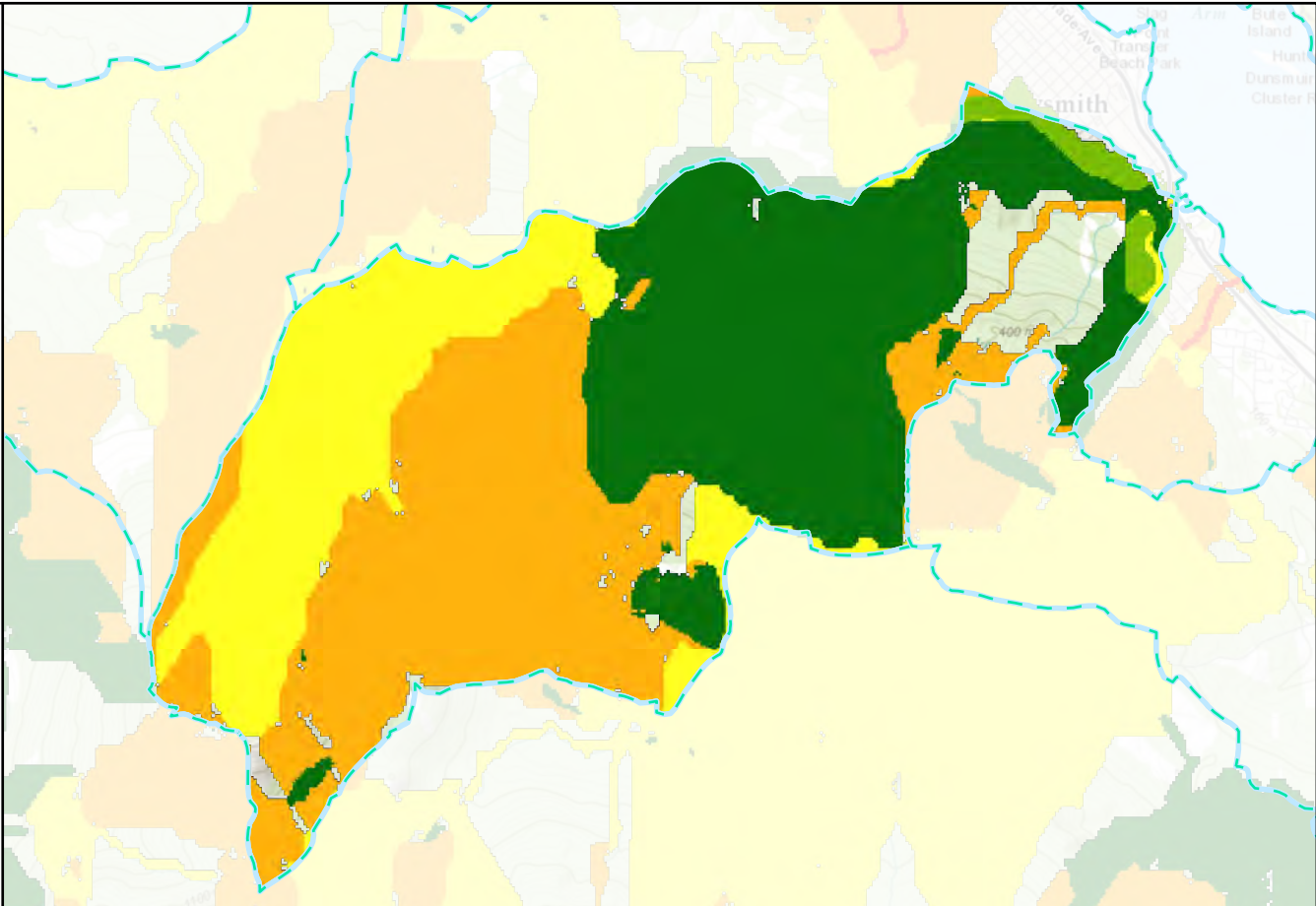
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

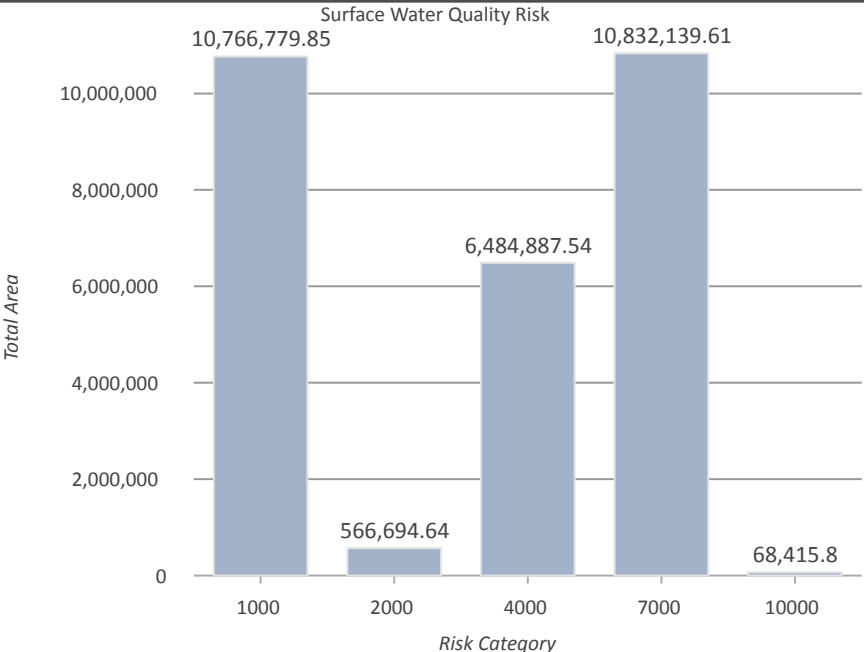
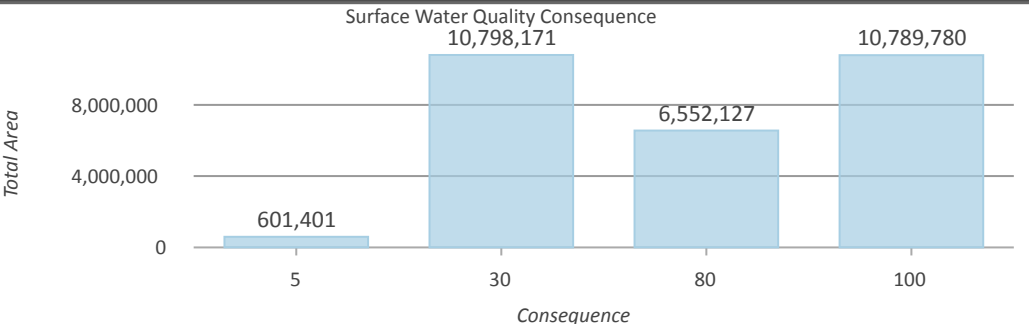
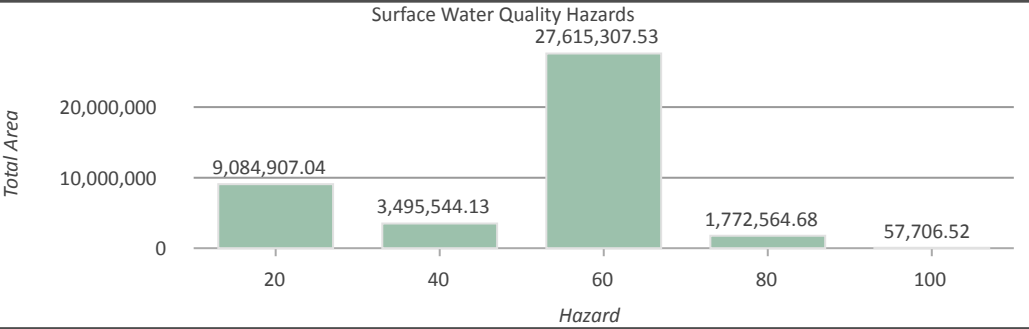


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
 ≤ 40
 ≤ 60
 ≤ 80
 ≤ 100

RISK

≤ 1000
 ≤ 2000
 ≤ 4000
 ≤ 7000
 ≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District/Holland Creek Watershed



Surface Water Quality Risk Assessment - Holland Creek

BY:

SCALE: 1:67,127

DATE: 2019/01/08

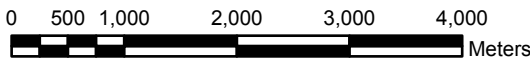
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REV: 0

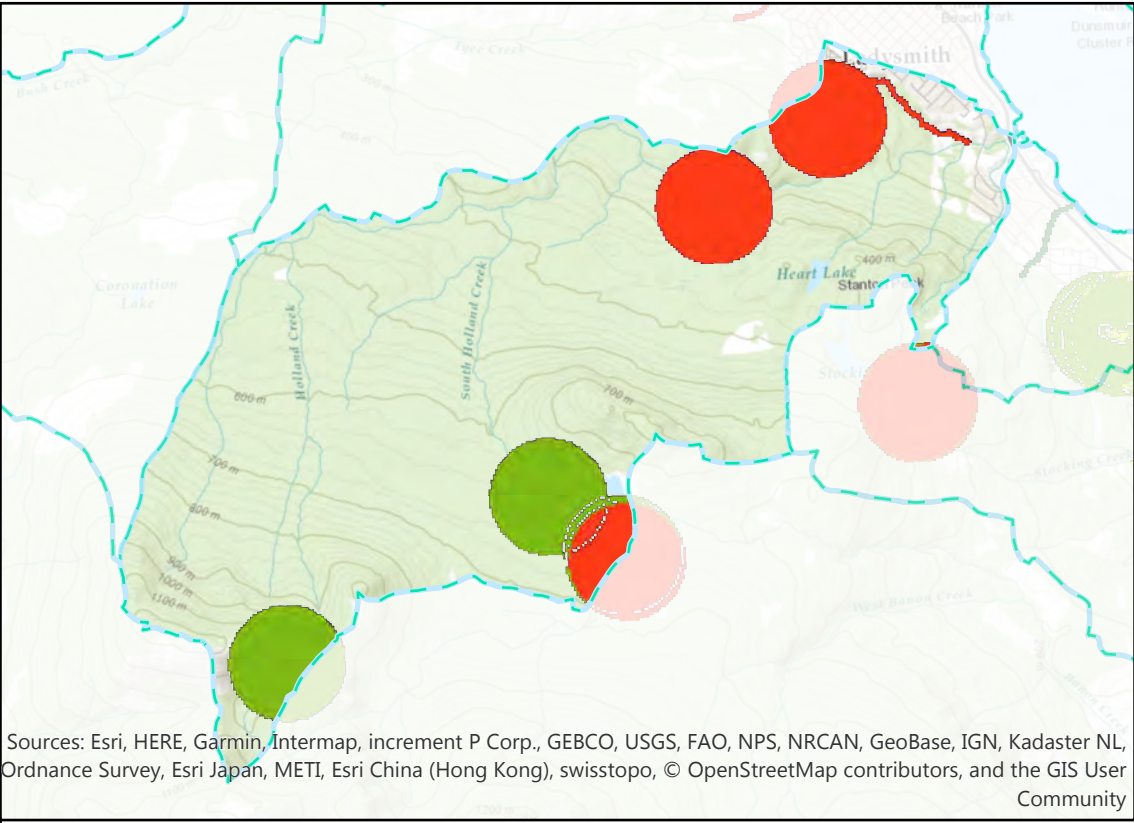
CHK'D:

Proj Coord Sys: PCS Albers

651957-104-HOLL

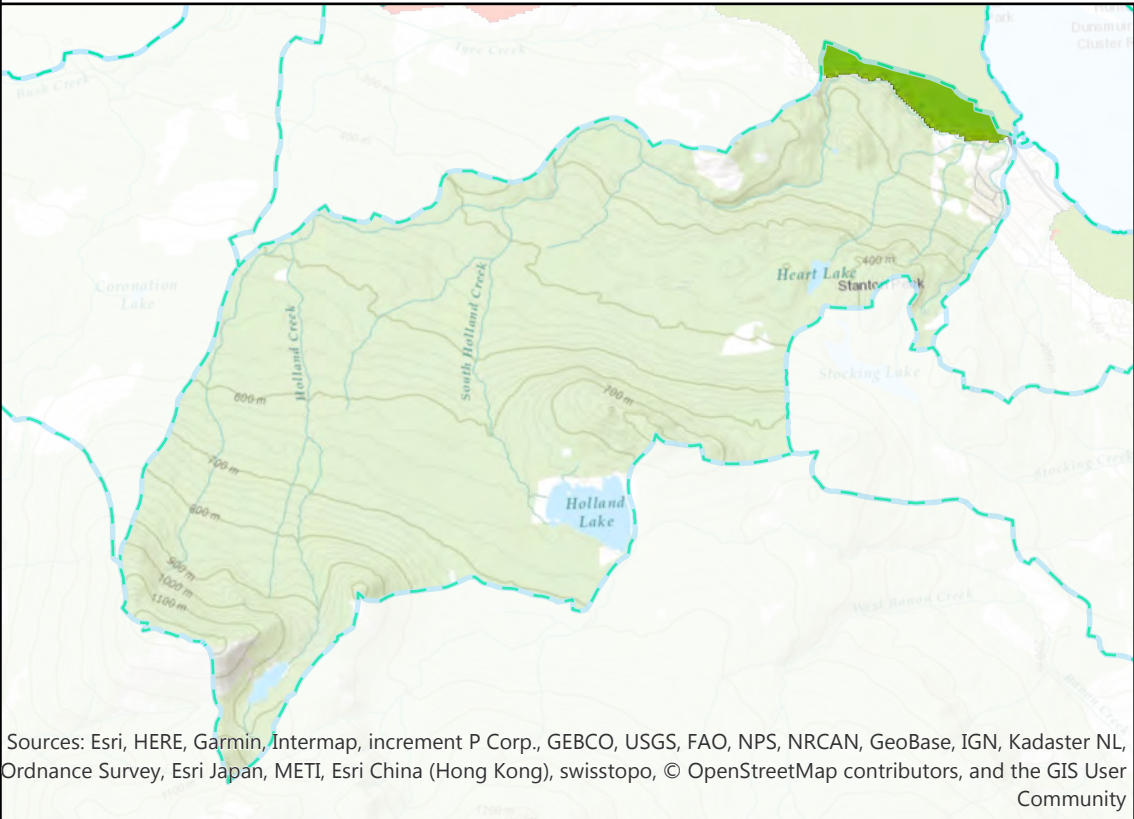


CONSEQUENCE



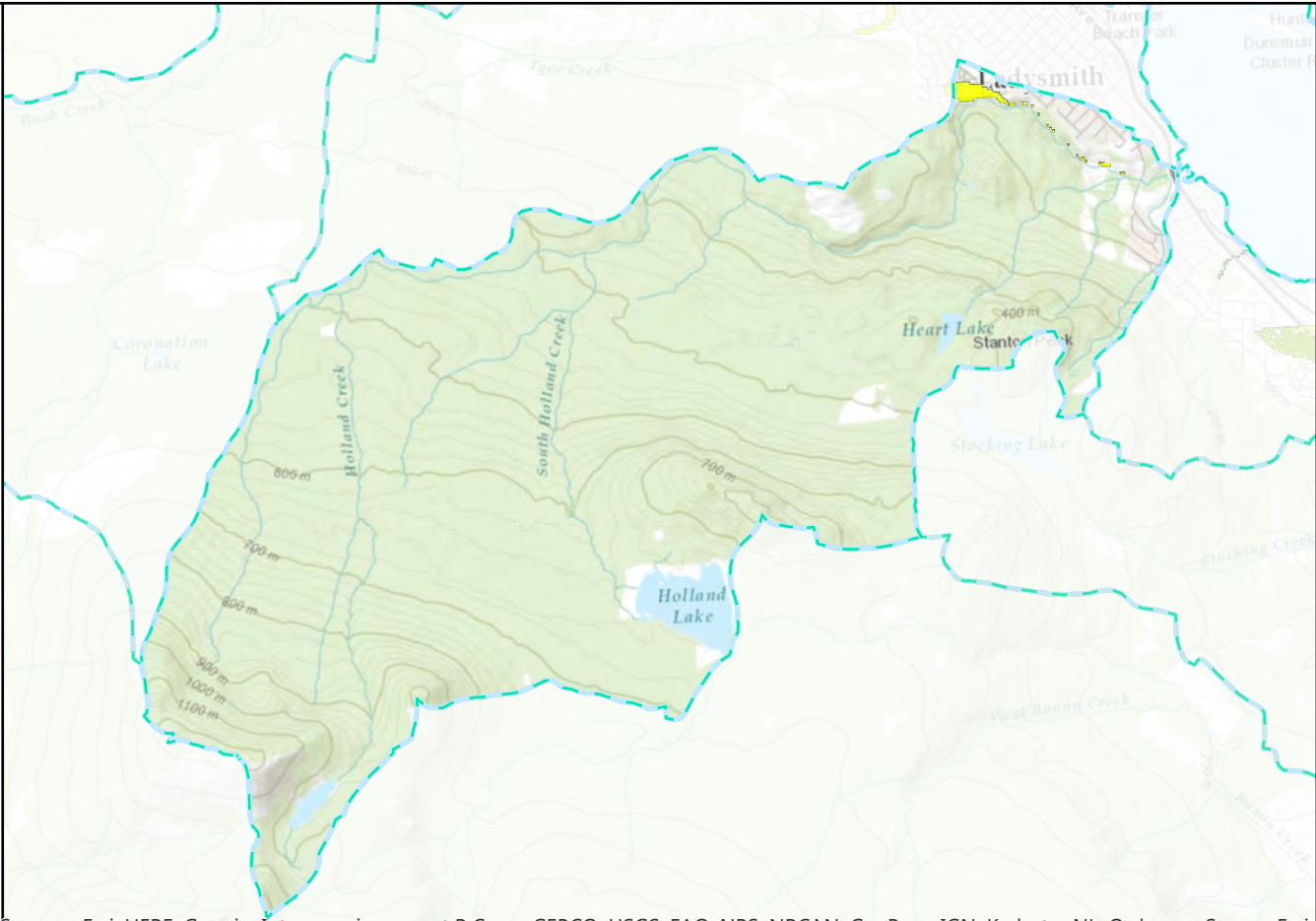
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

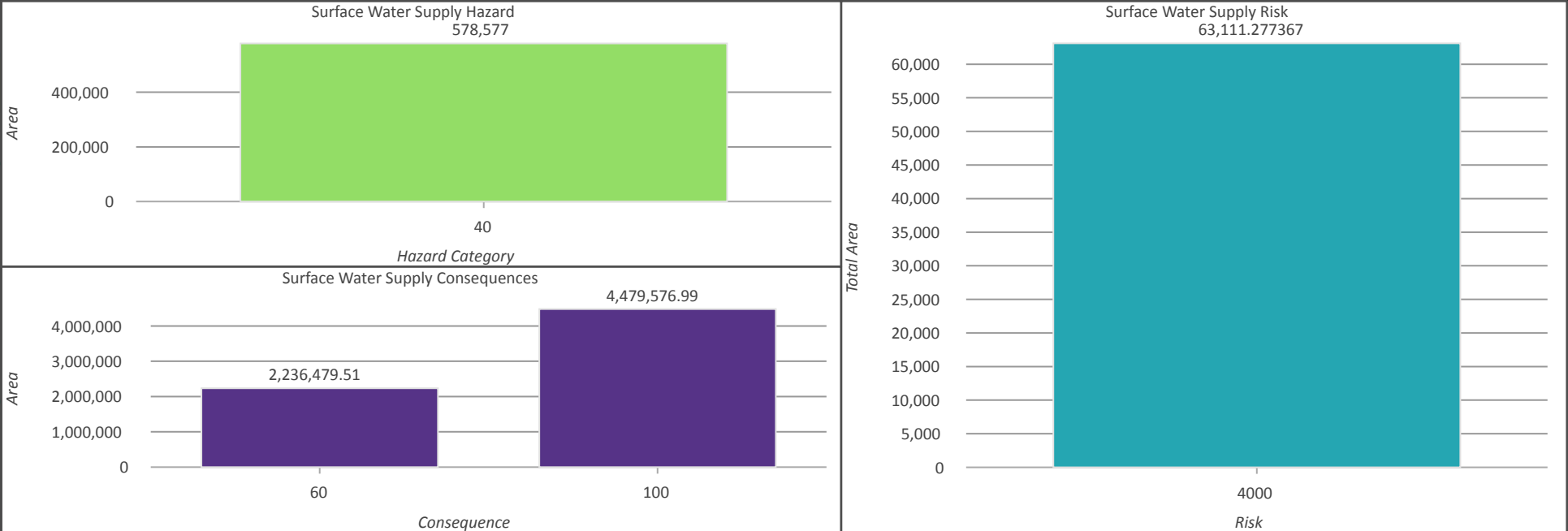


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20

≤ 40

≤ 60

≤ 80

≤ 100

RISK

≤ 1000

≤ 2000

≤ 4000

≤ 7000

≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional DistrictHolland Creek Watershed

Surface Water Supply Risk Assessment - Holland Creek

BY:

SCALE: 1:65,458

DATE: 2019/01/08

REF No:

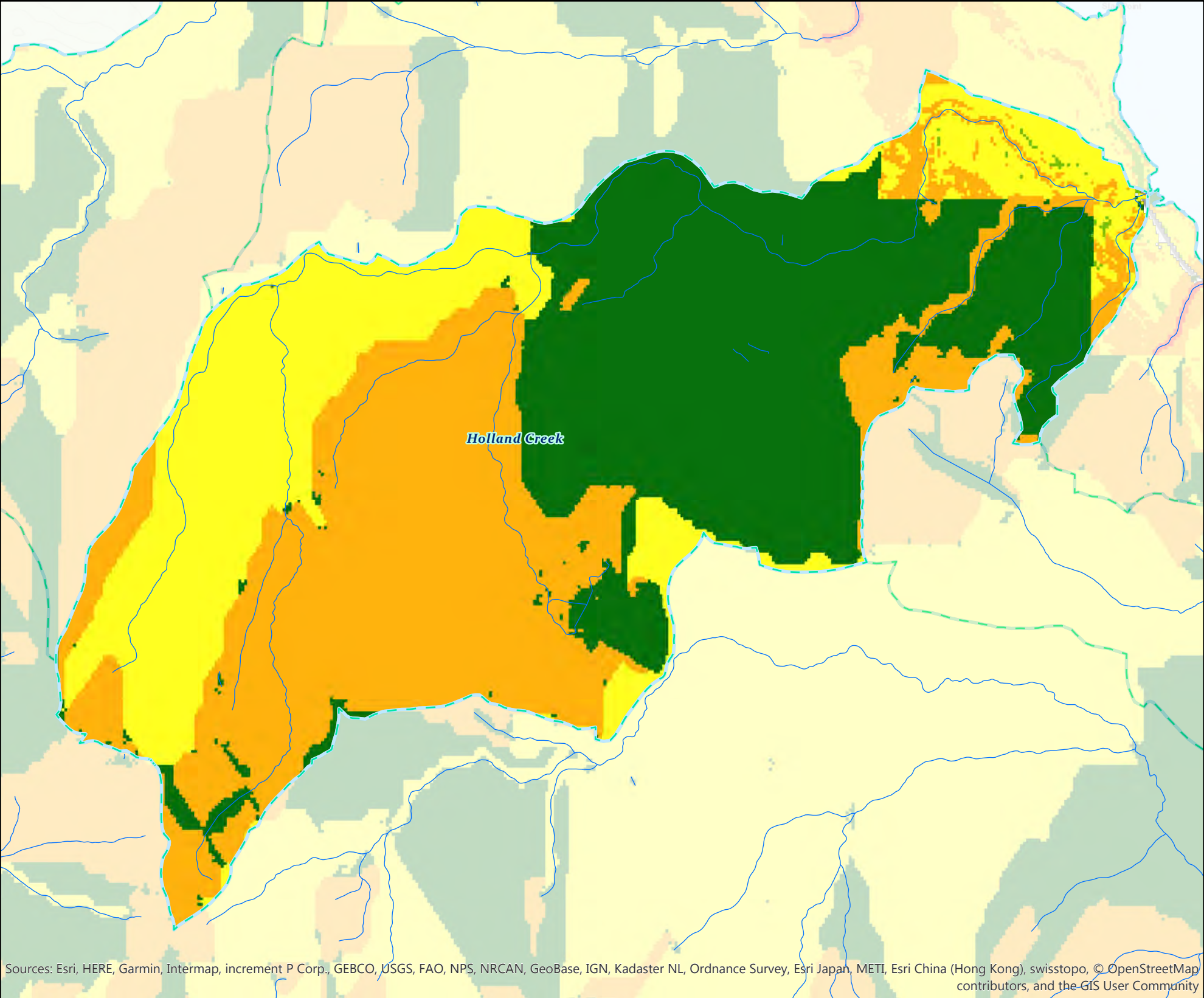
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CHK'D:

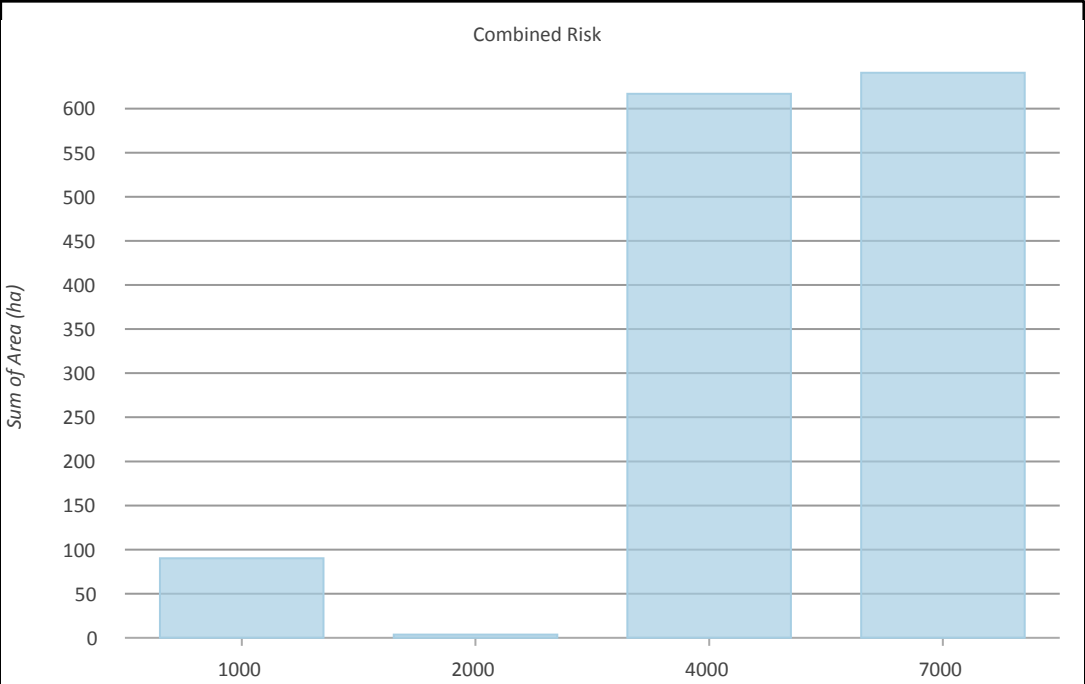
Proj Coord Sys: PCS Albers

651957-105-HOLL

0 500 1,000 2,000 3,000 4,000 Meters



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



NAME	Risk			
SHAWNIGAN CREEK	10047	10760	11613	12598
BUSH CREEK	0	0	0	0
KOKSILAH RIVER	5463	5851	6315	6850
HOLLAND CREEK	1302	1368	1446	1537
BONSALL CREEK	934	974	1019	1073
CHEMAINUS RIVER	1490	1461	1439	1421
COWICHAN RIVER	36368	37905	39683	41766
YELLOW POINT BENCHLANDS	2239	2352	2487	2643
LADYSMITH - SALTAIR BENCHLANDS	8410	8834	9342	9929
STOCKING CREEK	1531	1608	1701	1807
CHEMAINUS BENCHLANDS	3663	3818	3997	4207
SATELLITE CHANNEL BENCHLANDS	4390	4701	5074	5504
SANSUM NARROWS - COWICHAN BAY BENCHLANDS	4941	5150	5391	5674
MALAHAT BENCHLANDS	2829	3030	3271	3548

NAME	POP2001	POP2006	POP2011	POP2016
SHAWNIGAN CREEK	6348	8439	8925	9484
BUSH CREEK	0			
KOKSILAH RIVER	4555	4808	4954	5157
HOLLAND CREEK	1611	1114	1169	1245
BONSALL CREEK	672	830	815	890
CHEMAINUS RIVER	1423	1395	1497	1514
COWICHAN RIVER	29779	32673	34075	34647
YELLOW POINT BENCHLANDS	1167	1958	2021	2141
LADYSMITH - SALTAIR BENCHLANDS	5275	7488	7541	8042
STOCKING CREEK	1332	1003	1354	1464
CHEMAINUS BENCHLANDS	3177	3129	3085	3490
SATELLITE CHANNEL BENCHLANDS	5425	3902	3989	4144
SANSUM NARROWS - COWICHAN BAY BENCHLANDS	5993	4221	4500	4707
MALAHAT BENCHLANDS	1673	2472	2548	2671

Legend

WATERSHED BOUNDARIES

RISK

≤ 1000

≤ 2000

≤ 4000

≤ 7000

≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-30 - Issued - DK

CLIENT:

Cowichan Valley Regional District

PROJECT LOCATION:

Cowichan Valley Regional District
Holland Creek Watershed

Combined Risk Assessment - Holland Creek

BY: CJW

SCALE CONS: 1:39,000

DATE: 2019/01/08

REF No:

CHK'D: DK

Proj Coord Sys: NAD 1983 UTM Zone 10N

651957-106-HOLL

REV: 0

SNC • LAVALIN

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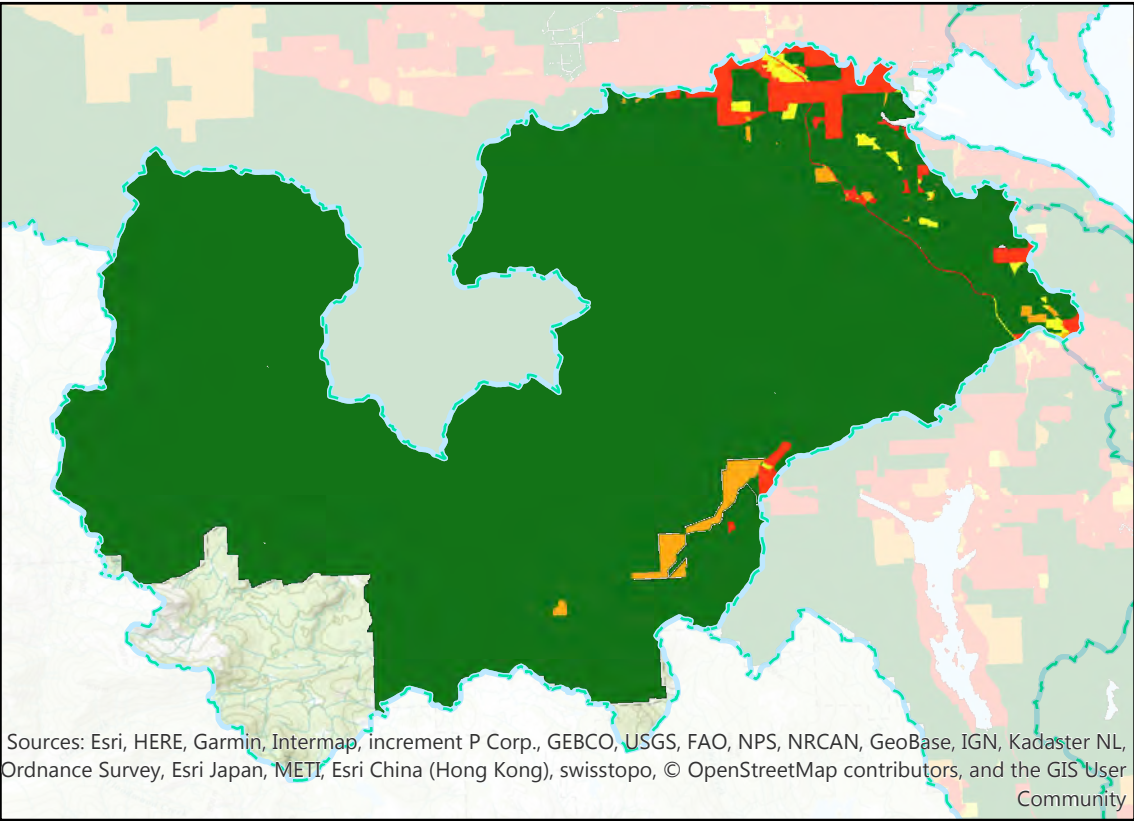
Project Path: P:\Current Projects\CVRD\651957\

P: 6-6

7. Koksilah River

Topic	Discussion
Slope Failure	<p>Hazard was determined qualitatively at a high level to describe areas based on the degree to which they may be prone to landslides and other mass movements using terrain characteristics. Hazard classifications were generated to show relative comparisons between terrain units within the CVRD watershed study area. Risk ratings derived from this analysis are relative, and should be used to guide prioritization of further detailed studies.</p> <p>Hazard is greatest in the upper reaches of the Koksilah river due to the relatively steep slopes and logging activity. Hazard decreases towards Deerholme, Cowichan Station, and Hillbank, as the topography becomes gentler. Consequence is considered moderate to low through the populated areas closer to the ocean. Risk is considered moderate, with some high spots in these populated areas and is highest where slopes encroach on populated areas near Lake Cowichan.</p>
Flooding	Numerous rivers and creeks span the large watershed. Consequence and risk are greatest near Koksilah and the ocean.
Groundwater Contamination	Likelihood of groundwater contamination varies greatly throughout the watershed and is greatest in isolated small zones surrounding near the ocean and the highway, extending up towards Deerholme. Other higher risk areas are located within eastern section of the watershed in the vicinity of Highway 1 and where municipal supply wells are located.
Surface Water Quality	Hazard is greatest in the developed areas near the highway and the ocean. Consequence varies considerably, with moderate and low consequence zones scattered throughout the watershed where lower order streams are present. Due to the large area of the watershed risk also varies considerably throughout the watershed. Risk is generally greatest towards the highway and the ocean. These areas are projected to expand with increased populations that may increase the areas where risk is considered greatest.
Surface Water Supply	Hazard and consequence is greatest in areas around the highway and the ocean (and out towards Deerholme). Risk is greatest in small zones around the highway and the populated areas in that region. Population projections indicate a growing population for the Koksilah River watershed, and therefore pressures on groundwater supplies for residential are expected to increase the level of hazard or risk.
General Data Notes	Further work to understand Surface Water Supply risk could include consideration of timing volumes of water use for agricultural, commercial and industrial purposes both from surface water and groundwater, and climate change projections. Additional factors for consequence that could be expanded for this watershed include ecosystem service, and ecological impacts. As one of the larger watersheds (in terms of total area) the Koksilah River watershed has most of it's population focused along the highway towards the ocean, and out as far West as Deerholme. Risk is concentrated along the highway and ocean, in the populated areas, with the exception of Surface Water Quality.

CONSEQUENCE



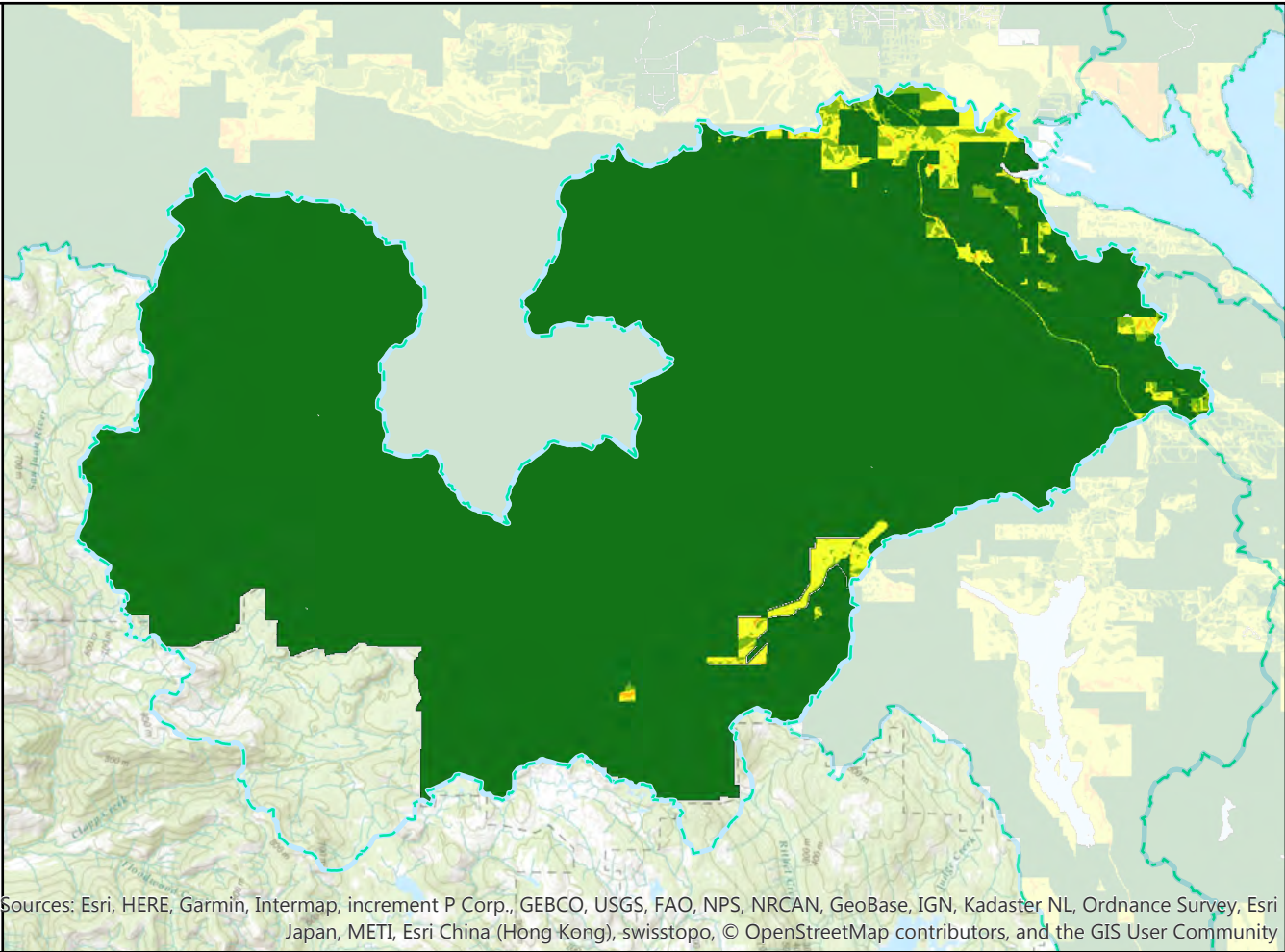
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

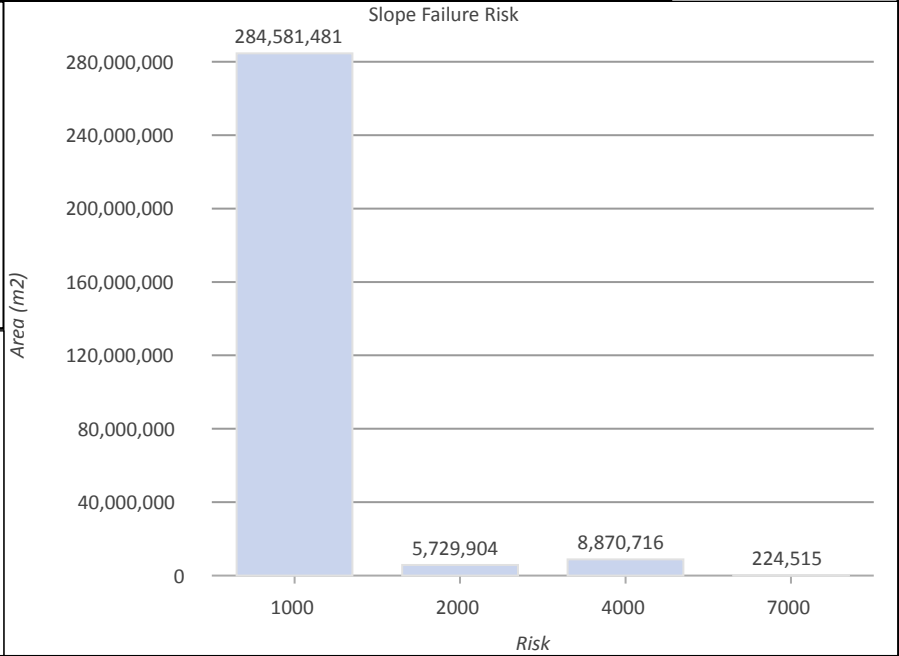
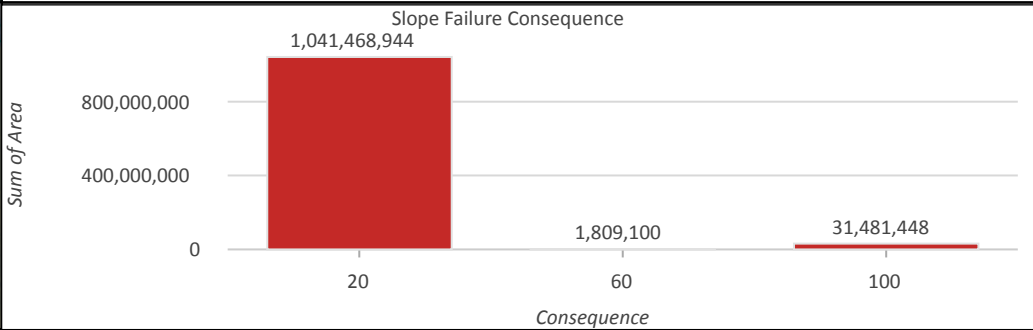
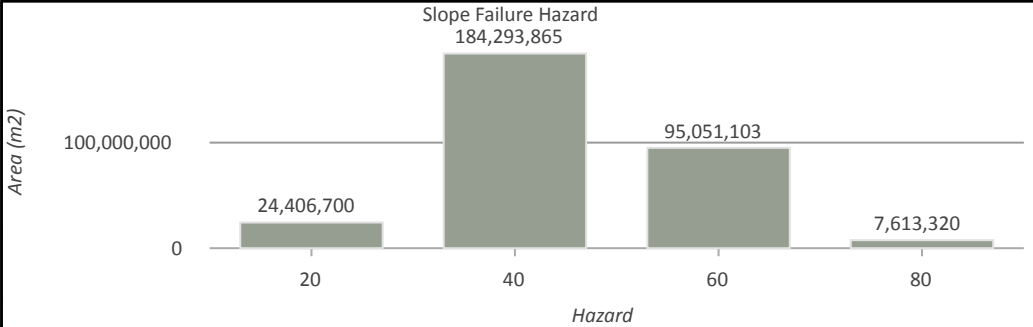


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Koksilah River Watershed



Slope Failure Risk Assessment - Koksilah River

BY: CJW

SCALE CONS: 1:183,902

DATE: 2019/01/07

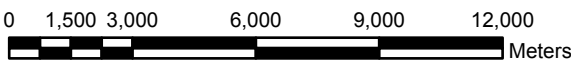
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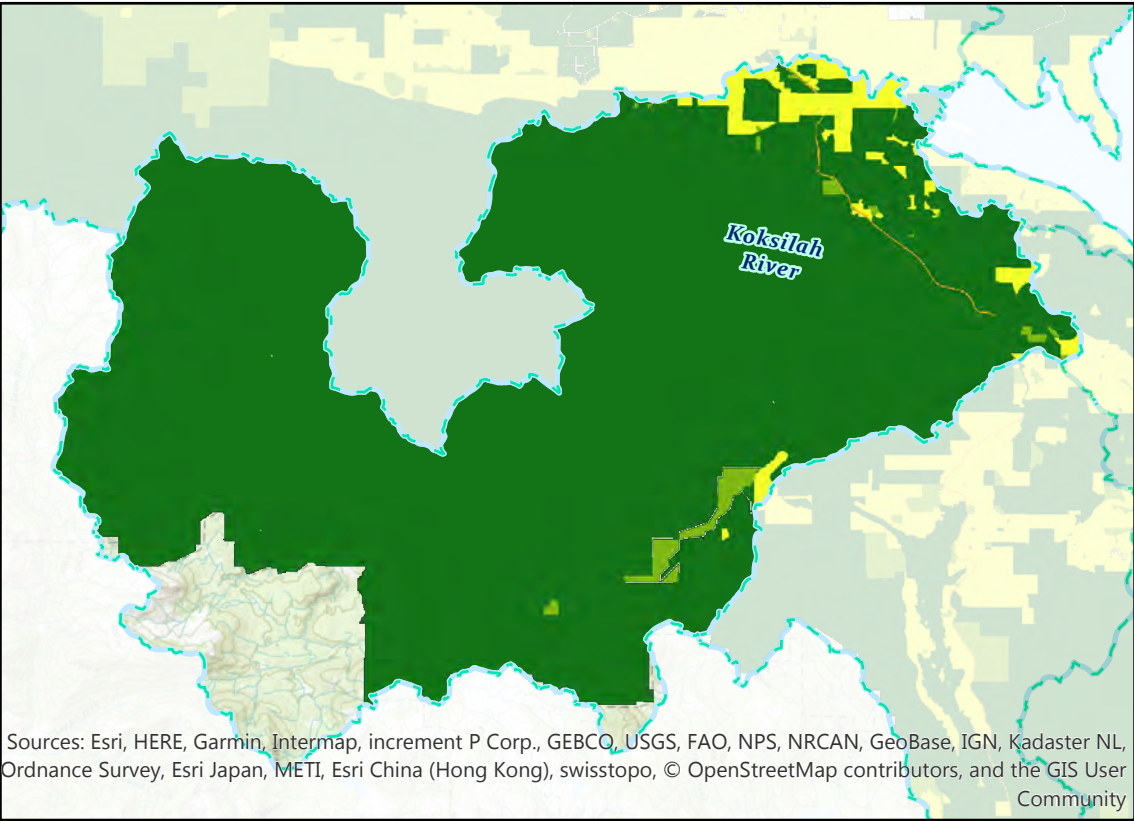
CHK'D: DK

Proj Coord Sys: PCS Albers

651957-101-KOKS

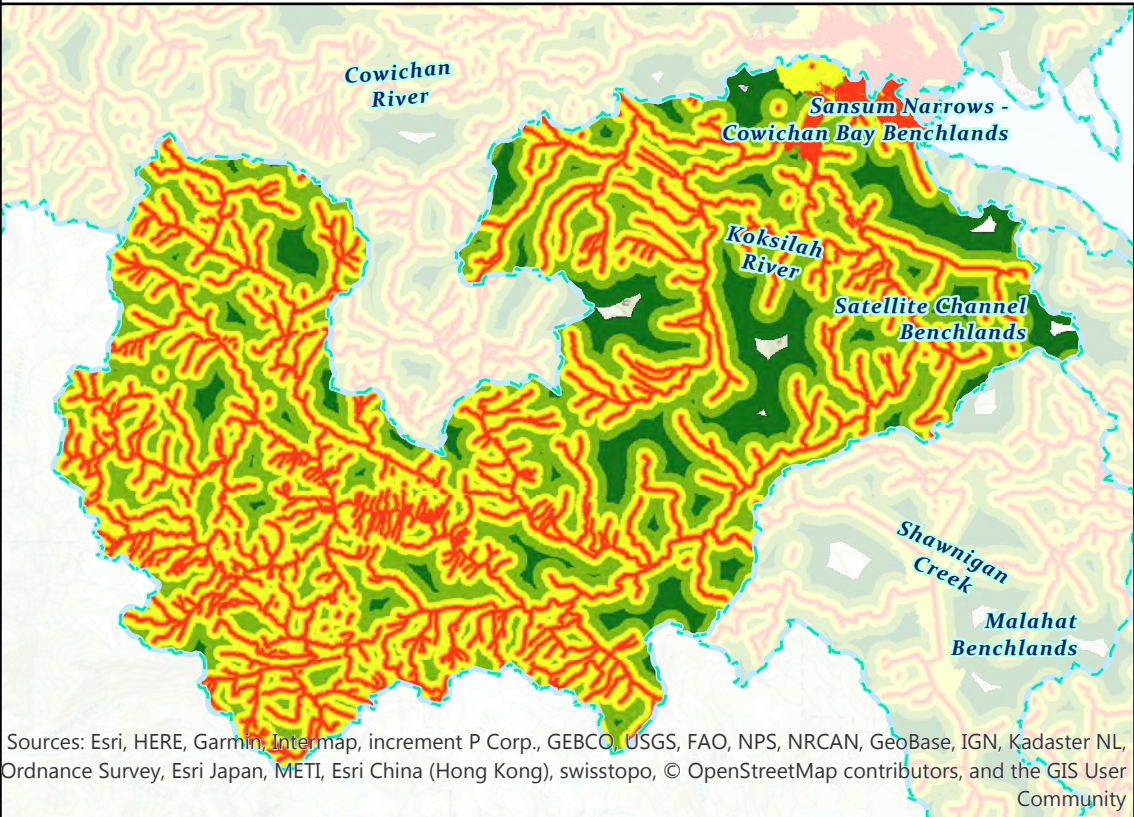


CONSEQUENCE



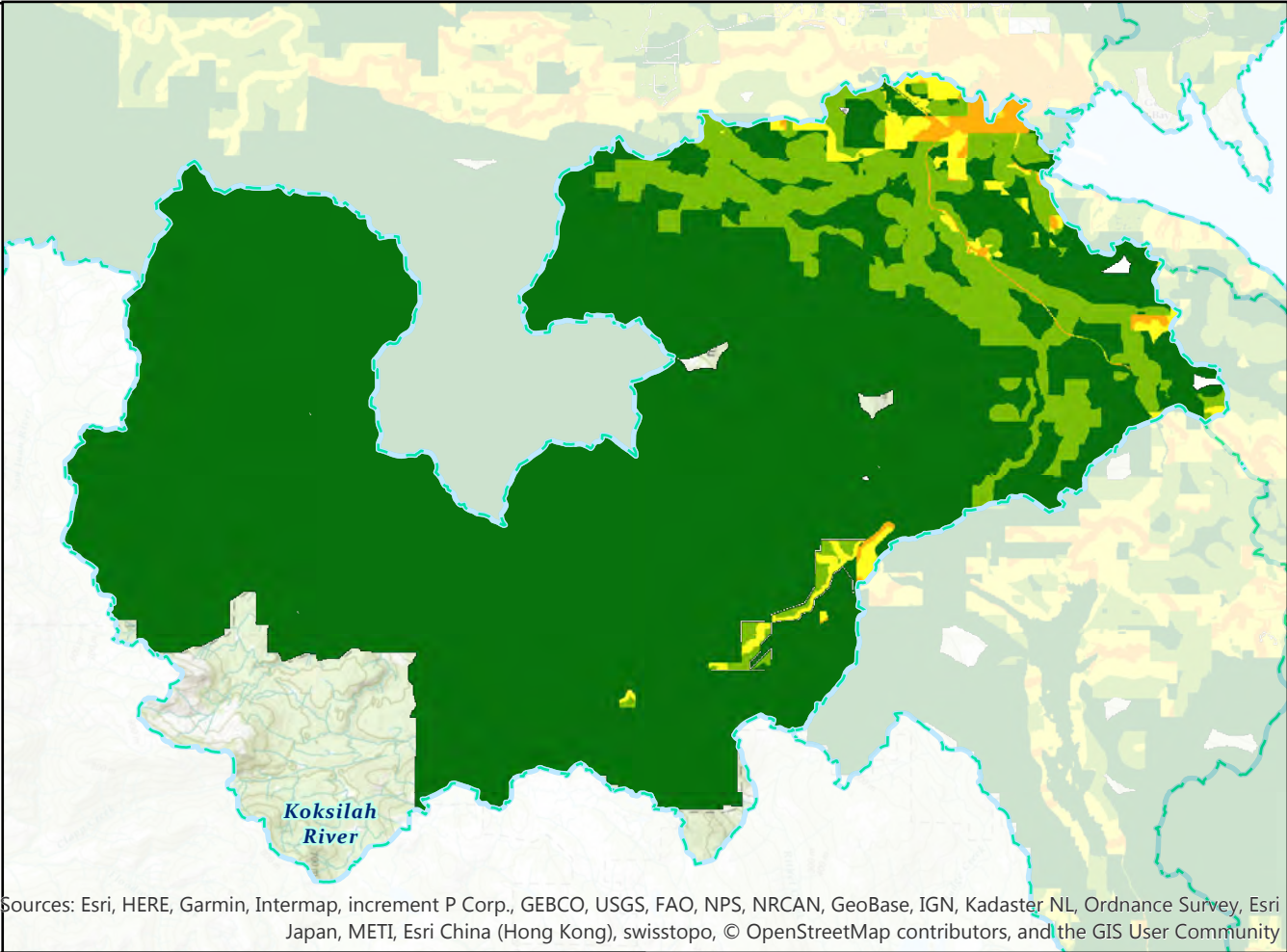
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

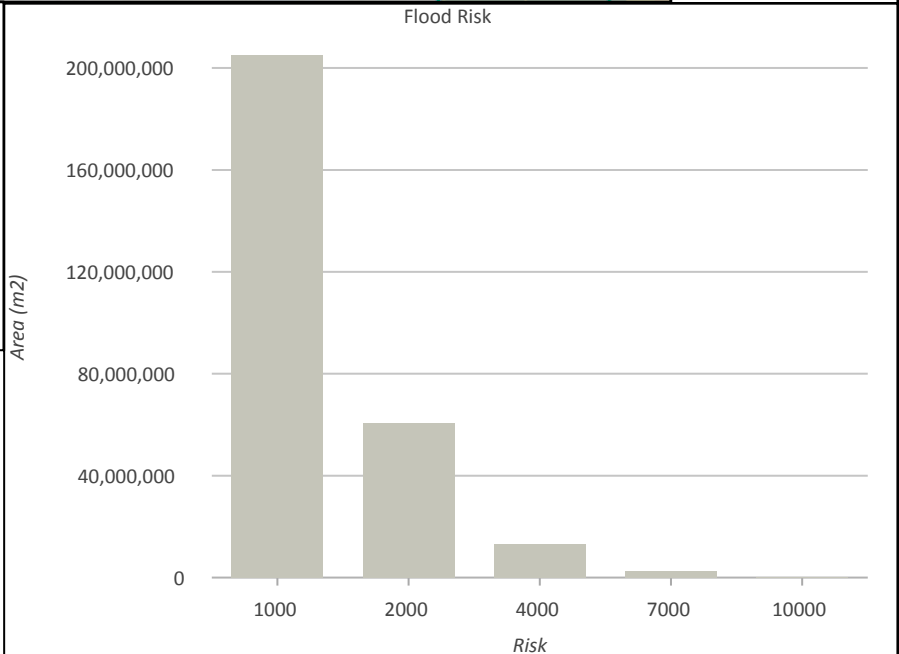
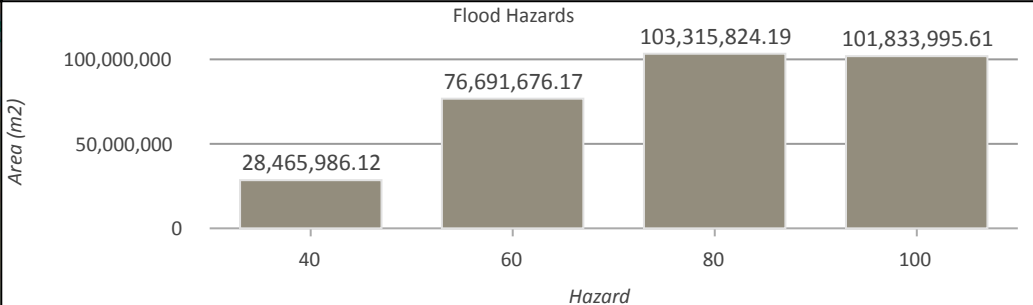
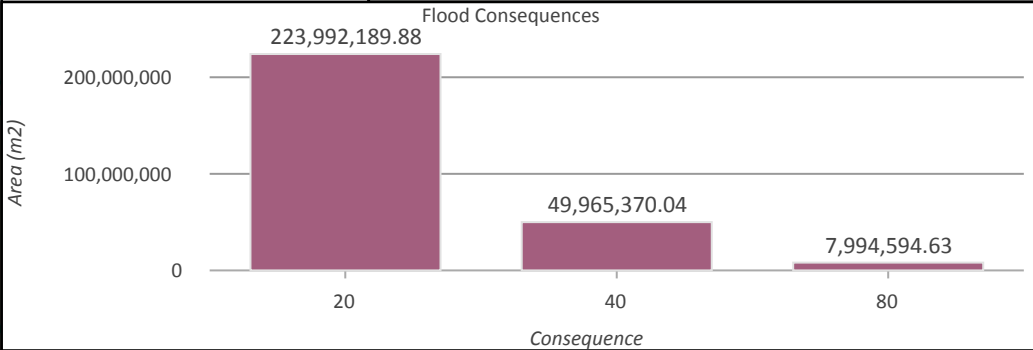


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

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≤ 2000
≤ 4000
≤ 7000
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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Koksilah River Watershed



Flood Risk Assessment - Koksilah River

BY: CJW

SCALE CONS: 1:179,371

DATE: 2019/01/08

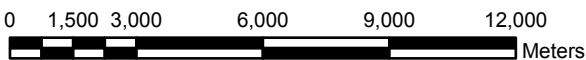
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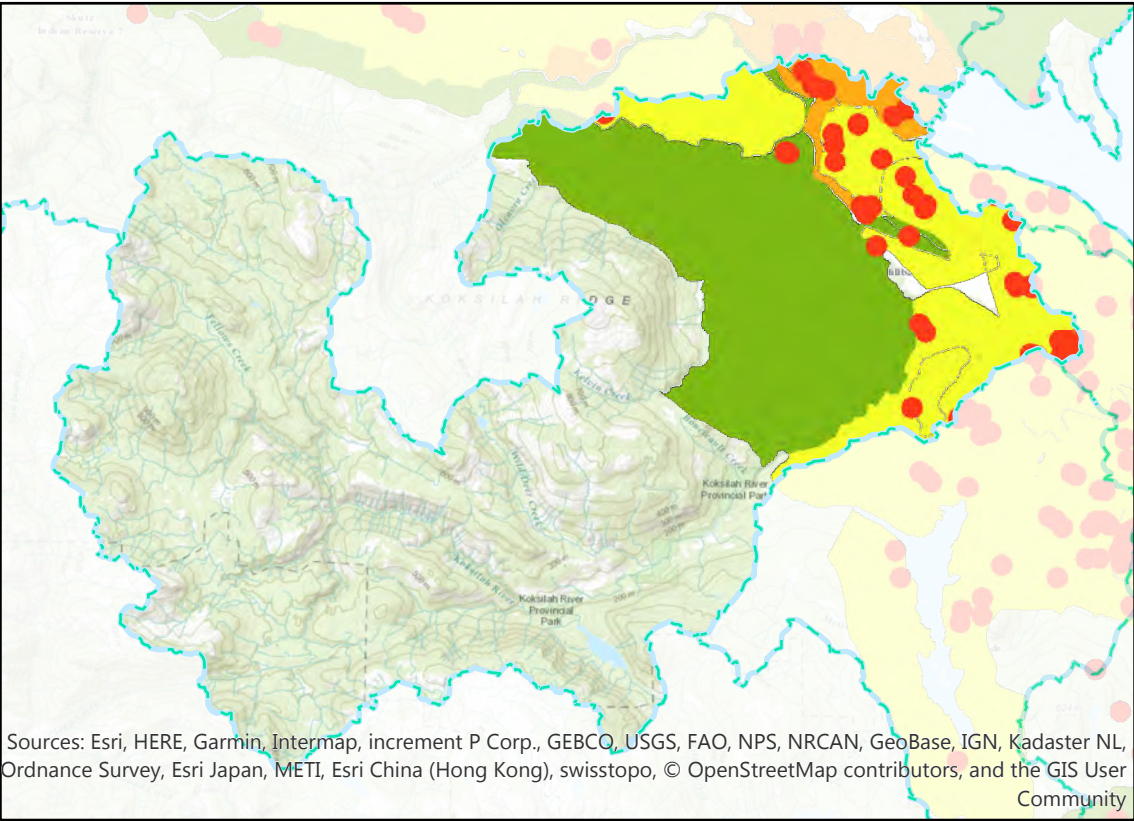
CHK'D: DK

Proj Coord Sys: NAD 1983 UTM Zone 10N

651957-102-KOKS

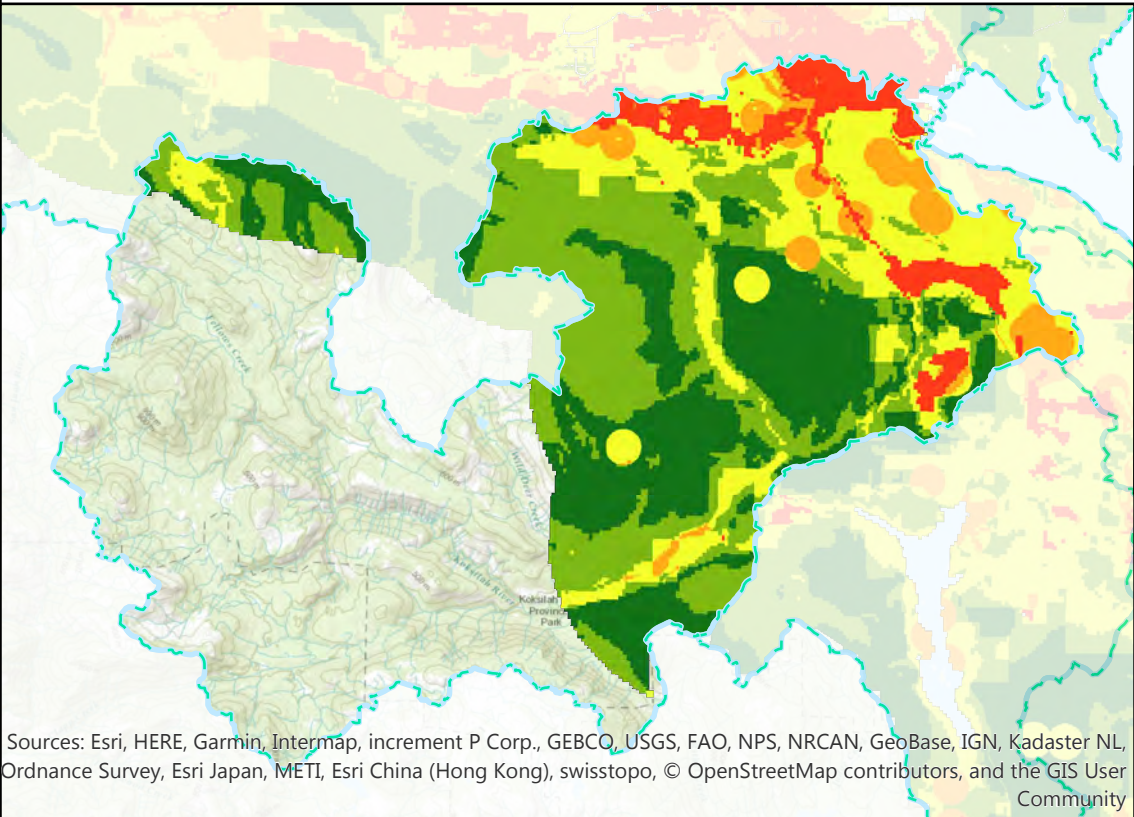


CONSEQUENCE



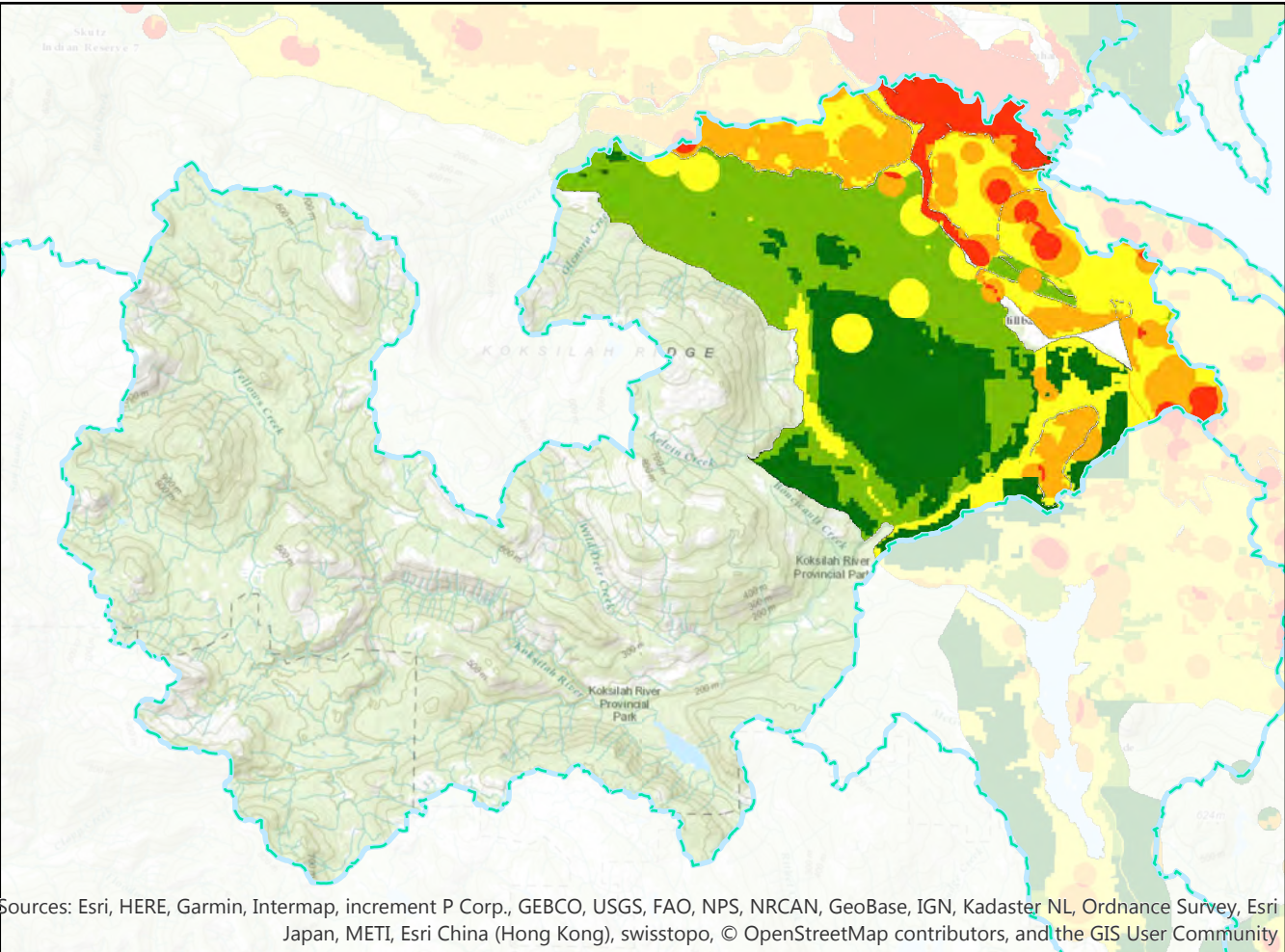
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

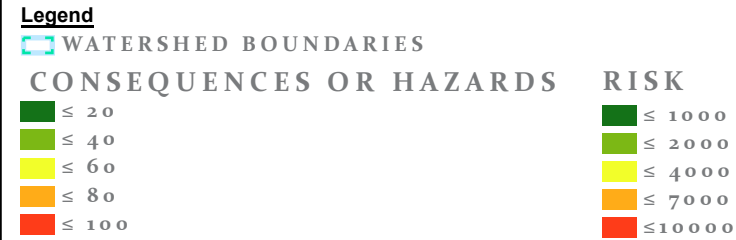
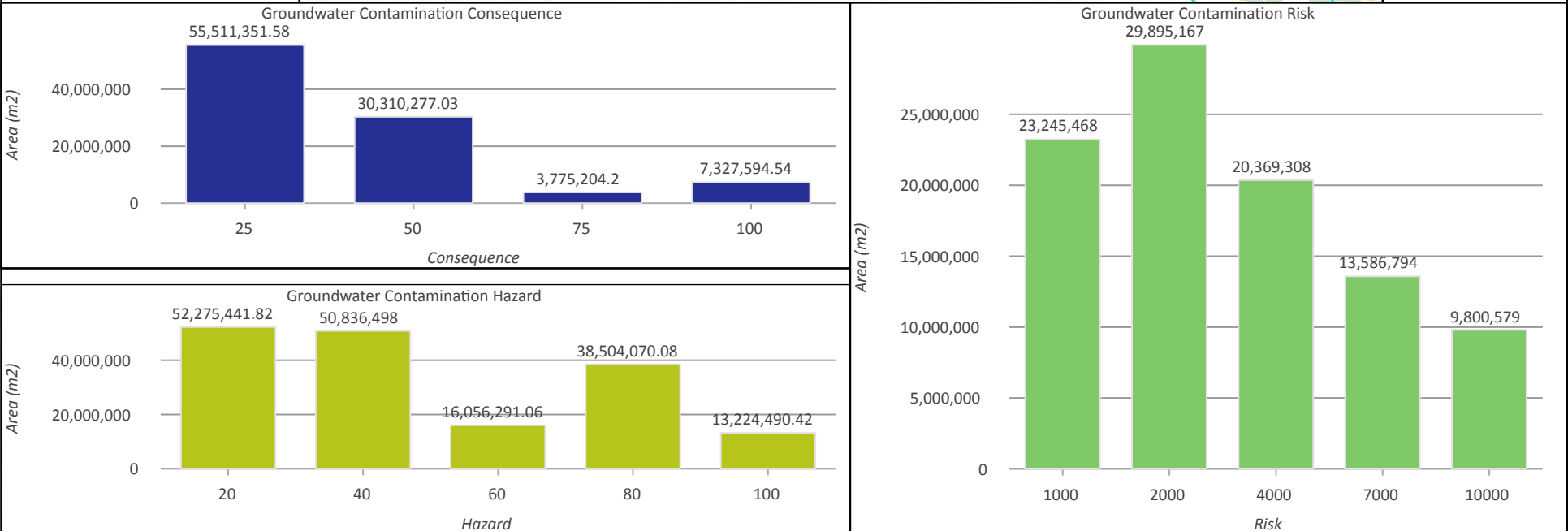


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

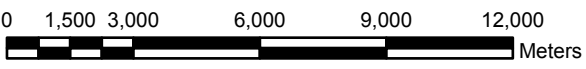
CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Koksilah River Watershed

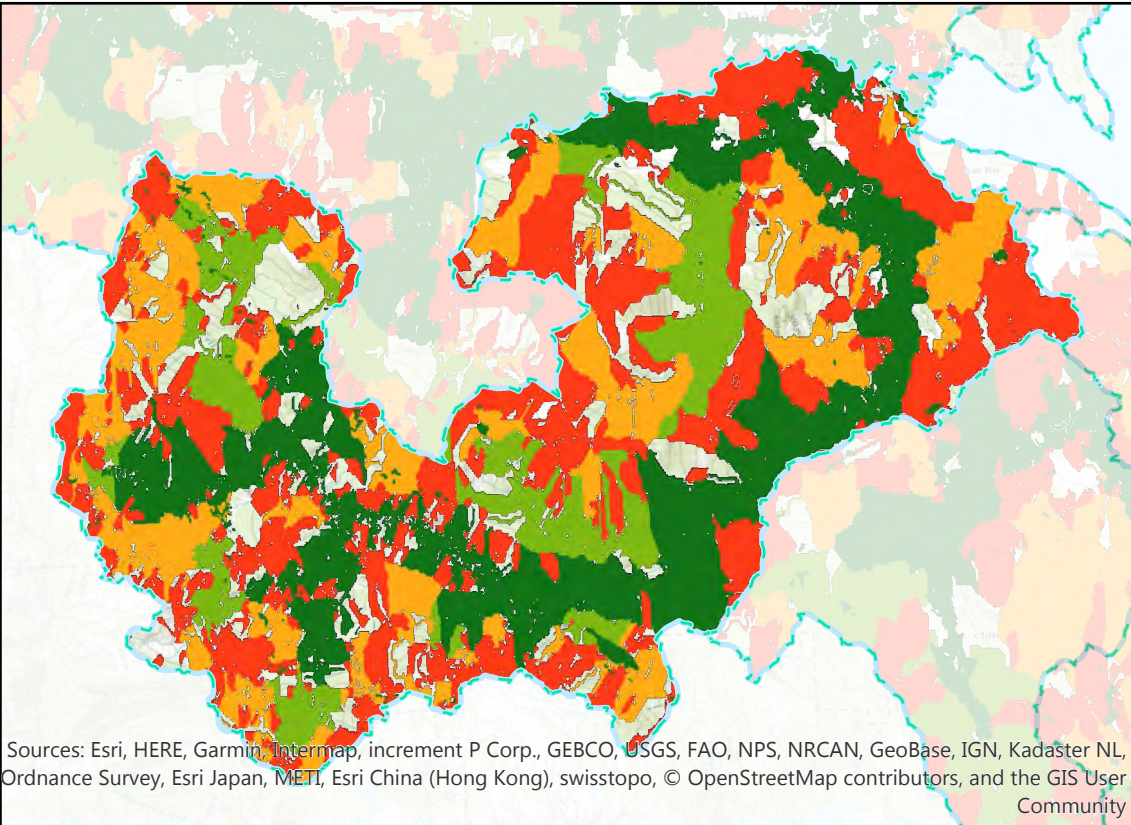


Groundwater Contamination Risk Assessment - Koksilah River

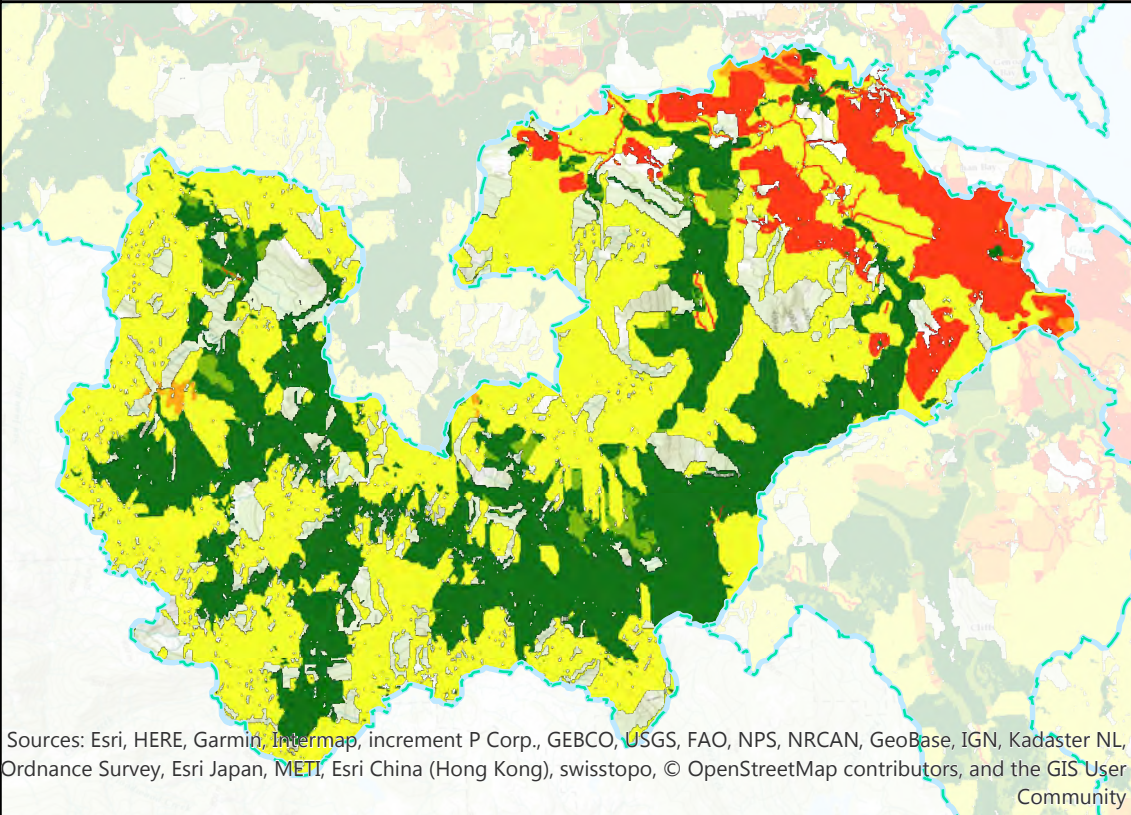
BY: CJW	SCALE CONS: 1:179,371	DATE: 2019/01/08	REF No:	REV: 0
CHK'D: DK	Proj Coord Sys: NAD 1983 UTM Zone 10N		651957-103-KOKS	



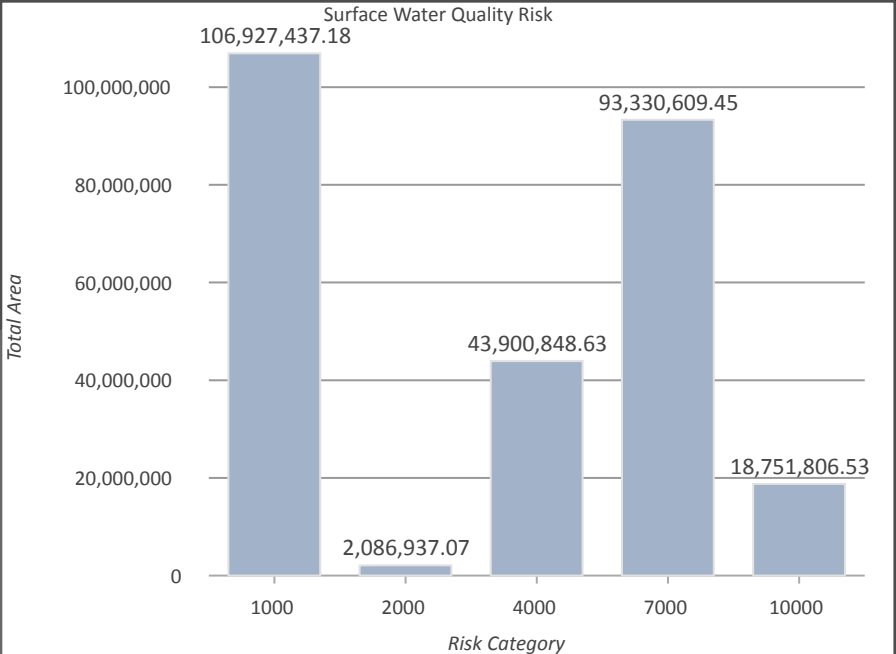
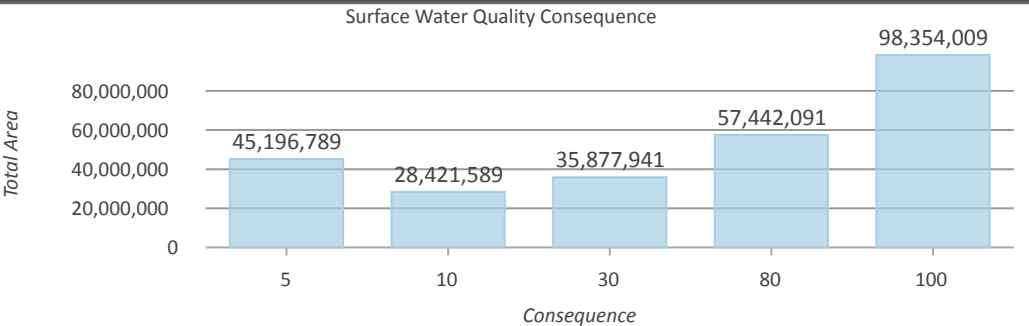
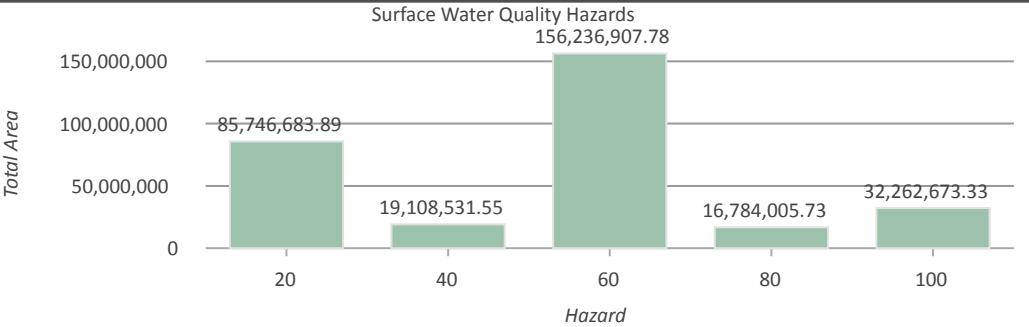
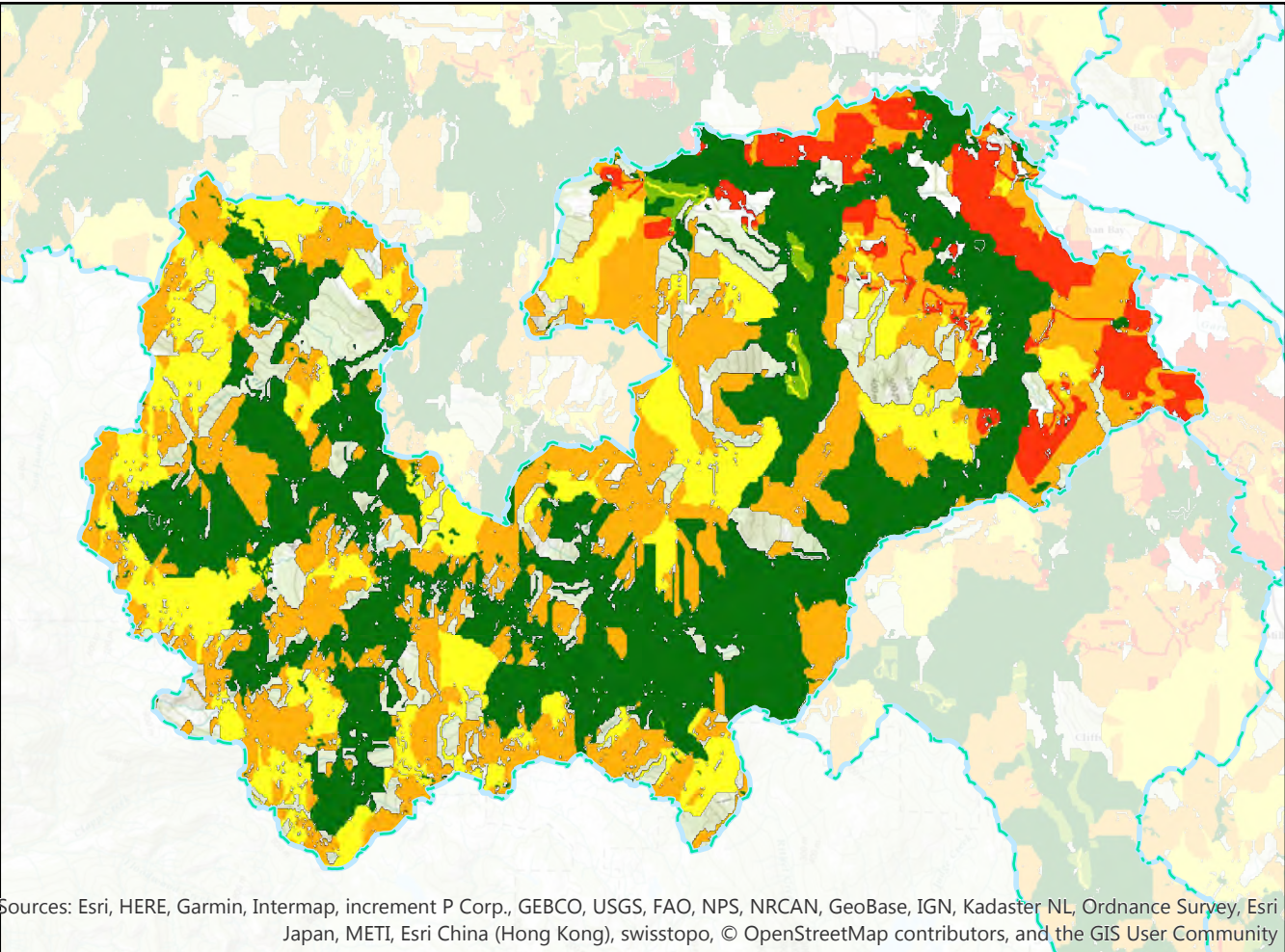
CONSEQUENCE



HAZARD



RISK



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
 ≤ 40
 ≤ 60
 ≤ 80
 ≤ 100

RISK

≤ 1000
 ≤ 2000
 ≤ 4000
 ≤ 7000
 ≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

NOTES:

1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.

REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District Koksilah River Watershed



SNC • LAVALIN

Surface Water Quality Risk Assessment - Koksilah River

BY:

SCALE: 1:185,563

DATE: 2019/01/08

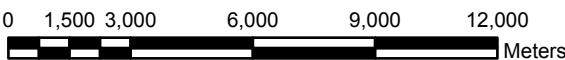
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REV: **0**

CHK'D:

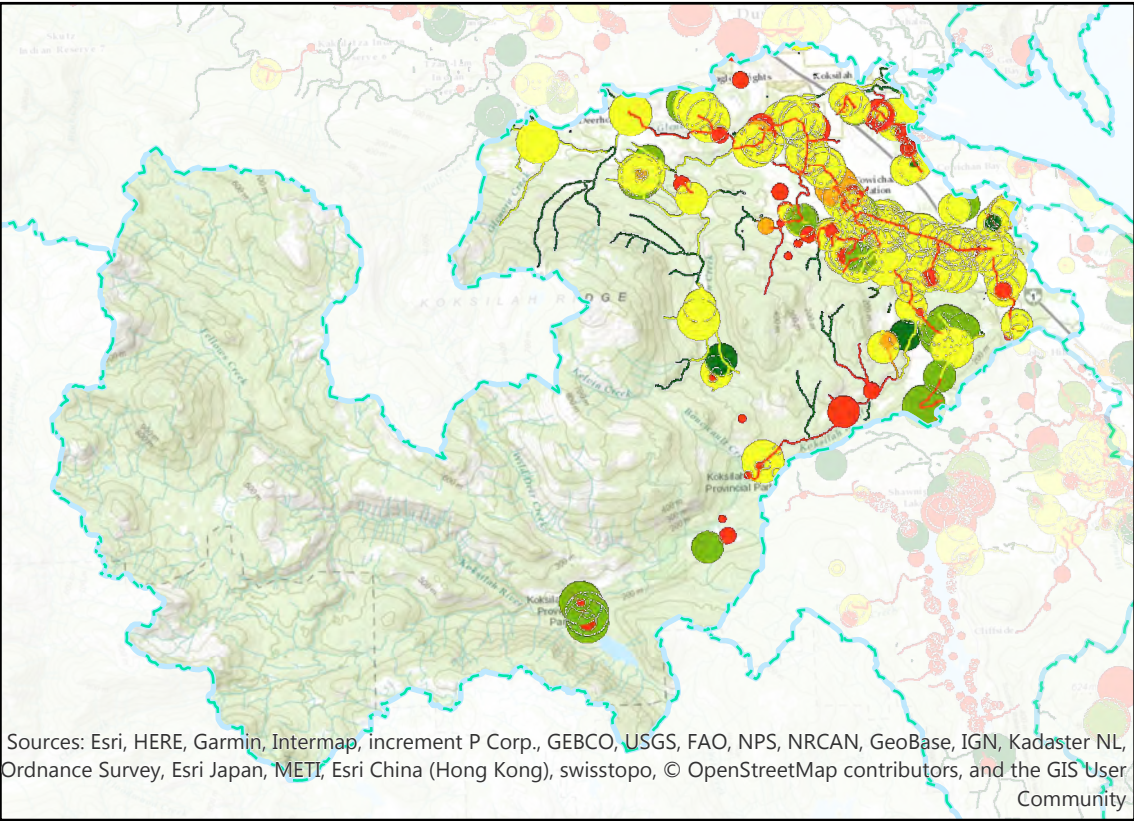
Proj Coord Sys: PCS Albers

651957-104-KOKS



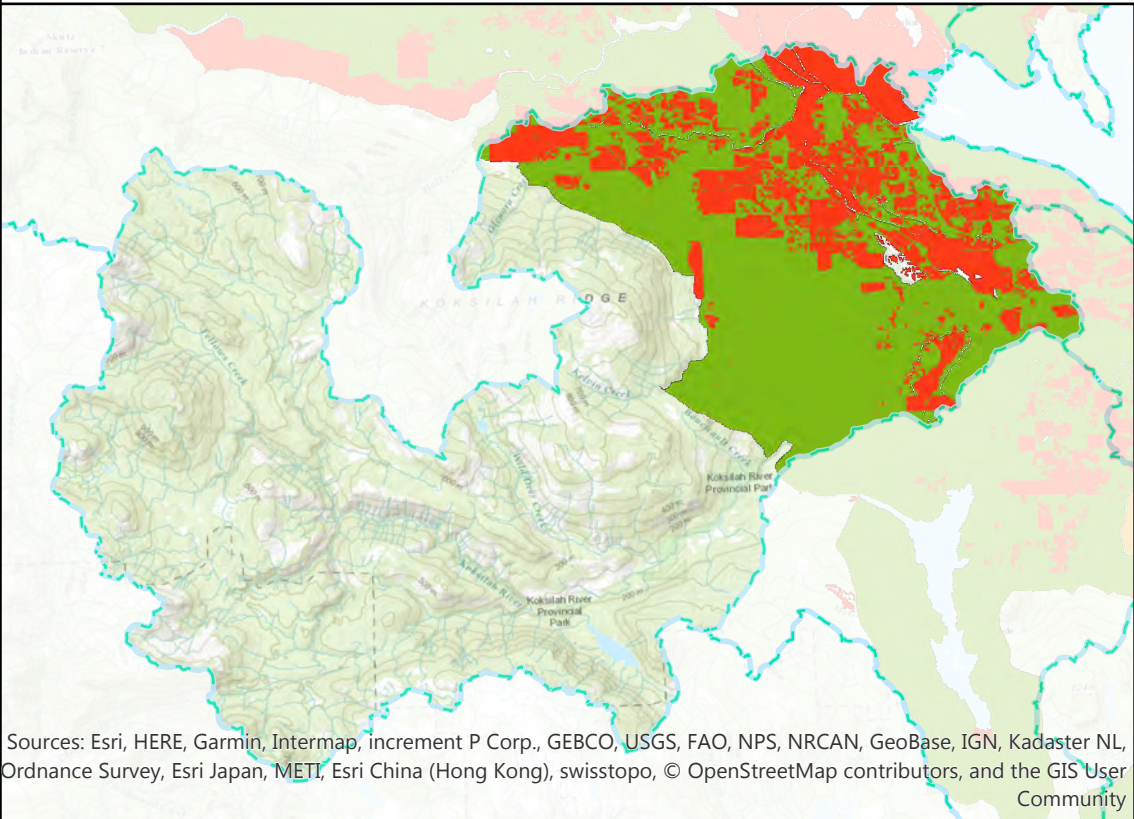
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CONSEQUENCE



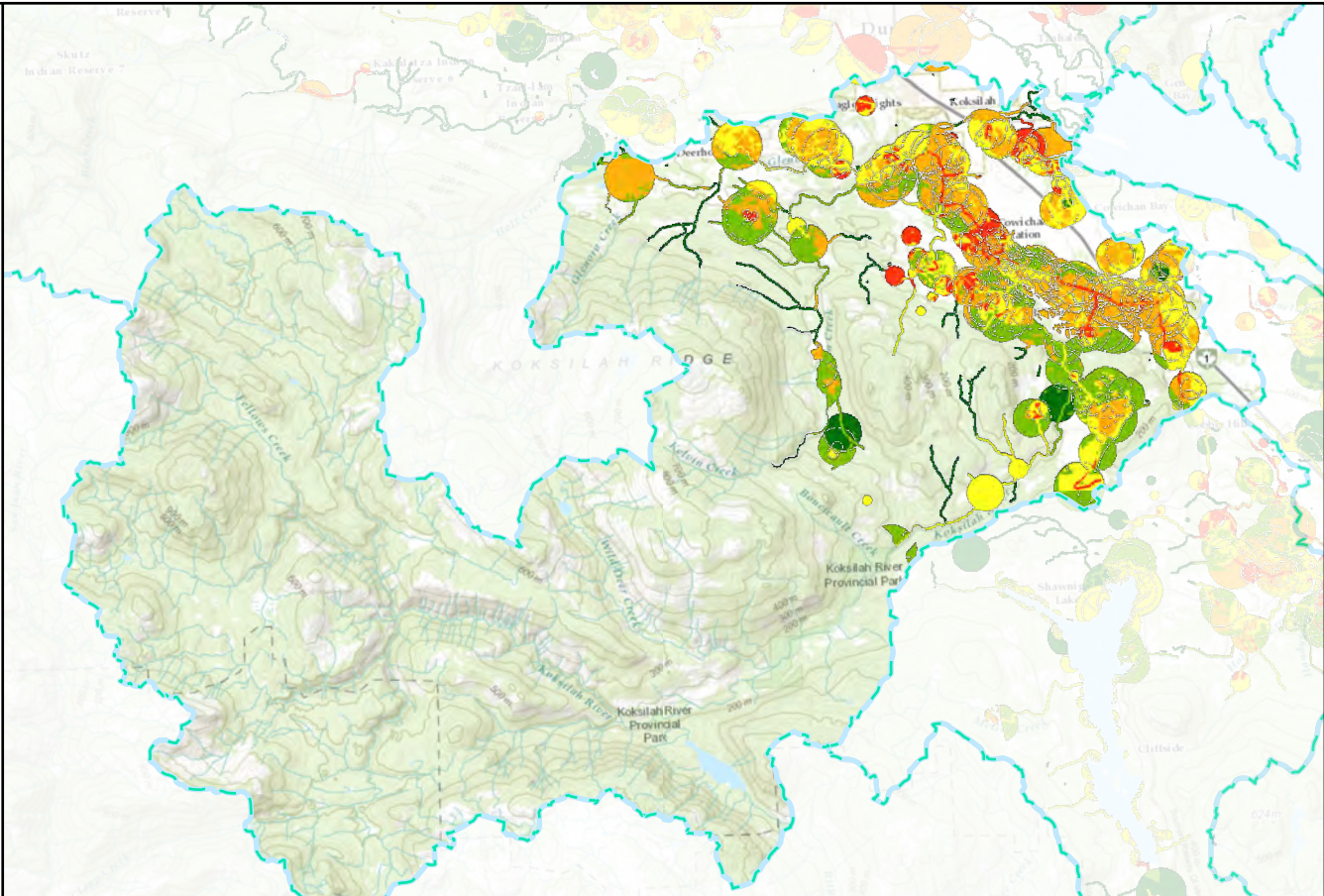
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

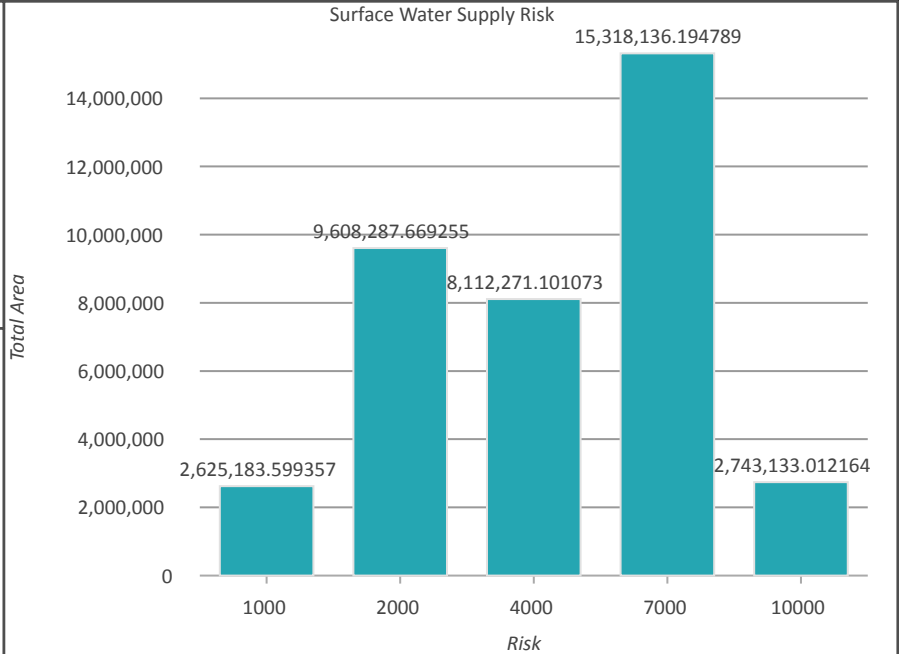
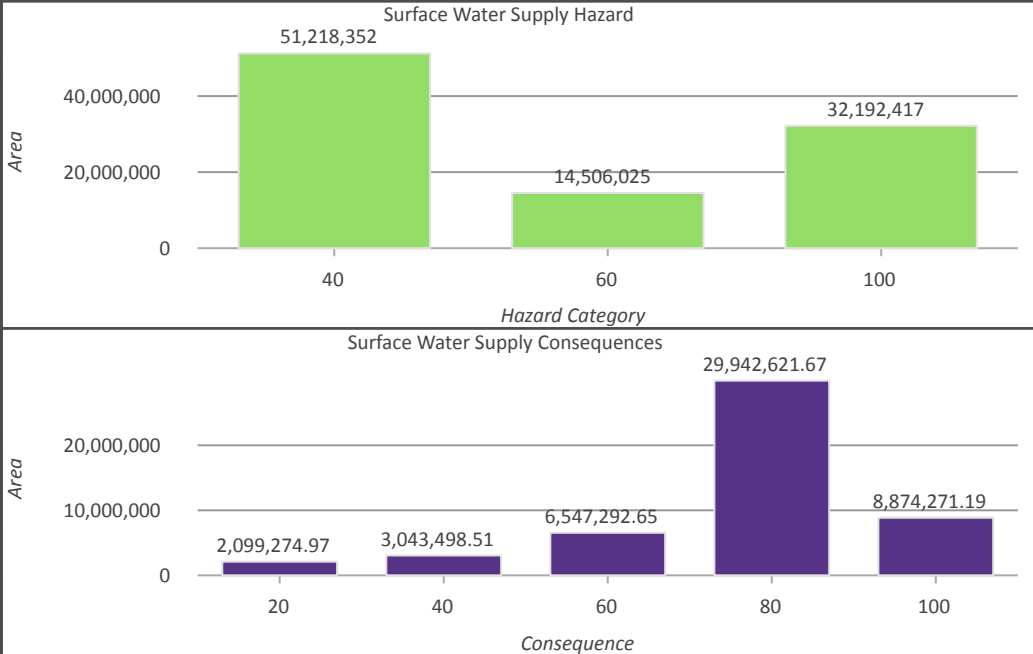


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District Koksilah River Watershed

BY:

CHK'D:

SNC • LAVALIN

Surface Water Supply Risk Assessment - Koksilah River

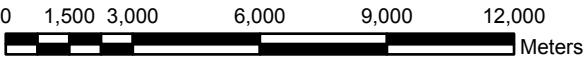
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DATE: 2019/01/08

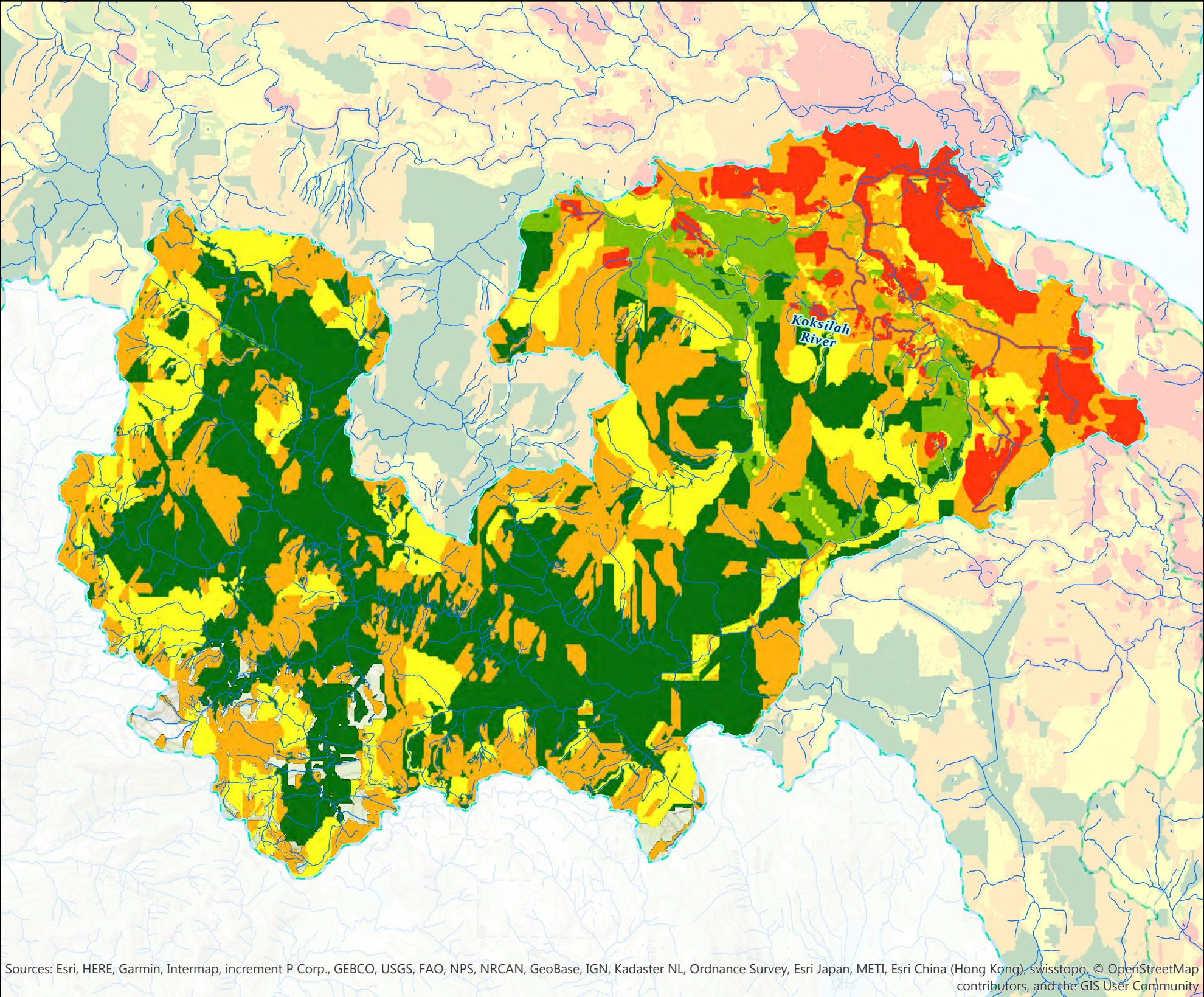
REF No:

REV: 0

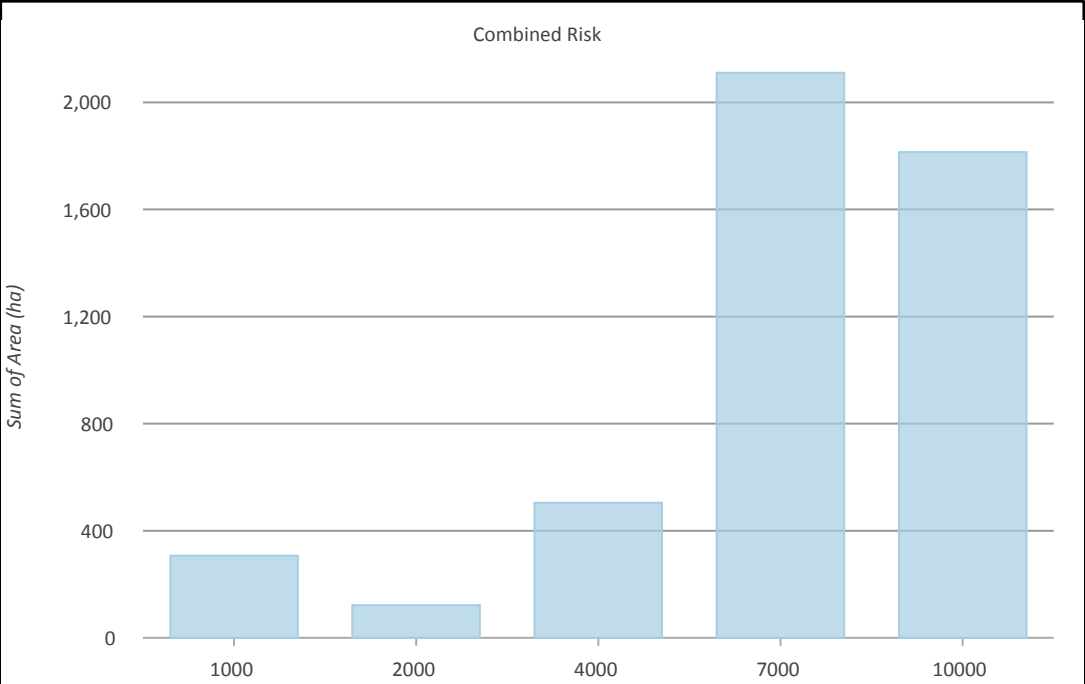
651957-105-KOKS



MXD Path: D:\Local\Projects\651957_CV\RD\GIS\CV\RD\Presentation\CV\RD\Presentation.aprx



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



NAME	Risk	POP2021	POP2026	POP2031	POP2036
SHAWNIGAN CREEK		10047	10760	11613	12598
BUSH CREEK		0	0	0	0
KOKSILAH RIVER		5463	5851	6315	6850
HOLLAND CREEK		1302	1368	1446	1537
BONSALL CREEK		934	974	1019	1073
CHEMAINUS RIVER		1490	1461	1439	1421
COWICHAN RIVER		36368	37905	39683	41766
YELLOW POINT BENCHLANDS		2239	2352	2487	2643
LADYSMITH - SALT AIR BENCHLANDS		8410	8834	9342	9929
STOCKING CREEK		1531	1608	1701	1807
CHEMAINUS BENCHLANDS		3663	3818	3997	4207
SATELLITE CHANNEL BENCHLANDS		4390	4701	5074	5504
SANSUM NARROWS - COWICHAN BAY BENCHLANDS		4941	5150	5391	5674
MALAHAT BENCHLANDS		2829	3030	3271	3548

NAME	POP2001	POP2006	POP2011	POP2016
SHAWNIGAN CREEK	6348	8439	8925	9484
BUSH CREEK	0			
KOKSILAH RIVER	4555	4808	4954	5157
HOLLAND CREEK	1611	1114	1169	1245
BONSALL CREEK	672	830	815	890
CHEMAINUS RIVER	1423	1395	1497	1514
COWICHAN RIVER	29779	32673	34075	34647
YELLOW POINT BENCHLANDS	1167	1958	2021	2141
LADYSMITH - SALT AIR BENCHLANDS	5275	7488	7541	8042
STOCKING CREEK	1332	1003	1354	1464
CHEMAINUS BENCHLANDS	3177	3129	3085	3490
SATELLITE CHANNEL BENCHLANDS	5425	3902	3989	4144
SANSUM NARROWS - COWICHAN BAY BENCHLANDS	5993	4221	4500	4707
MALAHAT BENCHLANDS	1673	2472	2548	2671

Legend

WATERSHED BOUNDARIES

RISK

	≤ 1000
	≤ 2000
	≤ 4000
	≤ 7000
	≤ 10000

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REVISIONS:

0 - CJW - 2018-11-30 - Issued - DK

CLIENT:
Cowichan Valley Regional District

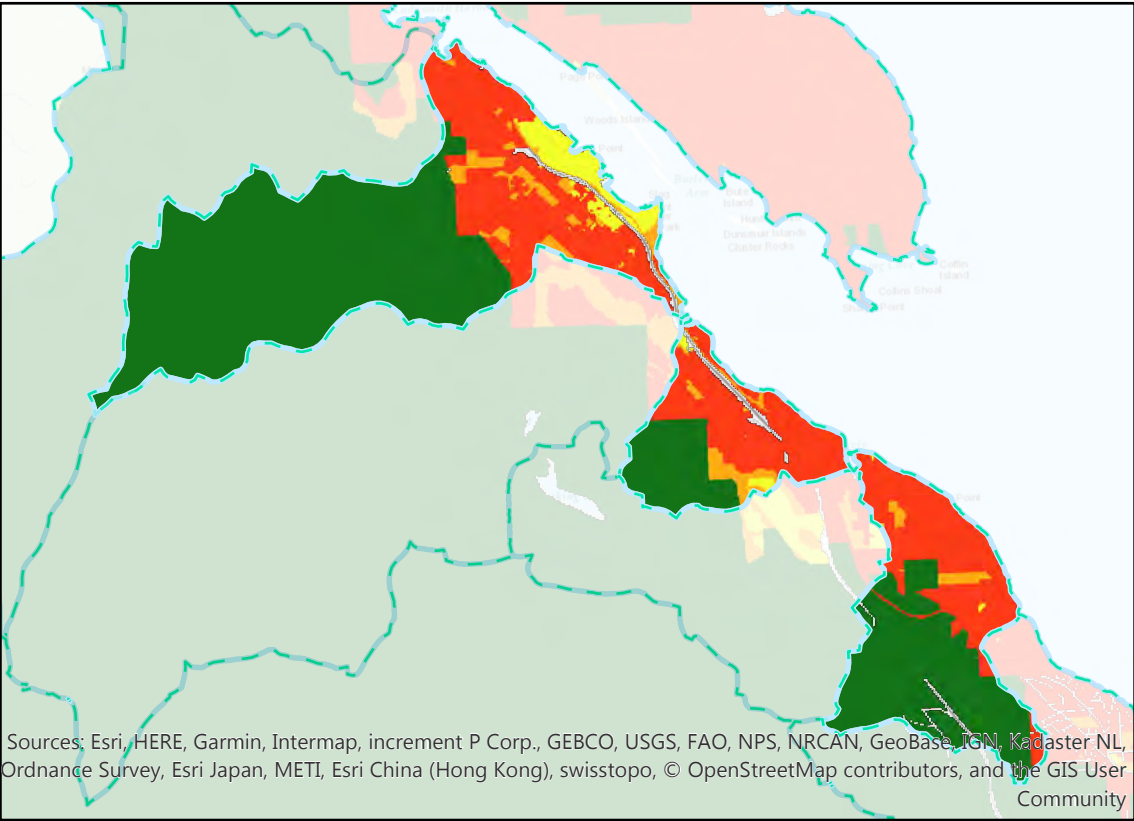
PROJECT LOCATION:
Cowichan Valley Regional District
Koksilah River Watershed

Combined Risk Assessment - Koksilah River

BY: CJW	SCALE CONS: 1:121,000	DATE: 2019/01/08	REF No:	REV: 0
CHK'D: DK	Proj Coord Sys: NAD 1983 UTM Zone 10N	651957-106-KOKS		

8. Ladysmith - Saltair Benchlands	
Topic	Discussion
Slope Failure	<p>Hazard was determined qualitatively at a high level to describe areas based on the degree to which they may be prone to landslides and other mass movements using terrain characteristics. Hazard classifications were generated to show relative comparisons between terrain units within the CVRD watershed study area. Risk ratings derived from this analysis are relative, and should be used to guide prioritization of further detailed studies.</p> <p>Hazard is generally low throughout the watershed. Hazard is greatest toward the upland areas at the southwestern edges of the watershed where logging has occurred on slopes. Consequence is considered high through the populated areas near the ocean between Ladysmith and Saltair. Risk is considered moderate in these populated areas.</p>
Flooding	<p>Only a few creeks are present within the watershed. The eastern side of the watershed contains the highest consequence and risk due to settlements in Ladysmith and along the coast between Ladysmith and Chemainus. Very low risk is presented outside of these areas.</p>
Groundwater Contamination	<p>Likelihood is greatest at populated areas in Ladysmith and nearby residential coastal communities south of the main town centre. Levels of risk are relatively low throughout the watershed.</p>
Surface Water Quality	<p>Hazard is greatest in the developed areas of Ladysmith and Saltair. Consequence is greatest surrounding Saltair, northeast of Stocking Lake, and portions of the forested or logged area west of Ladysmith where smaller streams are present. Risk is greatest in Ladysmith, along a smaller order stream near Davis Road, and surrounding Saltair where there is relatively greater impervious surface cover and agricultural areas. The extent of higher risk areas is expected to increase with projected population increases.</p>
Surface Water Supply	<p>Hazard is greatest in an inland zone west of Ladysmith, and in a zone southwest of Saltair. There is one small zone of moderate hazard along the coast, north of Ladysmith. Consequence is considered very low for the majority of the watershed areas, and is greatest in the stream that intersects the north end of Ladysmith. Risk is greatest in an isolated zone southeast of Saltair and along one of the stream corridors and moderate to low north of Ladysmith. Population is projected to increase across these watershed areas, and depending on distribution of the growth, there is potential to add pressure on groundwater sources that may increase the level of hazard and risk.</p>
General Data Notes	<p>As one of the more populous watersheds with a small proportion of the overall stream network in it, the contribution to risk is primarily around anthropogenically driven risks, such as surface water quality, groundwater contamination, and surface water supply. Some risk from slope and flooding is also present.</p>

CONSEQUENCE



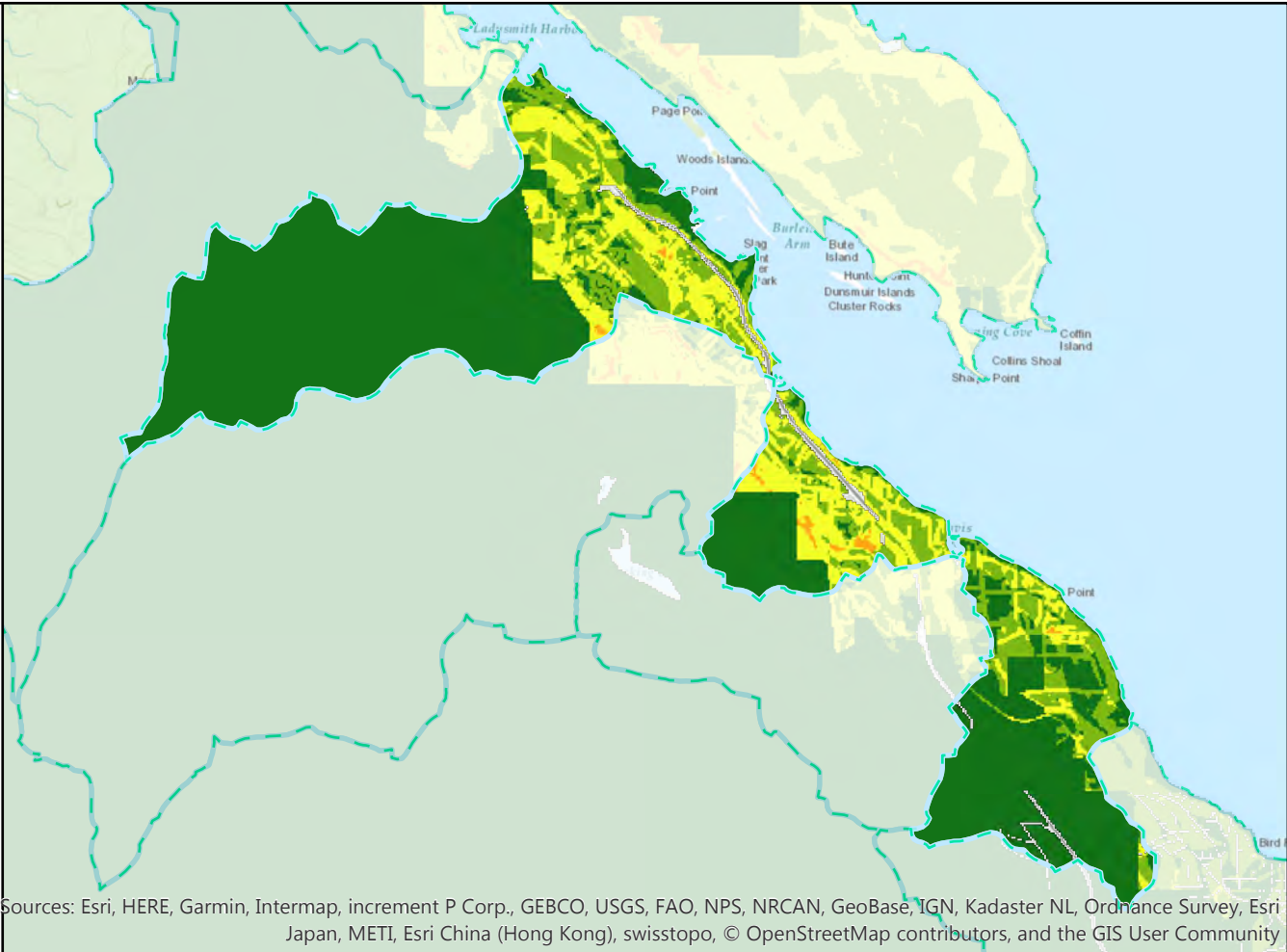
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

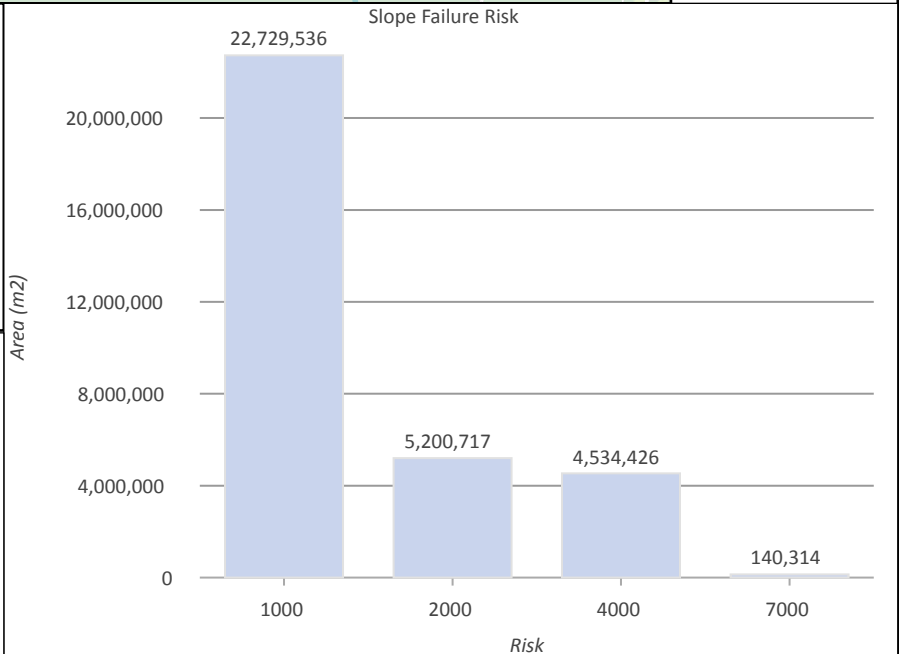
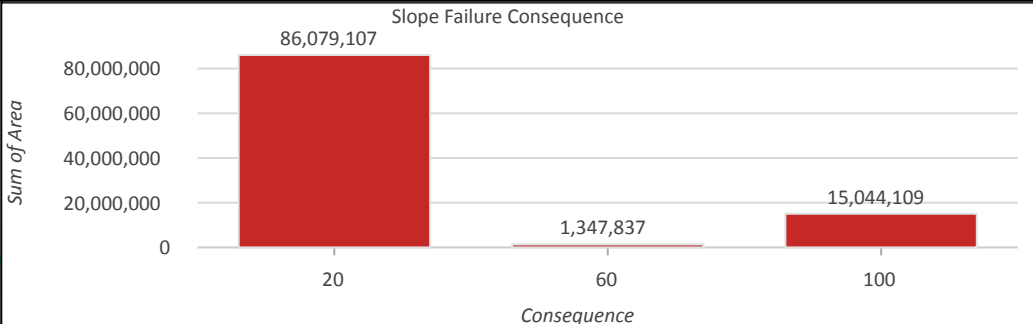
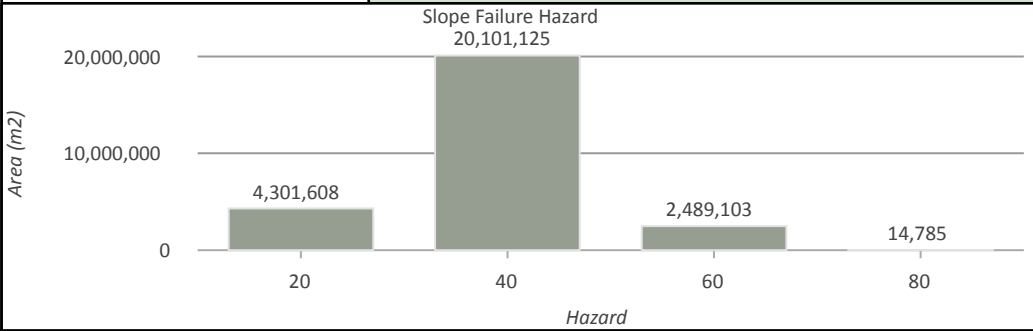


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Ladysmith - Saltair Benchlands Watershed



Slope Failure Risk Assessment - Ladysmith -

BY: CJW

SCALE CONS: 1:89,288

DATE: 2019/01/07

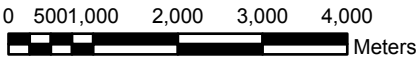
REF No:

REV: 0

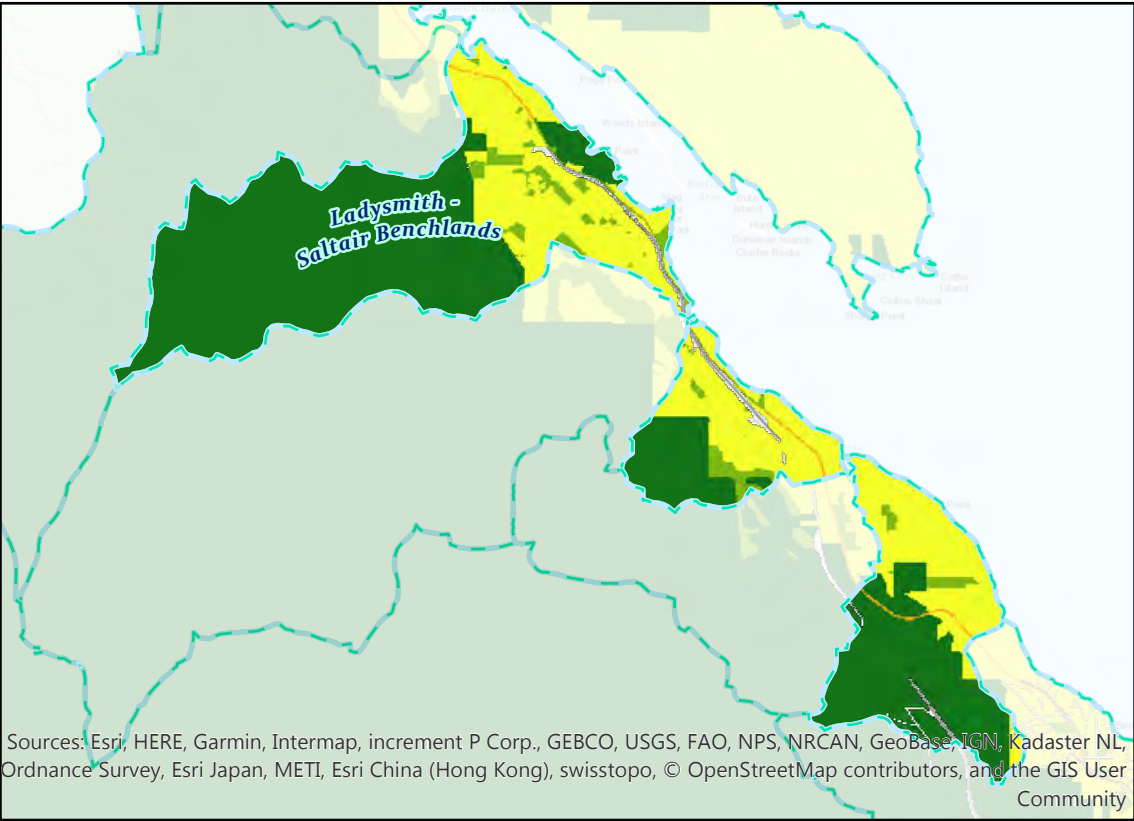
CHK'D: DK

Proj Coord Sys: PCS Albers

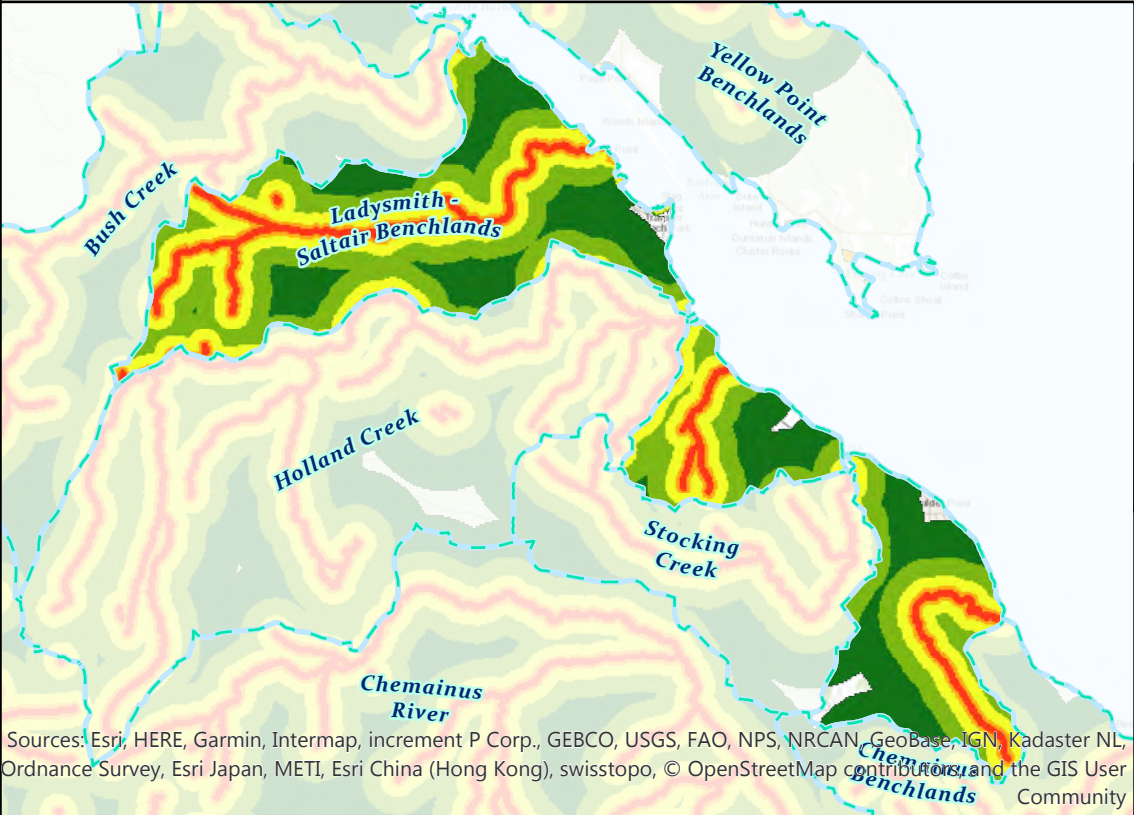
651957-101-LSSB



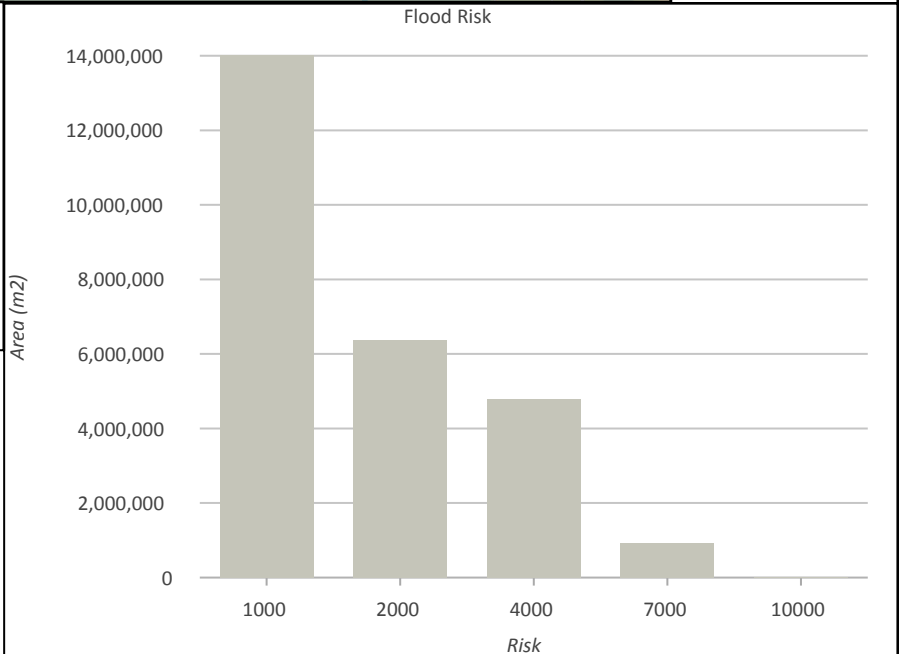
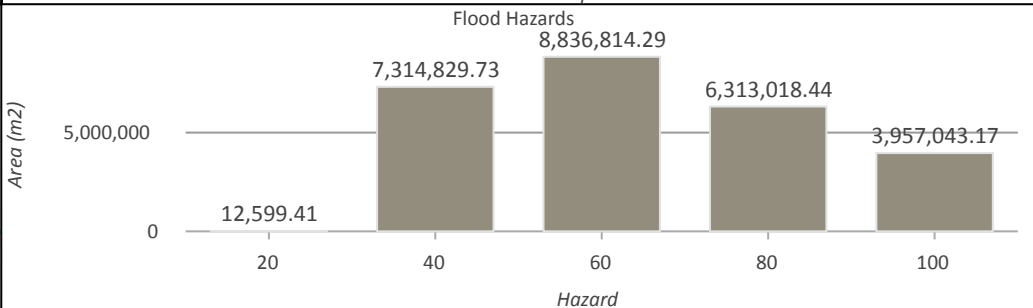
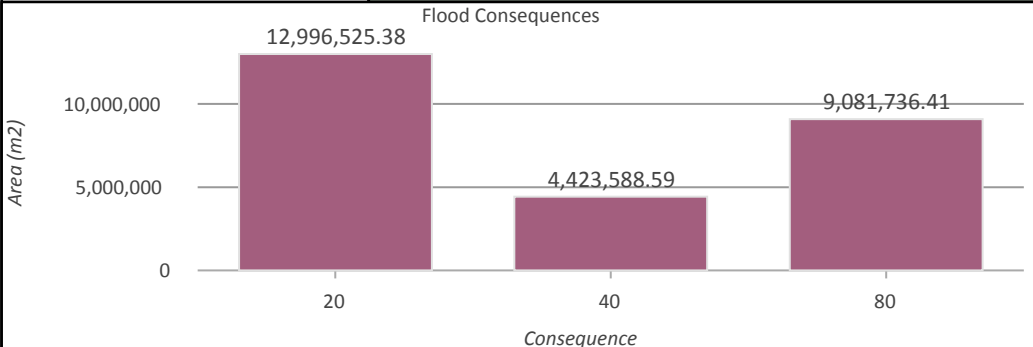
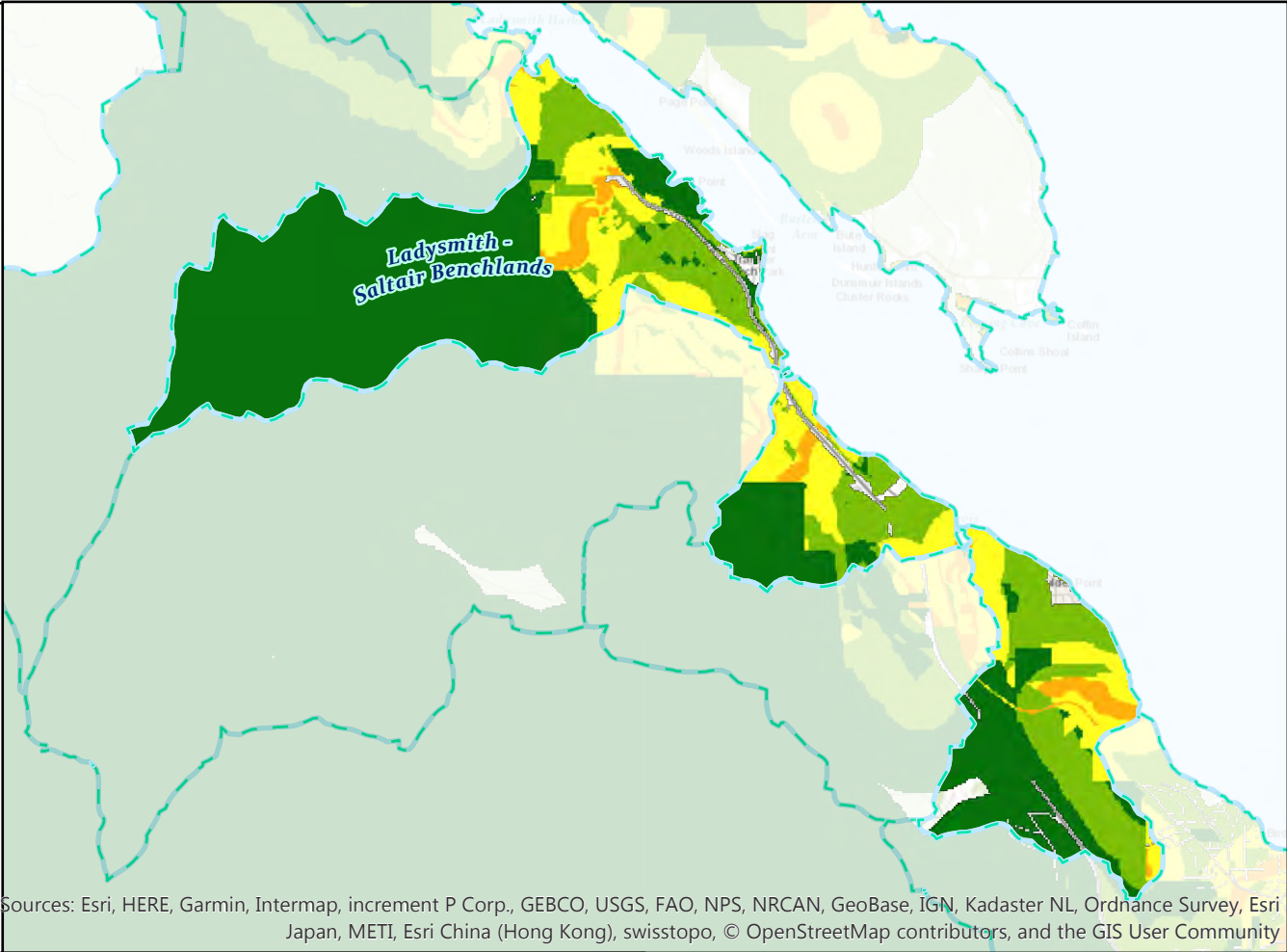
CONSEQUENCE



HAZARD



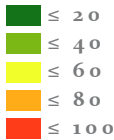
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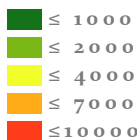
Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS



RISK



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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Ladysmith - Saltair Benchlands Watershed



Flood Risk Assessment - Ladysmith - Saltair Benchlands

BY:

CJW

SCALE CONS: 1:89,260

DATE: 2019/01/08

REF No:

REV: 0

CHK'D:

DK

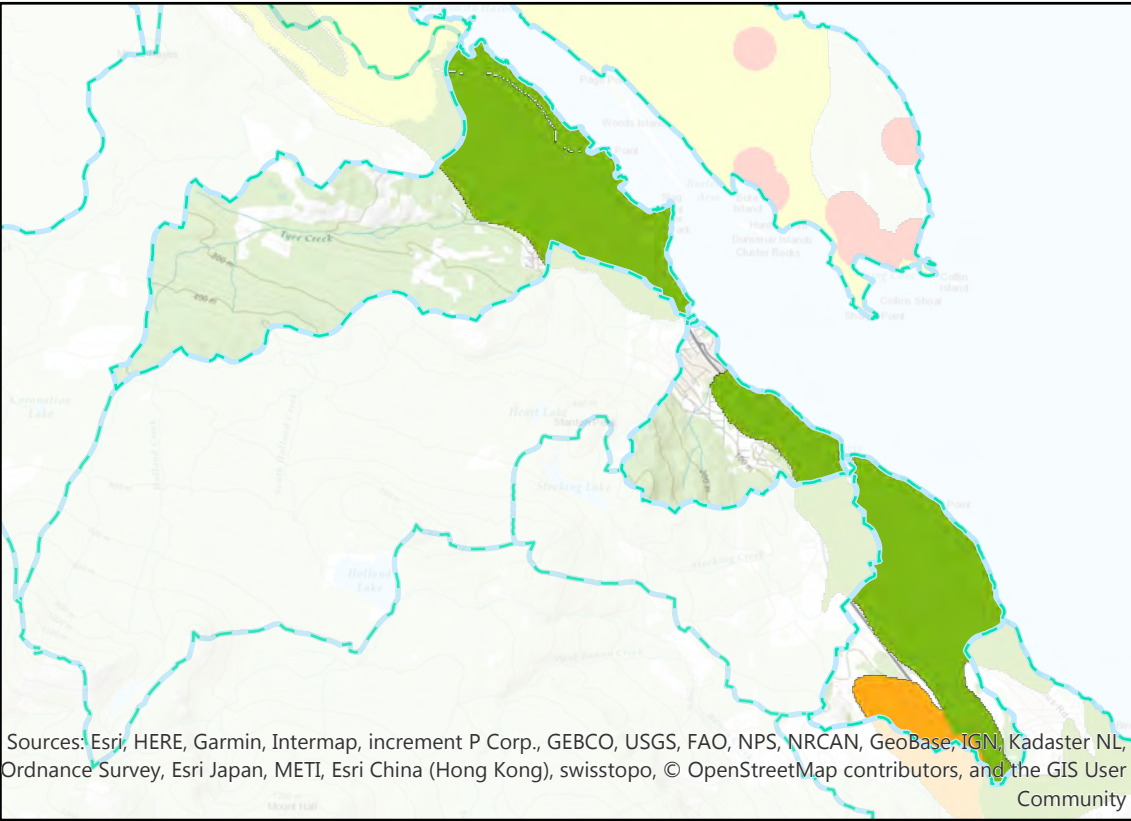
Proj Coord Sys: NAD 1983 UTM Zone 10N

651957-102-LSSB

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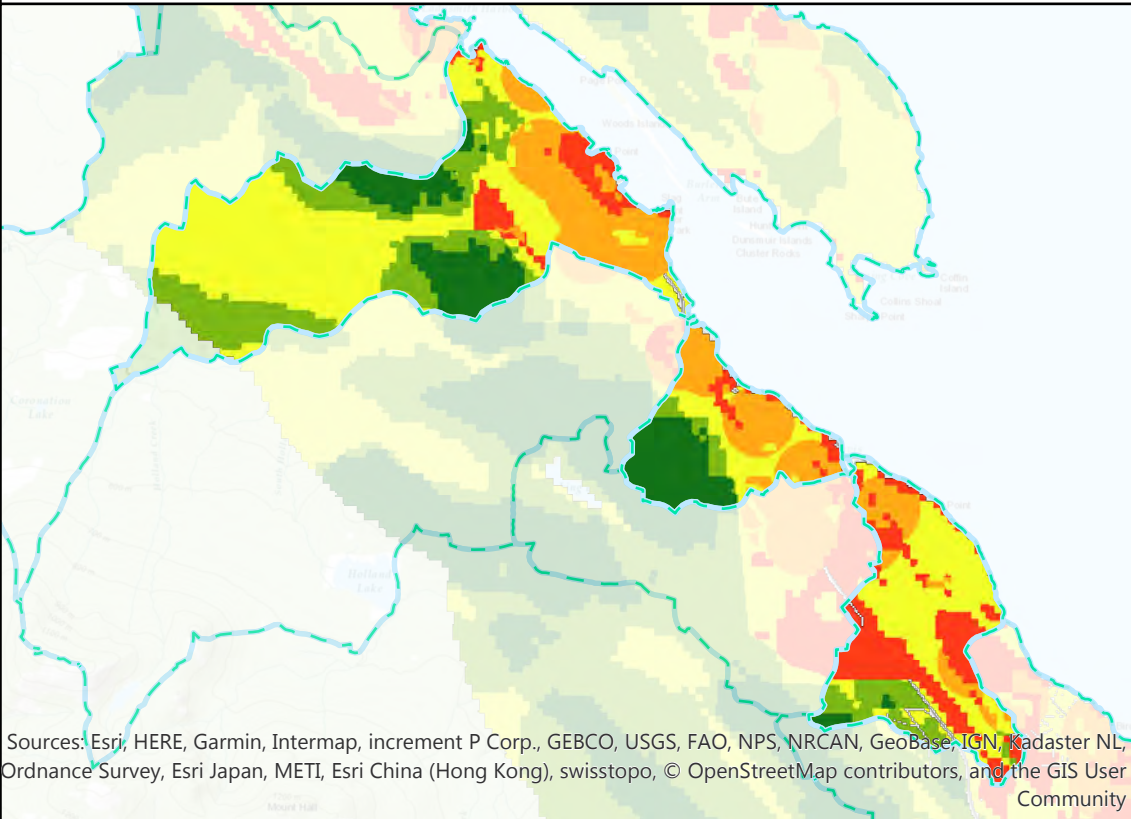
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CONSEQUENCE



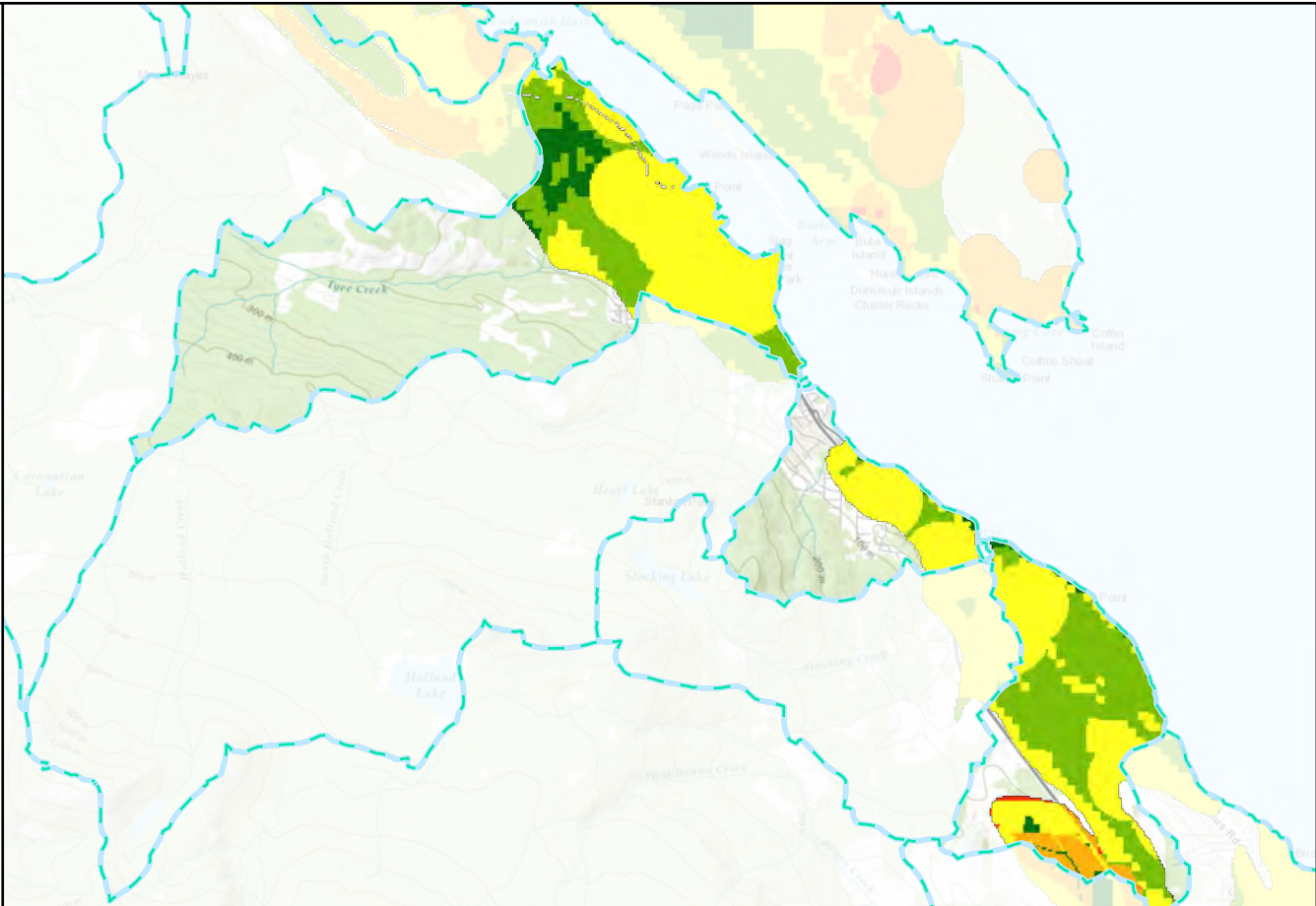
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

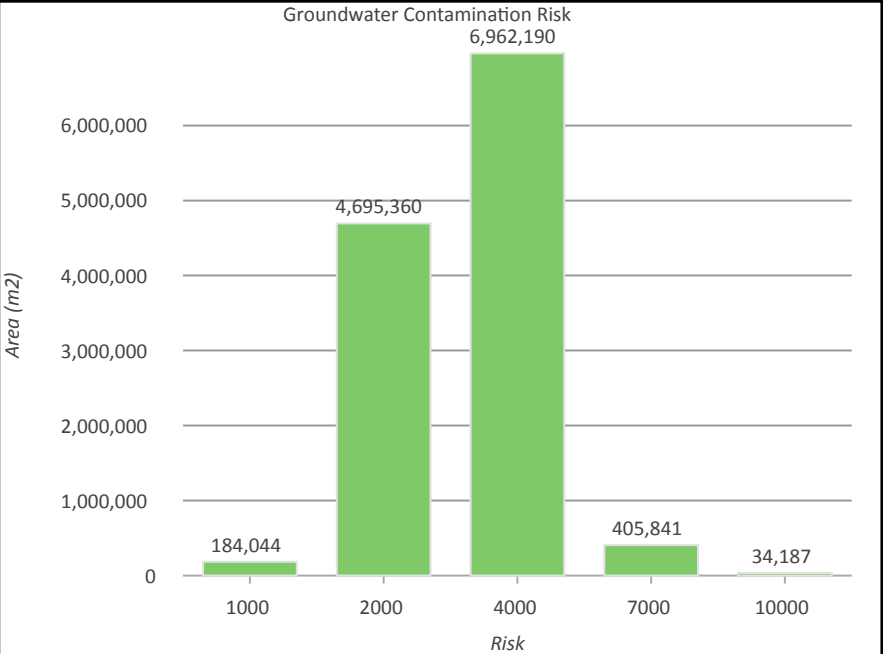
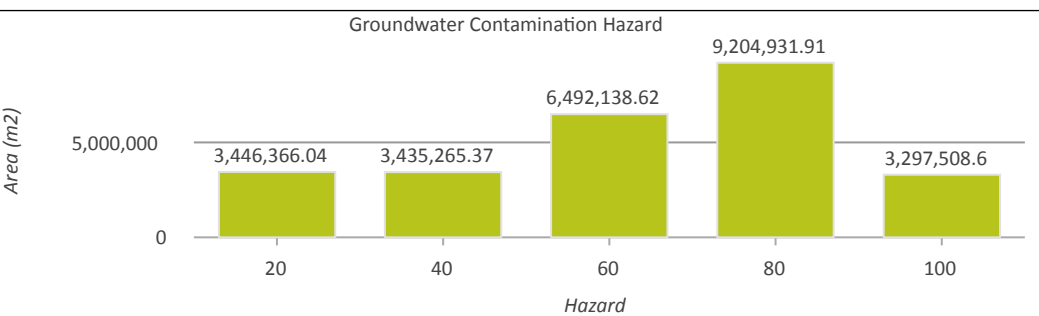
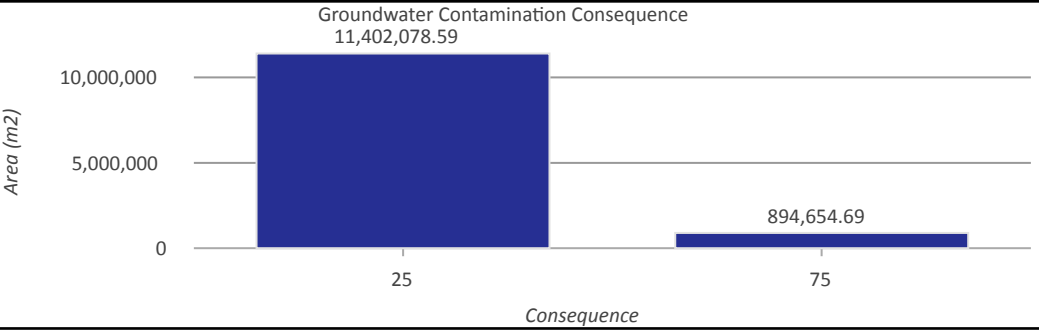


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



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Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Ladysmith - Saltair Benchlands Watershed



Groundwater Contamination Risk Assessment - Ladysmith - Saltair

BY: CJW

SCALE CONS: 1:89,260

DATE: 2019/01/08

REF No:

REV: 0

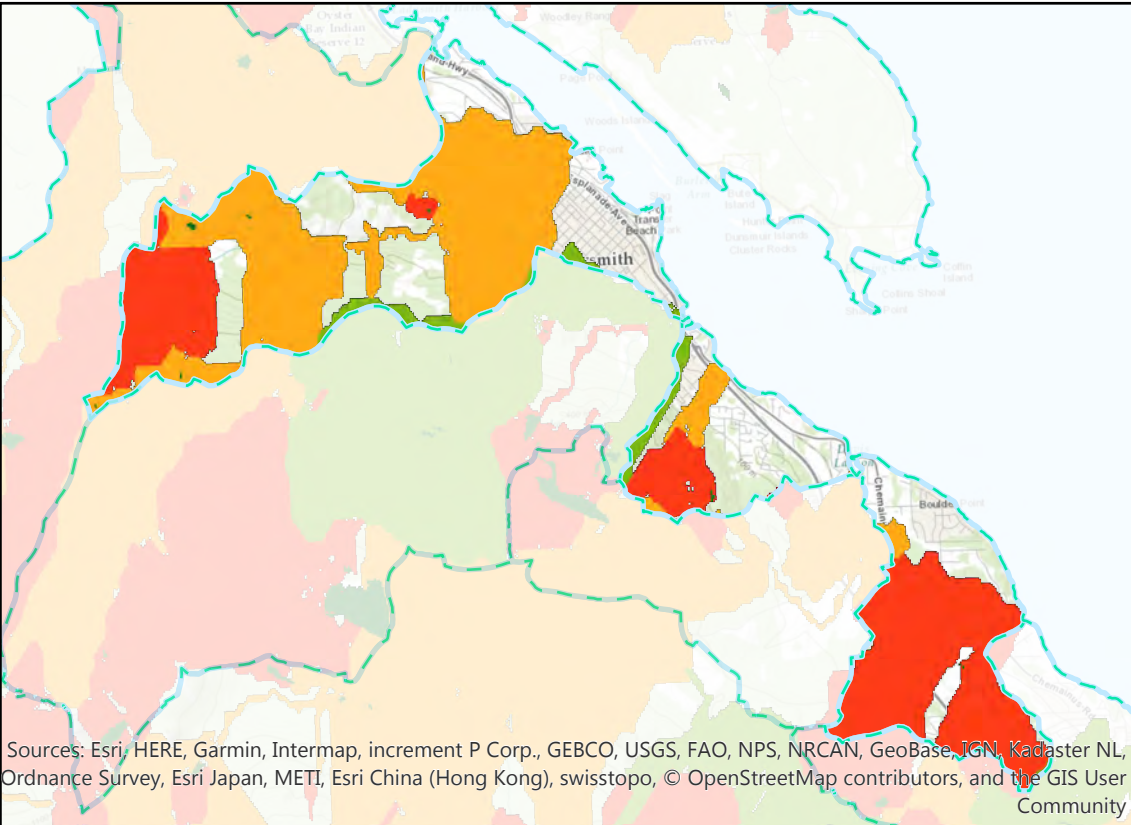
CHK'D: DK

Proj Coord Sys: NAD 1983 UTM Zone 10N

651957-103-LSSB

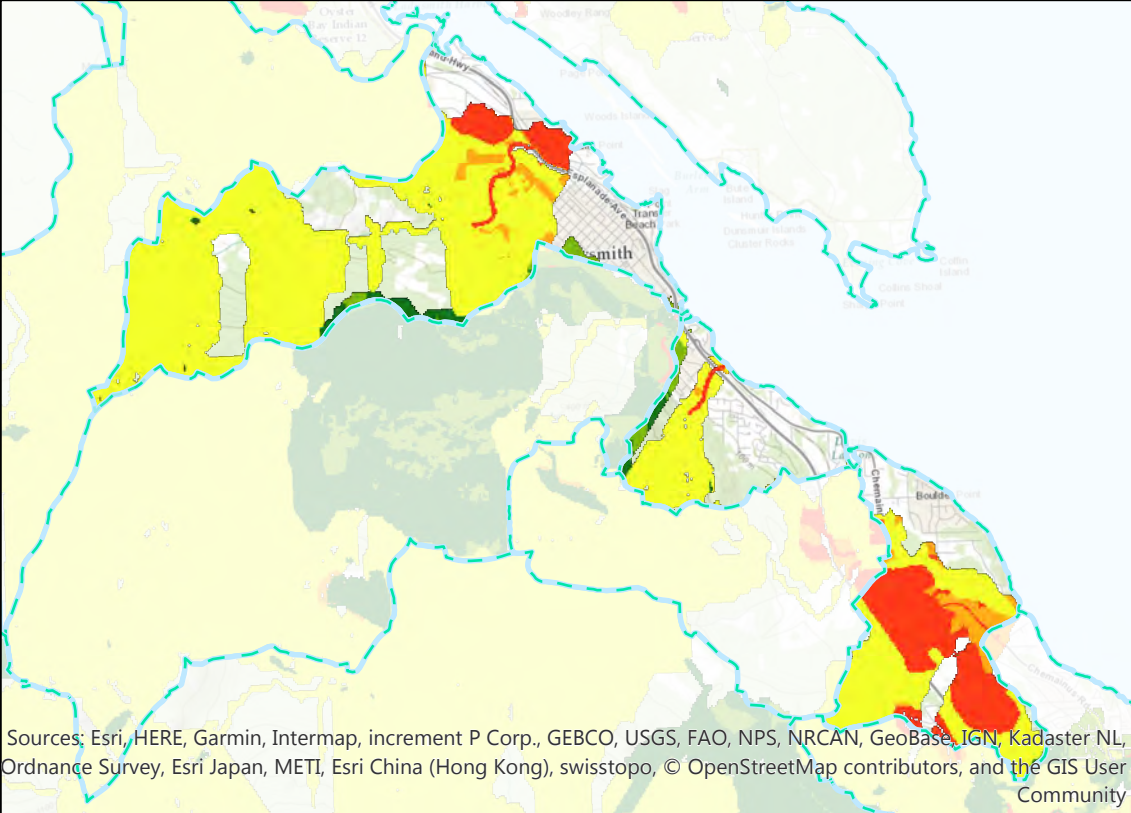


CONSEQUENCE



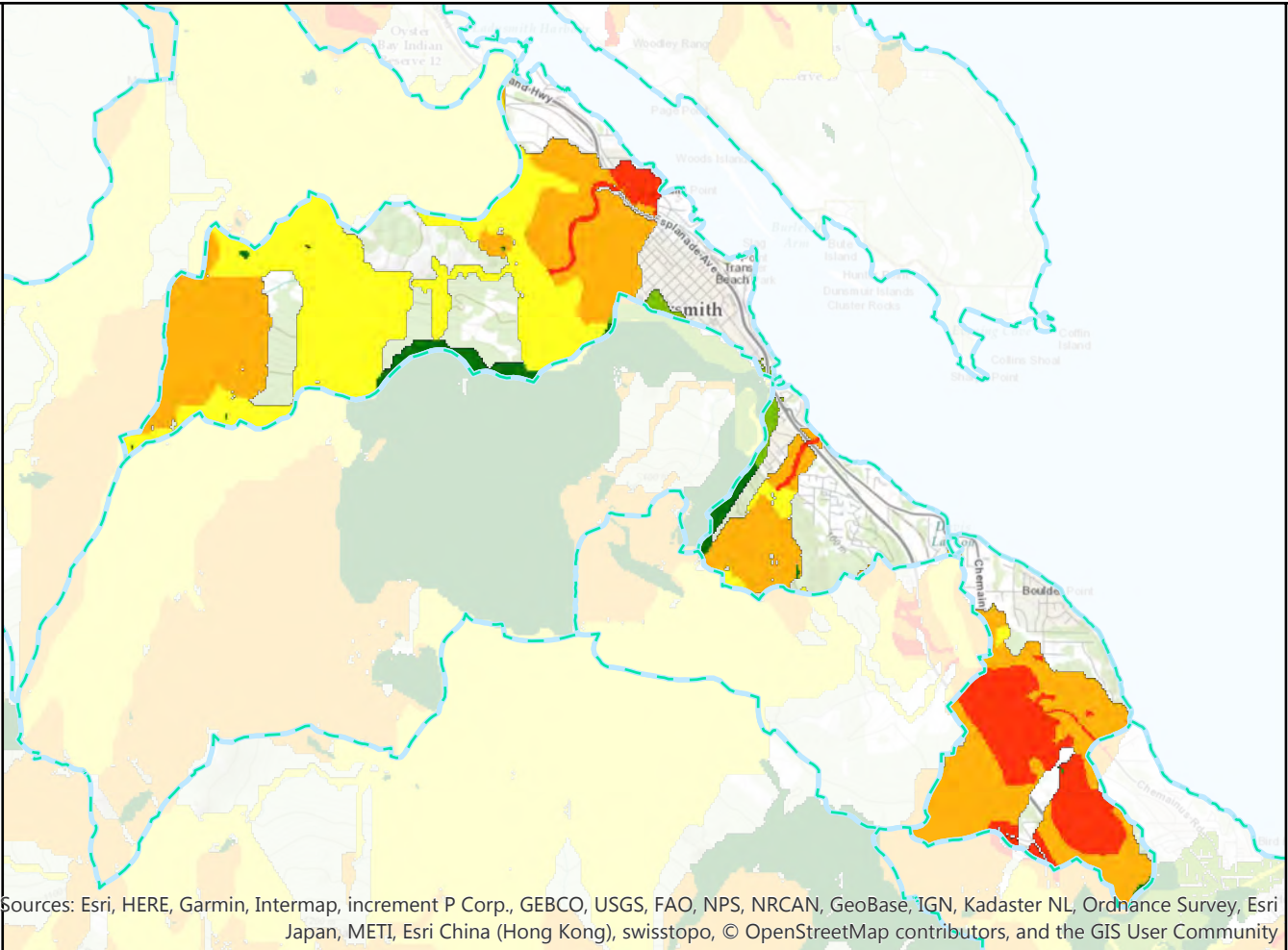
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HAZARD

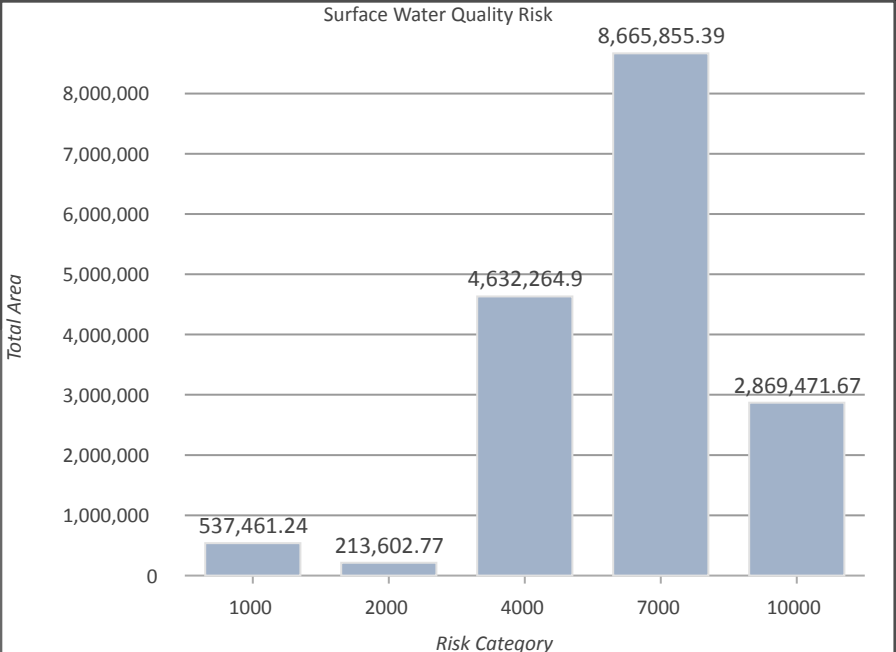
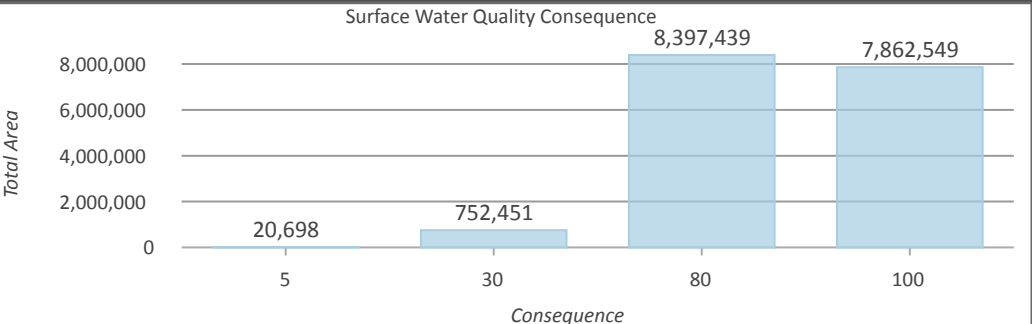
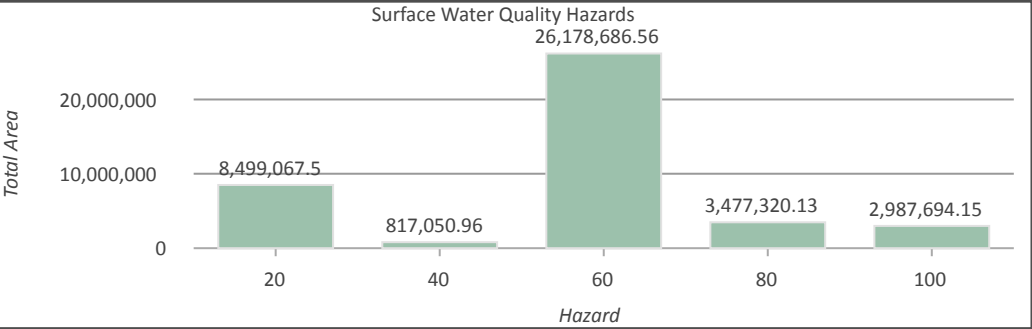


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RISK



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Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

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≤ 100

RISK

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional DistrictLadysmith -
Saltair Benchlands Watershed



Surface Water Quality Risk Assessment - Ladysmith - Saltair

BY:

SCALE: 1:89,211

DATE: 2019/01/08

REF No:

REV: 0

CHK'D:

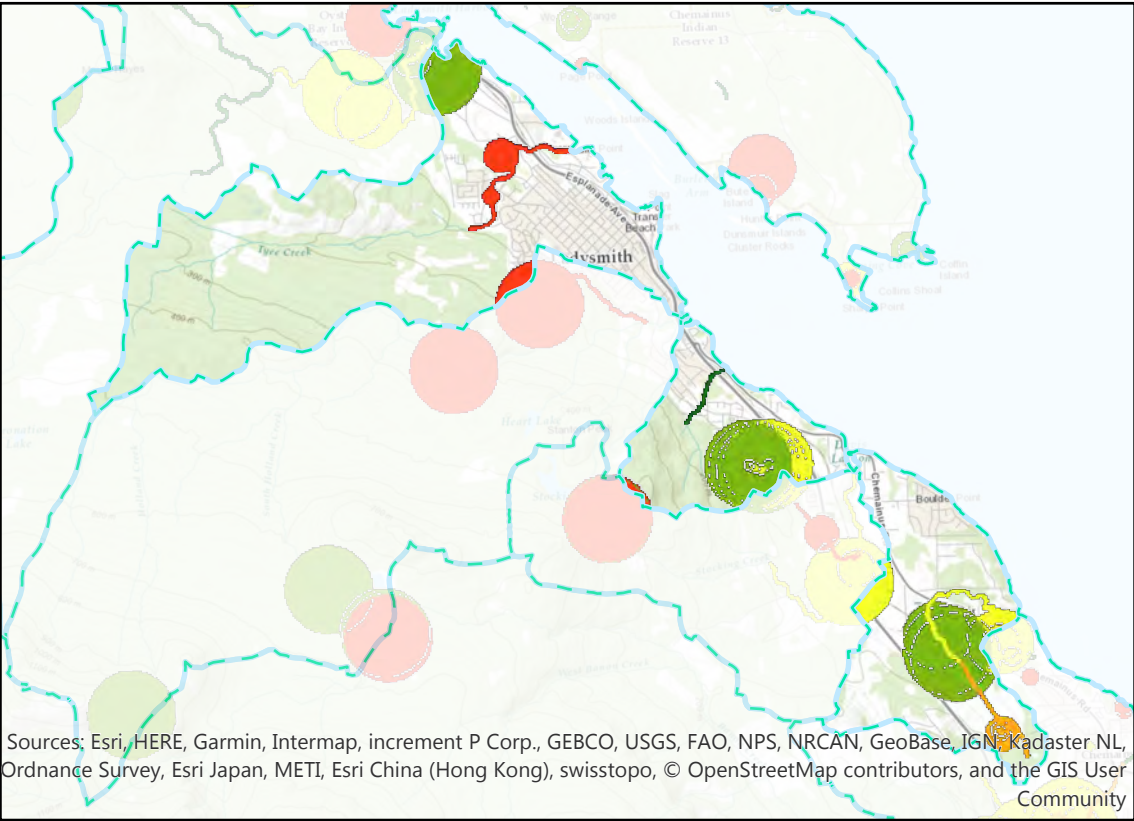
Proj Coord Sys: PCS Albers

651957-104-LSSB

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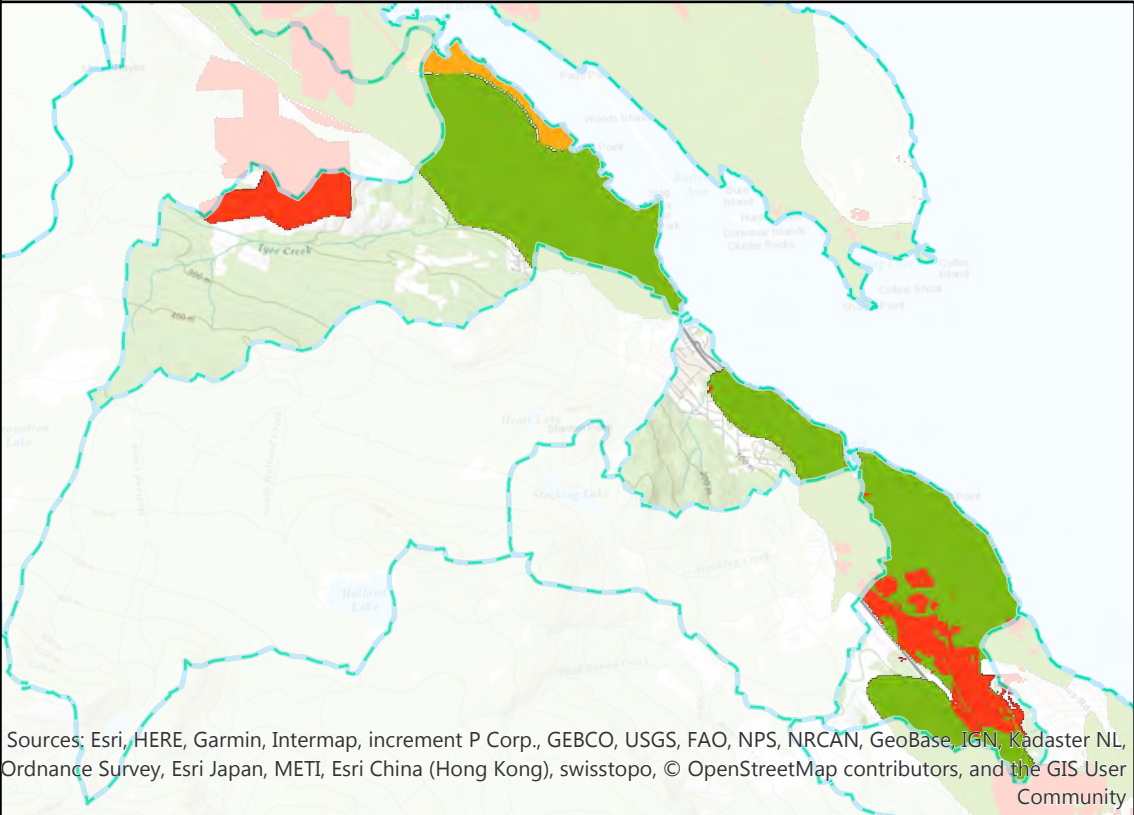
Meters

CONSEQUENCE



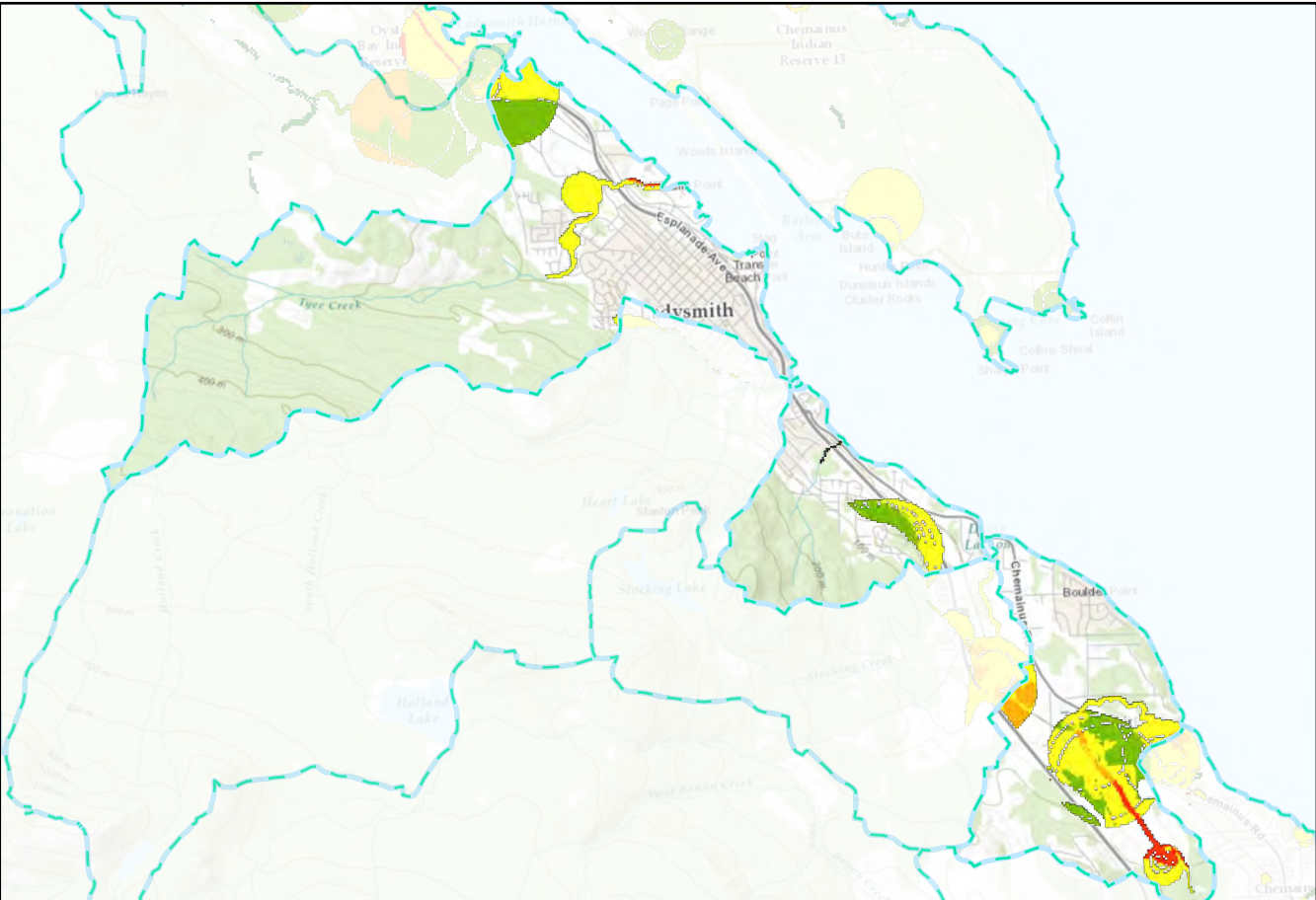
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

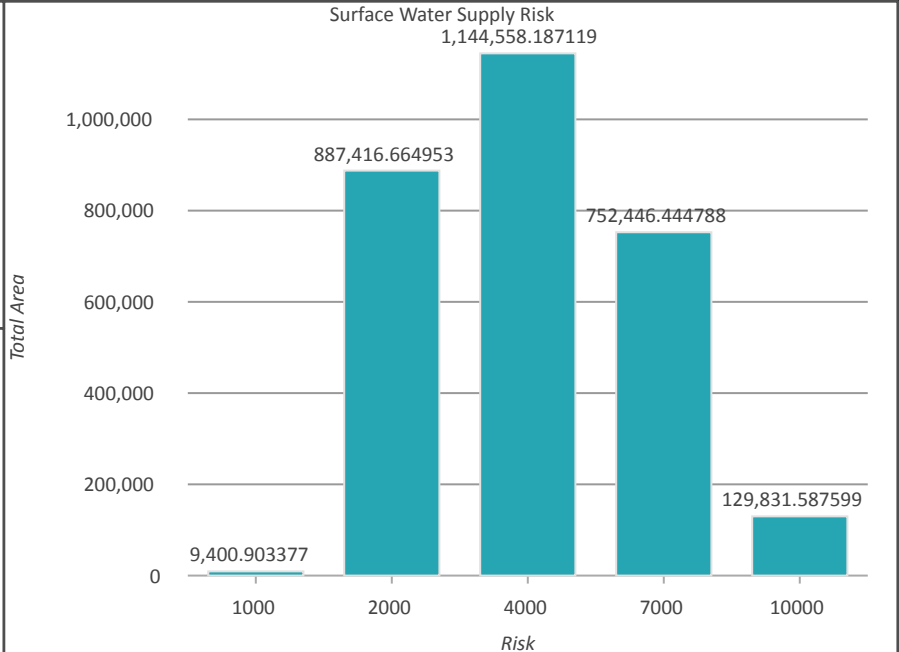
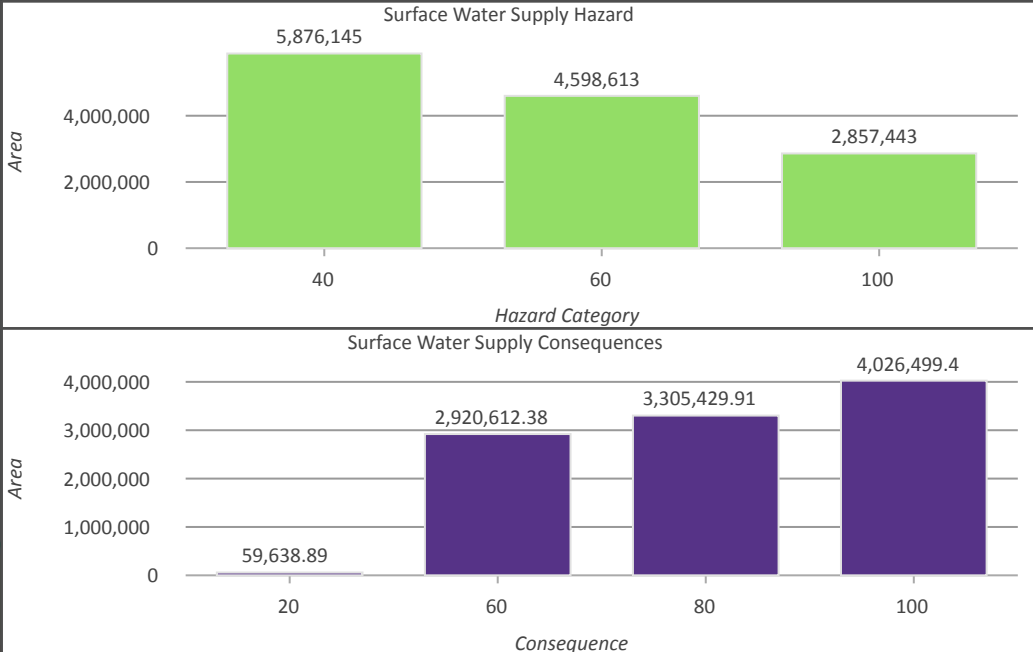


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

	≤ 20
	≤ 40
	≤ 60
	≤ 80
	≤ 100

RISK

	≤ 1000
	≤ 2000
	≤ 4000
	≤ 7000
	≤ 10000

REFERENCES:
1. Risk data compiled from various data sources provided by the Cowichan Vlalley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

NOTES:
1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.

REVISIONS:
0 - CJW - 2018-11-29 - Issued - DK

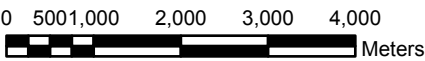
CLIENT:
Cowichan Valley Regional District

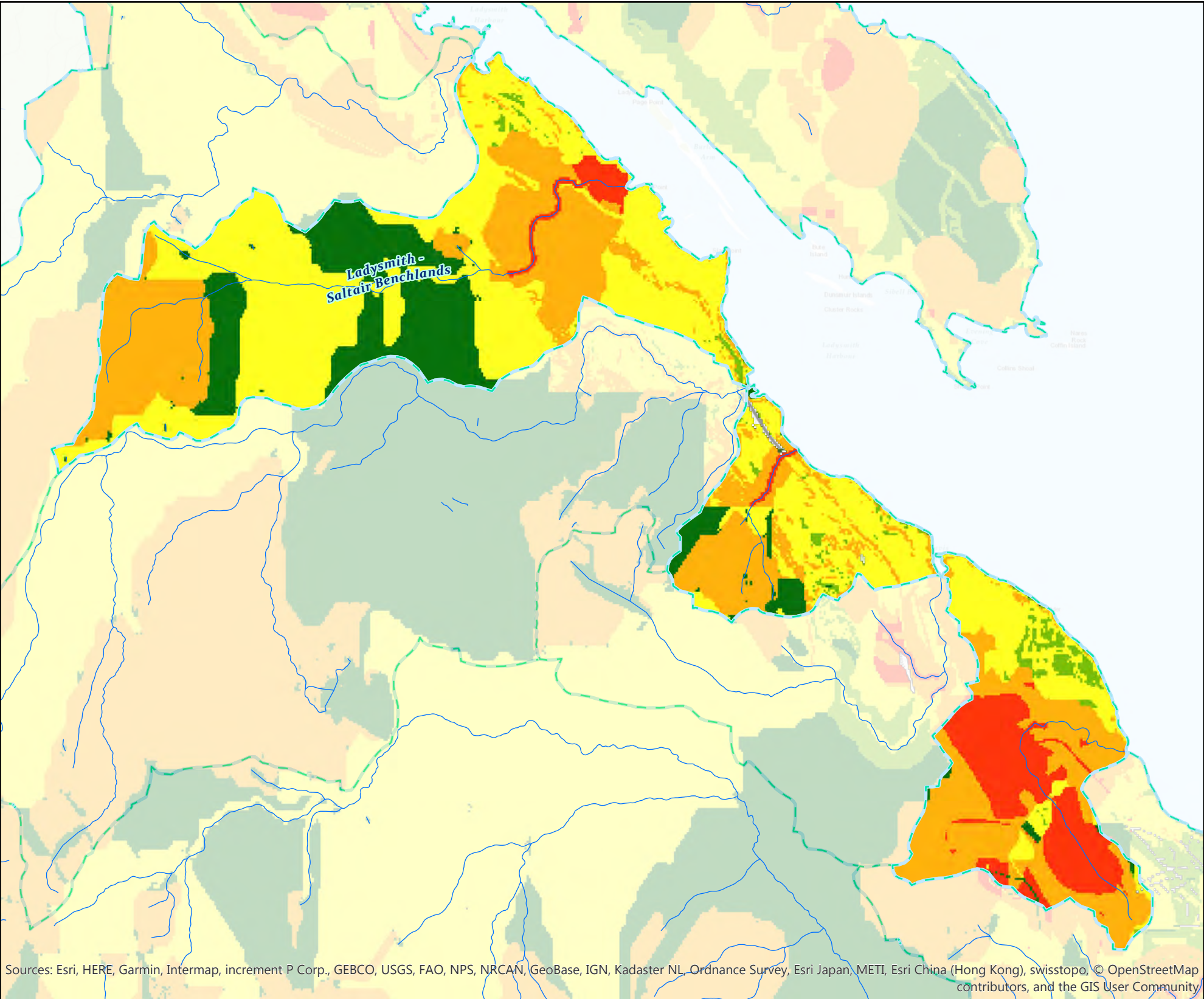
PROJECT LOCATION:
Cowichan Valley Regional DistrictLadysmith -
Saltair Benchlands Watershed

SNC • LAVALIN

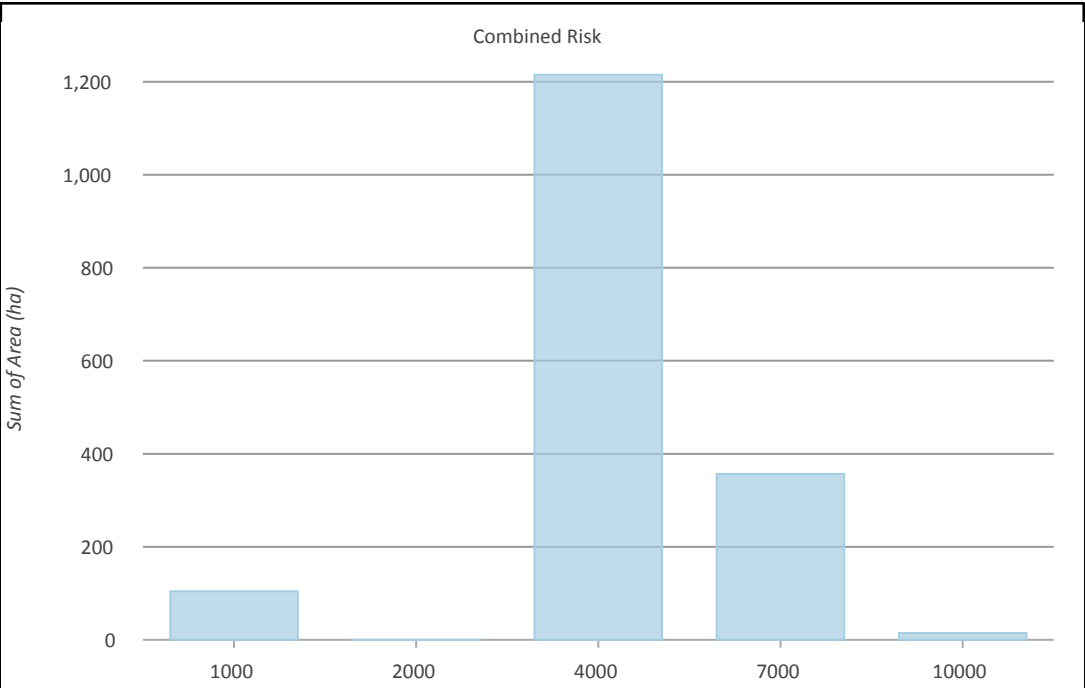
Surface Water Supply Risk Assessment - Ladysmith - Saltair

BY:	SCALE: 1:86,710	DATE: 2019/01/08	REF No:	REV: 0
CHK'D:	Proj Coord Sys: PCS Albers		651957-105-LSSB	





Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



NAME	Risk	POP ₂₀₂₁	POP ₂₀₂₆	POP ₂₀₃₁	POP ₂₀₃₆
SHAWNIGAN CREEK		10047	10760	11613	12598
BUSH CREEK		0	0	0	0
KOKSILAH RIVER		5463	5851	6315	6850
HOLLAND CREEK		1302	1368	1446	1537
BONSALL CREEK		934	974	1019	1073
CHEMAINUS RIVER		1490	1461	1439	1421
COWICHAN RIVER		36368	37905	39683	41766
YELLOW POINT BENCHLANDS		2239	2352	2487	2643
LADYSMITH - SALT AIR BENCHLANDS		8410	8834	9342	9929
STOCKING CREEK		1531	1608	1701	1807
CHEMAINUS BENCHLANDS		3663	3818	3997	4207
SATELLITE CHANNEL BENCHLANDS		4390	4701	5074	5504
SANSUM NARROWS - COWICHAN BAY BENCHLANDS		4941	5150	5391	5674
MALAHAT BENCHLANDS		2829	3030	3271	3548

NAME	POP ₂₀₀₁	POP ₂₀₀₆	POP ₂₀₁₁	POP ₂₀₁₆
SHAWNIGAN CREEK	6348	8439	8925	9484
BUSH CREEK	0			
KOKSILAH RIVER	4555	4808	4954	5157
HOLLAND CREEK	1611	1114	1169	1245
BONSALL CREEK	672	830	815	890
CHEMAINUS RIVER	1423	1395	1497	1514
COWICHAN RIVER	29779	32673	34075	34647
YELLOW POINT BENCHLANDS	1167	1958	2021	2141
LADYSMITH - SALT AIR BENCHLANDS	5275	7488	7541	8042
STOCKING CREEK	1332	1003	1354	1464
CHEMAINUS BENCHLANDS	3177	3129	3085	3490
SATELLITE CHANNEL BENCHLANDS	5425	3902	3989	4144
SANSUM NARROWS - COWICHAN BAY BENCHLANDS	5993	4221	4500	4707
MALAHAT BENCHLANDS	1673	2472	2548	2671

Legend

WATERSHED BOUNDARIES

RISK

≤ 1000

≤ 2000

≤ 4000

≤ 7000

≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

NOTES:

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REVISIONS:

0 - CJW - 2018-11-30 - Issued - DK

CLIENT:

Cowichan Valley Regional District

PROJECT LOCATION:

Cowichan Valley Regional District

Ladysmith - Saltair Benchlands Watershed

Combined Risk Assessment - Ladysmith - Saltair Benchlands

BY: CJW

SCALE CONS: 1:53,000

DATE: 2019/01/08

REF No:

CHK'D: DK

Proj Coord Sys: NAD 1983 UTM Zone 10N

651957-106-LSSB

REV: 0

SNC • LAVALIN

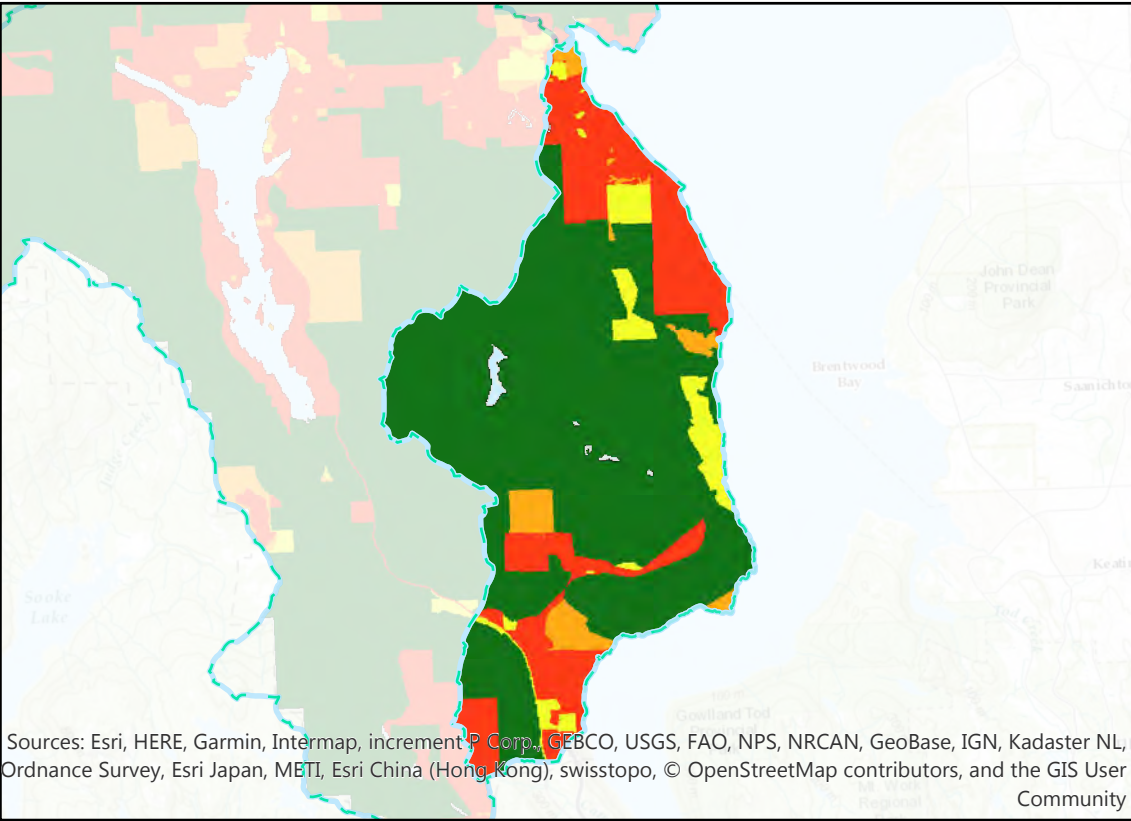
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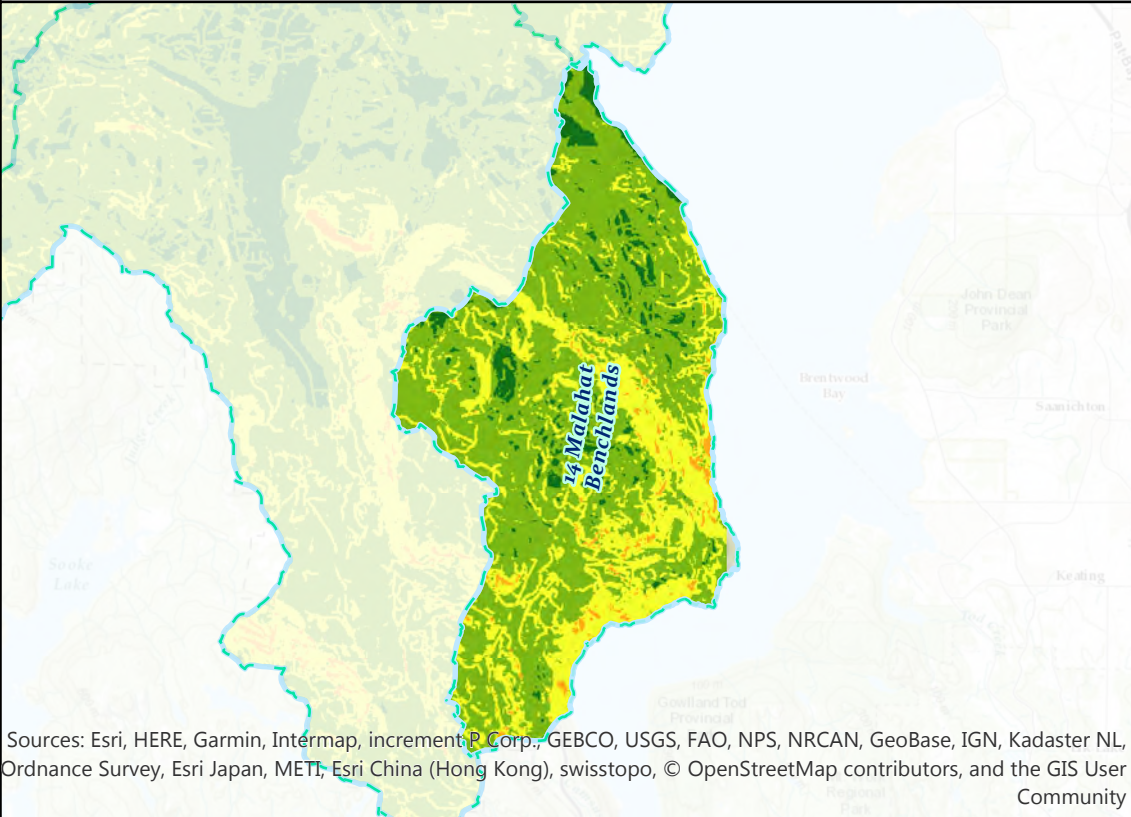
P: 8 - 6

9. Malahat Benchlands	
Topic	Discussion
Slope Failure	<p>Hazard was determined qualitatively at a high level to describe areas based on the degree to which they may be prone to landslides and other mass movements using terrain characteristics. Hazard classifications were generated to show relative comparisons between terrain units within the CVRD watershed study area. Risk ratings derived from this analysis are relative, and should be used to guide prioritization of further detailed studies.</p> <p>The Malahat Benchlands watershed is generally steep and rocky. Hazard is greatest along the east facing slopes extending down to the shoreline from Mount Jeffrey. Consequence is considered moderate to high through the populated areas extending through the central and eastern portion of the watershed. Risk is considered greatest where populated areas are located on relatively steep slopes such as the Mill Bay Ferry and Malahat Indian Reserve 11.</p>
Flooding	<p>Several creeks drain the watershed. Consequence is very low for the majority of the watershed, with relatively higher consequence located at the north-eastern coast at Mill Bay and southern coast at Malahat Indian Reserve 11, and follows Highway 1 and Shawnigan Lake Road. Risk is relatively greater at these locations.</p>
Groundwater Contamination	<p>Hazard is highest at the northern tip of the watershed at Mill Bay. Consequence is highest in the vicinity of municipal water supply wells throughout the watershed. Risk is highest at some of these well locations in the southern half of the watershed, at the Mill Bay ferry terminal, and at Mill Bay.</p>
Surface Water Quality	<p>Hazard is considered moderate for the majority of the watershed's area based on land development, land use type, and coverage of impermeable surfaces. Most of the watershed's area is considered high consequence due to the prevalence of lower order streams that are more susceptible to surface water supply / stream health issues than larger streams. Risk is considered relatively high for most of the watershed's area and is greatest at the mine in Bamberton and at the two homes along Glen Lane by the coast. Relatively rapid population growth is projected for the watershed that may enhance the pressure on surface water quality. The central portion of the watershed is currently considered low or lower in terms of hazard, consequence, and risk, and therefore may be suitable to accommodate growth.</p>
Surface Water Supply	<p>Hazard is overall low in the watershed with one zone of moderate hazard near Mill Bay. Consequence is variable across the watershed and is greatest near Malahat Indian Reserve 11, Bamberton, and Mill Bay. Risk is greatest near Mill Bay, west of the highway, and low to moderate east of the highway near Malahat Indian Reserve 11 and Bamberton. Projected population increase for the watershed is expected to add pressures on groundwater sources that may increase the level of hazard and risk around Mill Bay.</p>
General Data Notes	<p>The Malahat Benchlands has some contribution from surface water quality, a localized high risk at the north end from surface water supply, moderate (and likely overly stated) flood risk due to some stream presence. Slope failure risk is moderate and focused in the north west and south portions of the watershed, with groundwater contamination being a major contributor to overall risk.</p>

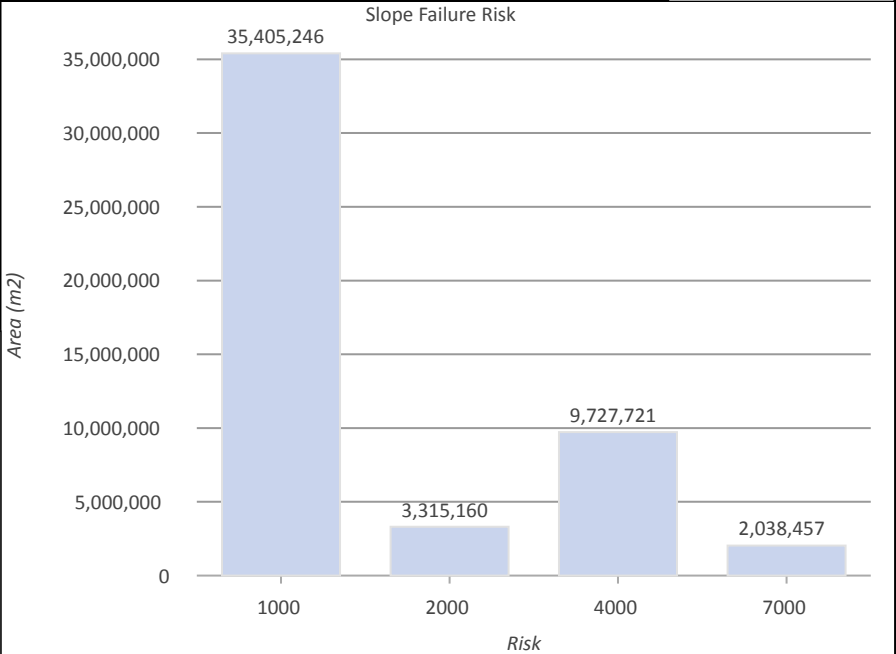
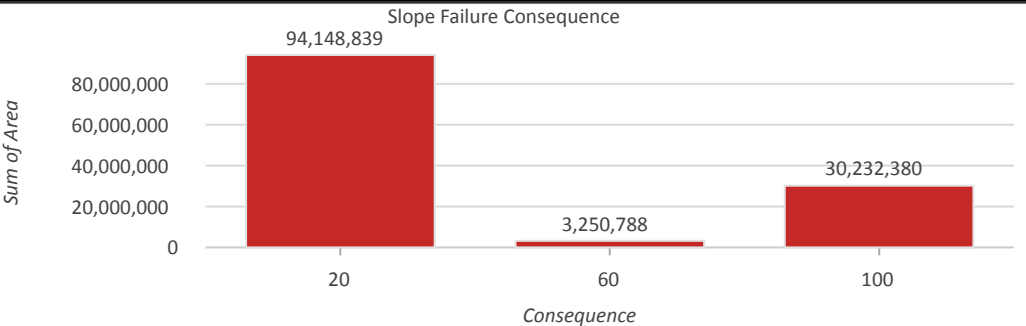
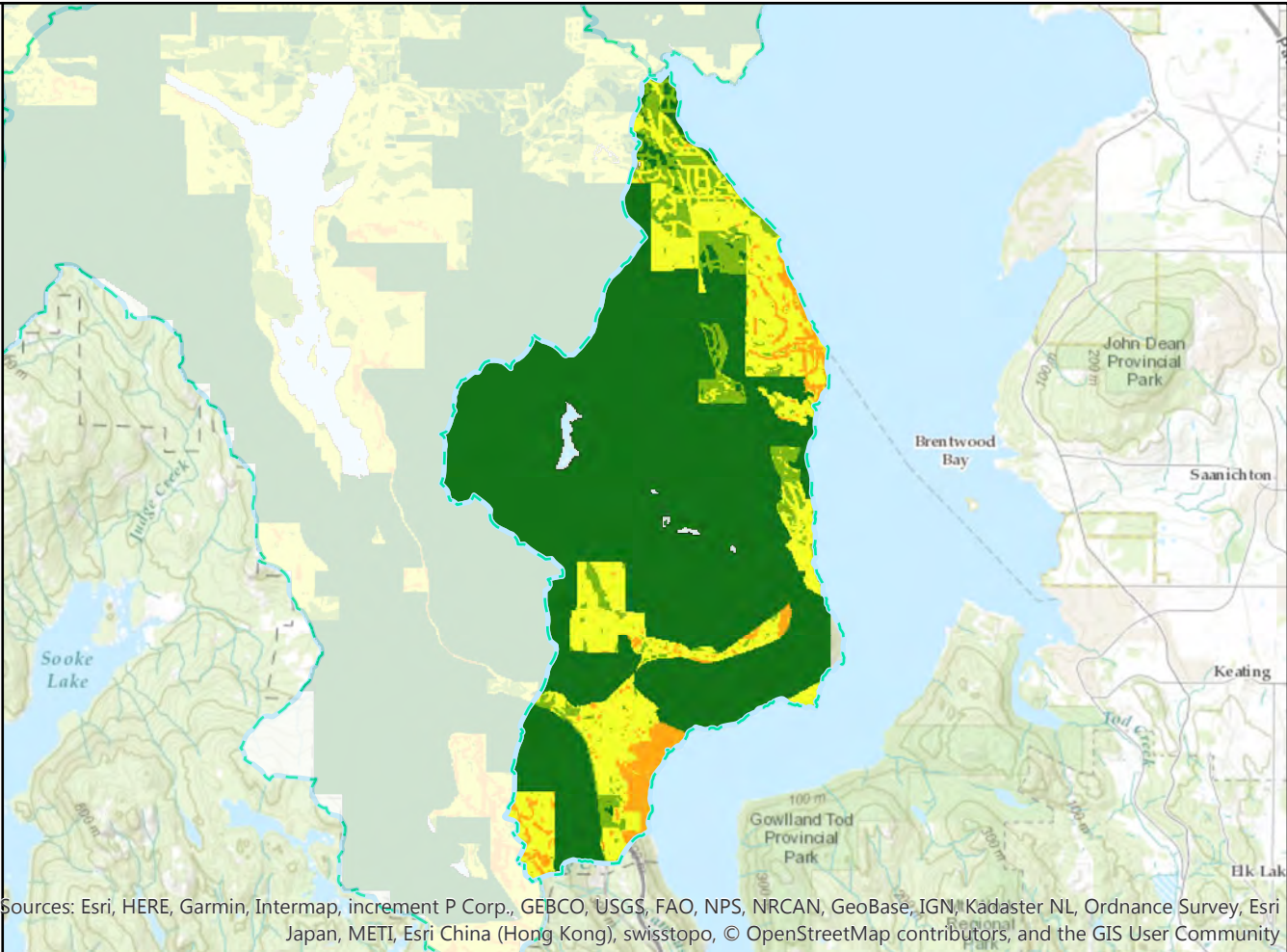
CONSEQUENCE



HAZARD



RISK



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
 ≤ 40
 ≤ 60
 ≤ 80
 ≤ 100

RISK

≤ 1000
 ≤ 2000
 ≤ 4000
 ≤ 7000
 ≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Malahat Benchlands Watershed



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Slope Failure Risk Assessment - Malahat

BY: CJW

SCALE CONS: 1:121,772

DATE: 2019/01/07

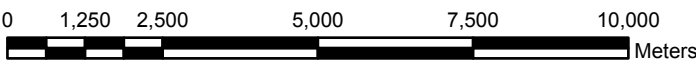
REF No:

REV: 0

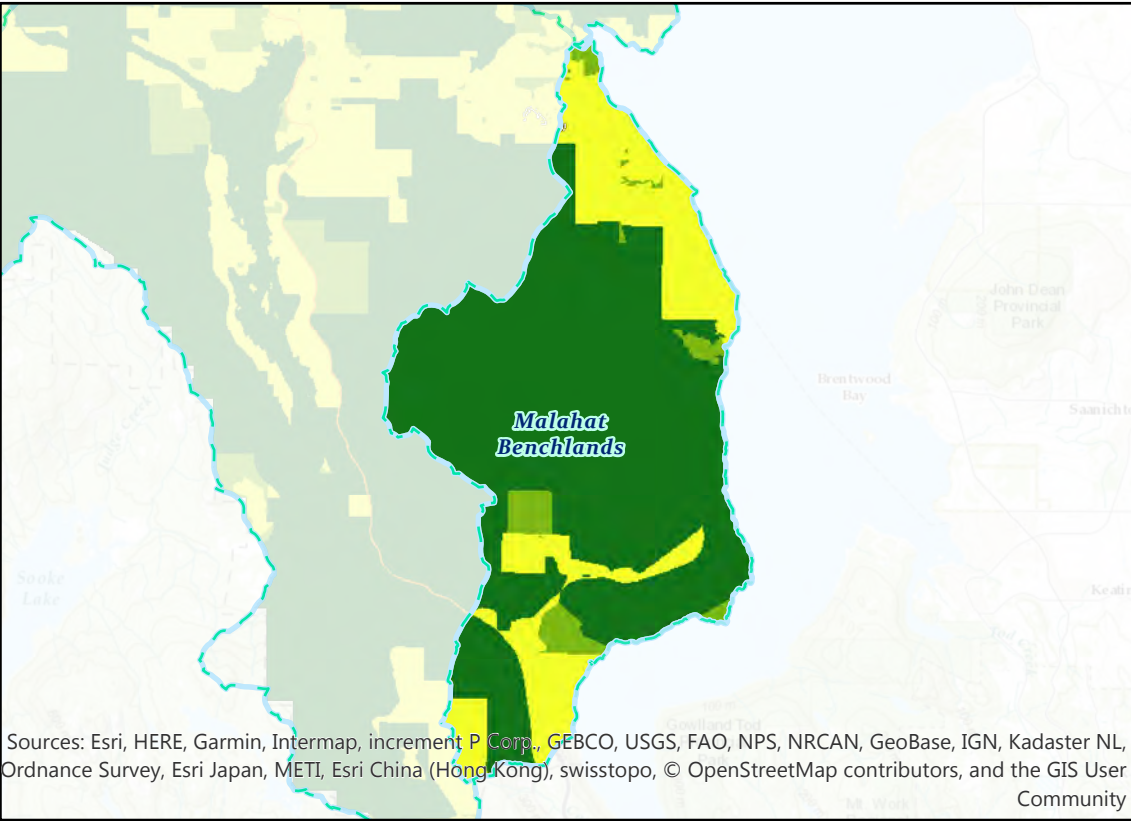
CHK'D: DK

Proj Coord Sys: PCS Albers

651957-101-MAL

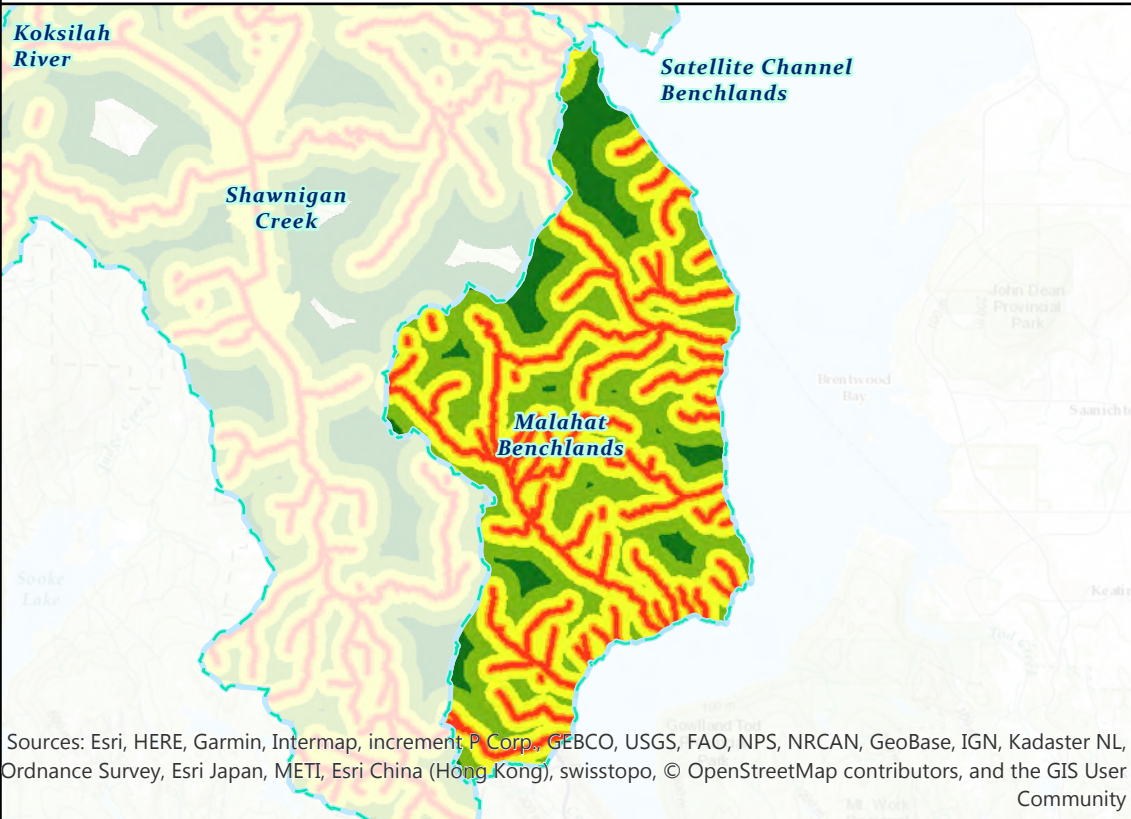


CONSEQUENCE



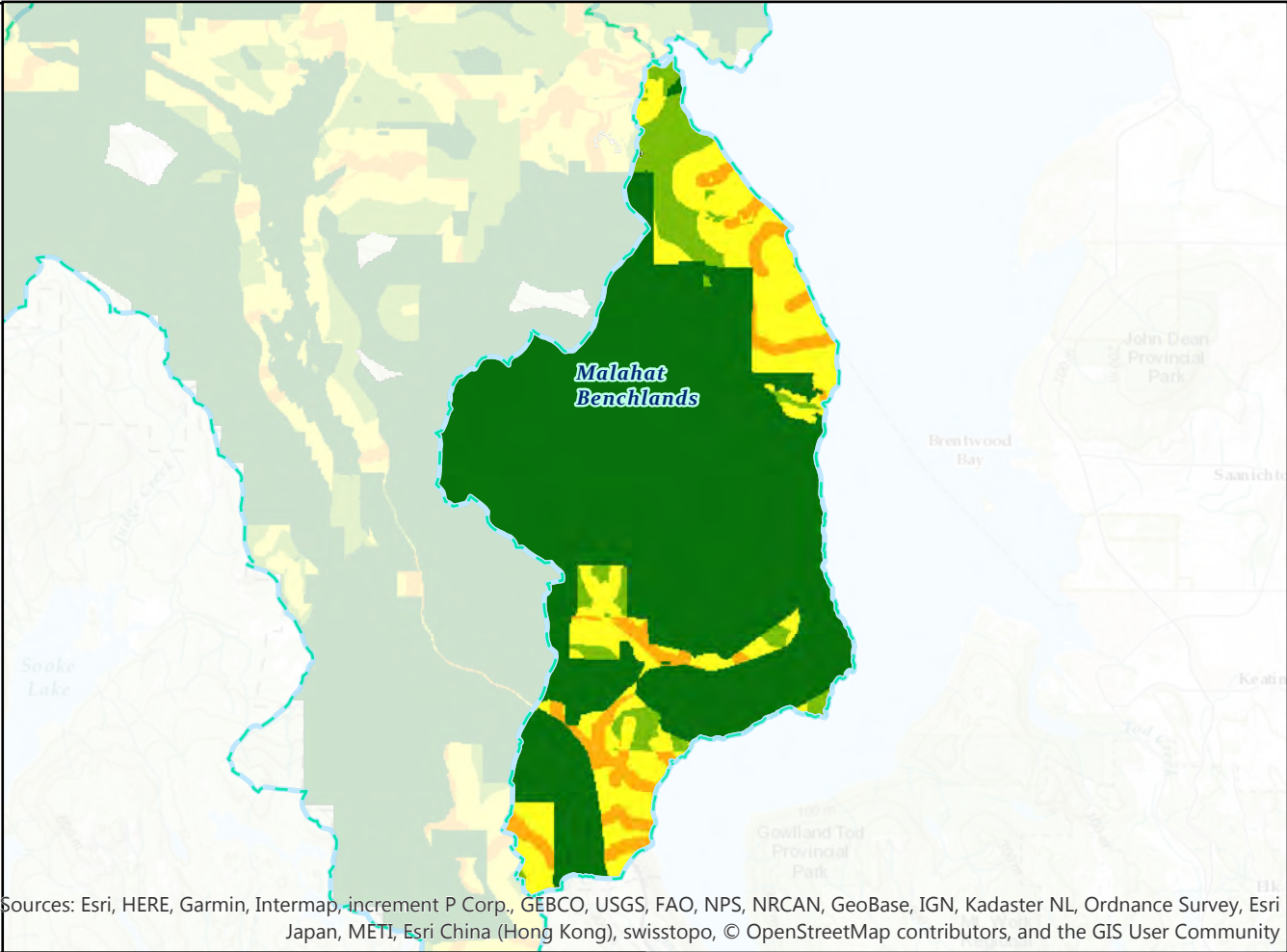
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HAZARD

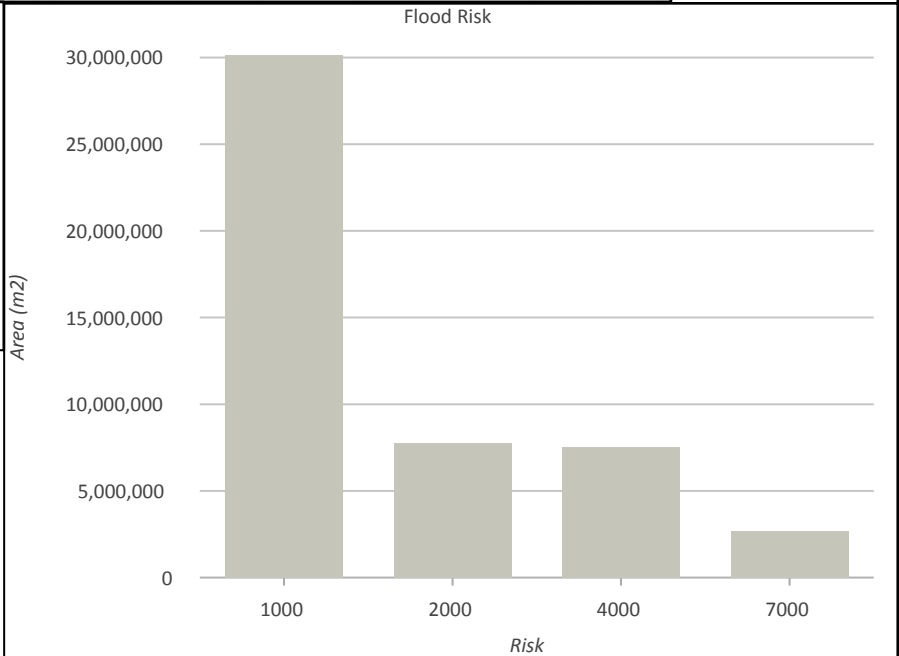
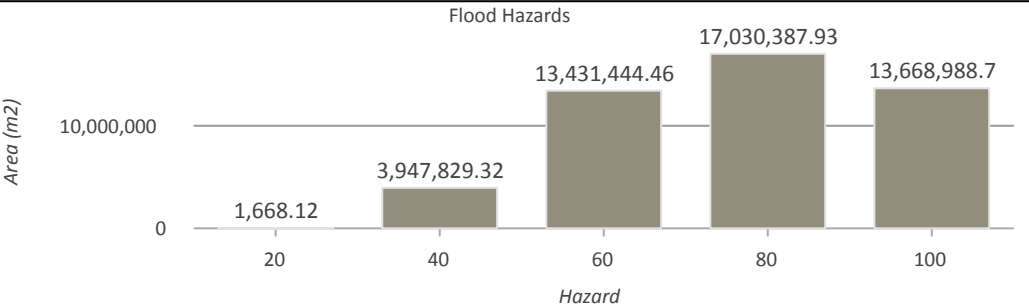
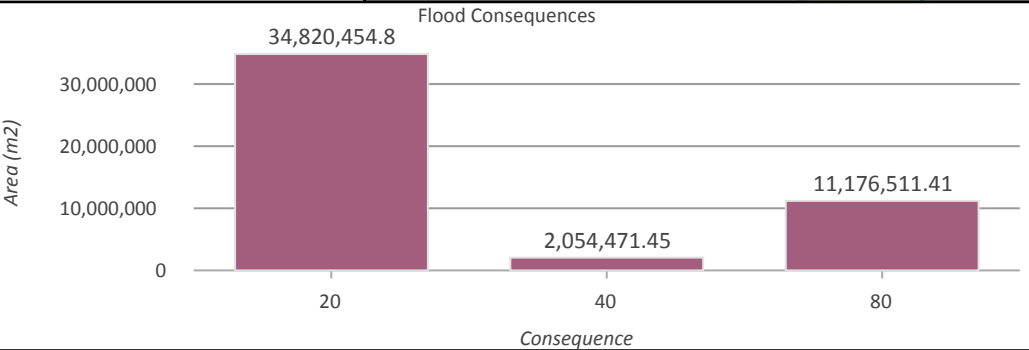


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



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Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
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≤ 10000

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Malahat Benchlands Watershed



Flood Risk Assessment - Malahat Benchlands

BY: CJW

SCALE CONS: 1:117,314

DATE: 2019/01/08

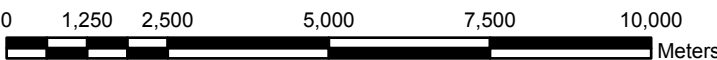
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REV: 0

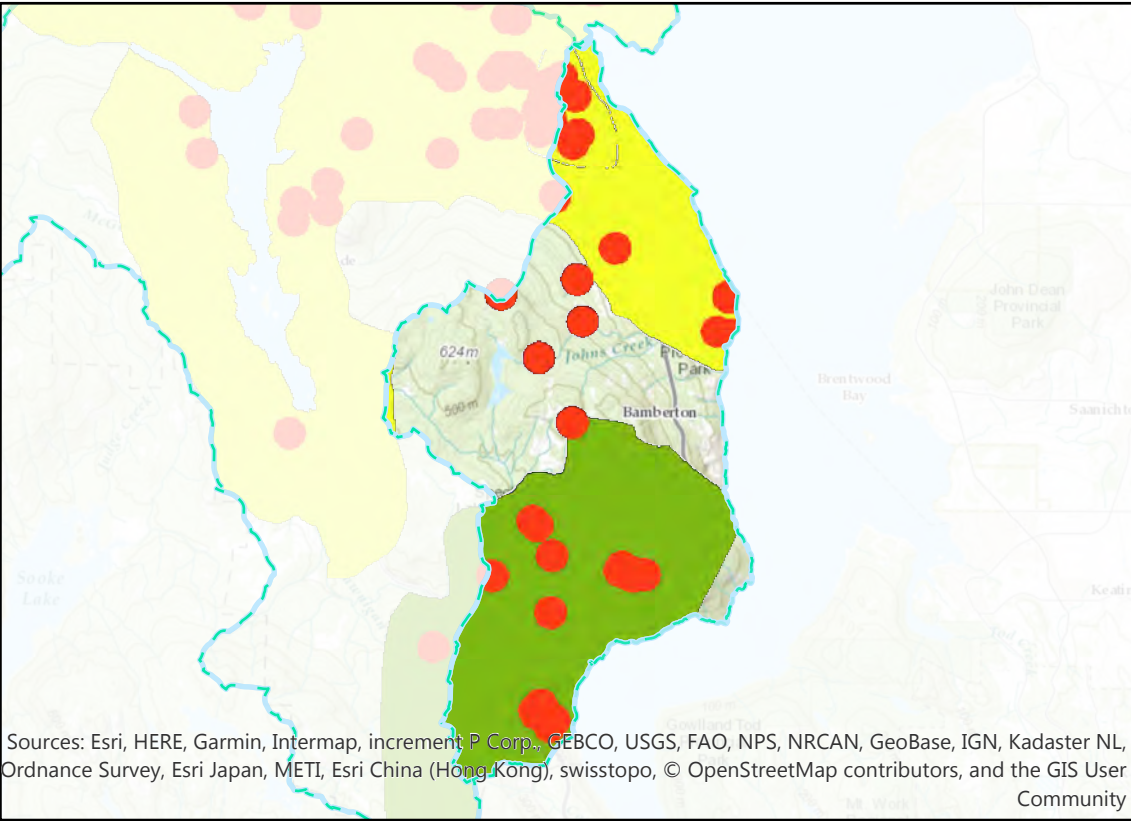
CHK'D: DK

Proj Coord Sys: NAD 1983 UTM Zone 10N

651957-102-MAL

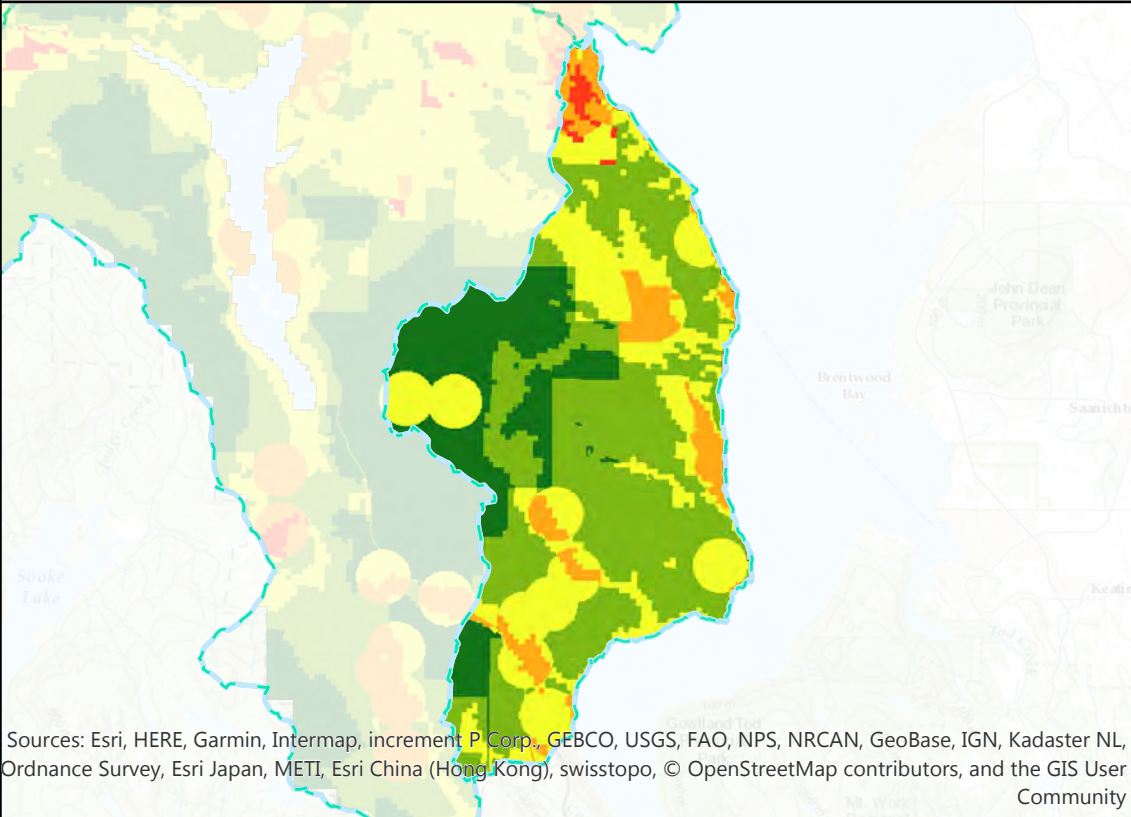


CONSEQUENCE



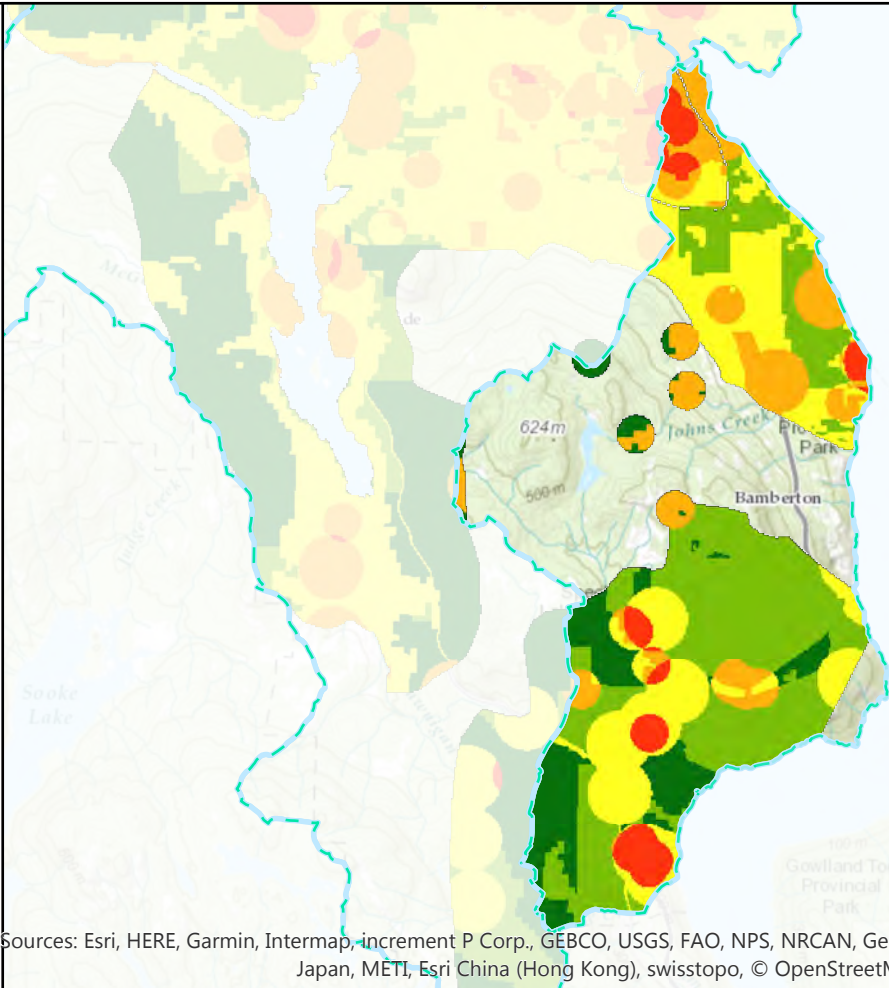
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HAZARD

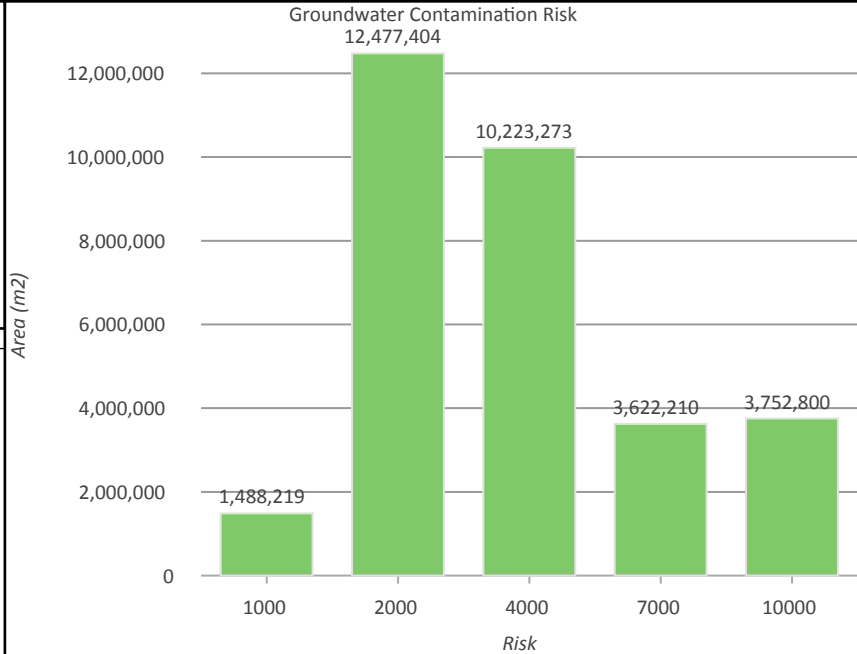
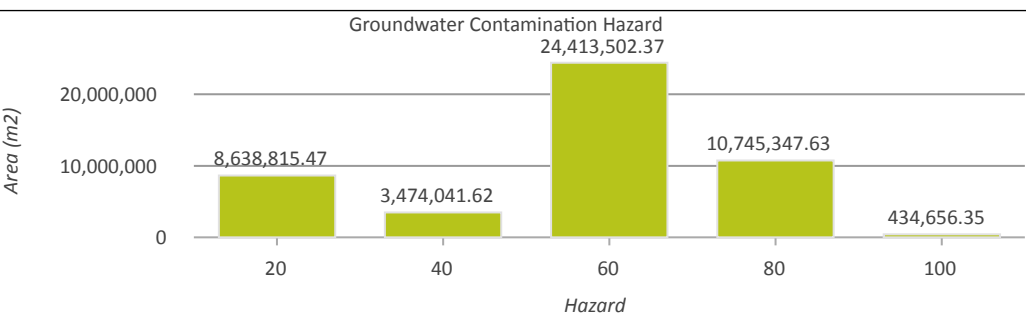
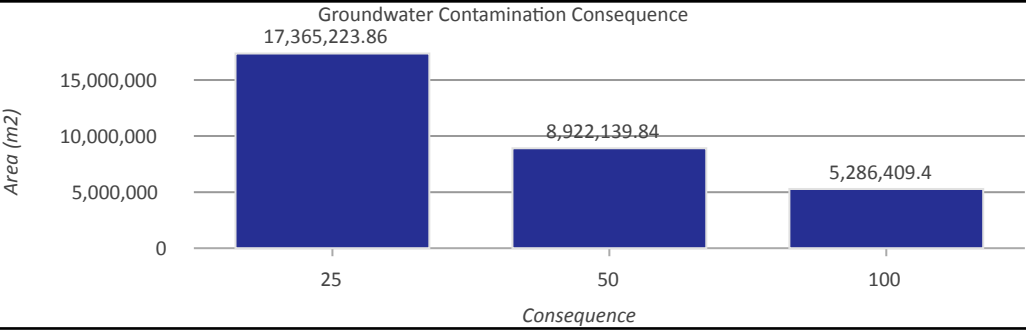


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



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Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

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RISK

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Malahat Benchlands Watershed



Groundwater Contamination Risk Assessment - Malahat Benchlands

BY: CJW

SCALE CONS: 1:117,314

DATE: 2019/01/08

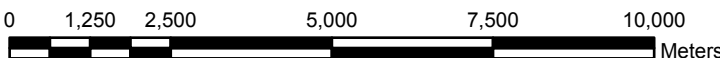
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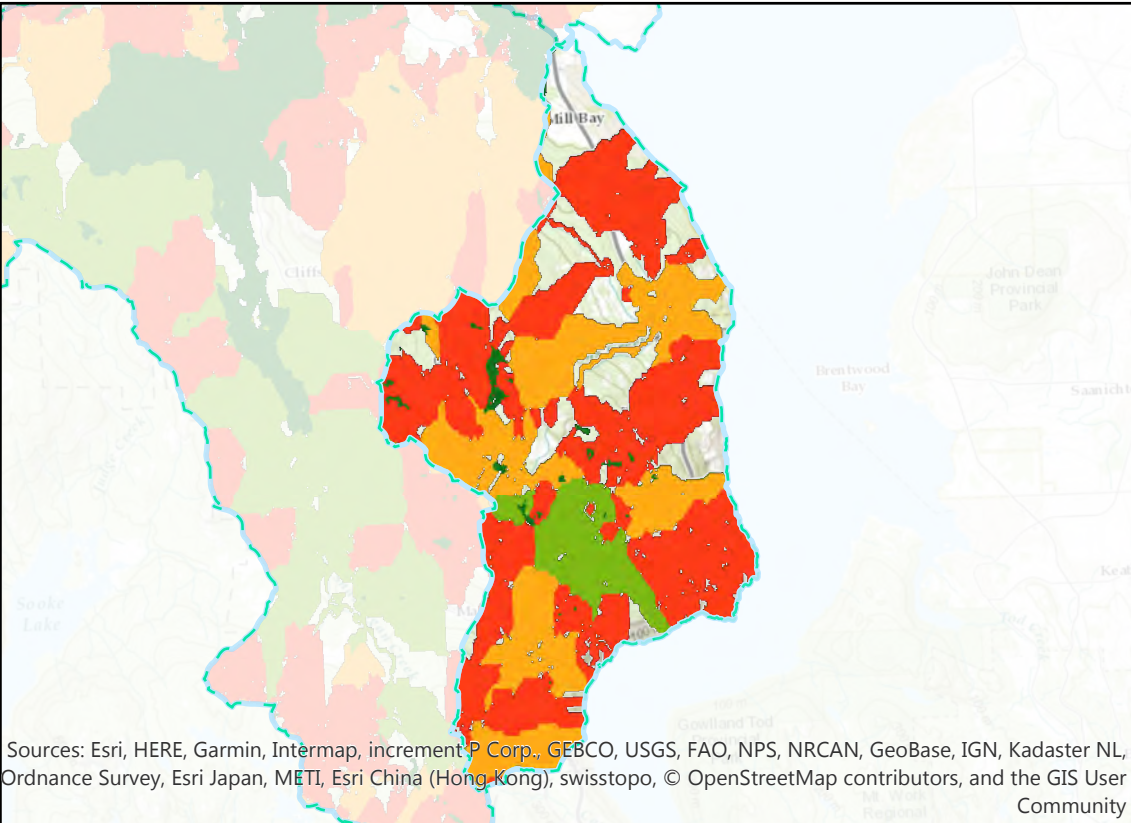
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Proj Coord Sys: NAD 1983 UTM Zone 10N

651957-103-MAL

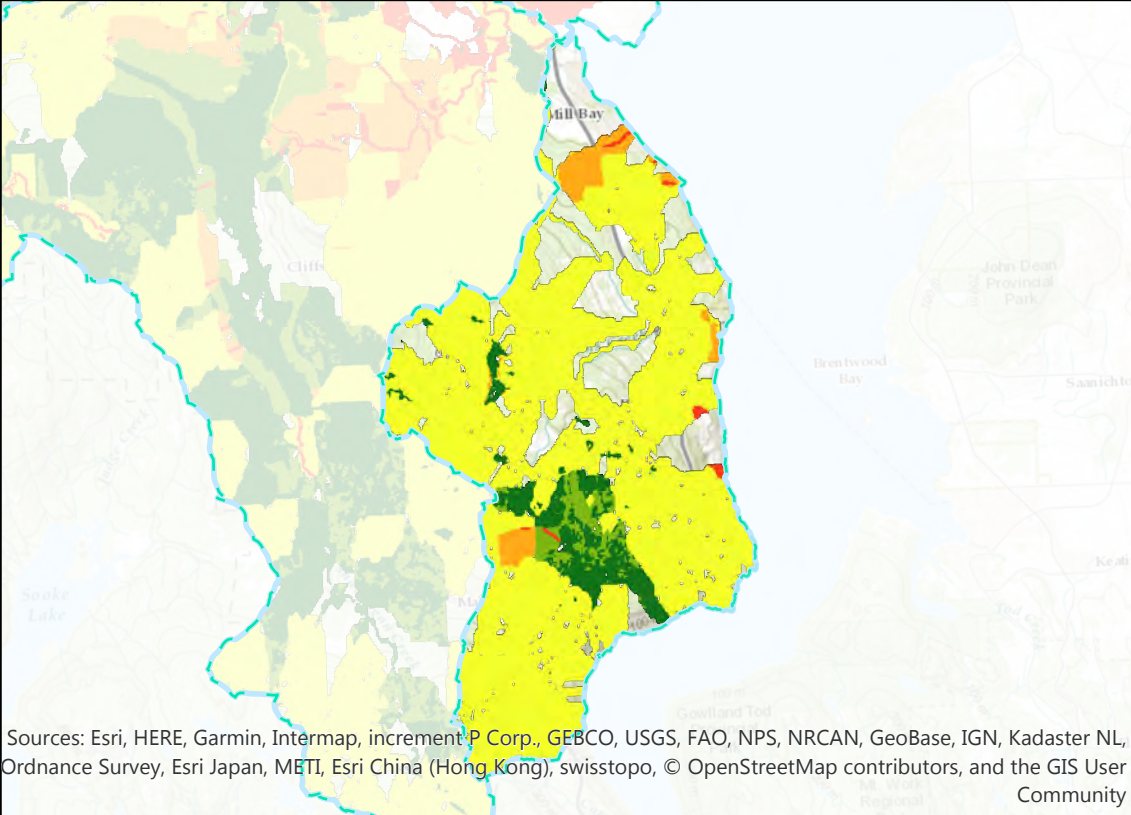


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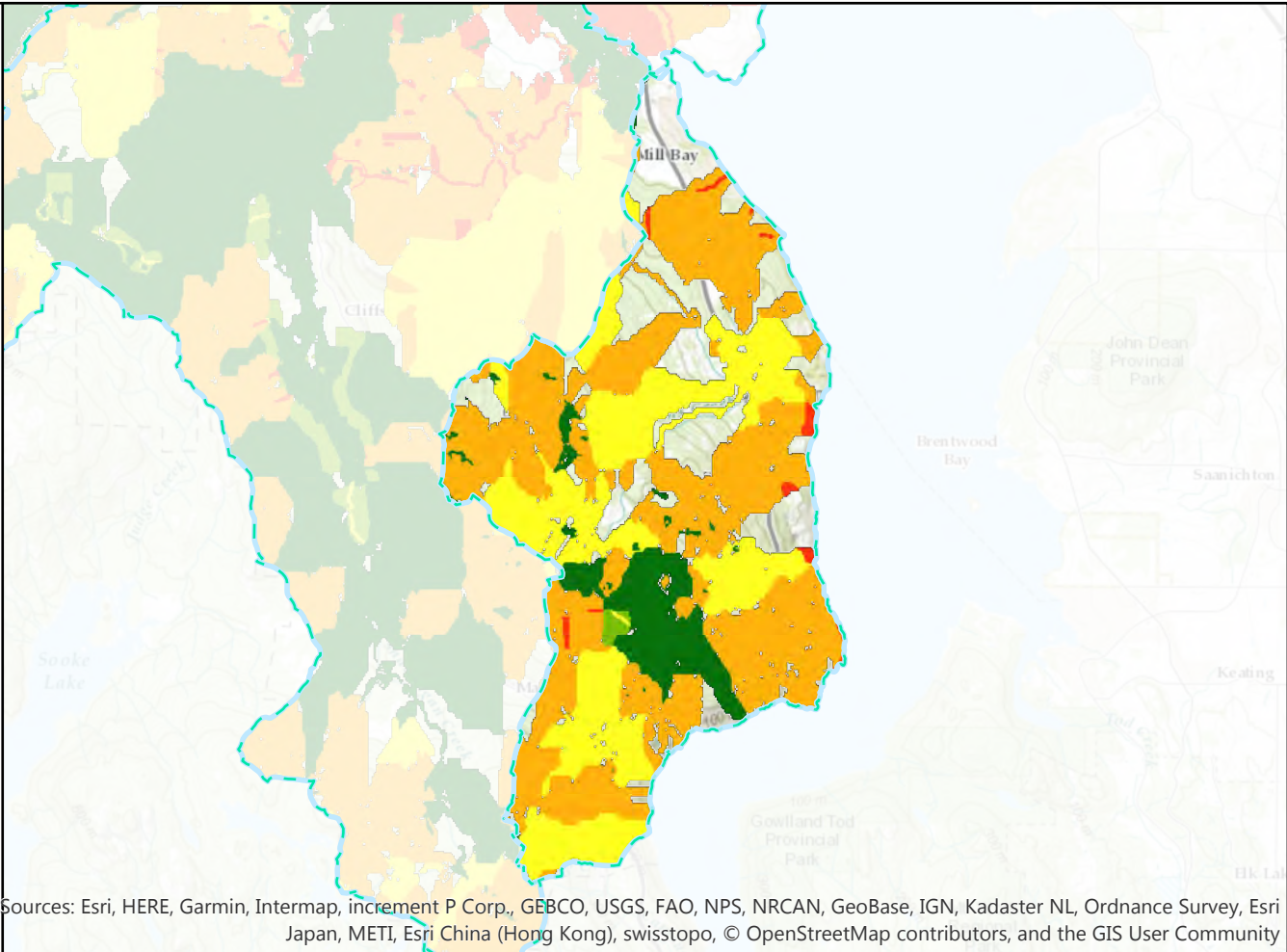
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HAZARD

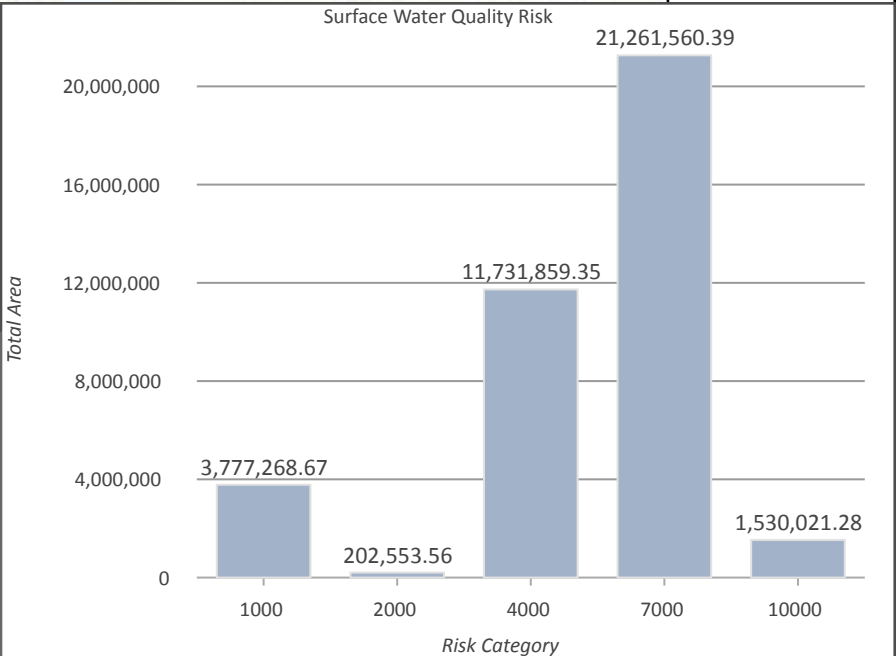
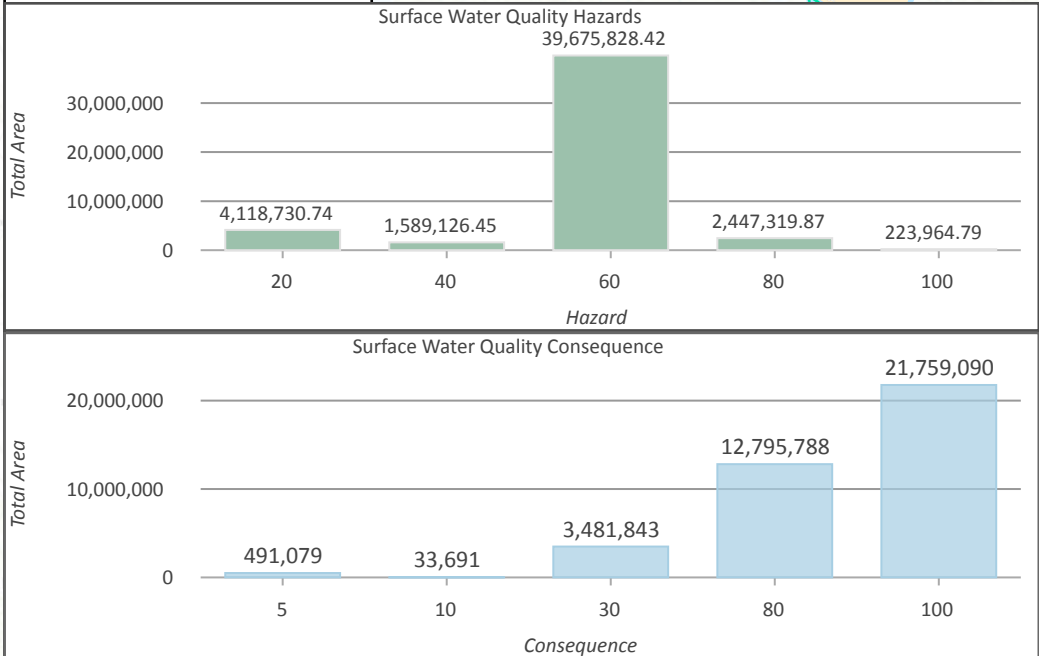


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RISK



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Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
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≤ 100

RISK

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REFERENCES:

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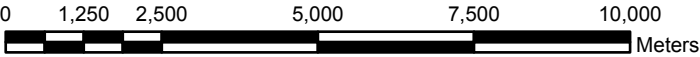
NOTES:

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REVISIONS:

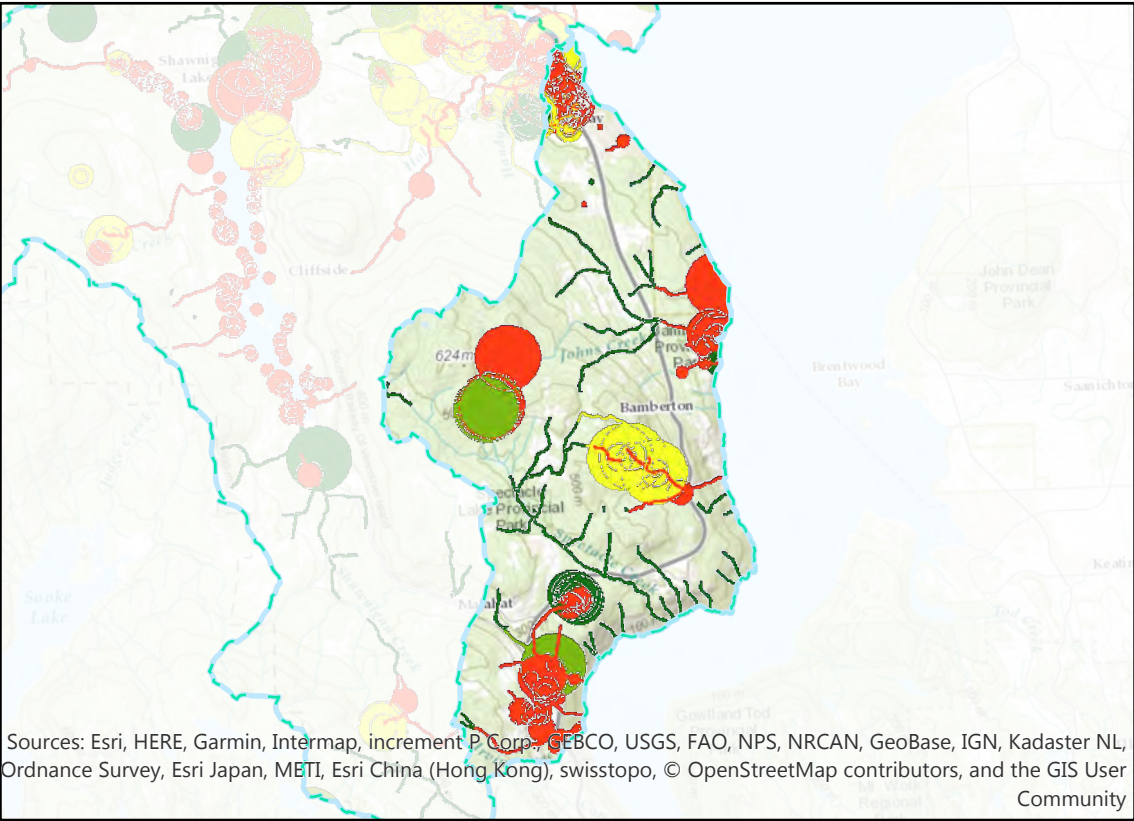
0 - C-JW - 2018-11-29 - Issued - DK

CLIENT: Cowichan Valley Regional District			
PROJECT LOCATION: Cowichan Valley Regional District/Malahat Benchlands Watershed			
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BY:	SCALE: 1:121,104	DATE: 2019/01/08	REF No:
CHK'D:	Proj Coord Sys: PCS Albers		REV: 0
651957-104-MAL			

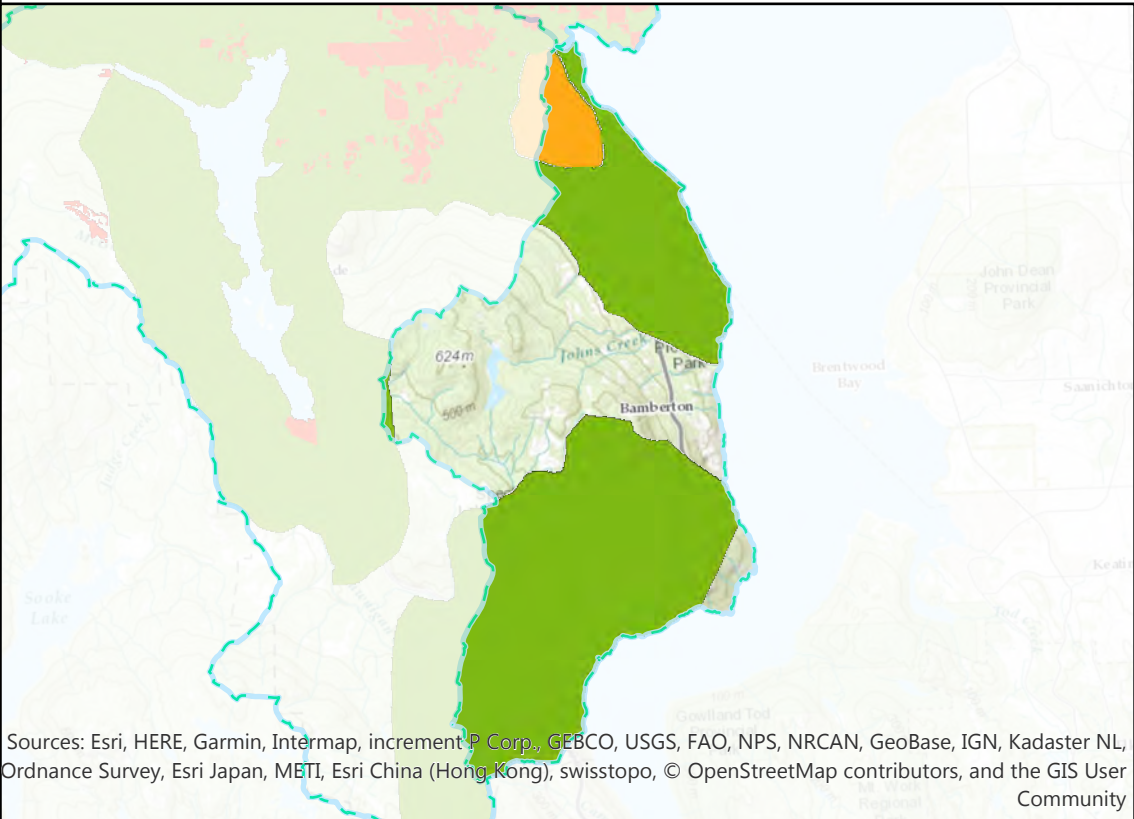


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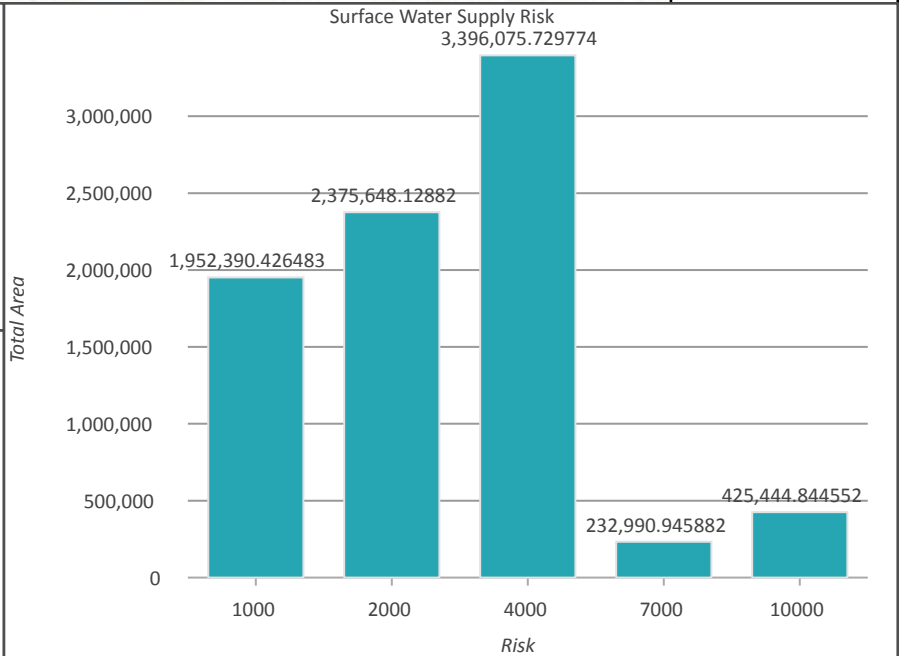
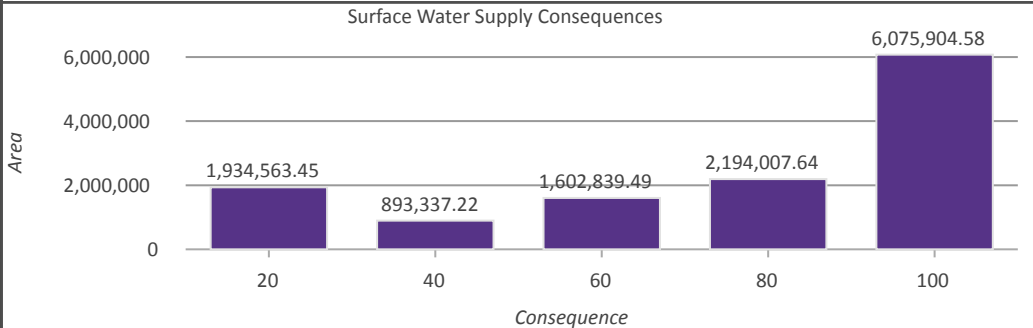
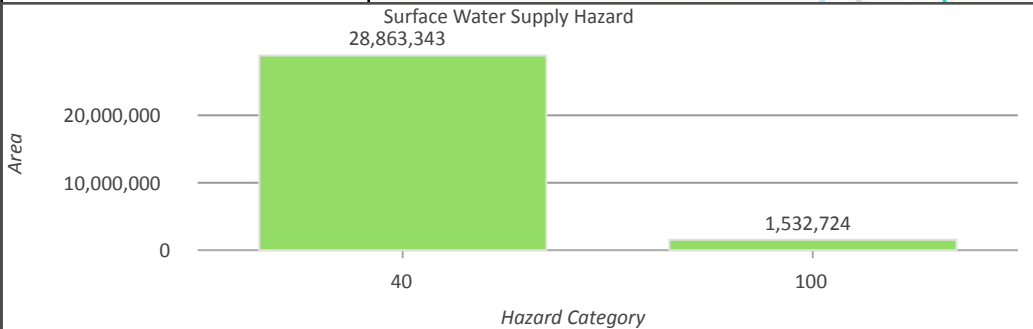
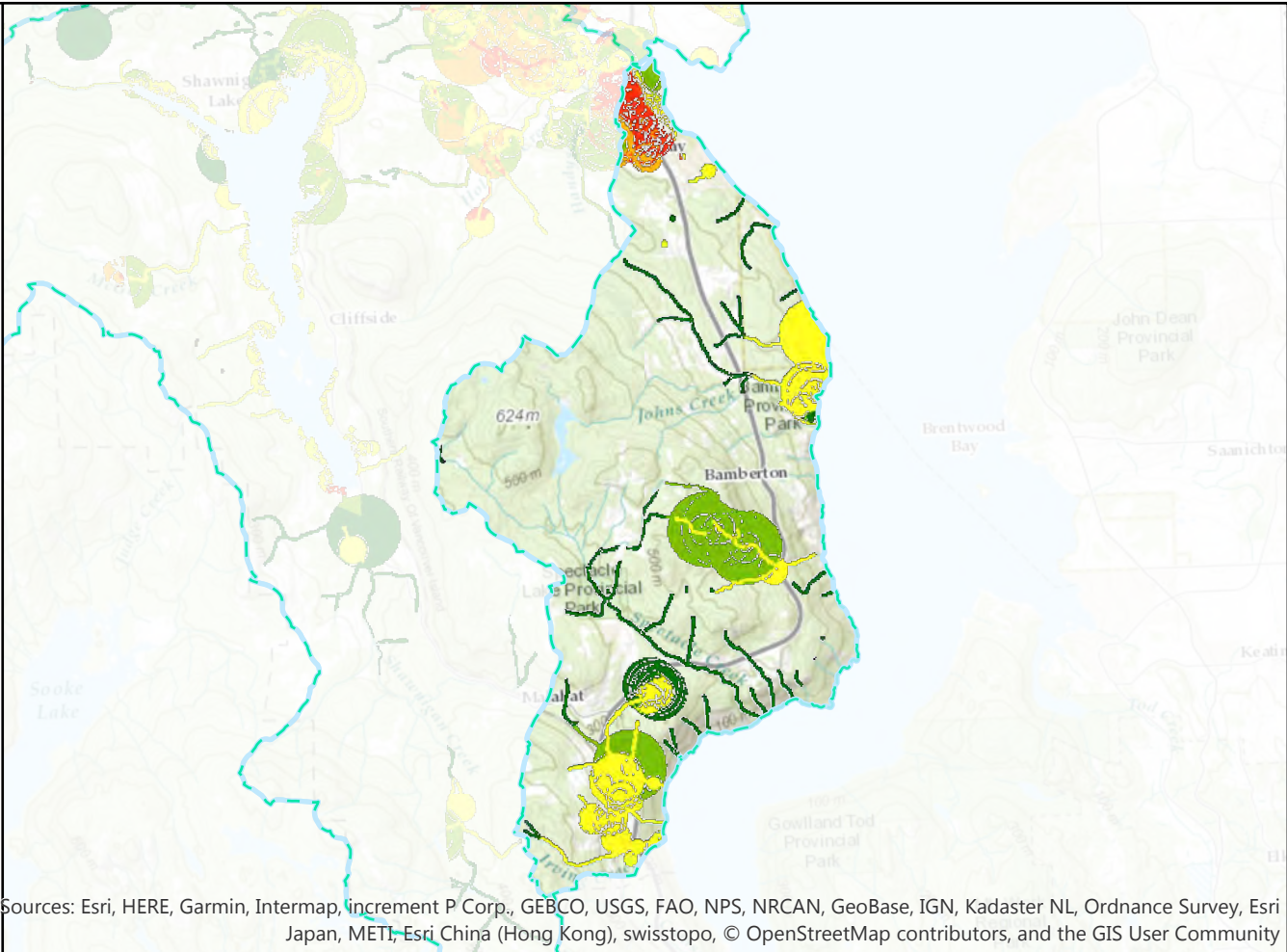
CONSEQUENCE



HAZARD



RISK



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

- ≤ 20
- ≤ 40
- ≤ 60
- ≤ 80
- ≤ 100

RISK

- ≤ 1000
- ≤ 2000
- ≤ 4000
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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

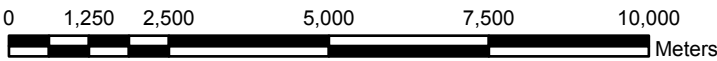
PROJECT LOCATION:
Cowichan Valley Regional District
Malahat
Benchlands Watershed



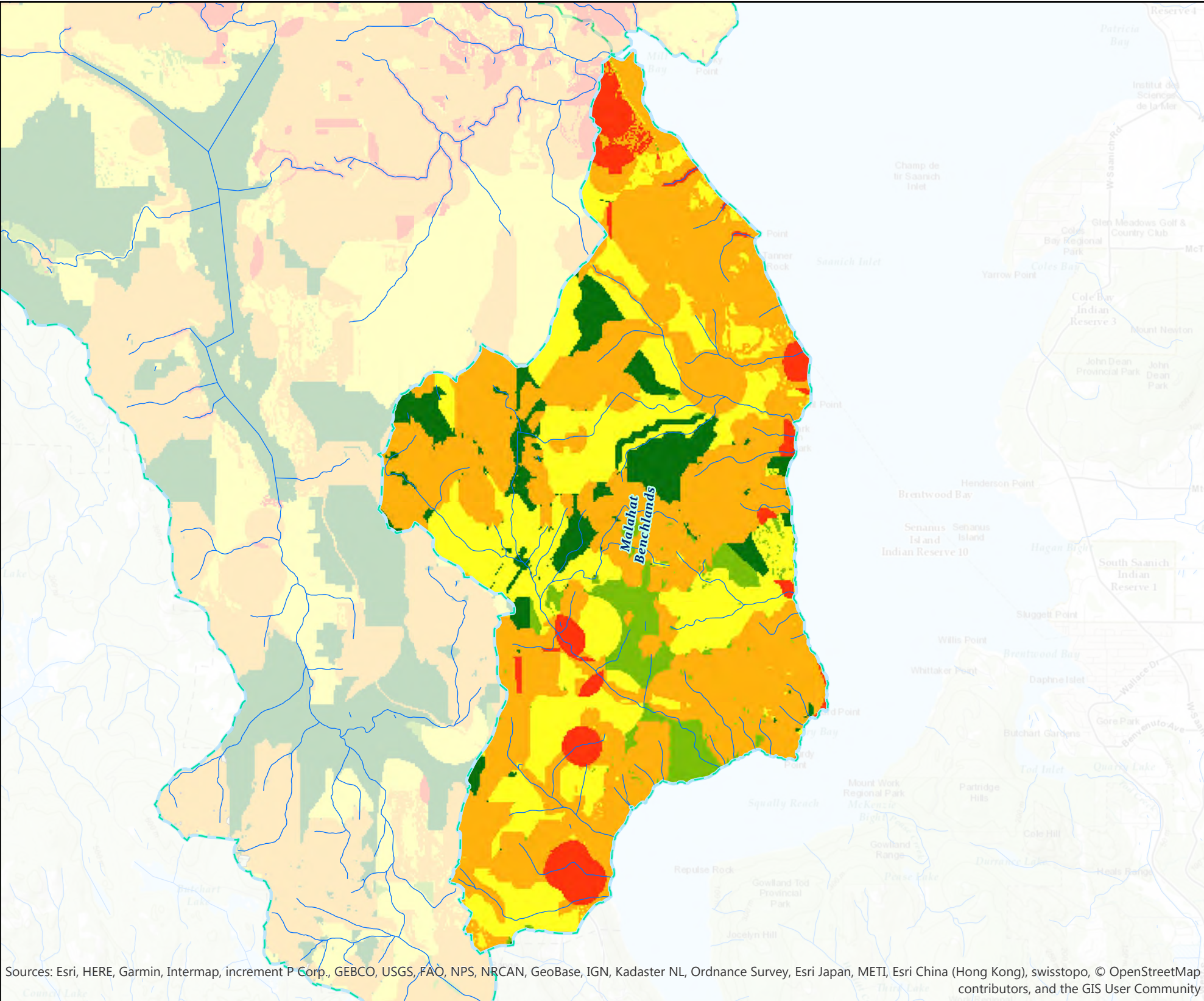
SNC • LAVALIN

Surface Water Supply Risk Assessment - Malahat Benchlands

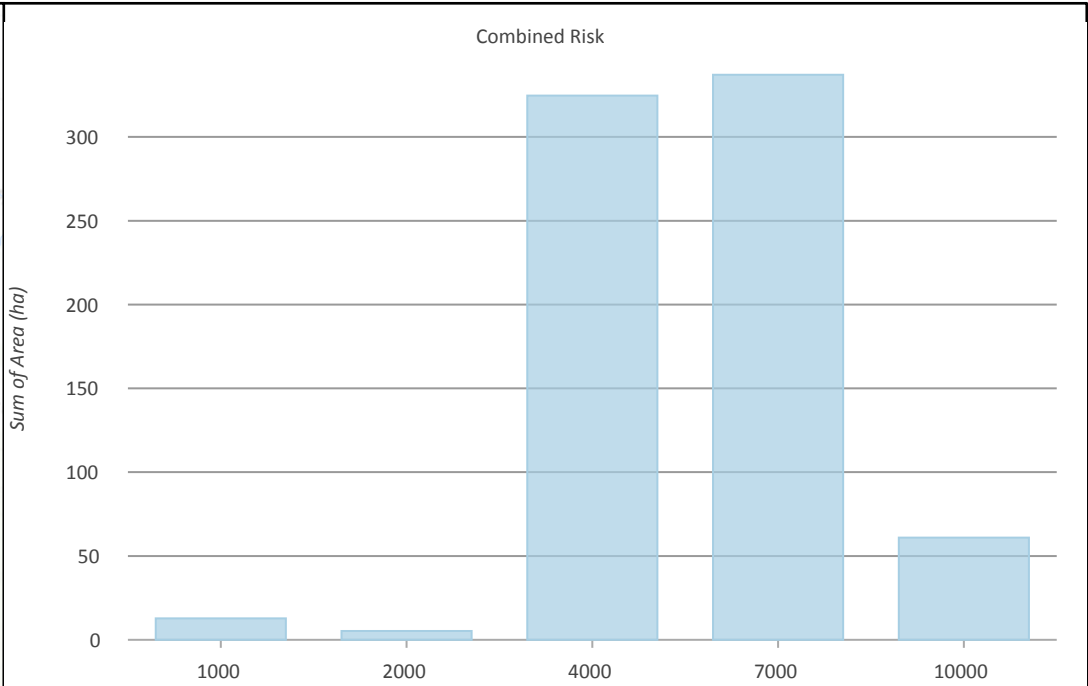
BY:	SCALE: 1:118,164	DATE: 2019/01/08	REF No:	REV: 0
CHK'D:	Proj Coord Sys: PCS Albers		651957-105-MAL	



MXD Path: D:\Local\Projects\651957_CVRD\GIS\CVRDPresentation\CVRDPresentation.aprx



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



NAME	Risk	POP ₂₀₂₁	POP ₂₀₂₆	POP ₂₀₃₁	POP ₂₀₃₆
SHAWNIGAN CREEK		10047	10760	11613	12598
BUSH CREEK		0	0	0	0
KOKSILAH RIVER		5463	5851	6315	6850
HOLLAND CREEK		1302	1368	1446	1537
BONSALL CREEK		934	974	1019	1073
CHEMAINUS RIVER		1490	1461	1439	1421
COWICHAN RIVER		36368	37905	39683	41766
YELLOW POINT BENCHLANDS		2239	2352	2487	2643
LADYSMITH - SALTAIR BENCHLANDS		8410	8834	9342	9929
STOCKING CREEK		1531	1608	1701	1807
CHEMAINUS BENCHLANDS		3663	3818	3997	4207
SATELLITE CHANNEL BENCHLANDS		4390	4701	5074	5504
SANSUM NARROWS - COWICHAN BAY BENCHLANDS		4941	5150	5391	5674
MALAHAT BENCHLANDS		2829	3030	3271	3548

NAME	POP ₂₀₀₁	POP ₂₀₀₆	POP ₂₀₁₁	POP ₂₀₁₆
SHAWNIGAN CREEK	6348	8439	8925	9484
BUSH CREEK	0			
KOKSILAH RIVER	4555	4808	4954	5157
HOLLAND CREEK	1611	1114	1169	1245
BONSALL CREEK	672	830	815	890
CHEMAINUS RIVER	1423	1395	1497	1514
COWICHAN RIVER	29779	32673	34075	34647
YELLOW POINT BENCHLANDS	1167	1958	2021	2141
LADYSMITH - SALTAIR BENCHLANDS	5275	7488	7541	8042
STOCKING CREEK	1332	1003	1354	1464
CHEMAINUS BENCHLANDS	3177	3129	3085	3490
SATELLITE CHANNEL BENCHLANDS	5425	3902	3989	4144
SANSUM NARROWS - COWICHAN BAY BENCHLANDS	5993	4221	4500	4707
MALAHAT BENCHLANDS	1673	2472	2548	2671

Legend

WATERSHED BOUNDARIES

RISK

≤ 1000

≤ 2000

≤ 4000

≤ 7000

≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

NOTES:

1. Original in colour.

2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.

3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.

REVISIONS:

0 - CJW - 2018-11-30 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Malahat Benchlands Watershed

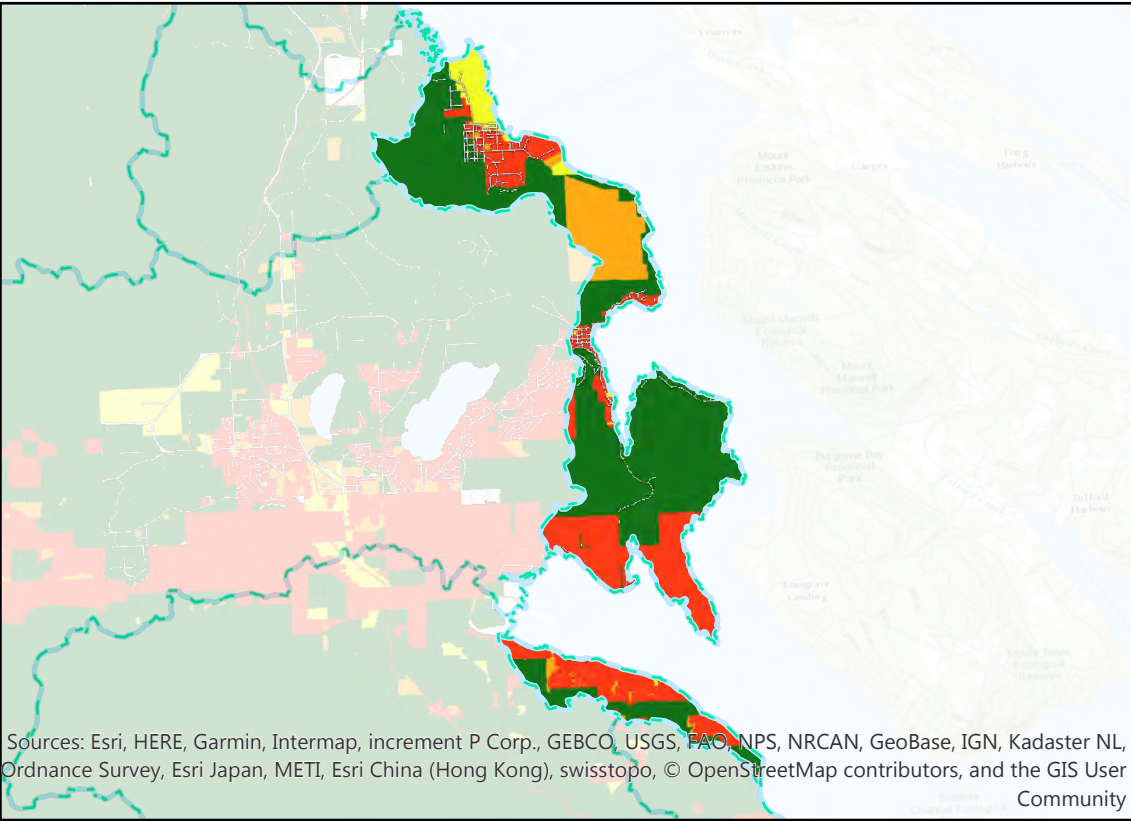
Combined Risk Assessment - Malahat Benchlands

BY: CJW SCALE CONS: 1:69,000 DATE: 2019/01/08 REF No: REV: **0**

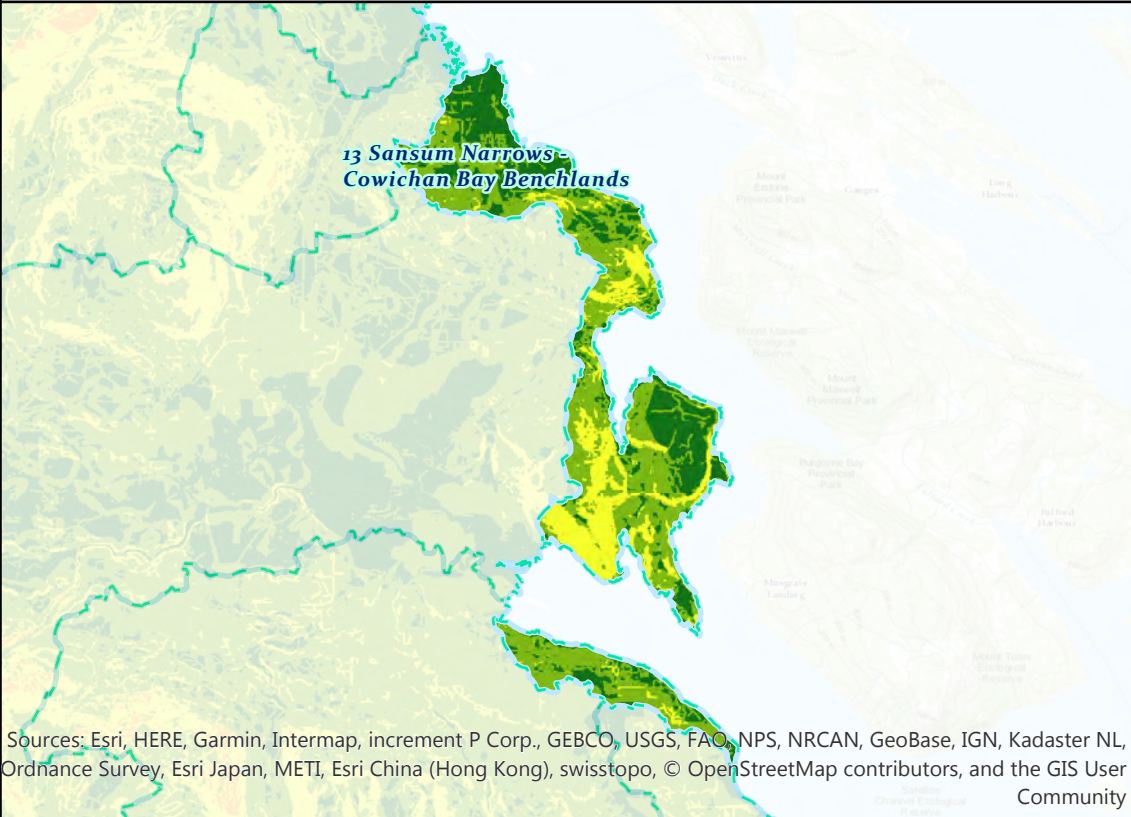
CHK'D: DK Proj Coord Sys: NAD 1983 UTM Zone 10N **651957-106-MAL**

10. Sansum Narrows – Cowichan Bay Benchlands	
Topic	Discussion
Slope Failure	<p>Hazard was determined qualitatively at a high level to describe areas based on the degree to which they may be prone to landslides and other mass movements using terrain characteristics. Hazard classifications were generated to show relative comparisons between terrain units within the CVRD watershed study area. Risk ratings derived from this analysis are relative, and should be used to guide prioritization of further detailed studies.</p> <p>Hazard is greatest on the relatively steep slopes near Mount Tzouhalem and Maple Mountain. These slopes generally extend down to the shoreline. Consequence is considered moderate to high through the populated areas distributed throughout the watershed. Risk is considered greatest near the populated areas below Mount Tzouhalem.</p>
Flooding	A few creeks drain the watershed where hazard is focused. Consequence and risk are relatively higher where the creeks outlet at Crofton and residential areas of Cowichan Bay.
Groundwater Contamination	Hazard is relatively low in this watershed compared to other watersheds. The higher hazards were noted in the northern and southern portions of the watershed surrounding Crofton and Cowichan Bay, respectively. Consequence is considered very low for the majority of the watershed except for areas adjacent to municipal water supply wells in and around Cowichan Bay. Risk generally reflects the consequence rating and is higher in the Cowichan Bay area.
Surface Water Quality	Hazard varies greatly throughout the watershed based on locations of residential and agricultural land use in the watershed. A significant proportion of the watershed contains low order streams that produce a high consequence ranking. Higher risk areas are present in the industrial area north of Crofton, the agricultural areas north of Genoa Bay, and portions of the residential and industrial areas surrounding Cowichan Bay. Population growth is anticipated for the watershed that is likely to add pressure to surface water quality since the vast majority of the watershed is currently considered at a relatively higher risk.
Surface Water Supply	<p>Greater hazard zones are present over a small proportion of the watersheds overall. There is a zone of greater hazard south of Cowichan Bay, across the agricultural lands north of Genoa Bay, and in small isolated zones around Crofton. In the Cowichan Bay area, greater consequences are present in isolated zones near the coastline, and along one stream south of the community. Between Genoa Bay and Maple Bay, the zones of greater consequence occupy isolated areas, and are a small portion of the area. Consequence is greater near Crofton, at isolated locations, and also along the length of the stream north of the community. Risk is greatest along the coast ling sough of Cowichan Bay and along short segments of the stream north of Crofton, occupying a very small proportion of the watershed's area. Projections indicate an increasing population and therefore additional pressures from residential use is expected on groundwater sources.</p>
General Data Notes	The Sansum Narrows – Cowichan Bay overall risk level is relatively high, with some contribution from surface water quality and groundwater contamination. Flood, slope failure and surface water supply all contribute as well, to a lesser degree.

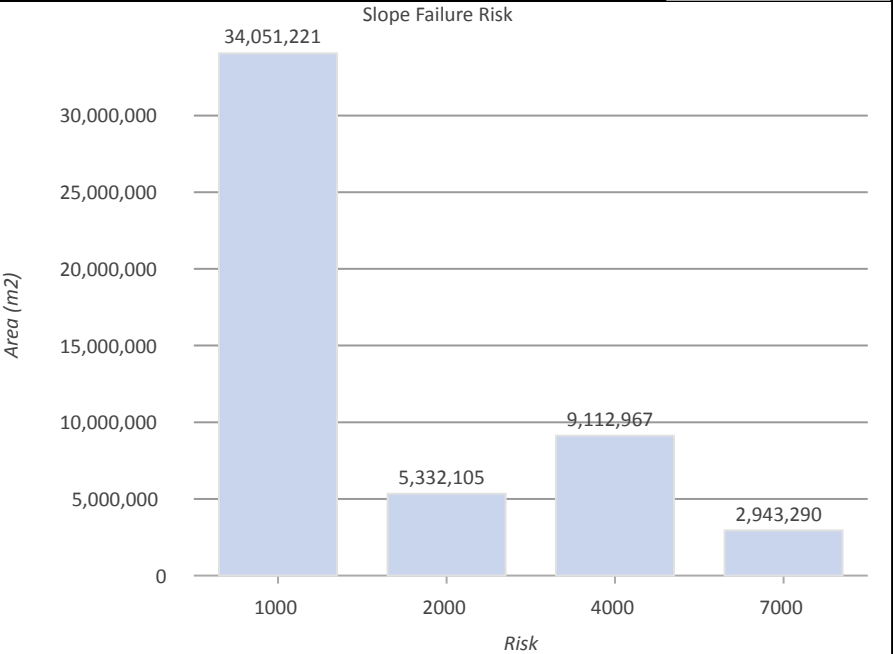
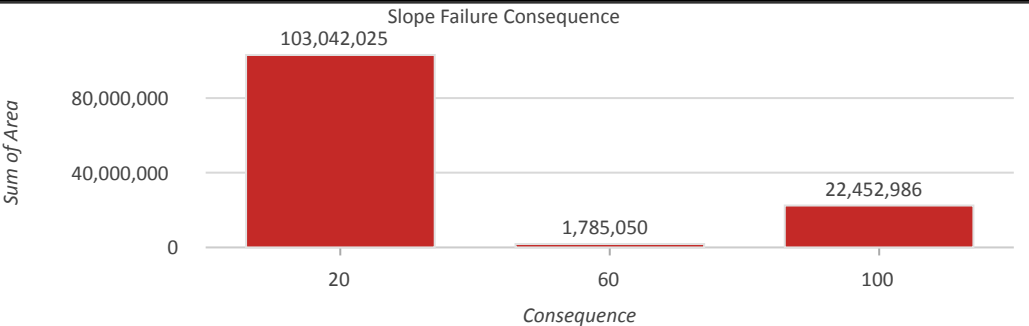
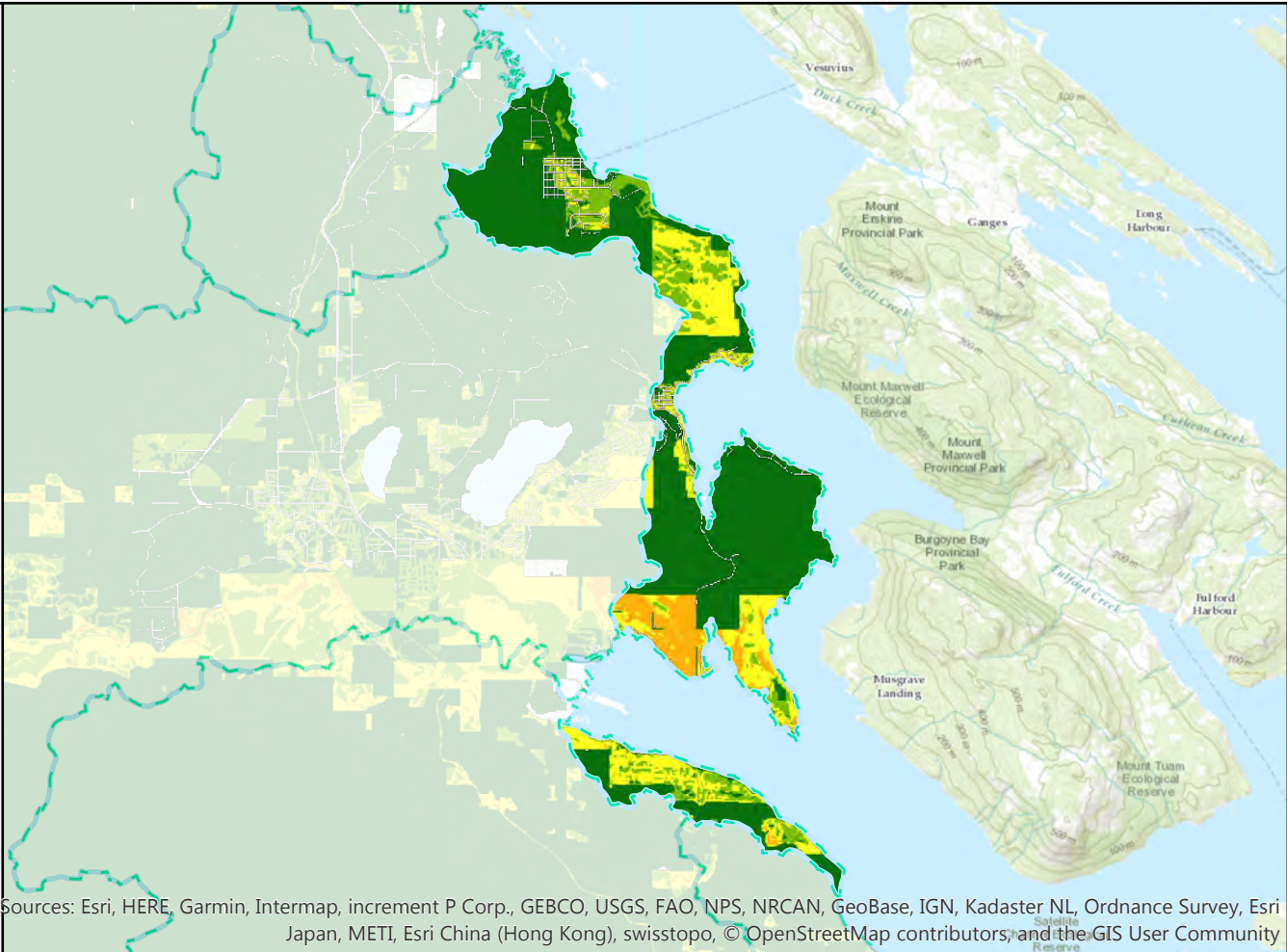
CONSEQUENCE



HAZARD



RISK



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Vlalley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

NOTES:

1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Sansum Narrows - Cowichan Bay Benchlands



Slope Failure Risk Assessment - Sansum Narrows

BY: CJW

SCALE CONS: 1:170,775

DATE: 2019/01/07

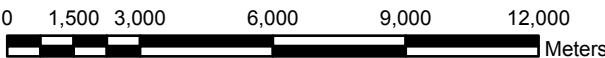
REF No:

REV: 0

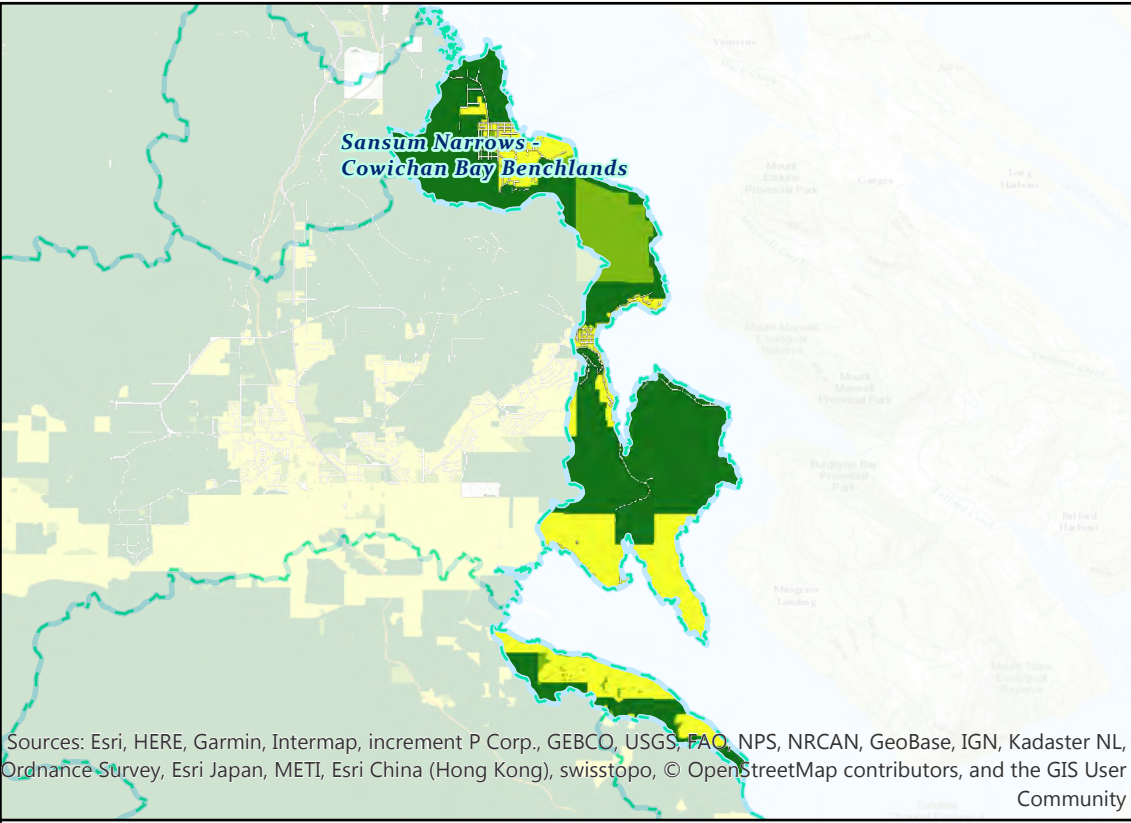
CHK'D: DK

Proj Coord Sys: PCS Albers

651957-101-SANS

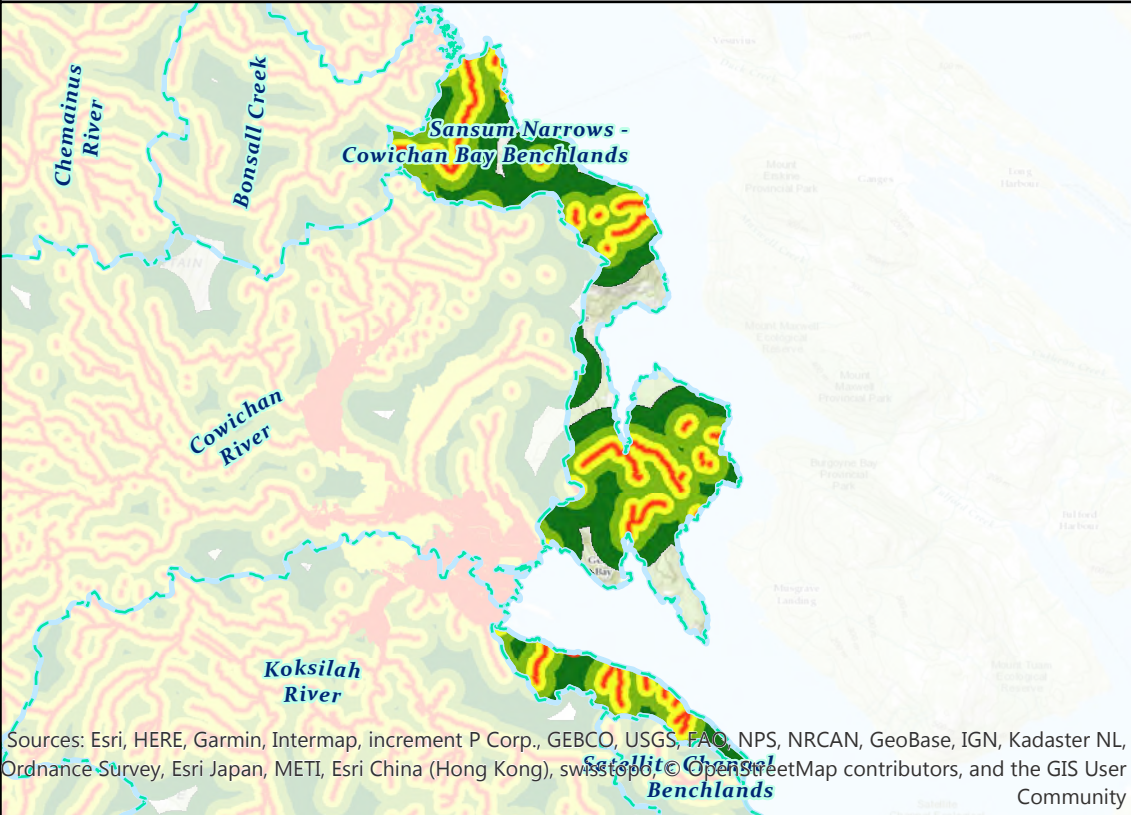


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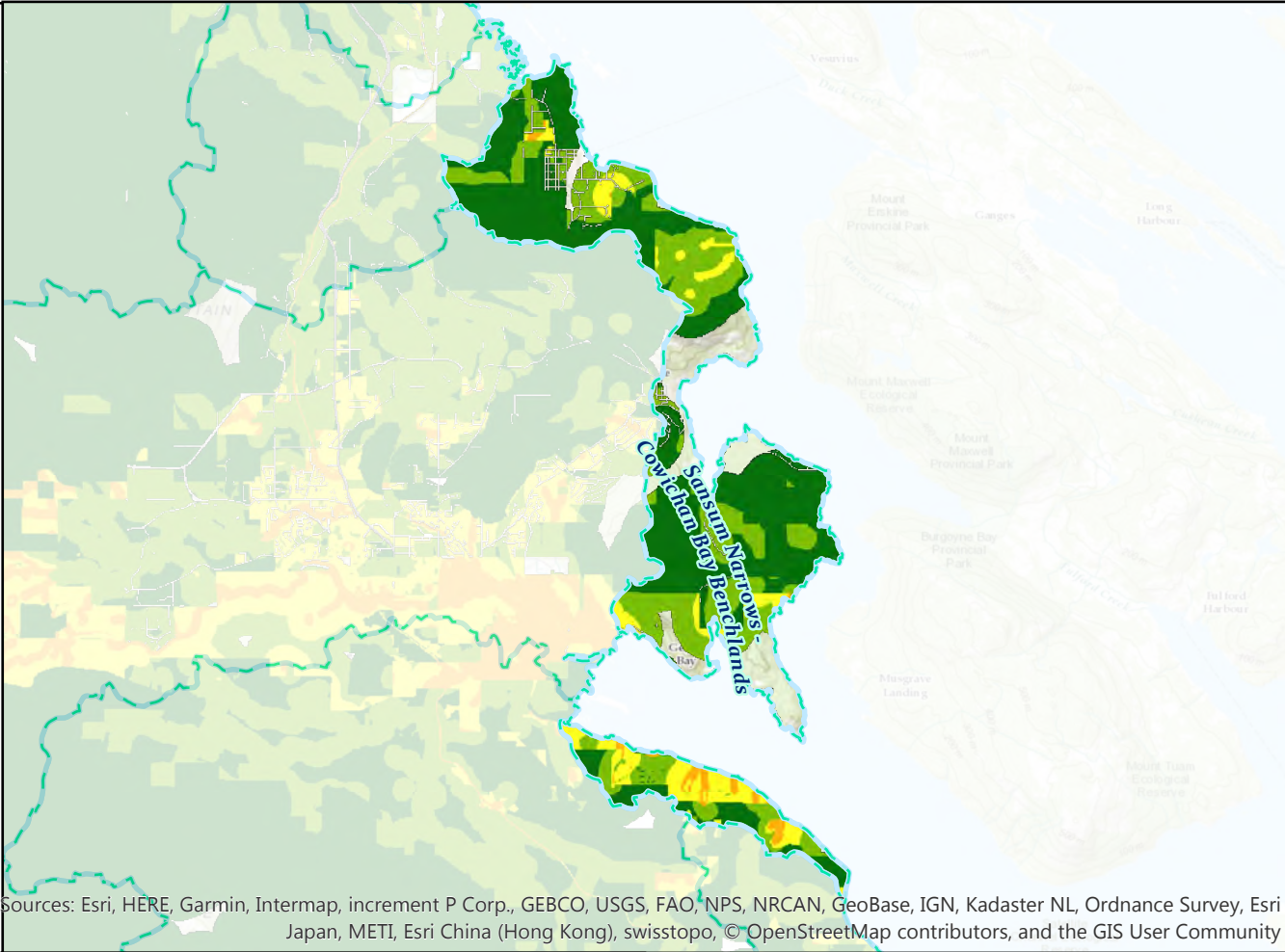
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HAZARD

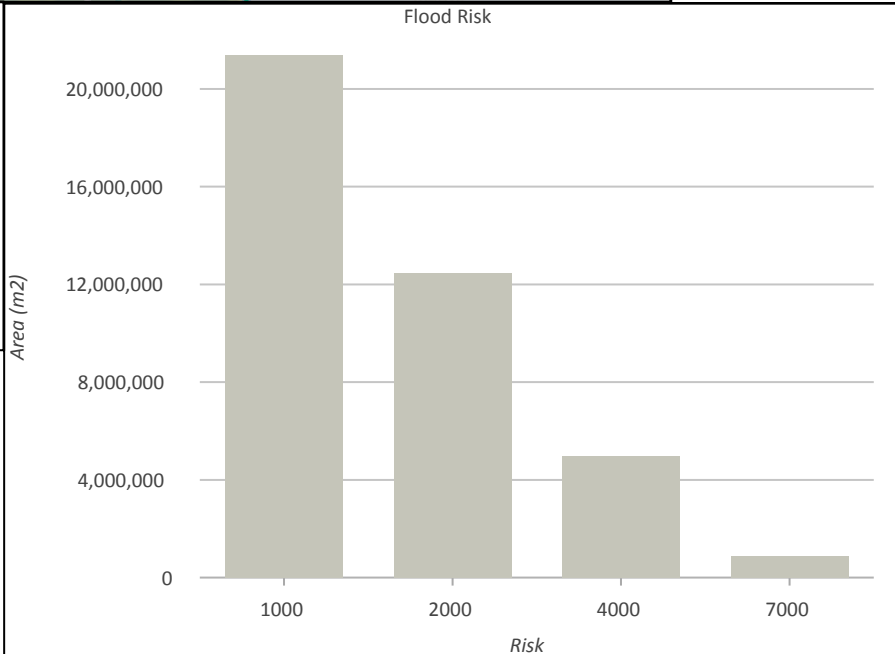
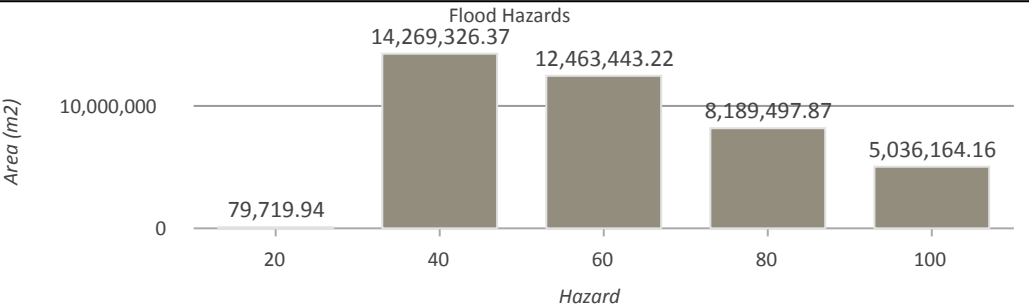
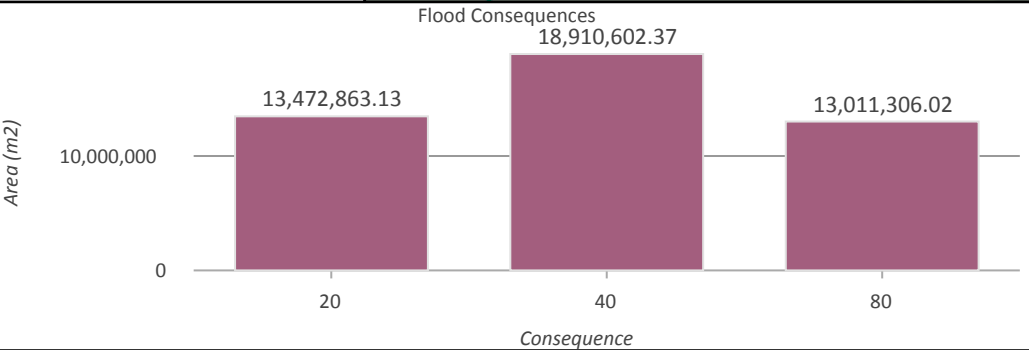


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Sansum Narrows - Cowichan Bay Benchlands



Flood Risk Assessment - Sansum Narrows - Cowichan Bay

BY: CJW

SCALE CONS: 1:168,319

DATE: 2019/01/08

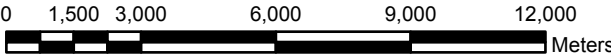
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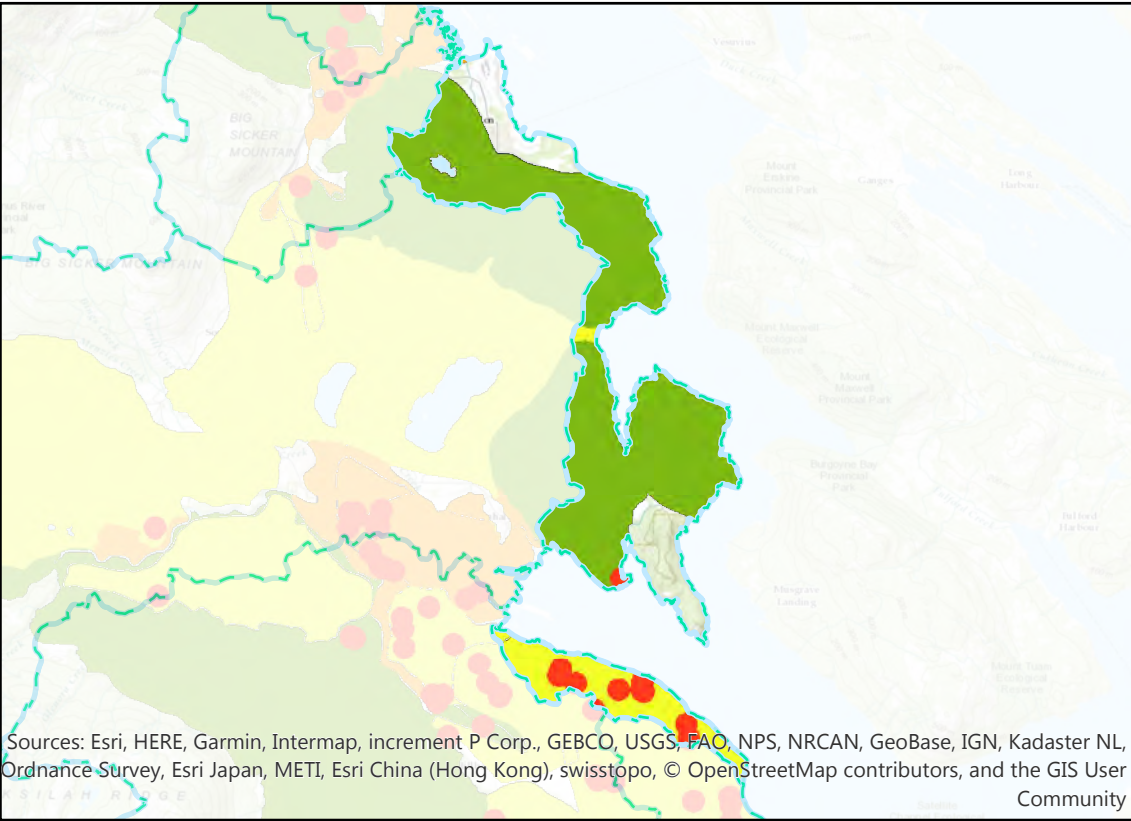
CHK'D: DK

Proj Coord Sys: NAD 1983 UTM Zone 10N

651957-102-SANS

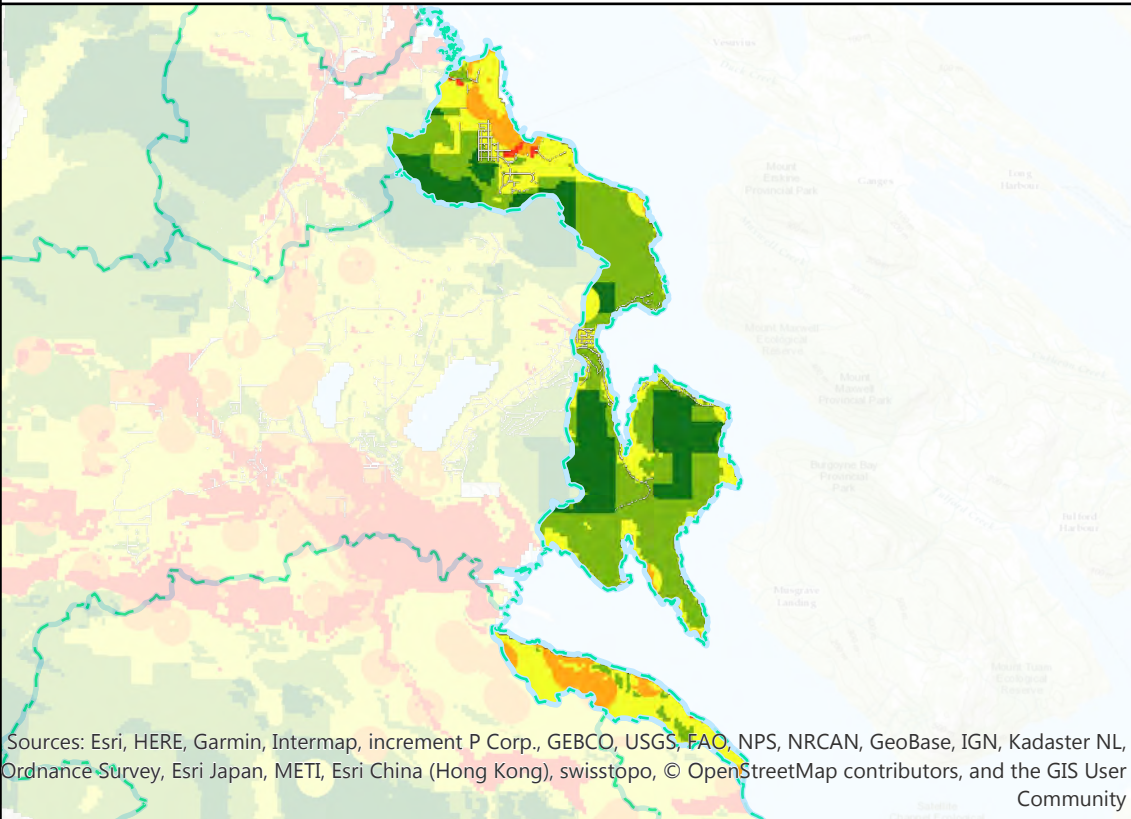


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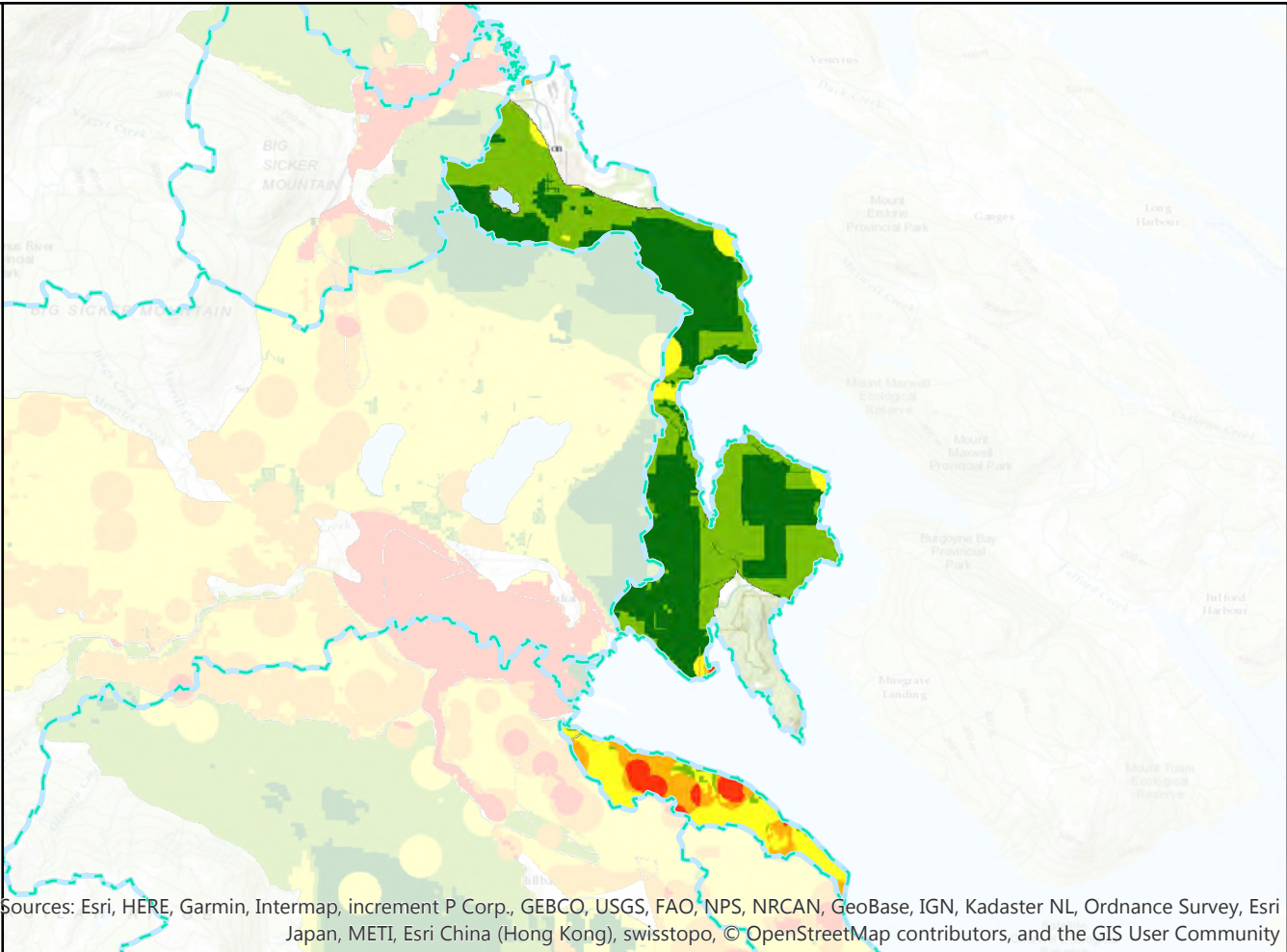
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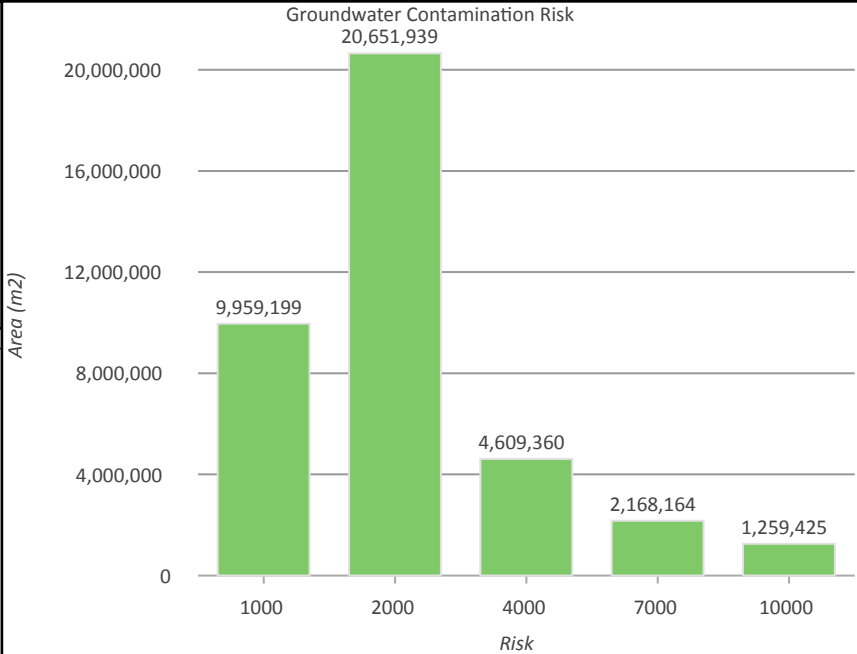
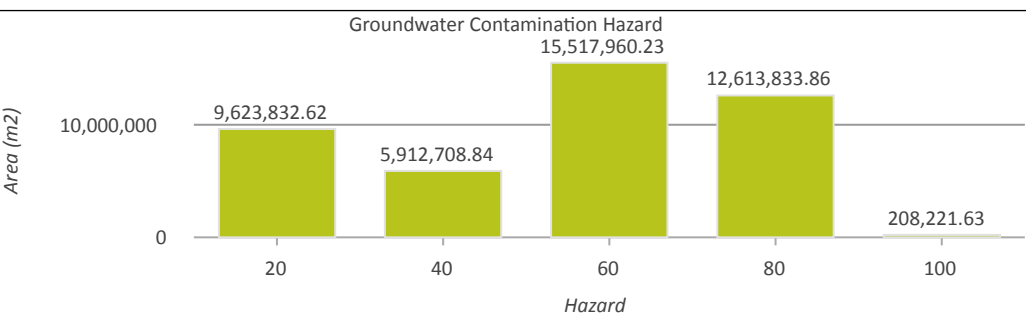
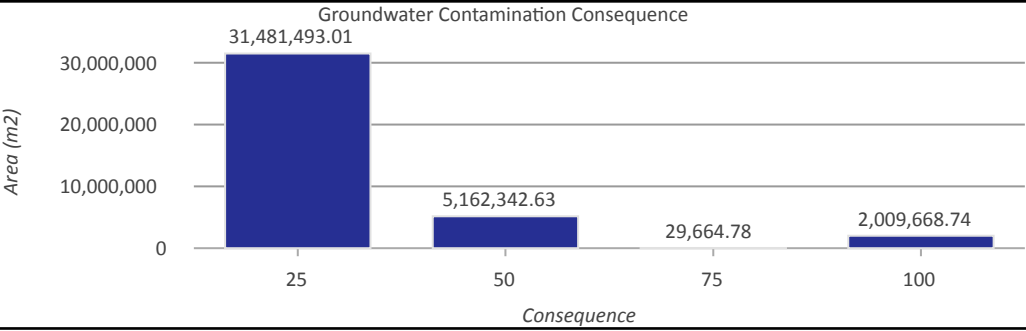


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RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Sansum Narrows - Cowichan Bay Benchlands



Groundwater Contamination Risk Assessment - Sansum Narrows -

BY: CJW

SCALE CONS: 1:168,319

DATE: 2019/01/08

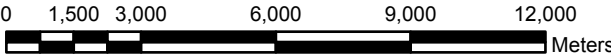
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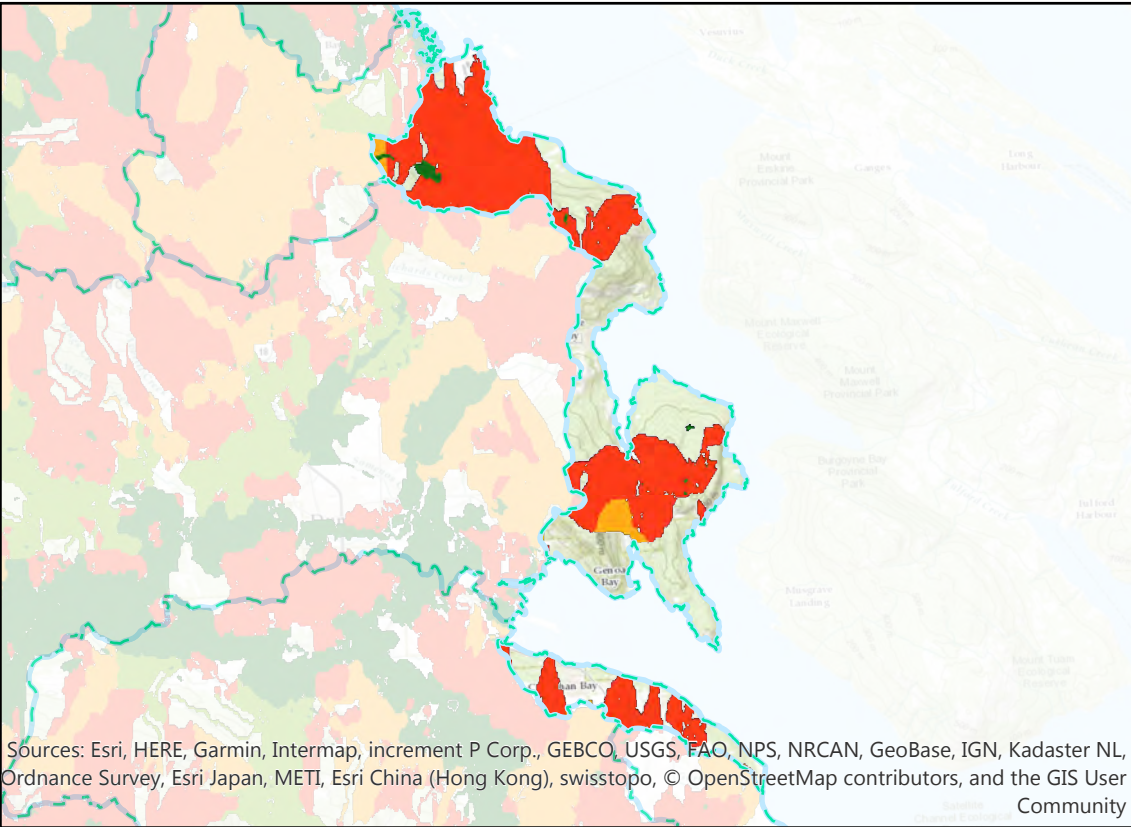
CHK'D: DK

Proj Coord Sys: NAD 1983 UTM Zone 10N

651957-103-SANS

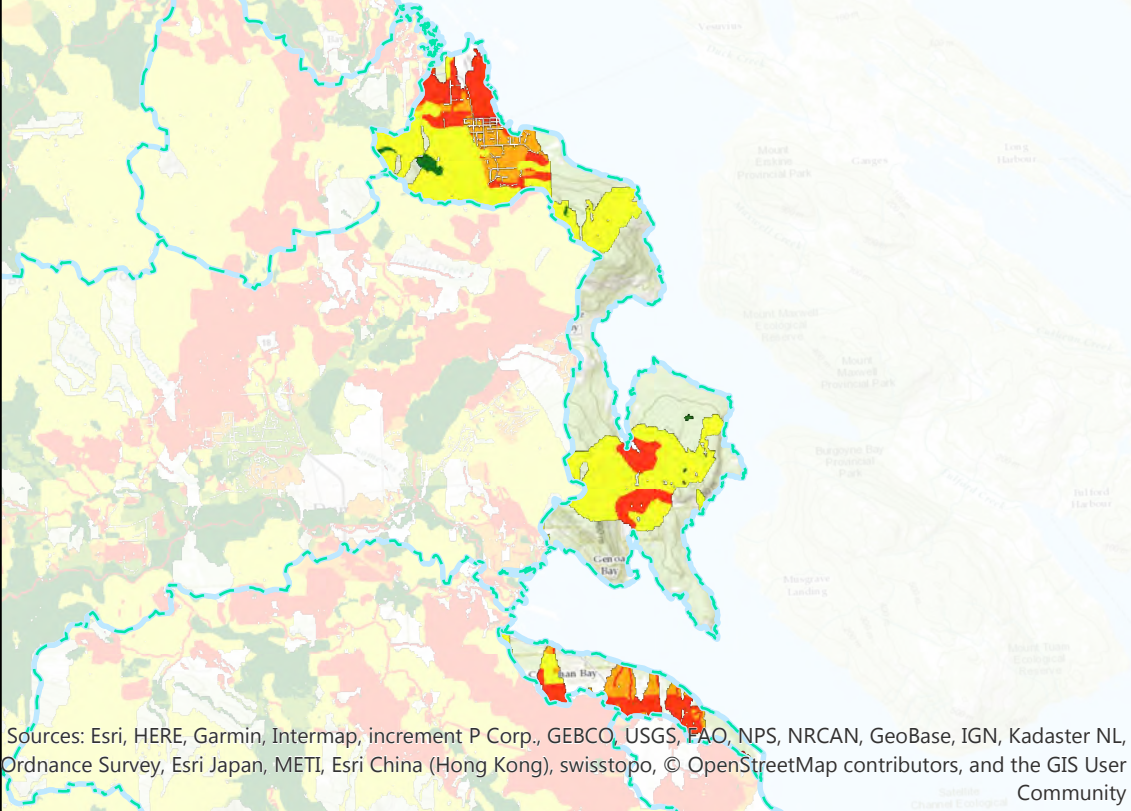


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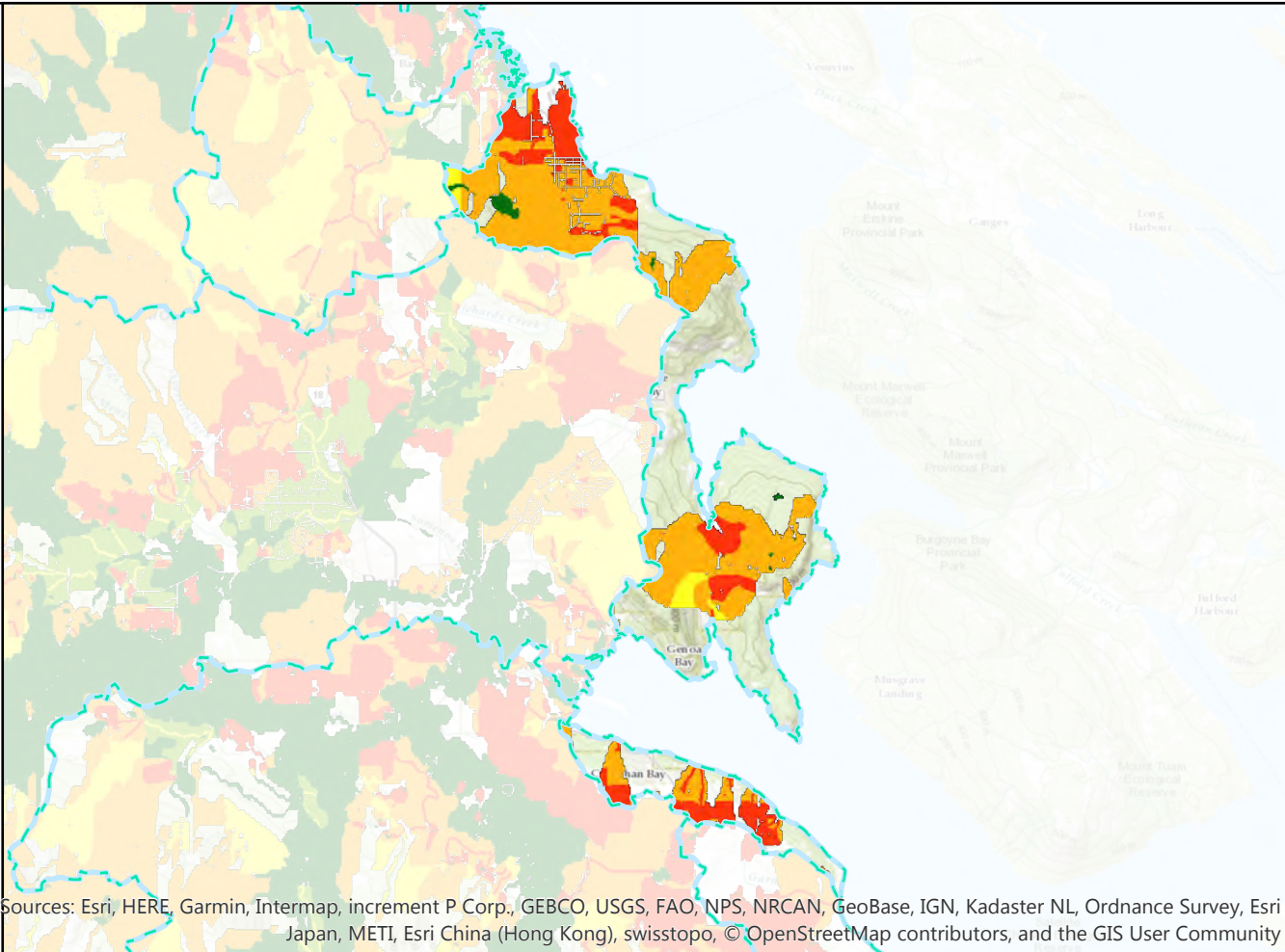
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HAZARD

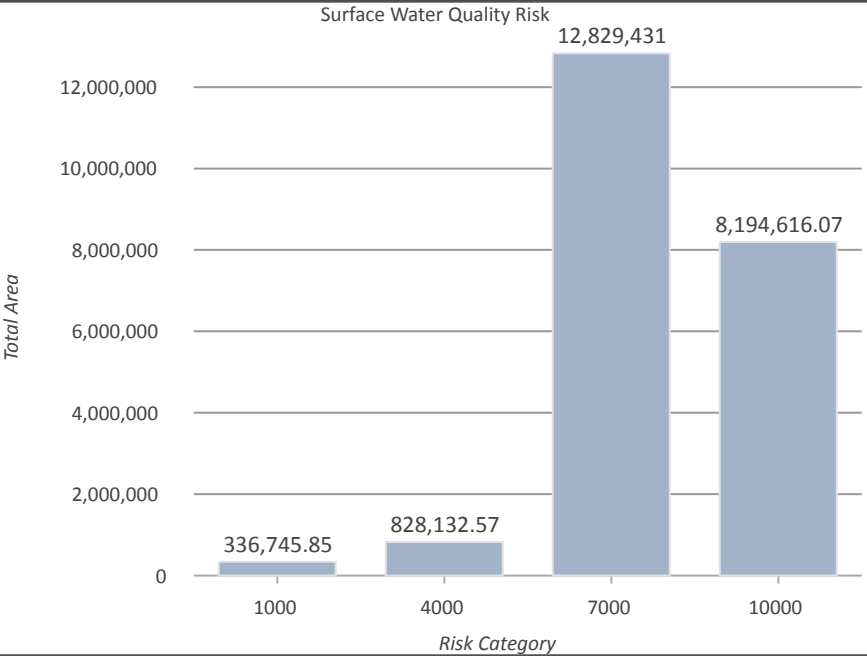
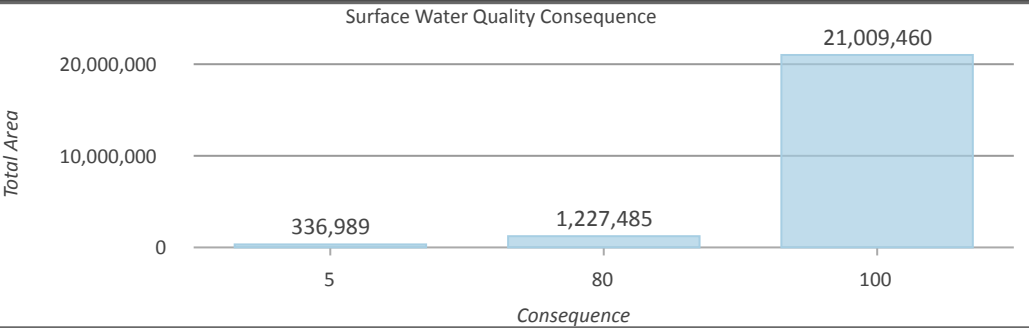
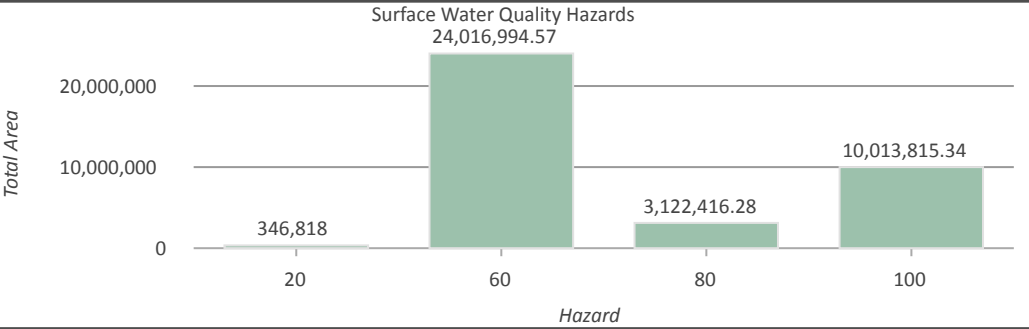


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
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≤ 100

RISK

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

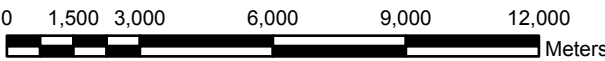
CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Narrows - Cowichan Bay Benchlands Watershed



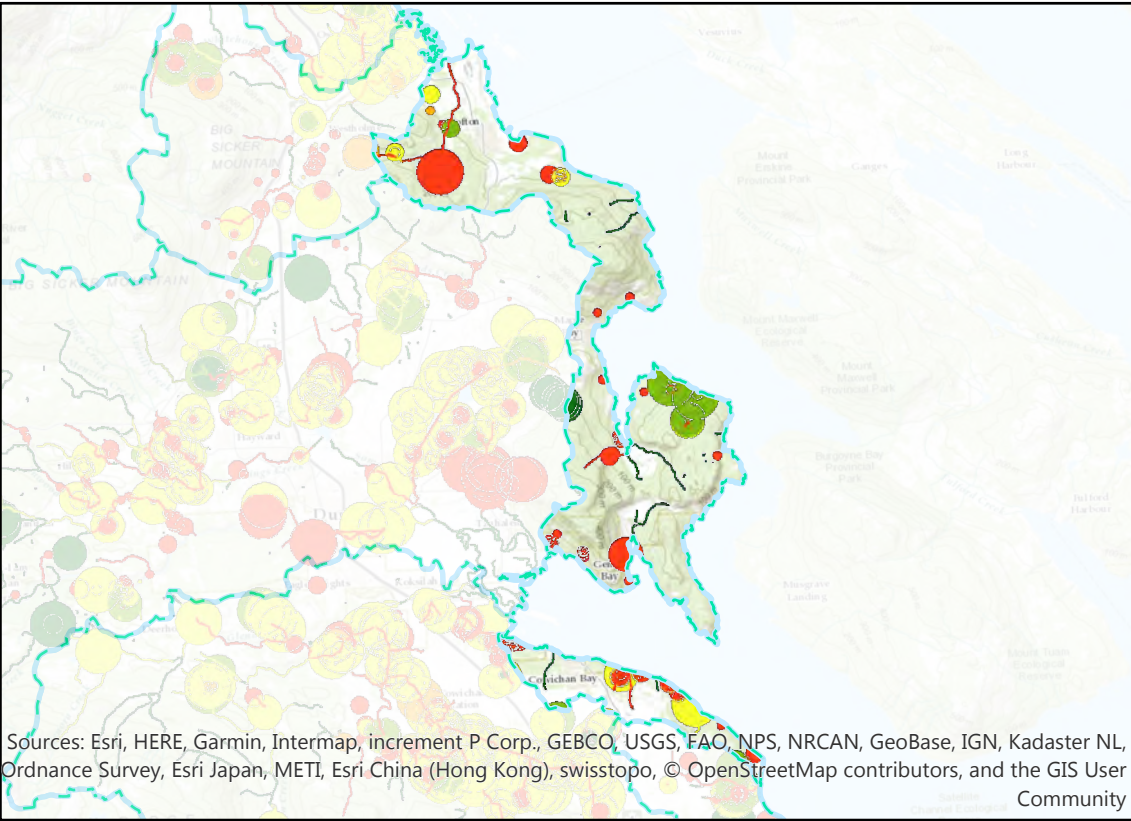
Surface Water Quality Risk Assessment - Sansum Narrows -

BY: SCALE: 1:170,549 DATE: 2019/01/08 REF No: REV: 0
CHK'D: Proj Coord Sys: PCS Albers 651957-104-SANS



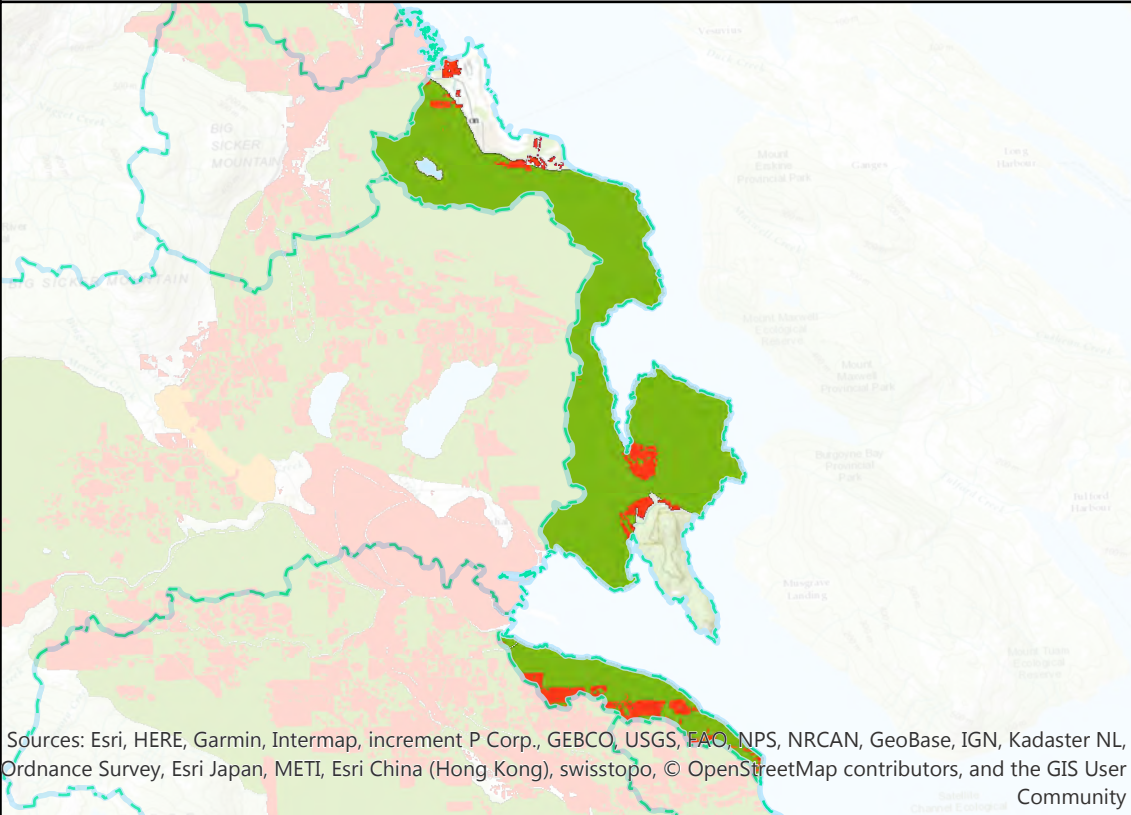
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CONSEQUENCE



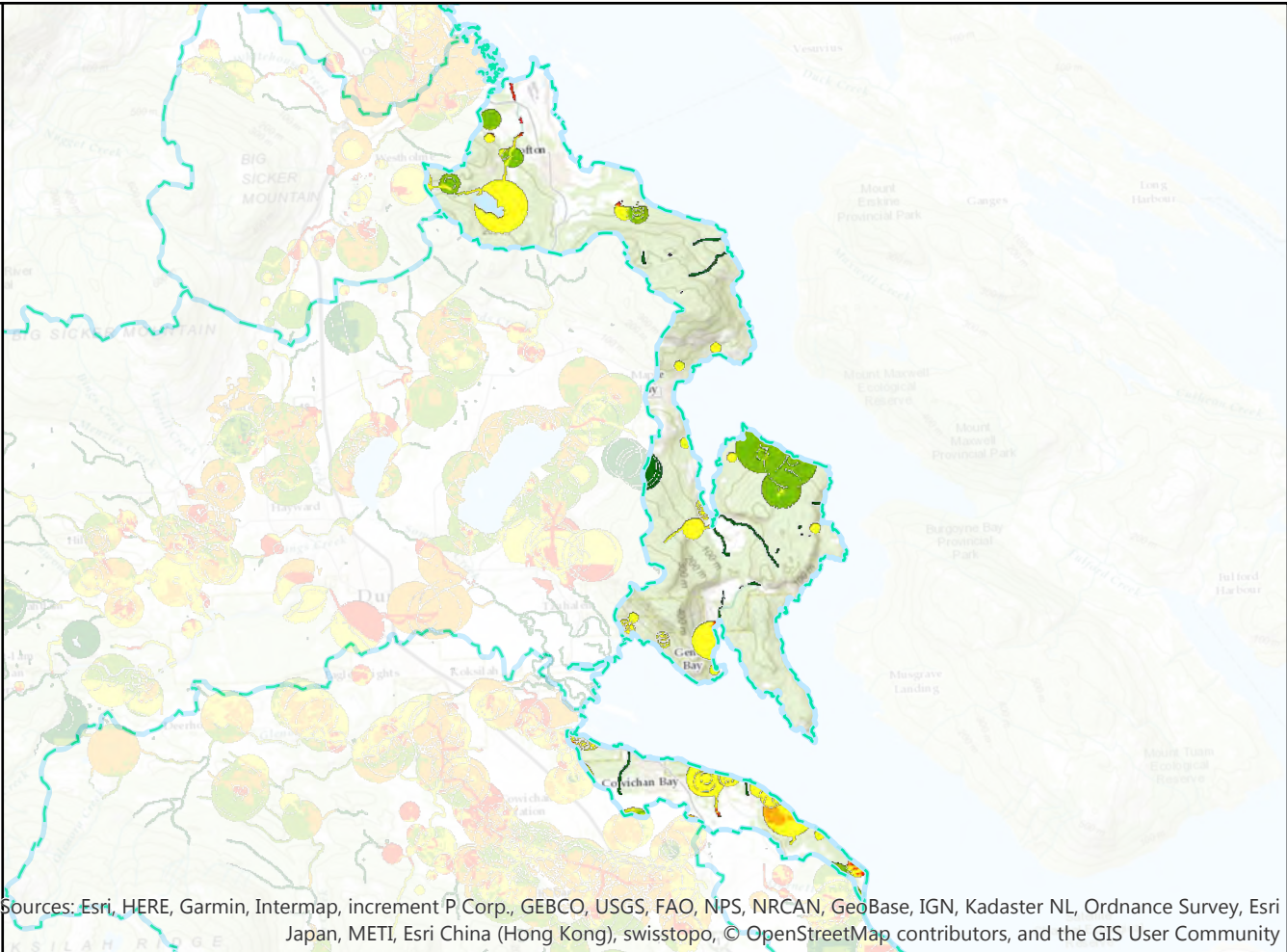
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HAZARD

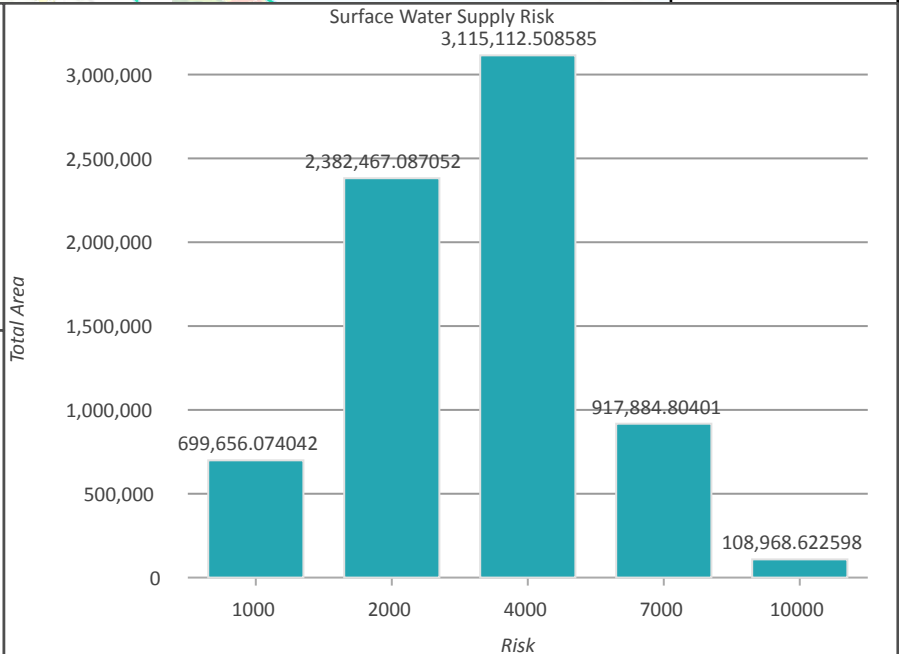
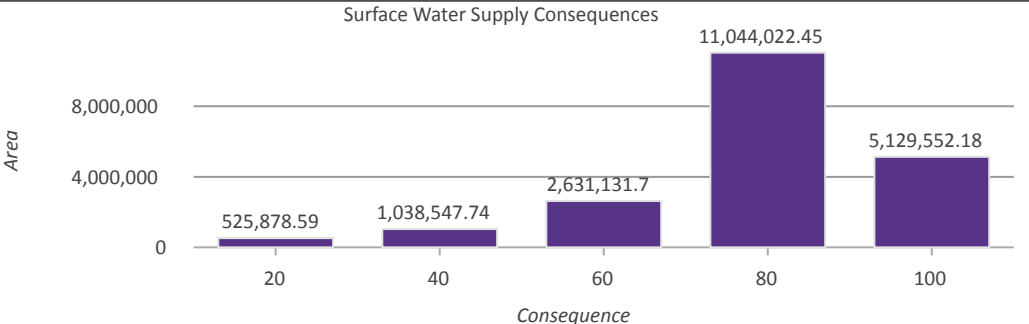
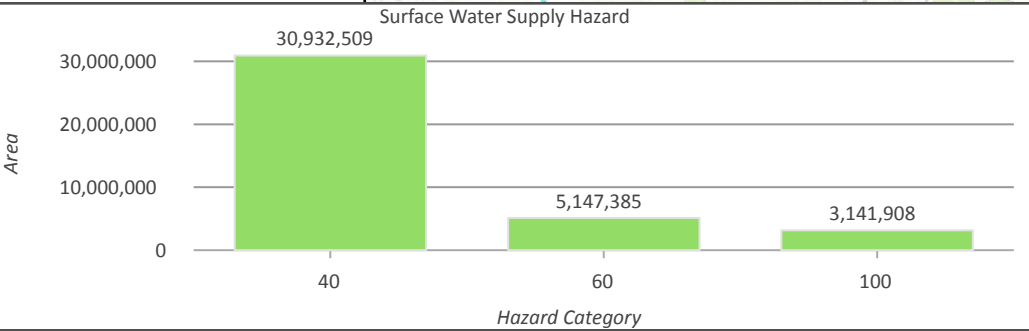


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Narrows - Cowichan Bay Benchlands Watershed



SNC • LAVALIN

Surface Water Supply Risk Assessment - Sansum Narrows -

BY:

SCALE: 1:165,769

DATE: 2019/01/08

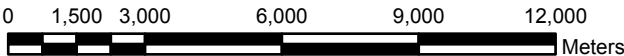
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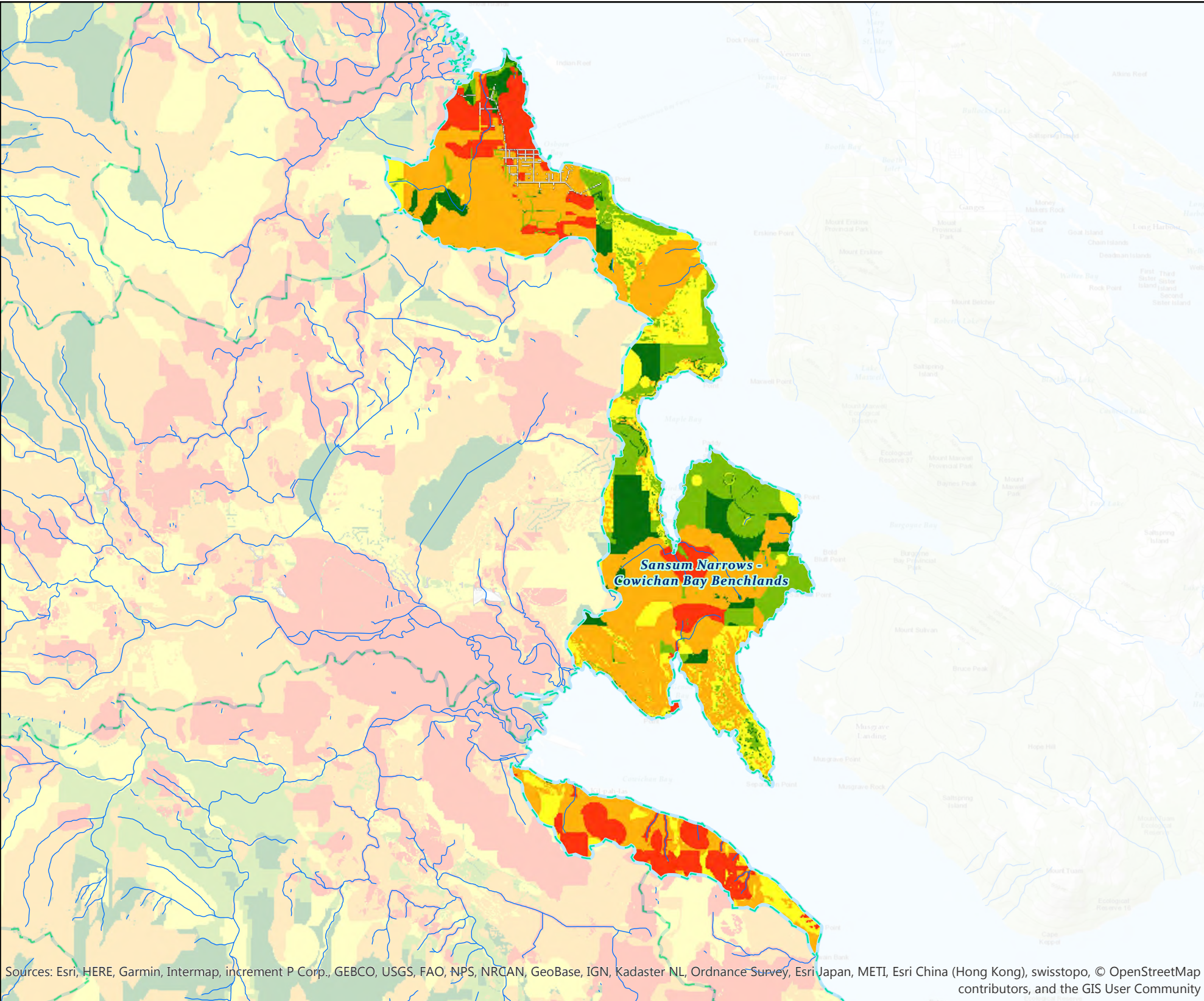
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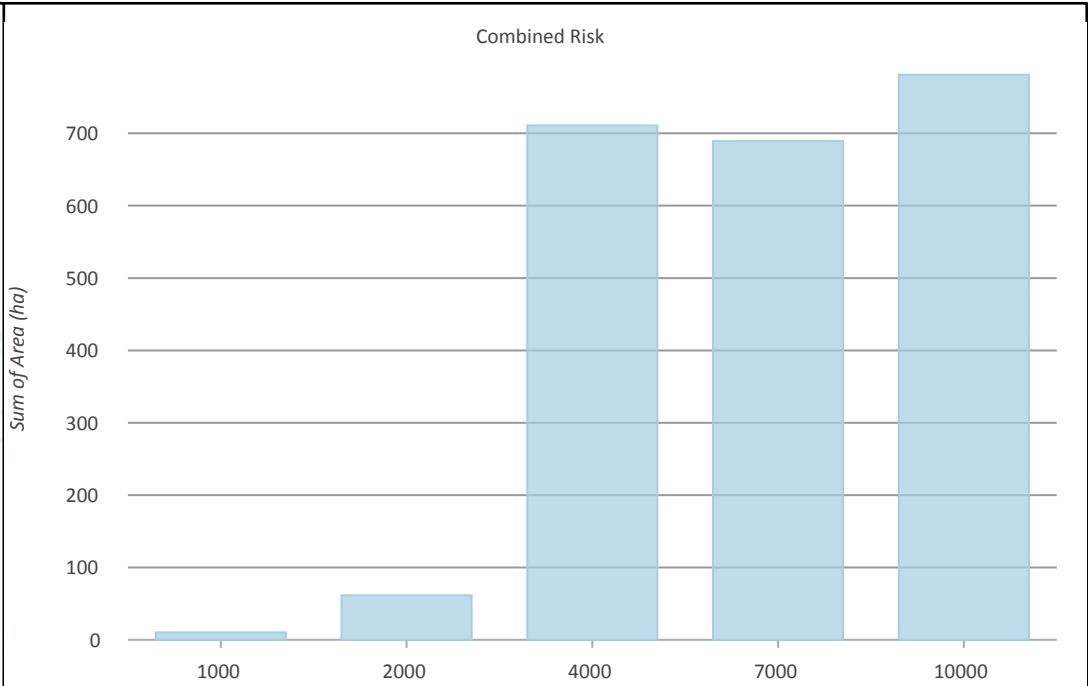
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651957-105-SANS





Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



NAME	Risk	POP ₂₀₂₁	POP ₂₀₂₆	POP ₂₀₃₁	POP ₂₀₃₆
SHAWNIGAN CREEK		10047	10760	11613	12598
BUSH CREEK		0	0	0	0
KOKSILAH RIVER		5463	5851	6315	6850
HOLLAND CREEK		1302	1368	1446	1537
BONSALL CREEK		934	974	1019	1073
CHEMAINUS RIVER		1490	1461	1439	1421
COWICHAN RIVER		36368	37905	39683	41766
YELLOW POINT BENCHLANDS		2239	2352	2487	2643
LADYSMITH - SALTAIR BENCHLANDS		8410	8834	9342	9929
STOCKING CREEK		1531	1608	1701	1807
CHEMAINUS BENCHLANDS		3663	3818	3997	4207
SATELLITE CHANNEL BENCHLANDS		4390	4701	5074	5504
SANSUM NARROWS - COWICHAN BAY BENCHLANDS		4941	5150	5391	5674
MALAHAT BENCHLANDS		2829	3030	3271	3548

NAME	POP ₂₀₀₁	POP ₂₀₀₆	POP ₂₀₁₁	POP ₂₀₁₆
SHAWNIGAN CREEK	6348	8439	8925	9484
BUSH CREEK	0			
KOKSILAH RIVER	4555	4808	4954	5157
HOLLAND CREEK	1611	1114	1169	1245
BONSALL CREEK	672	830	815	890
CHEMAINUS RIVER	1423	1395	1497	1514
COWICHAN RIVER	29779	32673	34075	34647
YELLOW POINT BENCHLANDS	1167	1958	2021	2141
LADYSMITH - SALTAIR BENCHLANDS	5275	7488	7541	8042
STOCKING CREEK	1332	1003	1354	1464
CHEMAINUS BENCHLANDS	3177	3129	3085	3490
SATELLITE CHANNEL BENCHLANDS	5425	3902	3989	4144
SANSUM NARROWS - COWICHAN BAY BENCHLANDS	5993	4221	4500	4707
MALAHAT BENCHLANDS	1673	2472	2548	2671

Legend

WATERSHED BOUNDARIES

RISK

- ≤ 1000
- ≤ 2000
- ≤ 4000
- ≤ 7000
- ≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

NOTES:

1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.

REVISIONS:

0 - CJW - 2018-11-30 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Sansum Narrows - Cowichan Bay Benchlands

Combined Risk Assessment - Sansum Narrows - Cowichan Bay

BY: CJW

CHK'D: DK

SCALE CONS: 1:99,000

Proj Coord Sys: NAD 1983 UTM Zone 10N

DATE: 2019/01/08

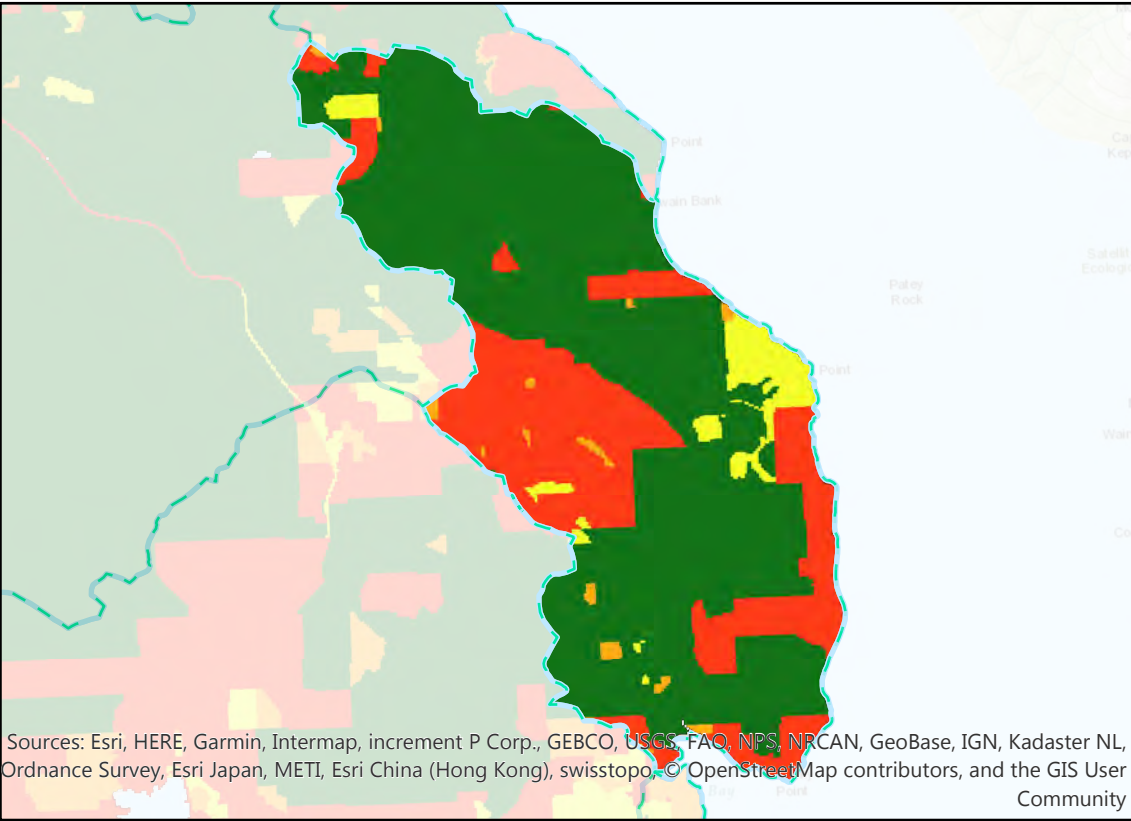
REF No: **651957-106-SANS**

REV: **0**

Project Path: P:\Current Projects\CVRD\651957\ P: 10 - 6

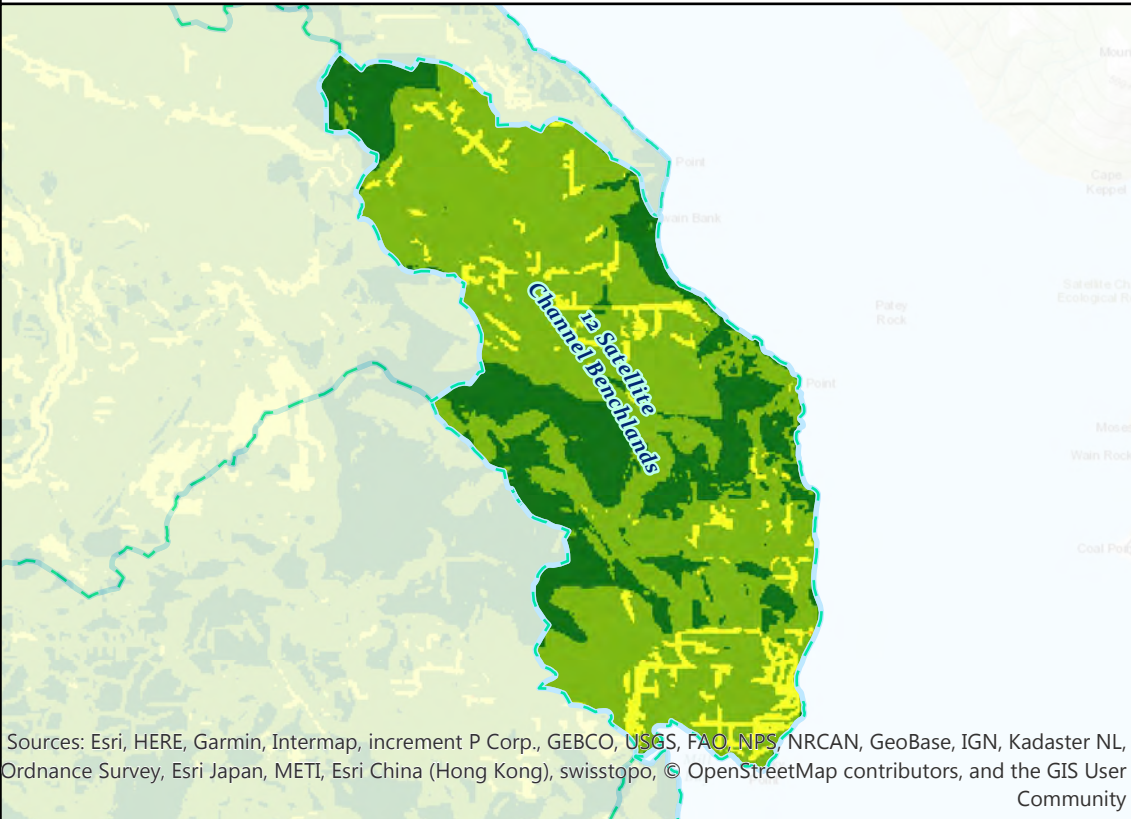
11. Satellite Channel Benchlands	
Topic	Discussion
Slope Failure	<p>Hazard was determined qualitatively at a high level to describe areas based on the degree to which they may be prone to landslides and other mass movements using terrain characteristics. Hazard classifications were generated to show relative comparisons between terrain units within the CVRD watershed study area. Risk ratings derived from this analysis are relative, and should be used to guide prioritization of further detailed studies.</p> <p>Hazard is generally low throughout the Satellite Channel Benchlands watershed due to the gentle slopes. Consequence is considered moderate to high through the populated areas which are scattered around the watershed. Risk is generally considered low throughout the watershed.</p>
Flooding	<p>Hazard is limited to the creeks and small water bodies within the watershed. Generally, consequence and risk are relatively greater in the residential areas along the west and east ends of the central portion of the watershed, separated by agricultural areas where consequence and risk are relatively lower.</p>
Groundwater Contamination	<p>Hazard is relatively low throughout the watershed. Consequence is focused at municipal water supply wells throughout the watershed, which reflect the locations of relatively higher risk.</p>
Surface Water Quality	<p>Areas of high hazard, consequence, and risk are similar in location and extent. Almost no area in the watershed is considered low or lower in terms of level of hazard, consequence, and risk. Higher hazard, consequence, and risk comprise roughly half of the watershed's total area based on impervious surface cover, land development, land use type, stream order, and the relative locations of each of these factors. The watershed mainly consists of residential and agricultural areas that place overall greater stress on surface water quality. Residential and agricultural areas in the central and south-western portions of the watershed are the largest higher risk zones. Projected population growth in the watershed is likely to place greater stress on stream health due to the prevalence of lower order streams and present dominance of high risk zones.</p>
Surface Water Supply	<p>Hazard is mixed across the watershed and associated with high vulnerability index and the presence of contaminated sites. Consequence is greater where municipal wells are located. Risk is mixed across the watershed with zones of greater risk along several stream segments across the watershed, and a zone near Hatch Point. Projections indicate an increasing population and therefore additional pressures from residential use is expected on groundwater sources.</p>
General Data Notes	<p>The combined risk for the Satellite Channel Benchlands is relatively high. Flood and slope failure risk is a low contributor, while groundwater contamination, surface water supply, and surface water quality are major contributors to overall risk.</p>

CONSEQUENCE



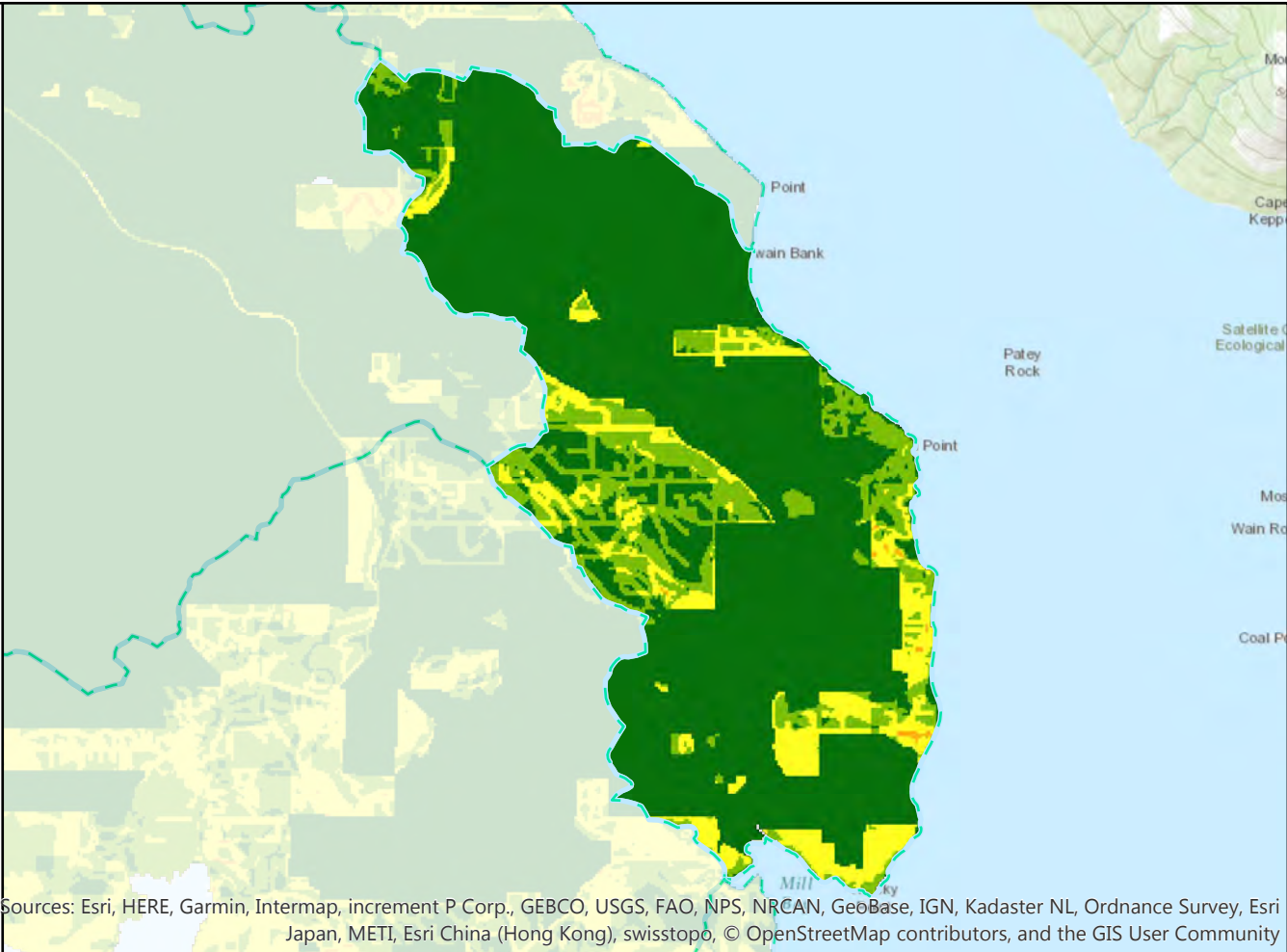
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

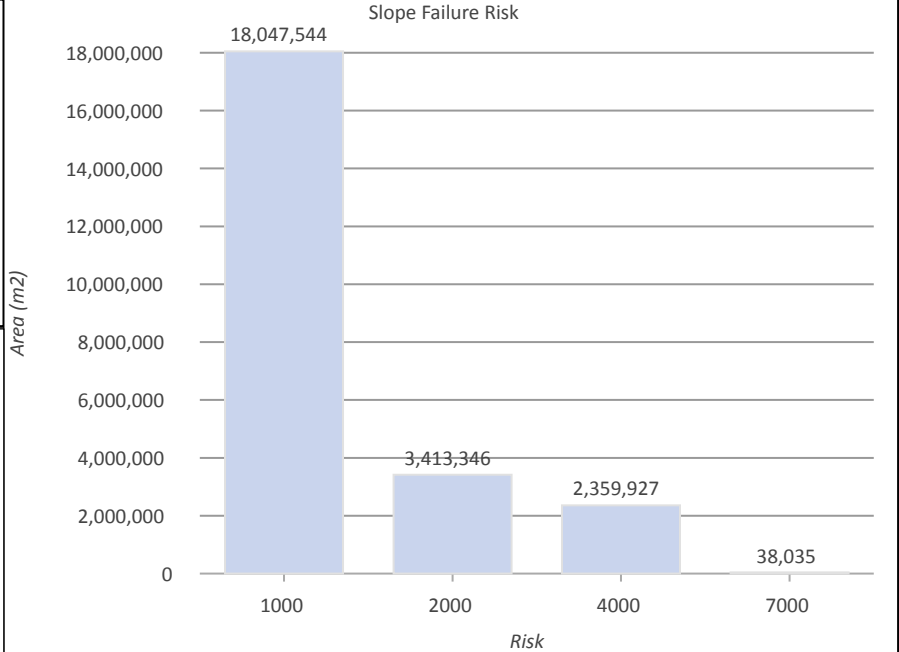
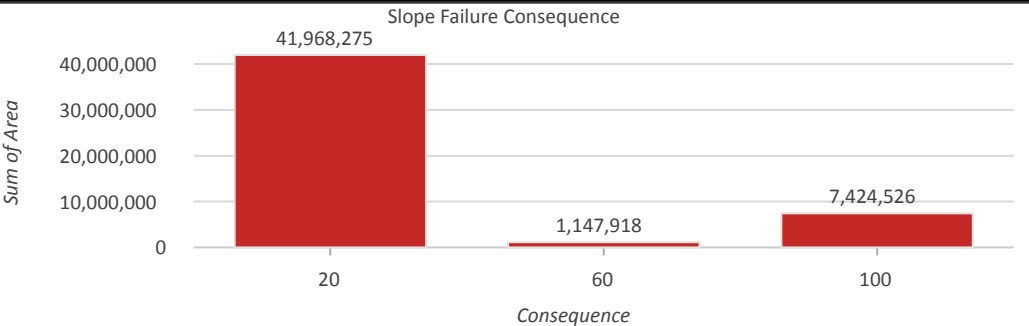


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Vlalley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

NOTES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Satellite Channel Benchlands Watershed



Slope Failure Risk Assessment - Satellite Channel

BY: CJW

SCALE CONS: 1:70,075

DATE: 2019/01/07

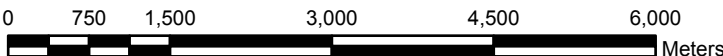
REF No:

REV: 0

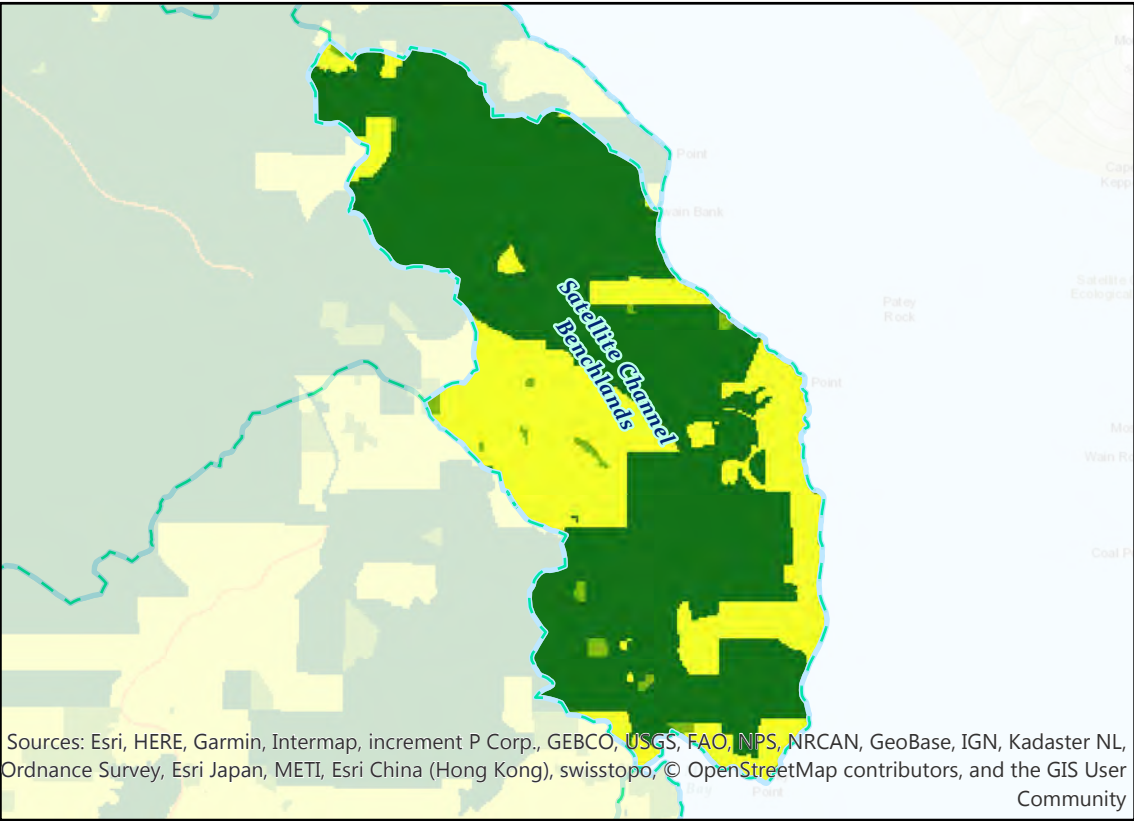
CHK'D: DK

Proj Coord Sys: PCS Albers

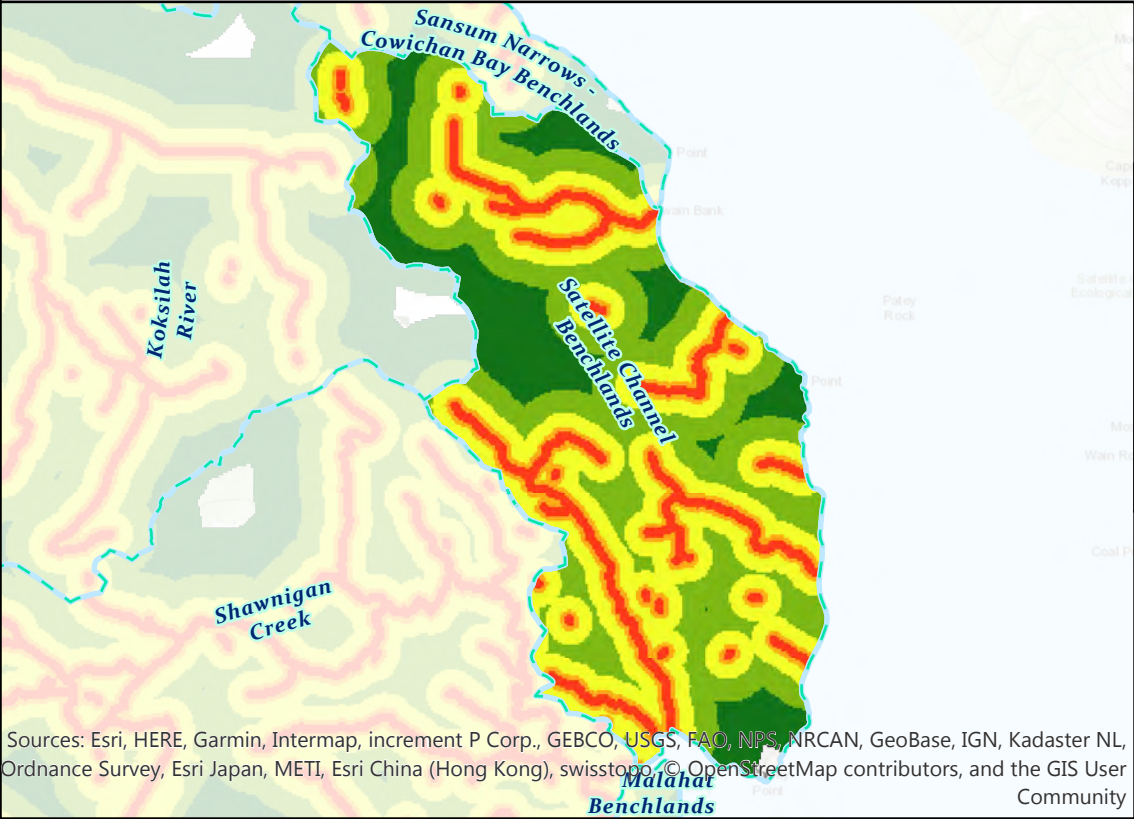
651957-101-SATC



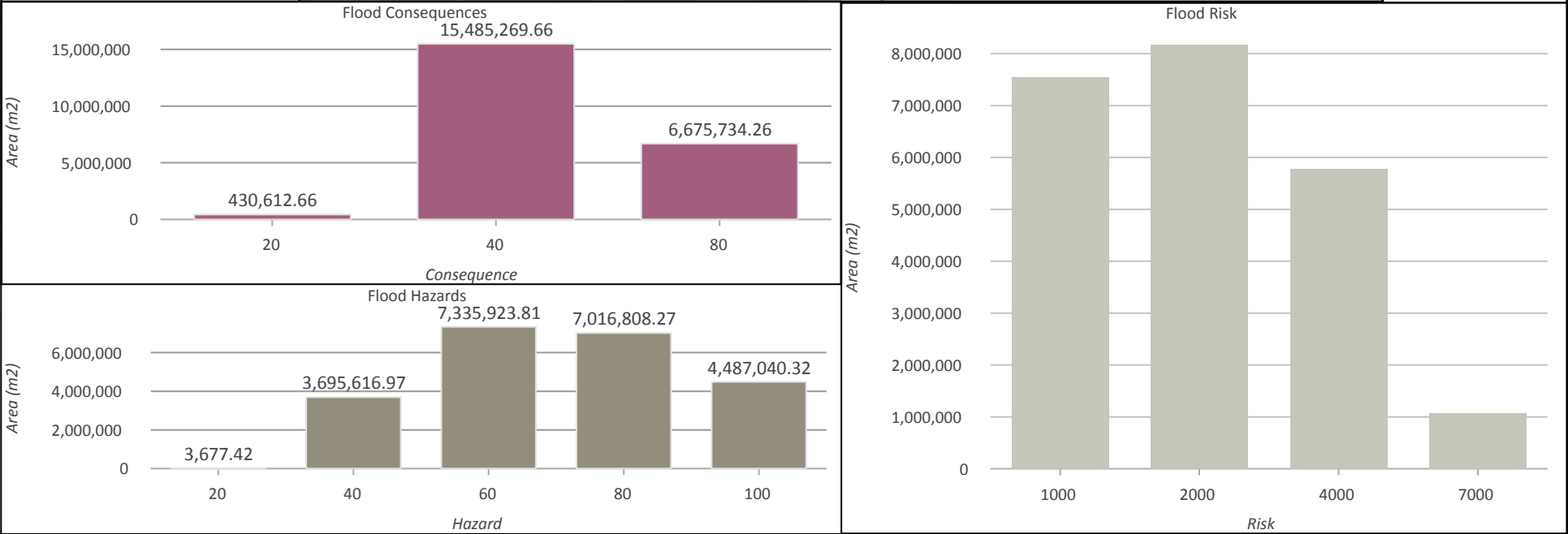
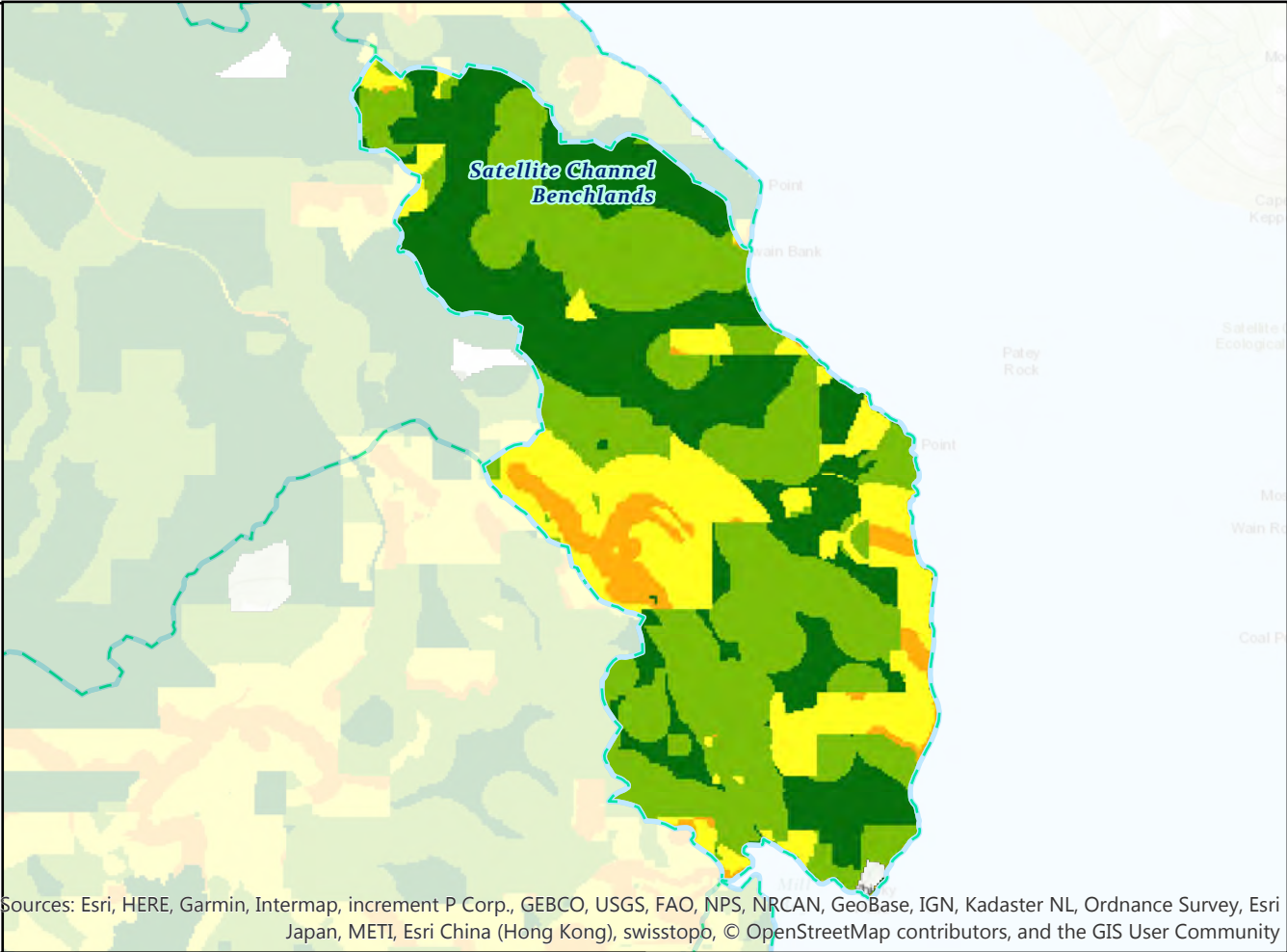
CONSEQUENCE



HAZARD



RISK



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

	≤ 20
	≤ 40
	≤ 60
	≤ 80
	≤ 100

RISK

	≤ 1000
	≤ 2000
	≤ 4000
	≤ 7000
	≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Satellite Channel Benchlands Watershed

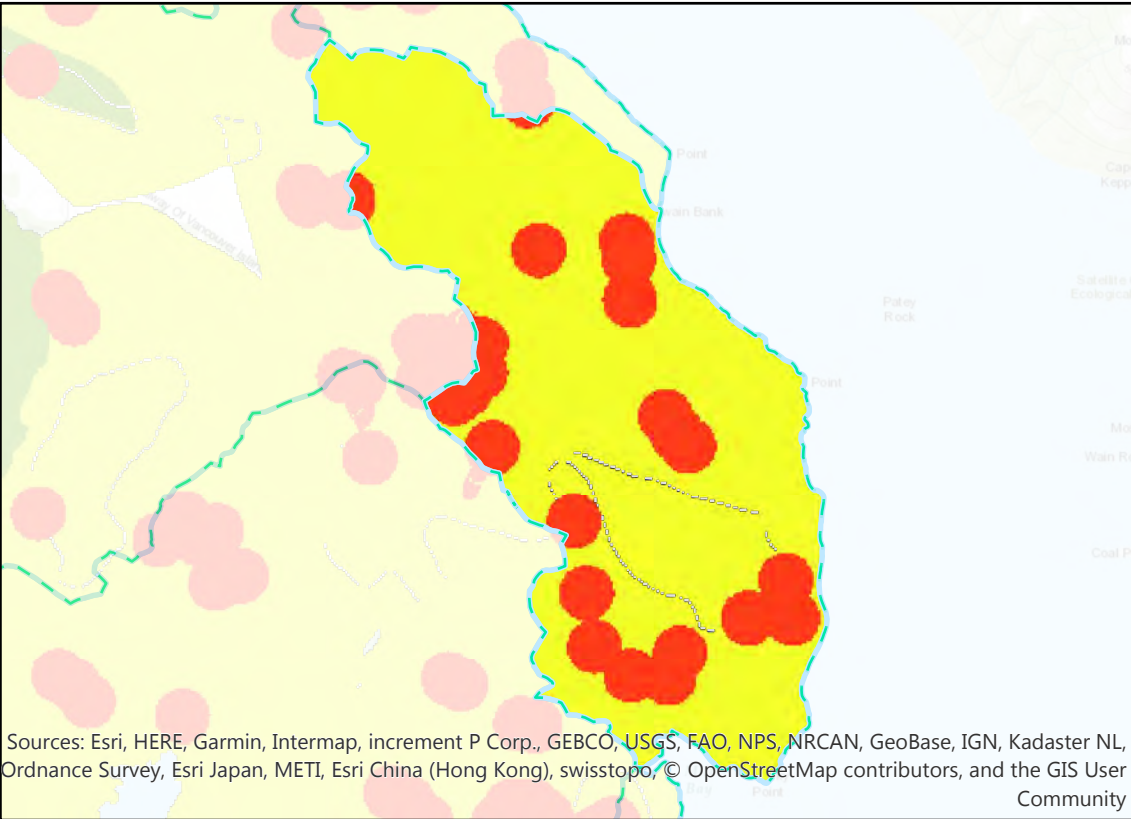
Flood Risk Assessment - Satellite Channel Benchlands

BY: CJW SCALE CONS: 1:69,708 DATE: 2019/01/08 REF No: REV: 0

CHK'D: DK Proj Coord Sys: NAD 1983 UTM Zone 10N **651957-102-SATC**

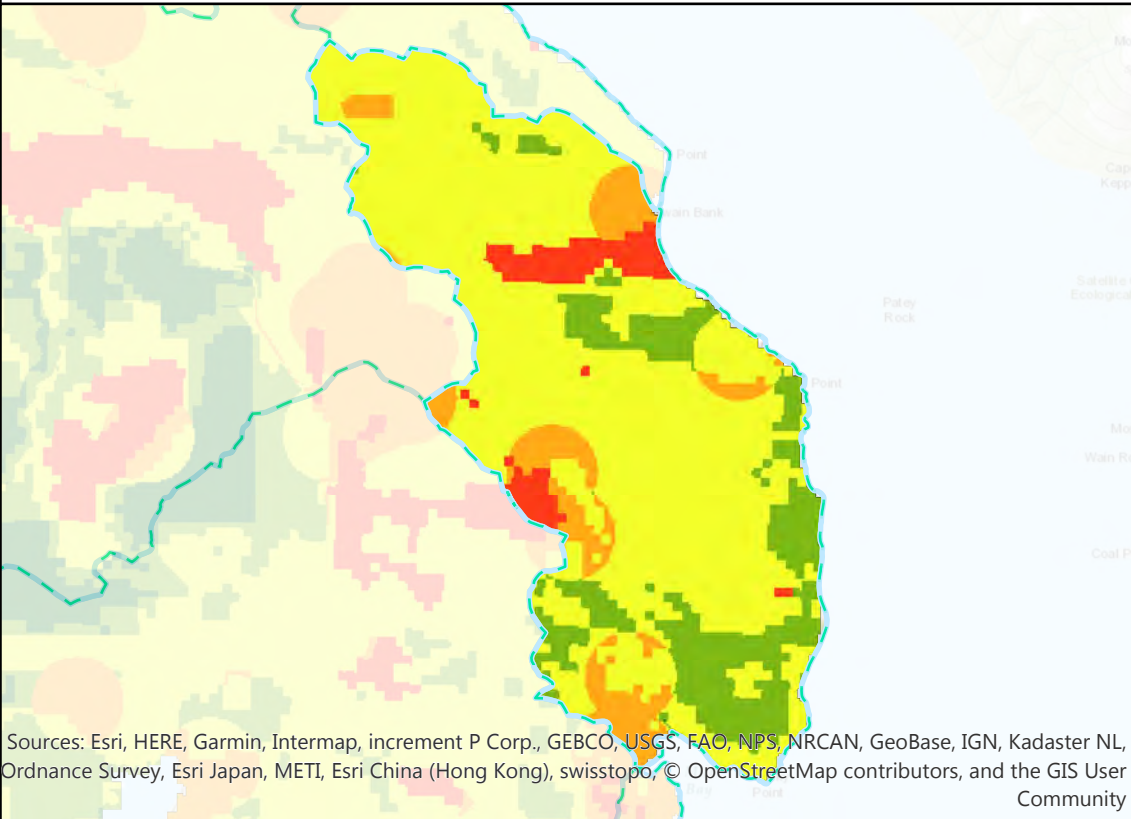
0 500 1,000 2,000 3,000 4,000 Meters

CONSEQUENCE



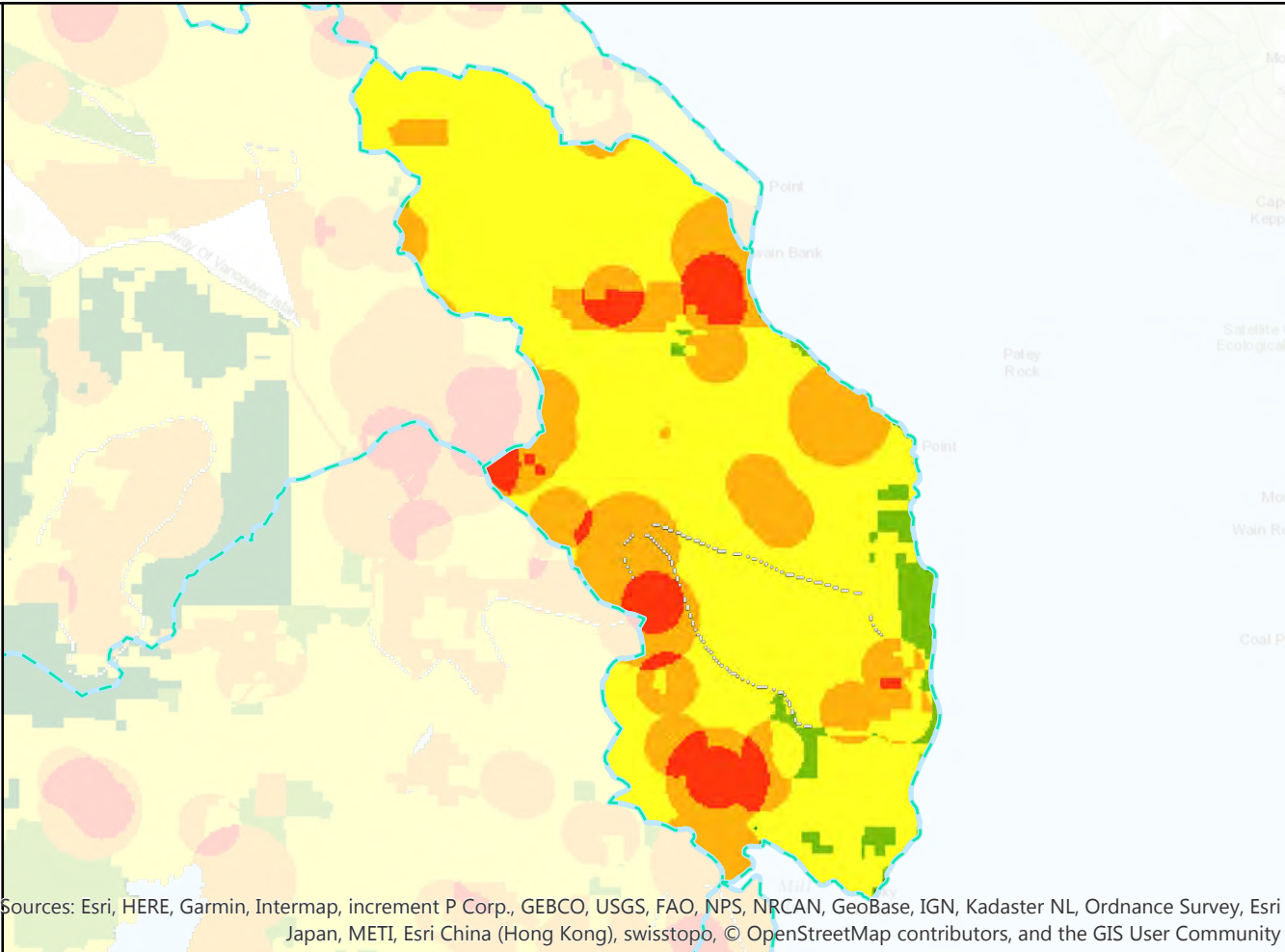
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

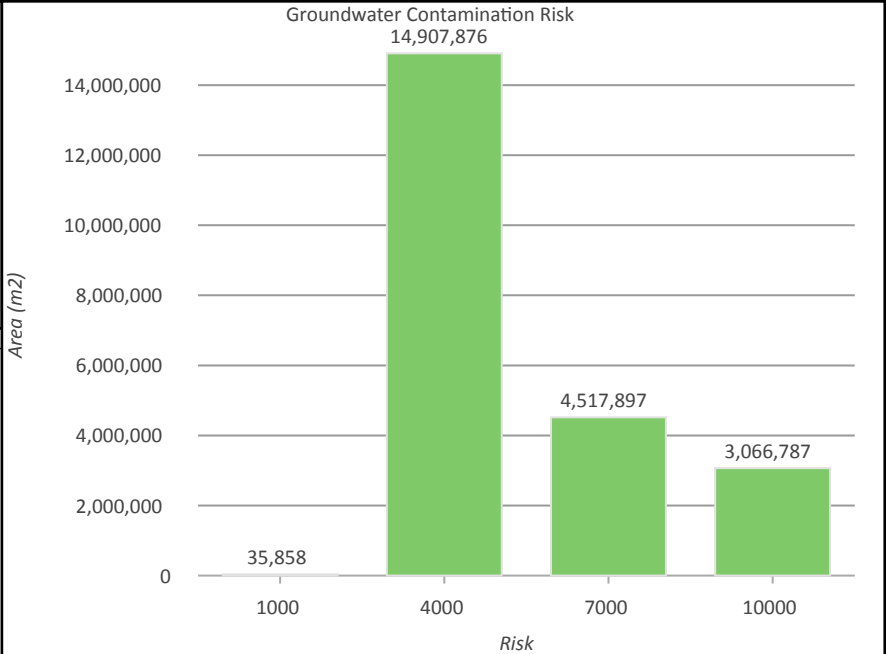
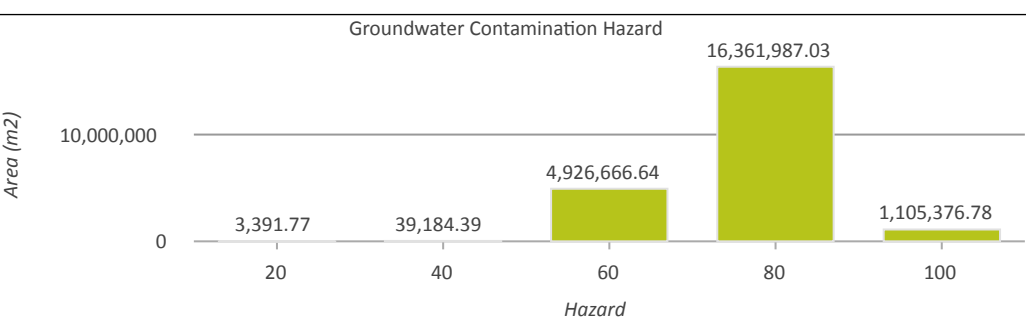
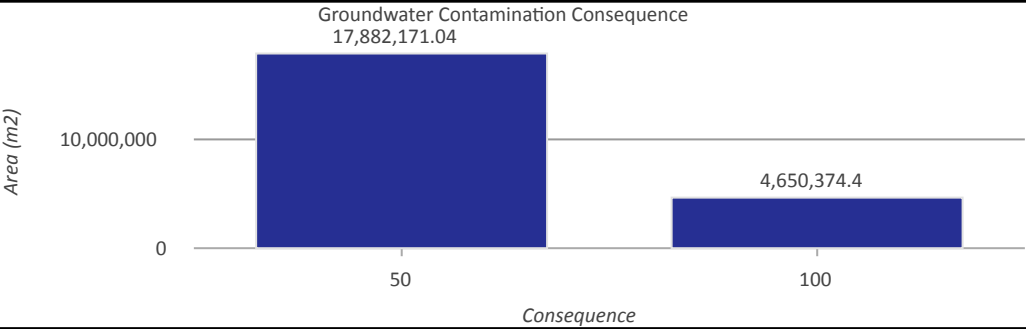


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

RISK

Consequences or Hazards	Risk
≤ 20	≤ 1000
≤ 40	≤ 2000
≤ 60	≤ 4000
≤ 80	≤ 7000
≤ 100	≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Vlalley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

NOTES:

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3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.

REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:

Cowichan Valley Regional District

PROJECT LOCATION:

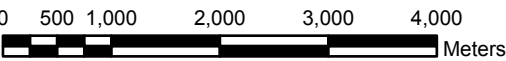
Cowichan Valley Regional District

Satellite Channel Benchlands Watershed

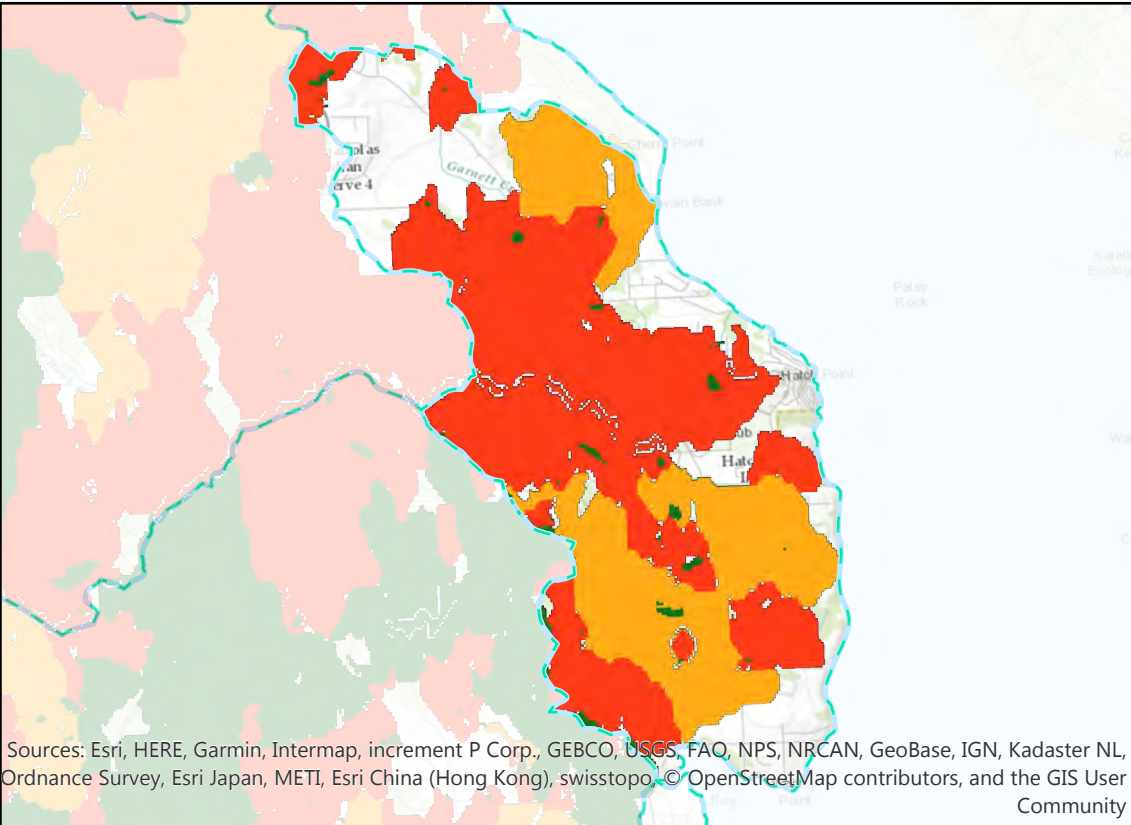


Groundwater Contamination Risk Assessment - Satellite Channel

BY: CJW	SCALE CONS: 1:69,708	DATE: 2019/01/08	REF No:	REV: 0
CHK'D: DK	Proj Coord Sys: NAD 1983 UTM Zone 10N	651957-103-SATC		

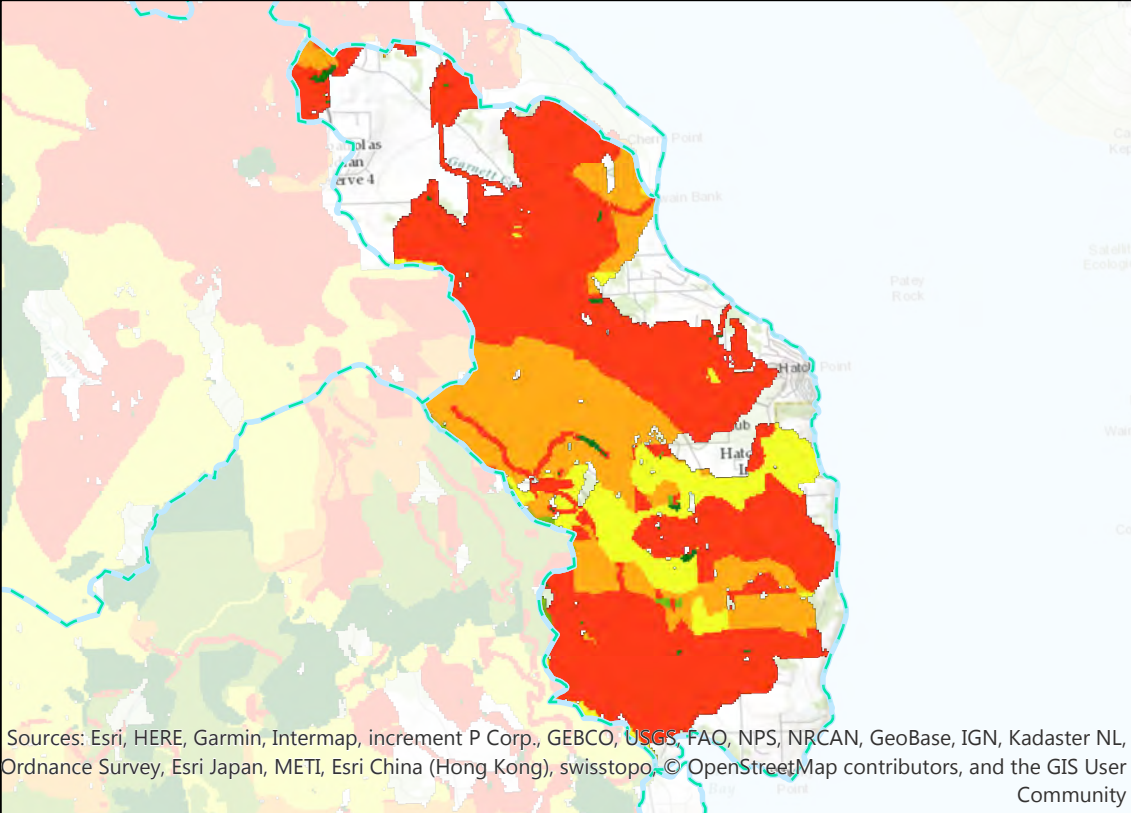


CONSEQUENCE



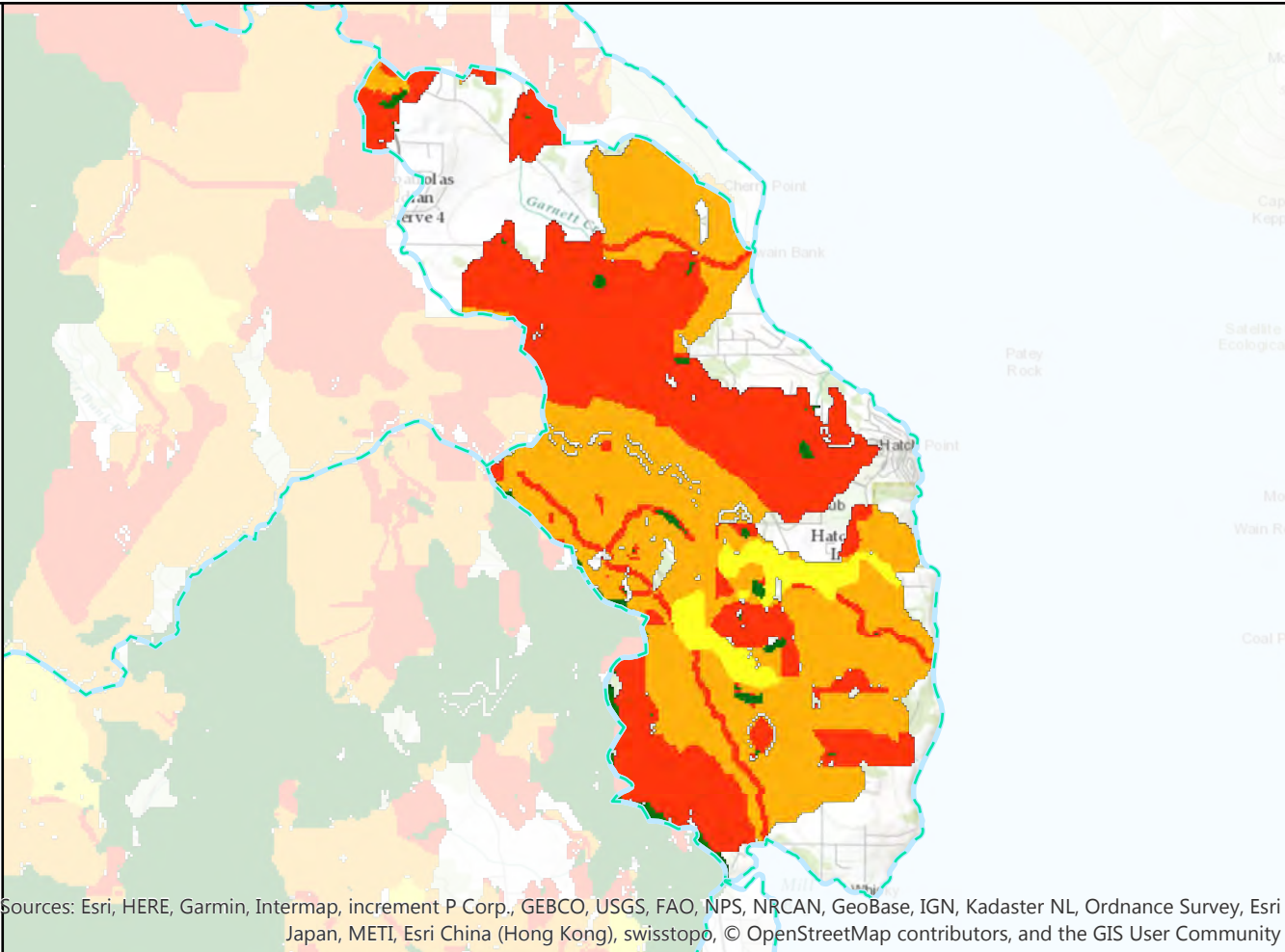
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

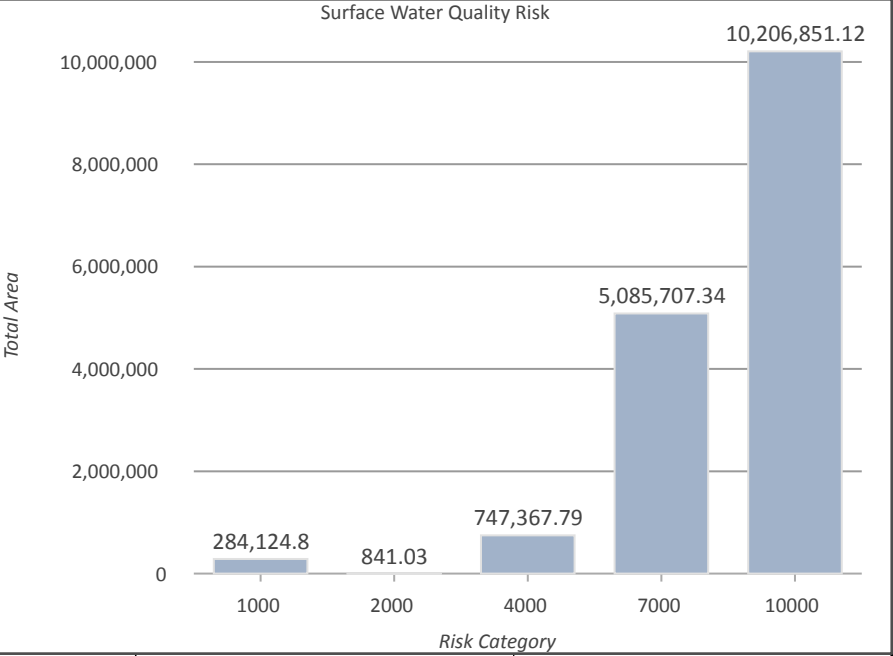
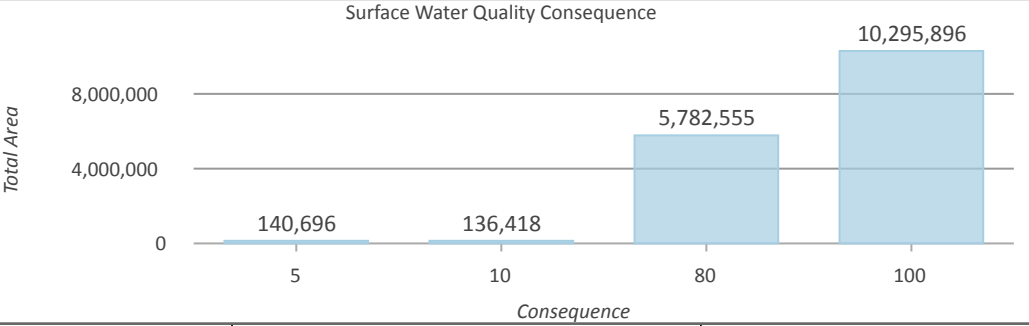
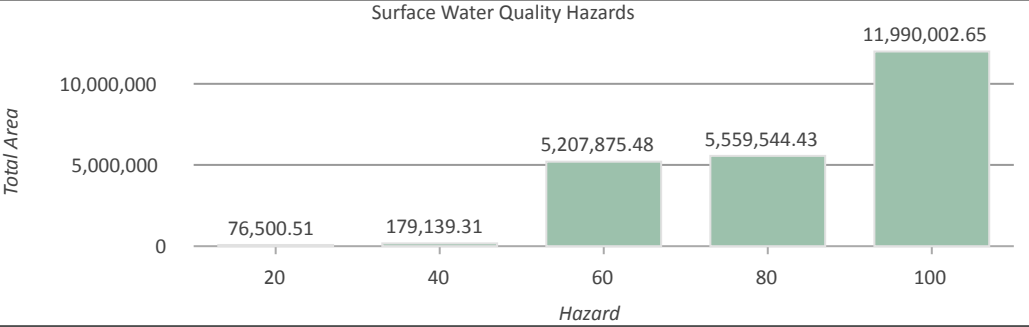


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

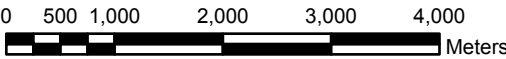
CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Satellite Channel Benchlands Watershed

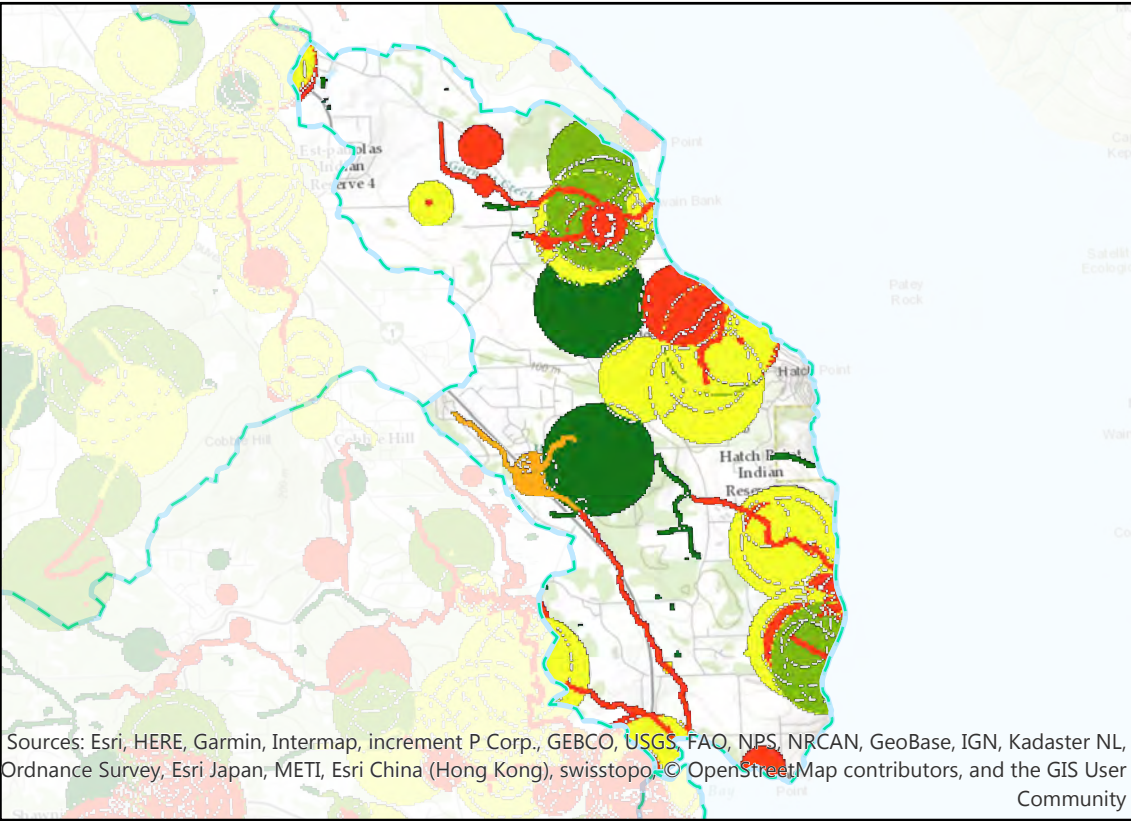


Surface Water Quality Risk Assessment - Satellite Channel

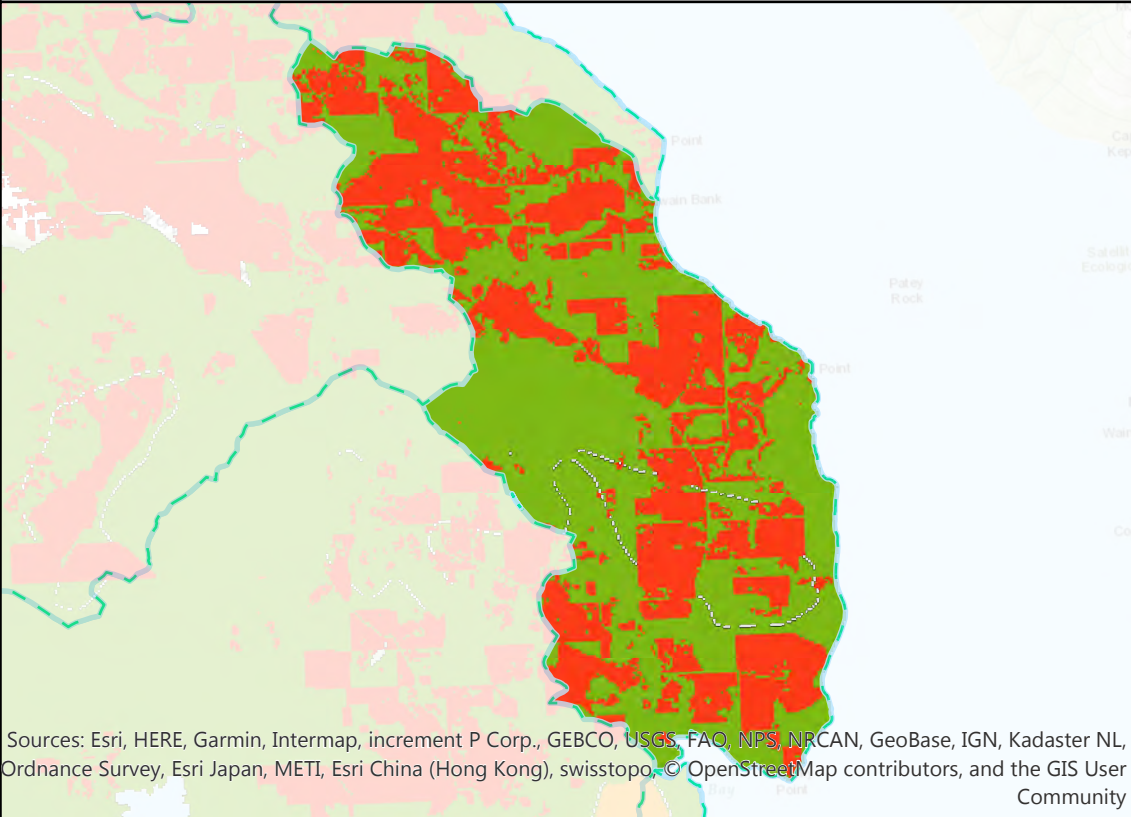
BY: SCALE: 1:69,824 DATE: 2019/01/08 REF No: REV: 0
CHK'D: Proj Coord Sys: PCS Albers 651957-104-SATC



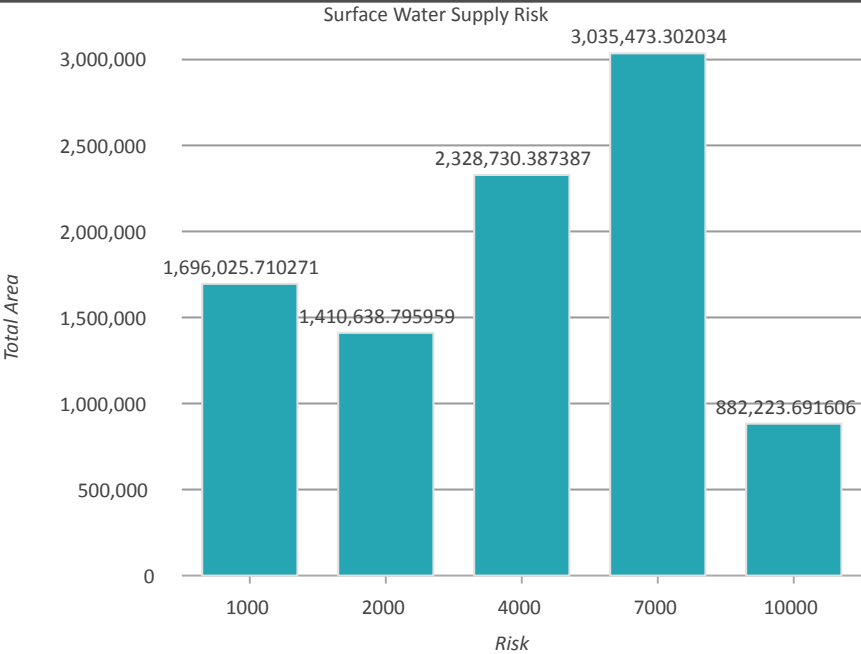
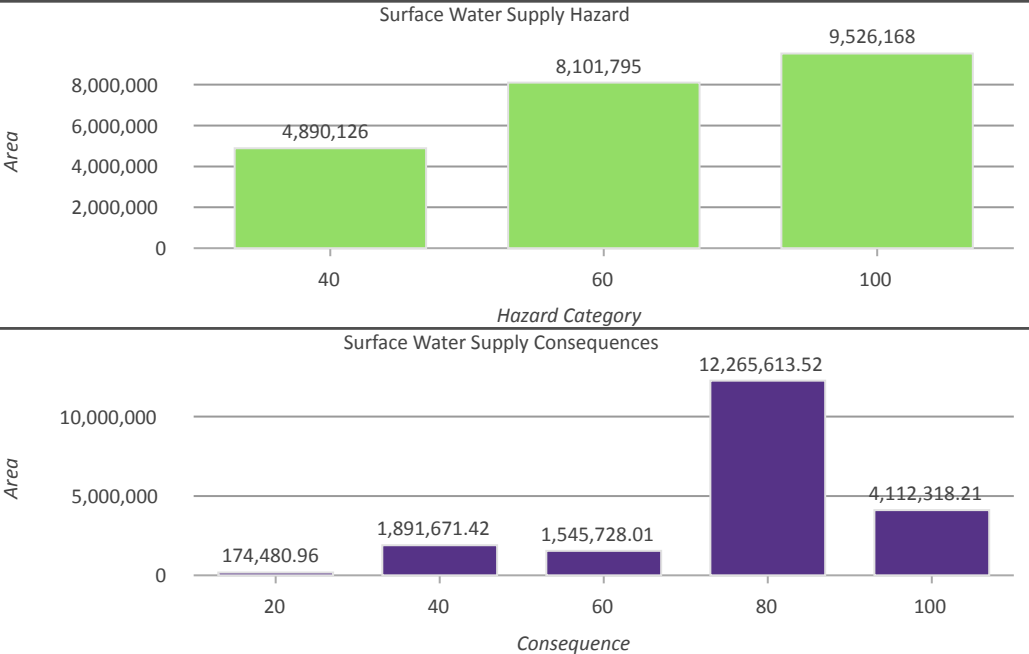
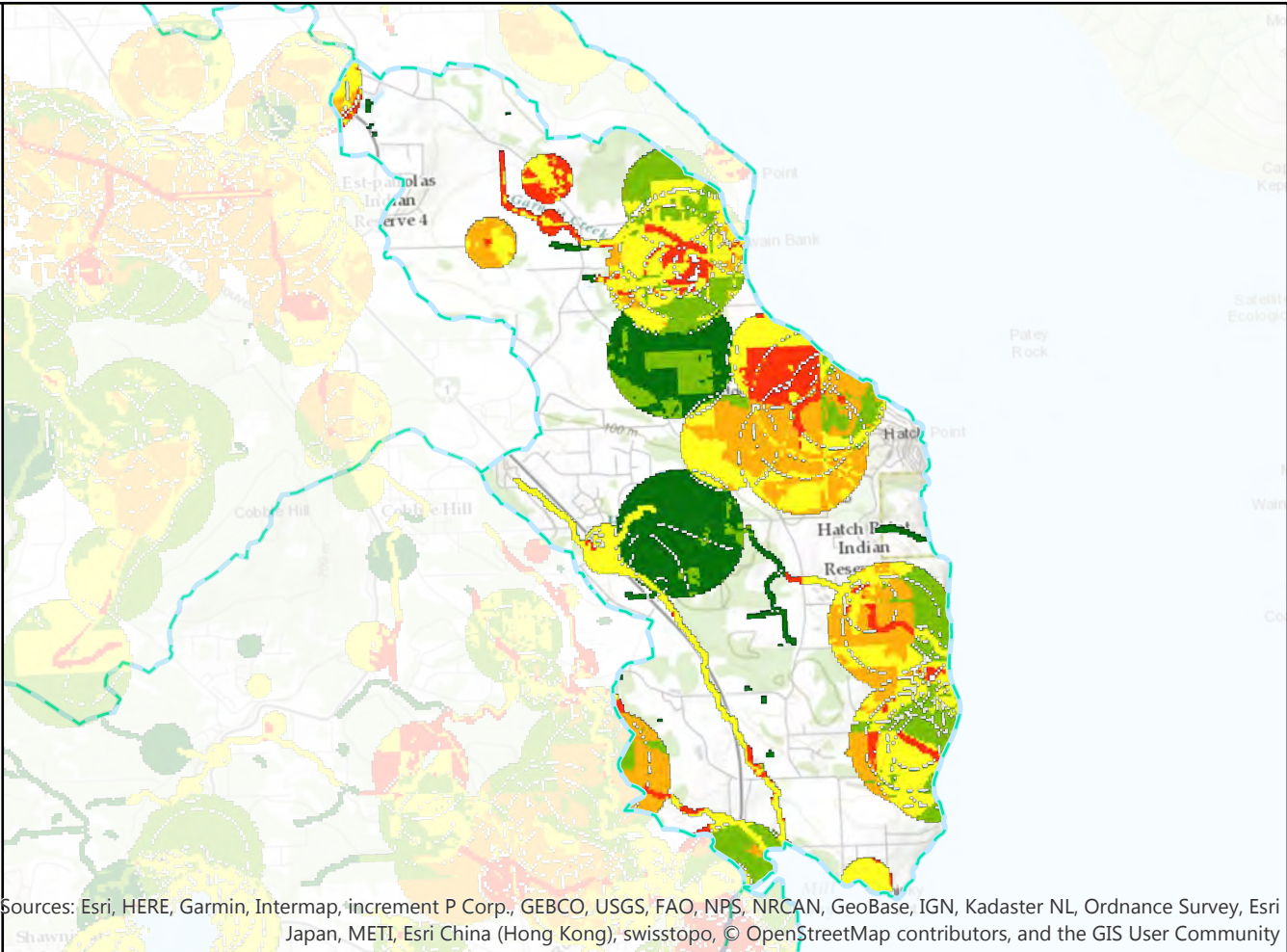
CONSEQUENCE



HAZARD



RISK



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

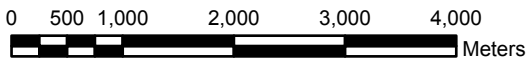
CLIENT:
Cowichan Valley Regional District

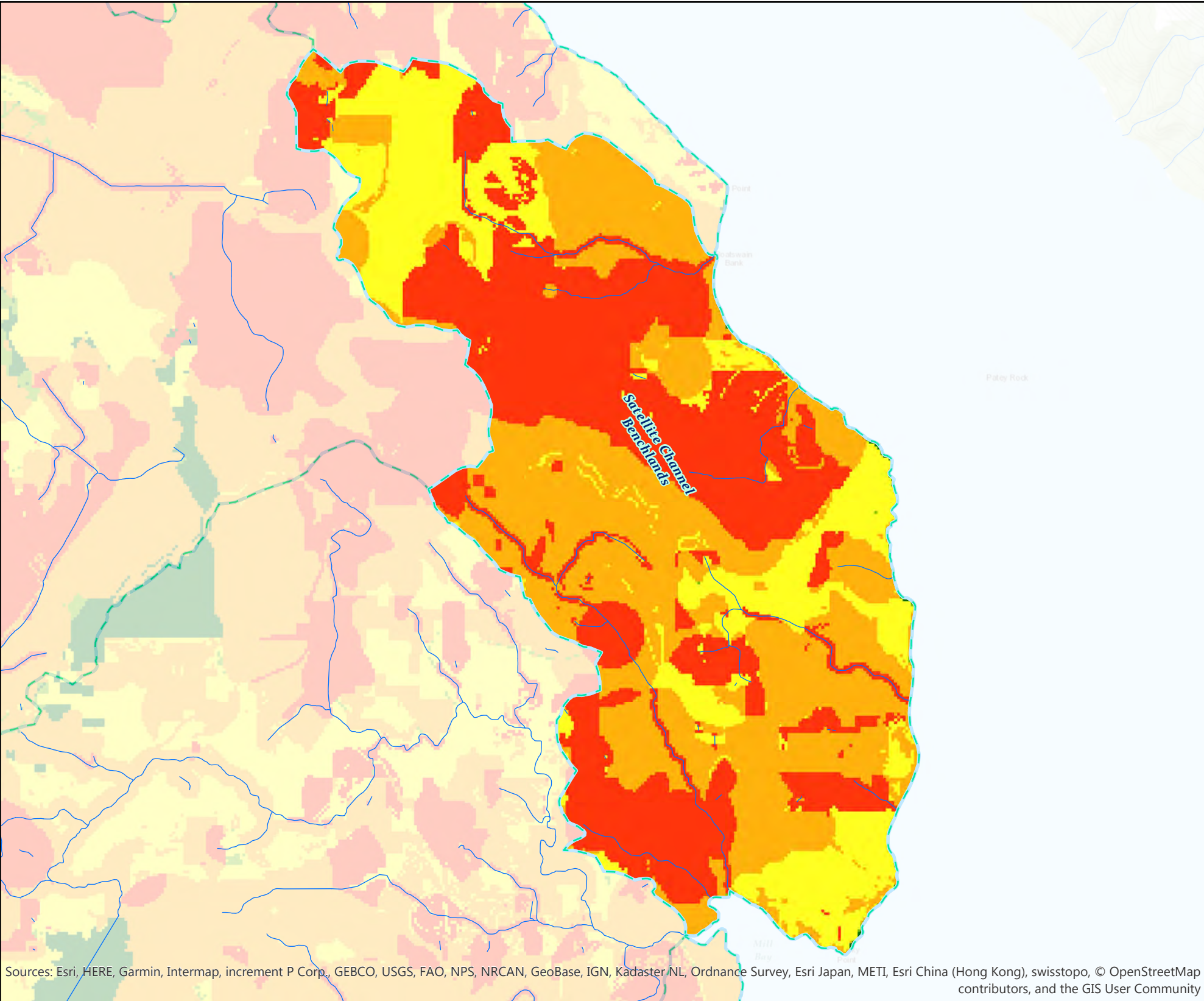
PROJECT LOCATION:
Cowichan Valley Regional District
Satellite Channel Benchlands Watershed



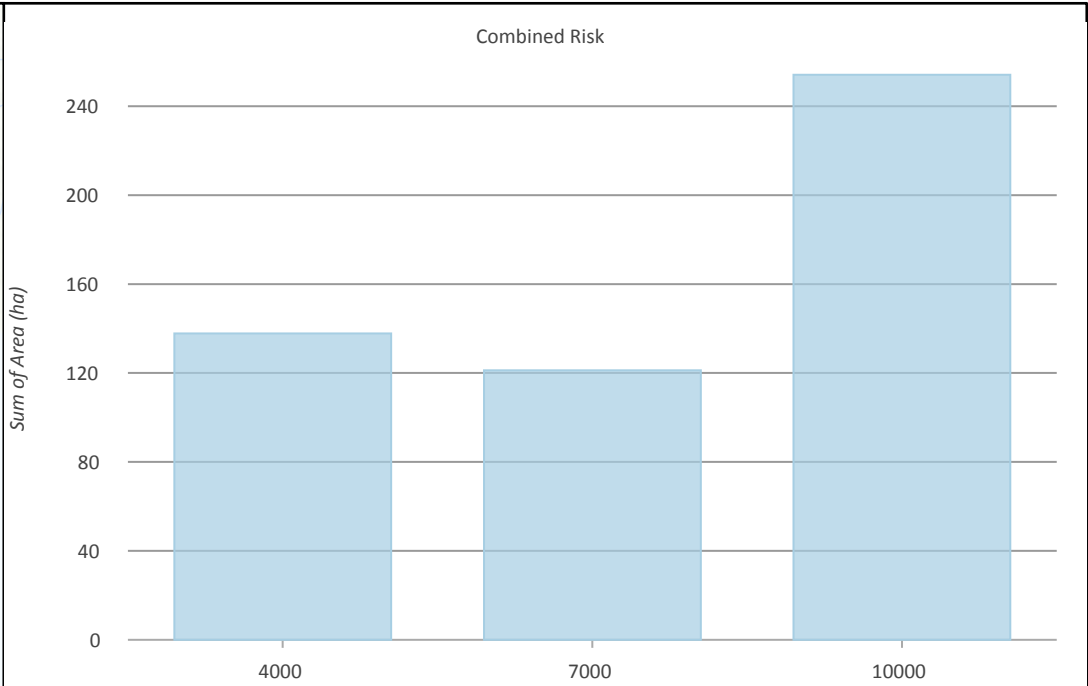
Surface Water Supply Risk Assessment - Satellite Channel

BY: SCALE: 1:68,008 DATE: 2019/01/08 REF No: REV: 0
CHK'D: Proj Coord Sys: PCS Albers 651957-105-SATC





Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



NAME	POP ₂₀₂₁	POP ₂₀₂₆	POP ₂₀₃₁	POP ₂₀₃₆
SHAWNIGAN CREEK	10047	10760	11613	12598
BUSH CREEK	0	0	0	0
KOKSILAH RIVER	5463	5851	6315	6850
HOLLAND CREEK	1302	1368	1446	1537
BONSALL CREEK	934	974	1019	1073
CHEMAINUS RIVER	1490	1461	1439	1421
COWICHAN RIVER	36368	37905	39683	41766
YELLOW POINT BENCHLANDS	2239	2352	2487	2643
LADYSMITH - SALTAIR BENCHLANDS	8410	8834	9342	9929
STOCKING CREEK	1531	1608	1701	1807
CHEMAINUS BENCHLANDS	3663	3818	3997	4207
SATELLITE CHANNEL BENCHLANDS	4390	4701	5074	5504
SANSUM NARROWS - COWICHAN BAY BENCHLANDS	4941	5150	5391	5674
MALAHAT BENCHLANDS	2829	3030	3271	3548

NAME	POP ₂₀₀₁	POP ₂₀₀₆	POP ₂₀₁₁	POP ₂₀₁₆
SHAWNIGAN CREEK	6348	8439	8925	9484
BUSH CREEK	0			
KOKSILAH RIVER	4555	4808	4954	5157
HOLLAND CREEK	1611	1114	1169	1245
BONSALL CREEK	672	830	815	890
CHEMAINUS RIVER	1423	1395	1497	1514
COWICHAN RIVER	29779	32673	34075	34647
YELLOW POINT BENCHLANDS	1167	1958	2021	2141
LADYSMITH - SALTAIR BENCHLANDS	5275	7488	7541	8042
STOCKING CREEK	1332	1003	1354	1464
CHEMAINUS BENCHLANDS	3177	3129	3085	3490
SATELLITE CHANNEL BENCHLANDS	5425	3902	3989	4144
SANSUM NARROWS - COWICHAN BAY BENCHLANDS	5993	4221	4500	4707
MALAHAT BENCHLANDS	1673	2472	2548	2671

Legend

WATERSHED BOUNDARIES

RISK

	≤ 1000
	≤ 2000
	≤ 4000
	≤ 7000
	≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

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REVISIONS:

0 - CJW - 2018-11-30 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Satellite Channel Benchlands Watershed

Combined Risk Assessment - Satellite Channel Benchlands

BY: CJW	SCALE CONS: 1:41,000	DATE: 2019/01/08	REF No:	REV: 0
CHK'D: DK	Proj Coord Sys: NAD 1983 UTM Zone 10N	651957-106-SATC		

12. Shawnigan Creek

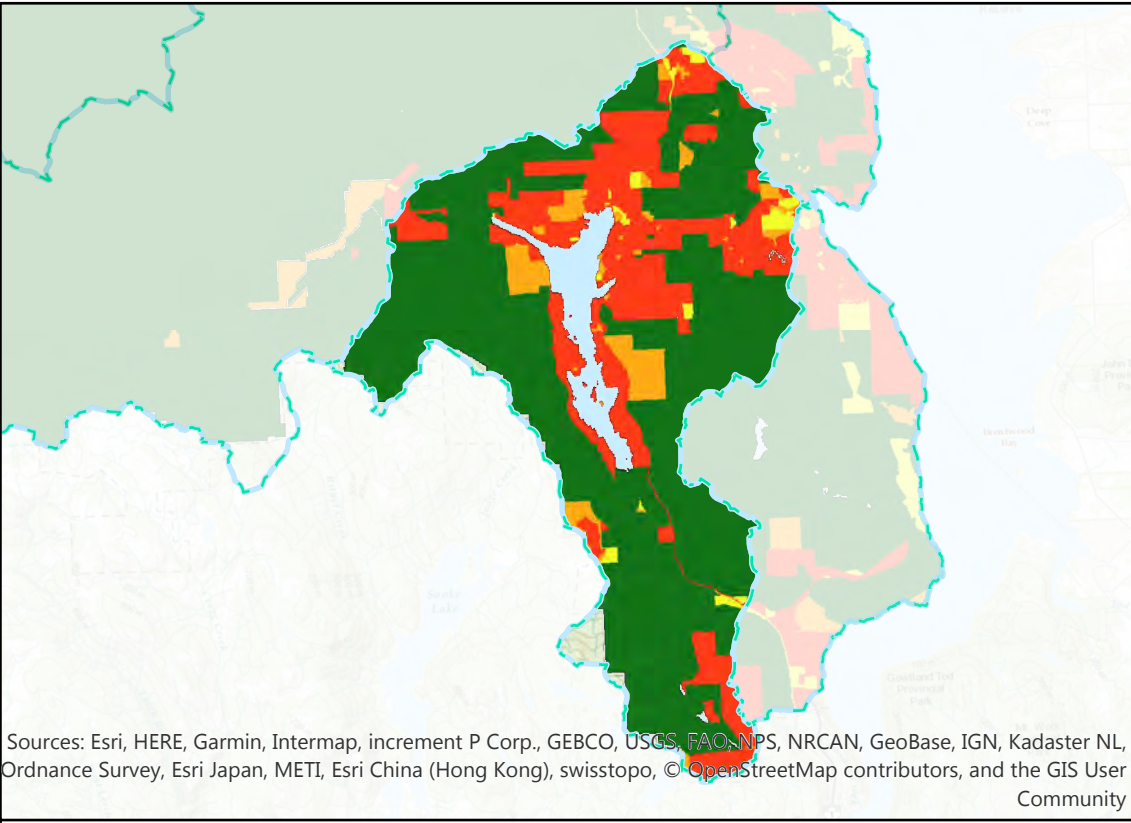
Topic	Discussion
Slope Failure	<p>Hazard was determined qualitatively at a high level to describe areas based on the degree to which they may be prone to landslides and other mass movements using terrain characteristics. Hazard classifications were generated to show relative comparisons between terrain units within the CVRD watershed study area. Risk ratings derived from this analysis are relative, and should be used to guide prioritization of further detailed studies.</p> <p>Hazard is greatest along the steeper slopes east of Shawnigan Lake (Old Baldy Mountain) and portions of the southern end of the watershed where logging activities have occurred along relatively steep slopes. Consequence is greatest at populated areas surrounding Lake Shawnigan, Cobble Hill, and Mill Bay, and at the mine situated northwest of the Malahat Benchlands. Risk is greatest at the mine and along the slope immediately to the south, as well as the areas of Cliffside and around the southern portion of Shawnigan Lake that are adjacent to relatively steep slopes.</p>
Flooding	<p>Some floodplain mapping has been completed around Shawnigan Lake with some potential flood risk around Shawnigan Lake. Additionally there is considered to be some potential for flooding in the areas of the various rivers and streams, however this is likely over-stated within the hazard analysis provided. Additional modelling and flood analysis is recommended since most of the populated areas are either in close proximity to Shawnigan Lake or the streams and rivers. This should incorporate information such as that contained in the 2002 Shawnigan Lake Water Supply report, and a flood frequency analysis. Here, consequence and risk are therefore considered higher near the streams and rivers and along Shawnigan Lake in the northern half of the watershed where the vast majority of the population resides. Projected population increases in the watershed are expected to enhance consequence and risk. Also, likelihood may be enhanced with increased population depending on the nature of development and stormwater runoff.</p>
Groundwater Contamination	<p>Likelihood of groundwater contamination varies greatly throughout the watershed and is expected to increase in populated areas that continue to expand their population. The DRASTIC vulnerability value and the presence of contaminated sites are the main drivers in this watershed. Consequence is maximized in the vicinity of a municipal water supply wells. Risk is greatest in populated areas such as Cobble Hill, Mill Bay, and specific residential neighbourhoods situated at or near Shawnigan Lake.</p>
Surface Water Quality	<p>Hazard is greatest in developed areas surrounding Shawnigan Lake and Cobble Hill and along streams that outlet Shawnigan Lake where there is low or no forest cover. These areas occupy a relatively large cumulative area of the watershed. Consequence is greatest at low order streams around Cobble Hill and Mill Bay, although the extents of higher consequence are small relative to the size of the watershed. Risk is greatest along specific low order streams in the Cobble Hill area and occupy a small proportion of the watershed's area. Projected population increases in the watershed will add more high risk areas where permeable surfaces are replaced with impermeable surfaces and where forest cover is reduced.</p>
Surface Water Supply	<p>Hazard is greatest in small isolated zones surrounding Shawnigan Lake and to the south of Cobble Hill. Consequence is considered very low for the majority of the watershed and is greatest south of Cobble Hill. Risk is greatest within small zones to the south of Cobble Hill and within Mill Bay, occupying a very small proportion of the watershed's area. Projected population increase for the watershed is expected to add pressures on groundwater sources that may increase the level of hazard and risk.</p>

12. Shawnigan Creek

General Data
Notes and
Multivariate Risk

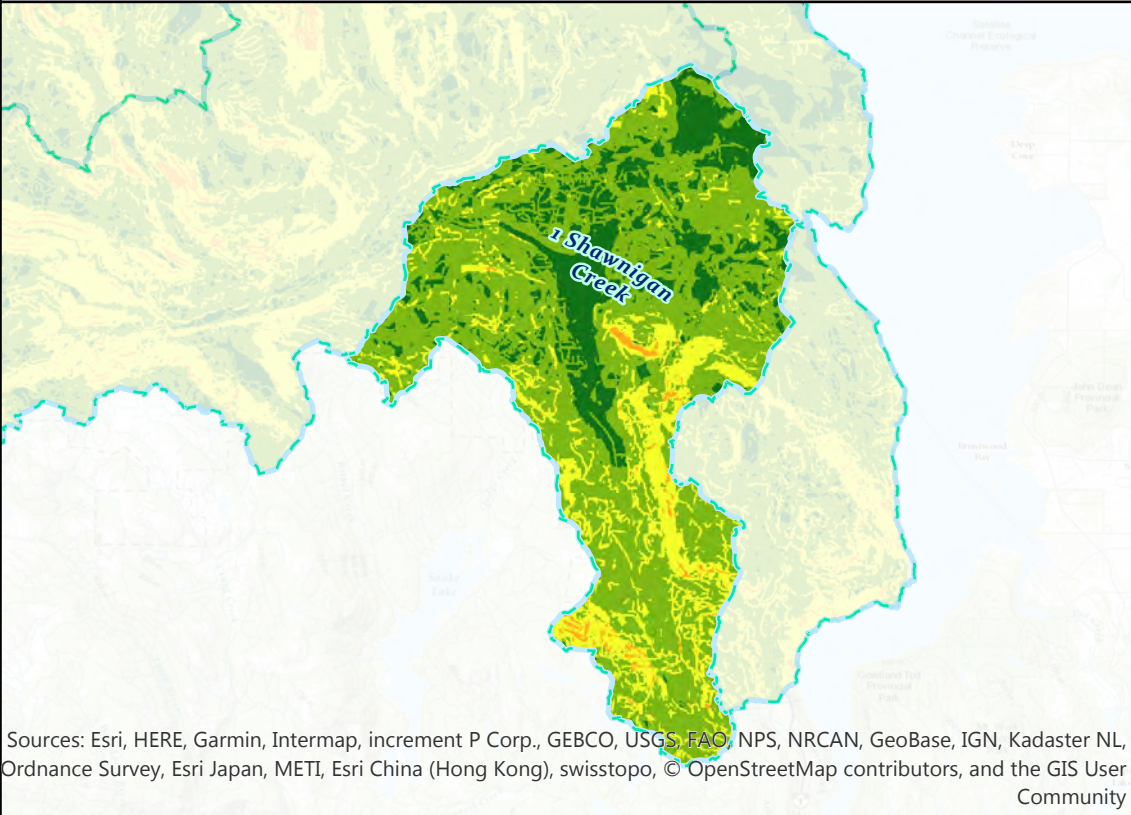
Risk is higher in the populated northeast part of the watershed, with contributions from Surface Water Supply / Stream Health, Groundwater Contamination, and, to a lesser degree, Flooding and Slope Failure. Shawnigan Creek is part of the southern region defined in the LAM population study, and is expected to grow by approximately 33% in the next twenty years. Additional refinement of consequences and risk is recommended to better understand how to plan for this growth.

CONSEQUENCE



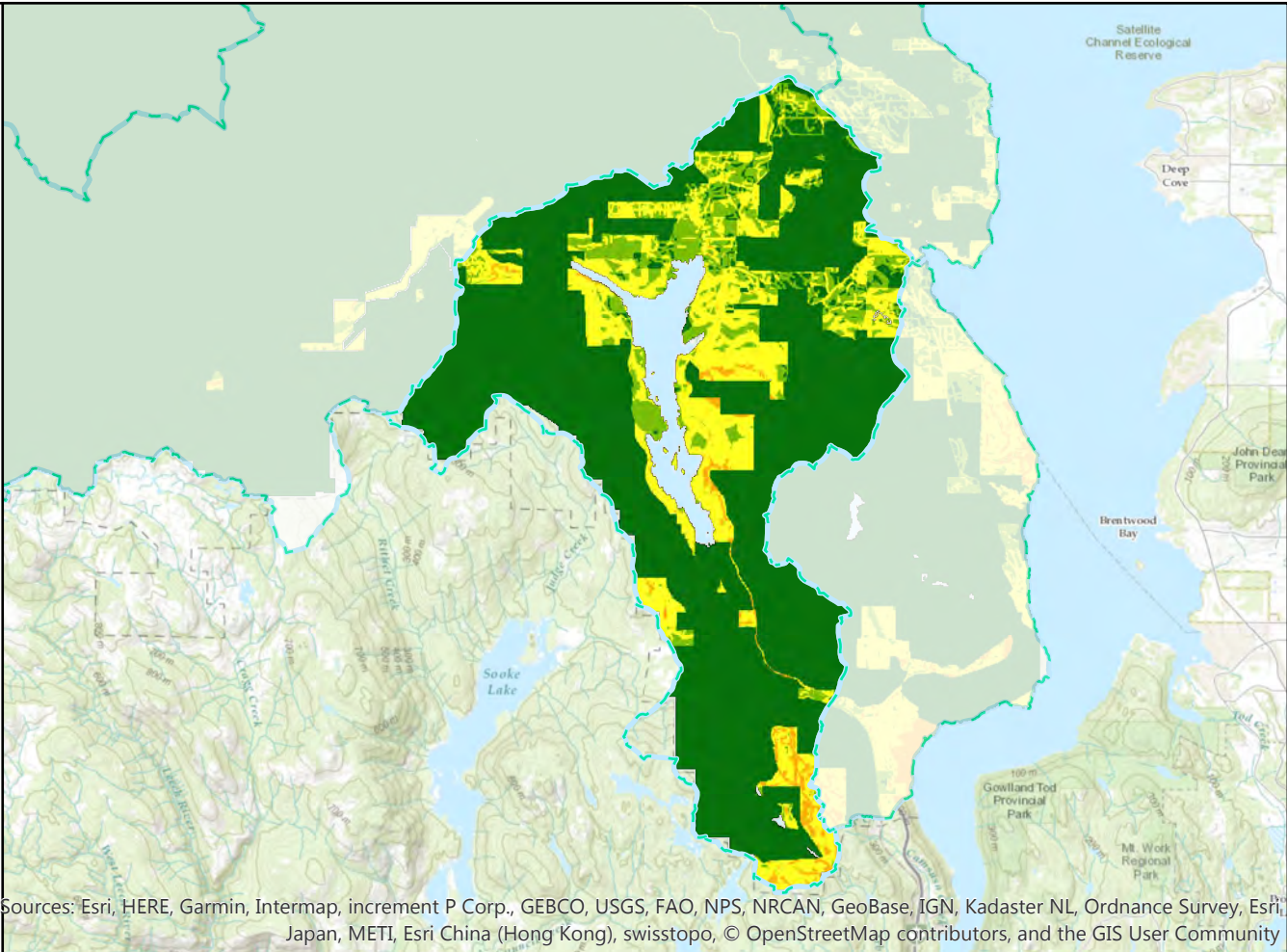
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

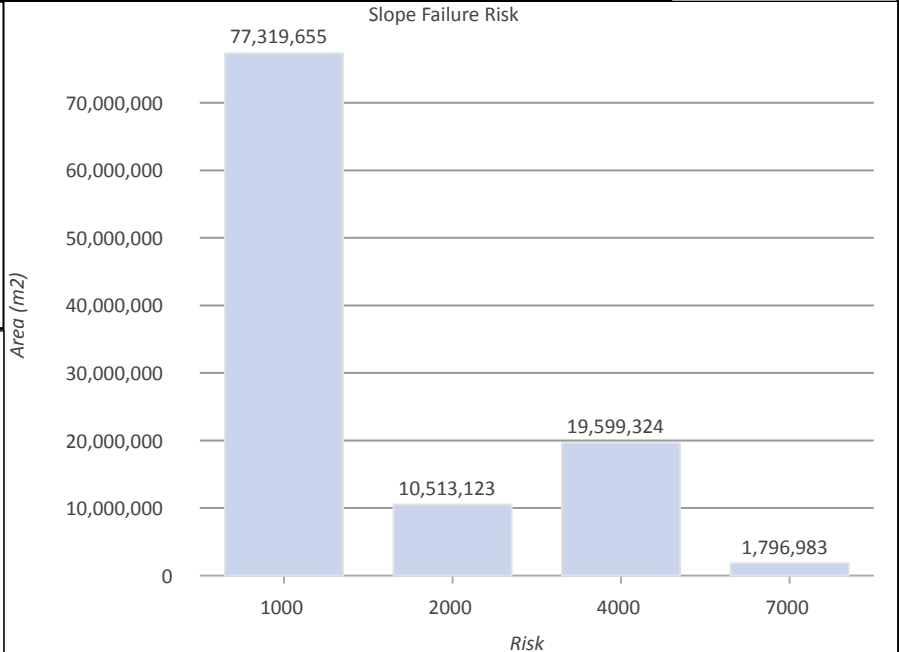
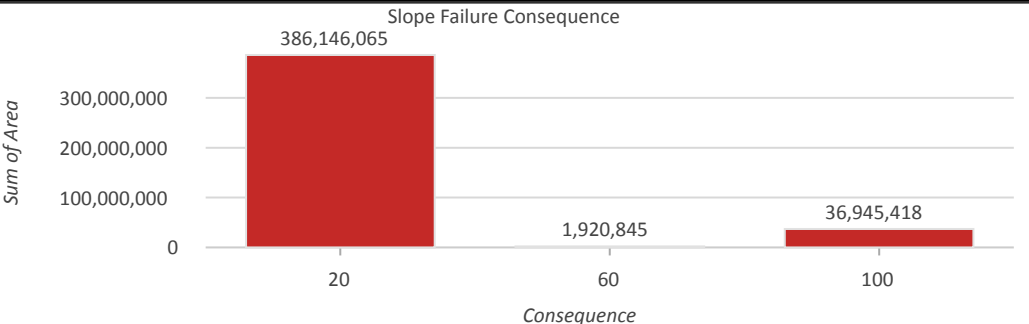
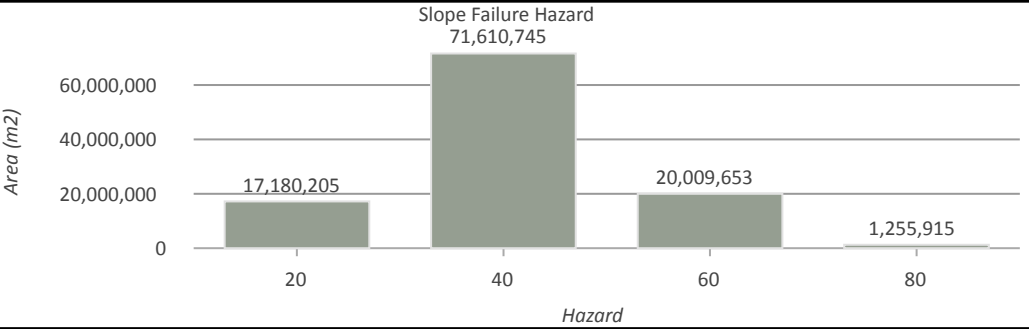


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Vlalley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

NOTES:

1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.

REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Shawnigan Creek Watershed



SNC • LAVALIN

Slope Failure Risk Assessment - Shawnigan Creek

BY: CJW

SCALE CONS: 1:172,562

DATE: 2019/01/07

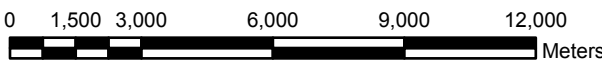
REF No:

REV: 0

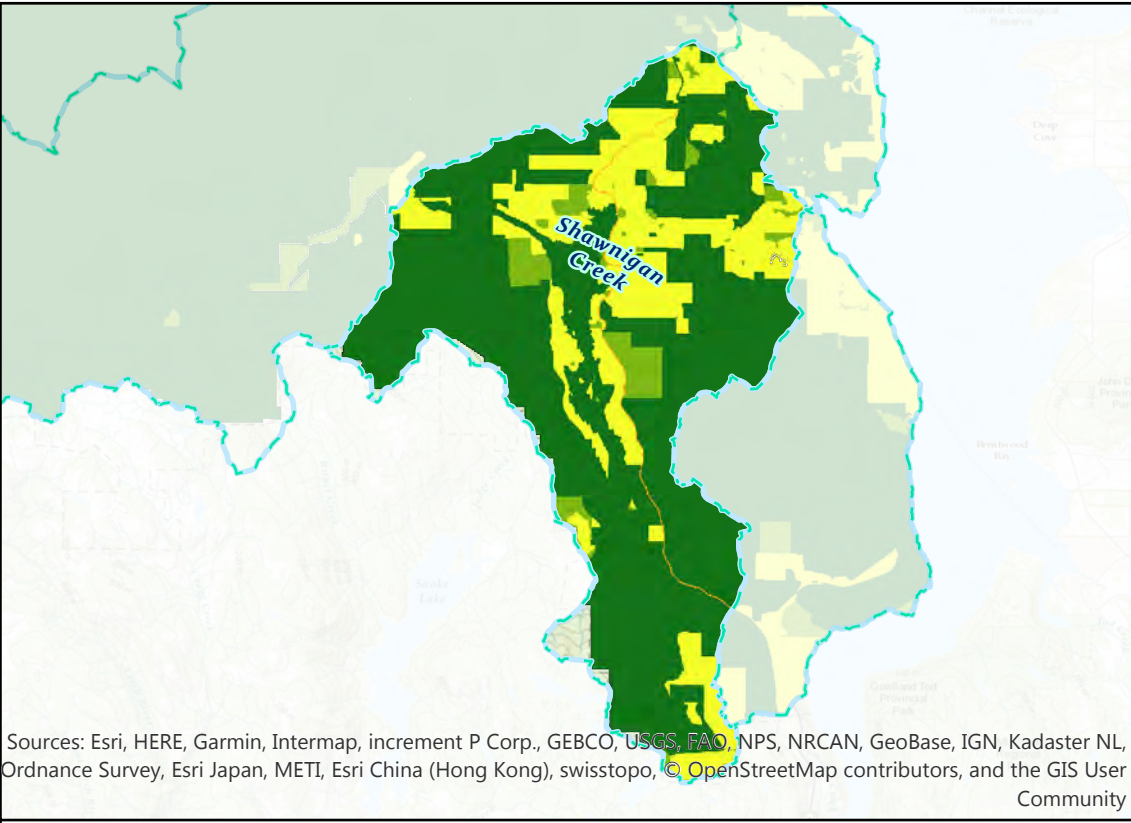
CHK'D: DK

Proj Coord Sys: PCS Albers

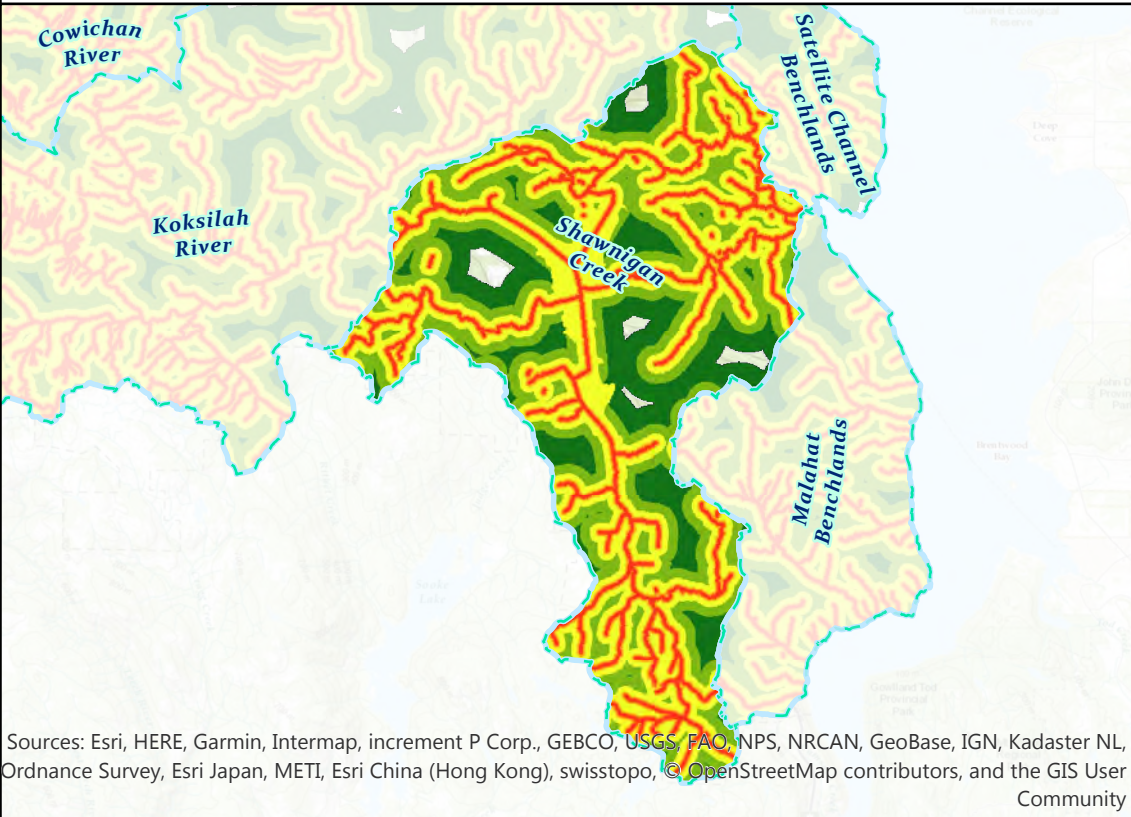
651957-101-SHAWN



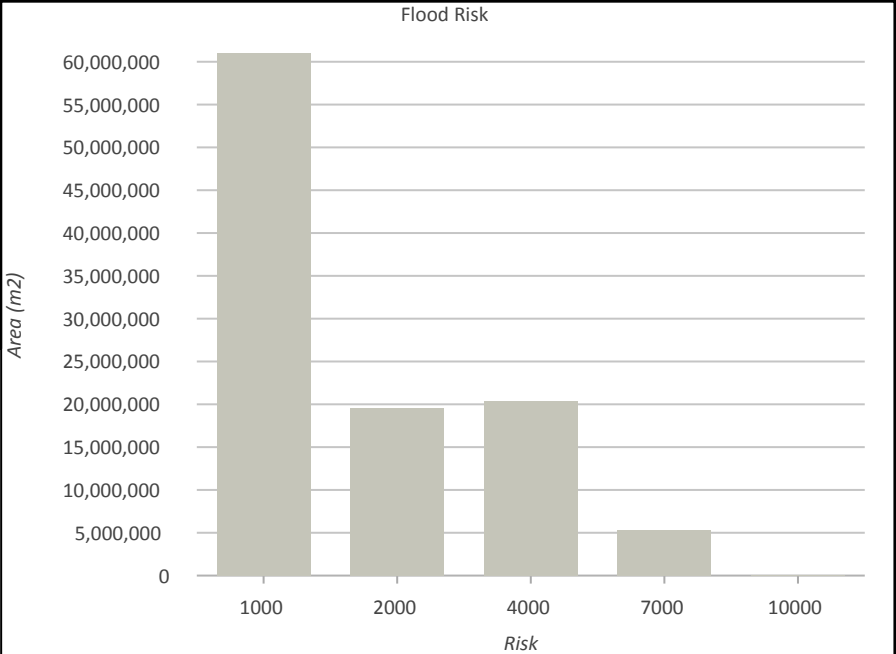
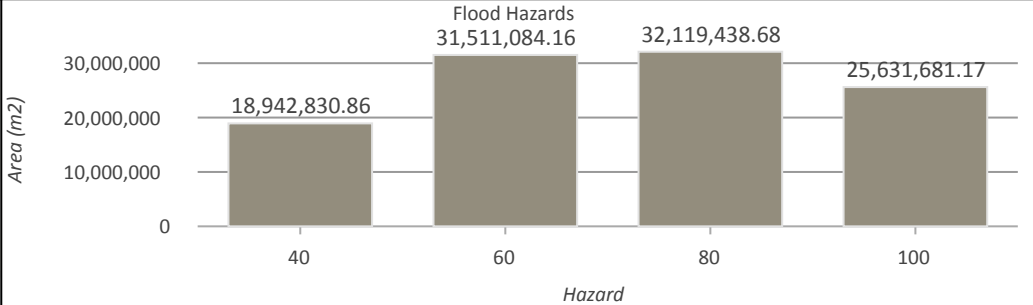
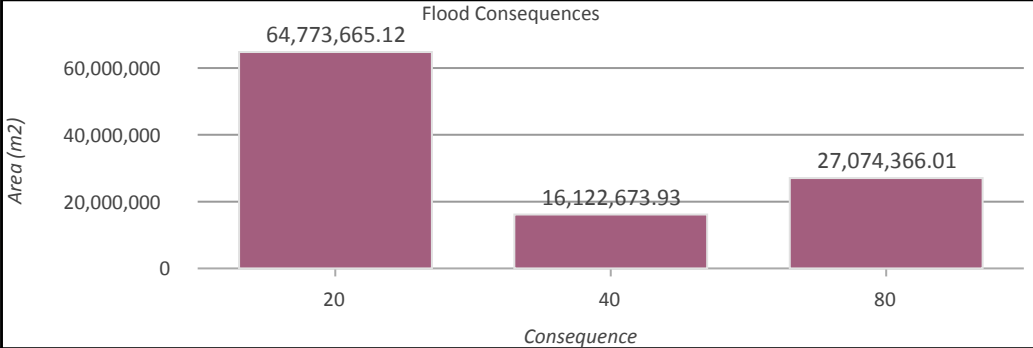
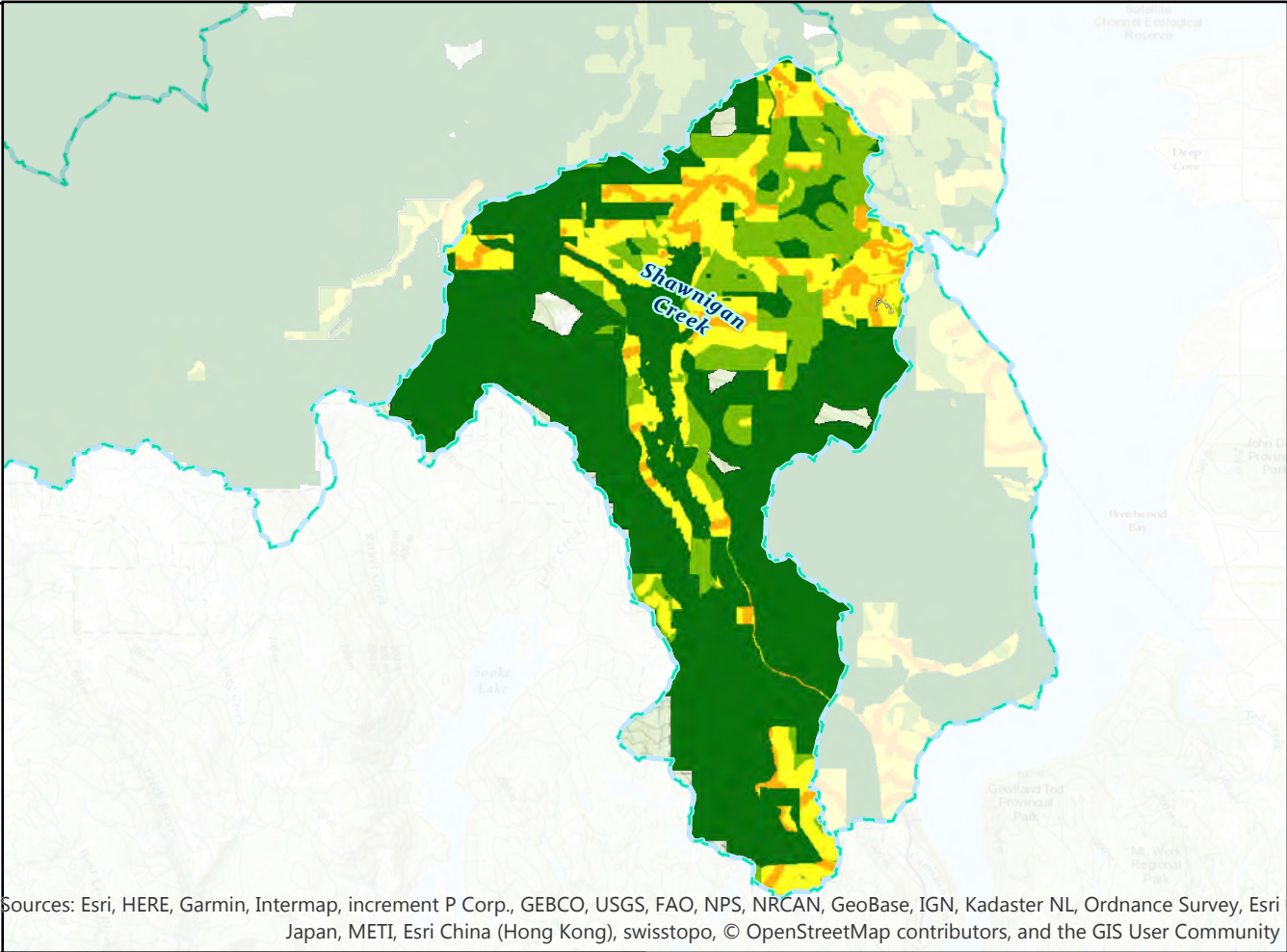
CONSEQUENCE



HAZARD



RISK



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Shawnigan Creek Watershed

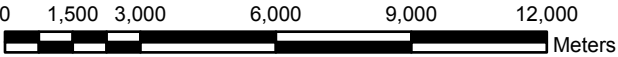
BY: CJW
CHK'D: DK

SCALE CONS: 1:167,469
Proj Coord Sys: NAD 1983 UTM Zone 10N

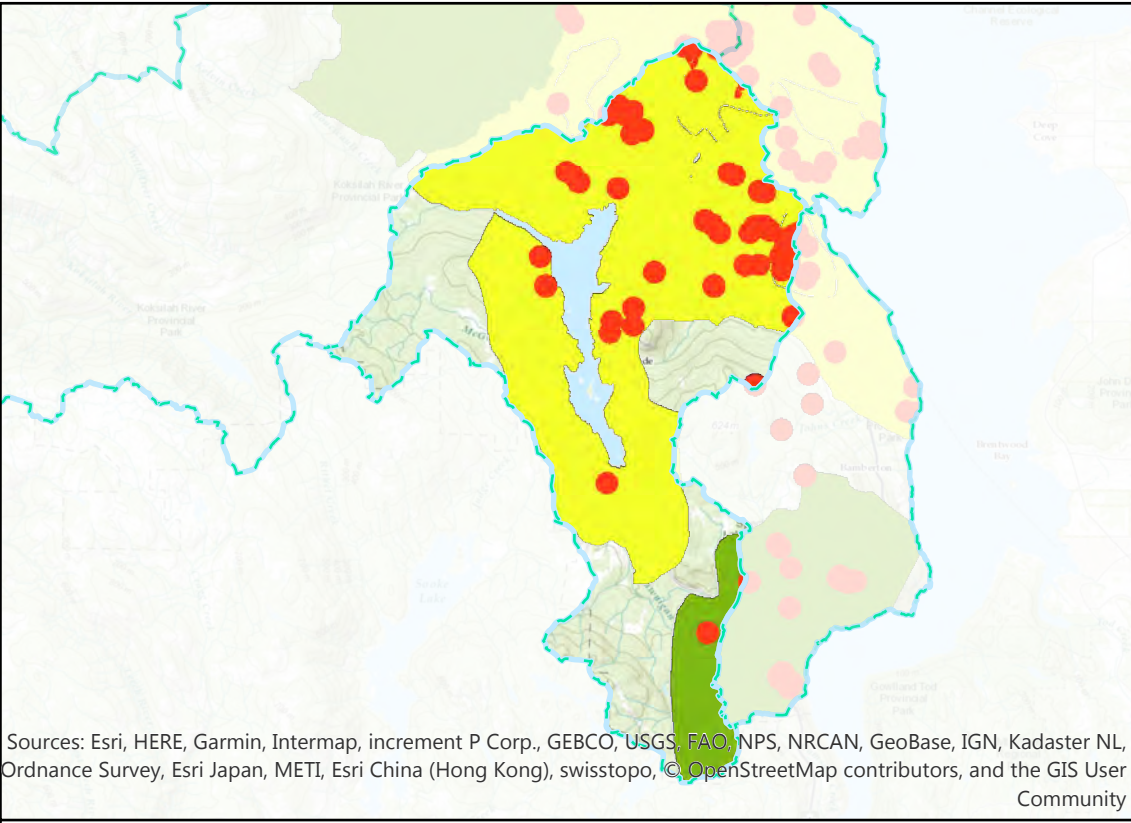
SNC • LAVALIN

Flood Risk Assessment - Shawnigan Creek

REF No: 651957-102-SHAWN
REV: 0

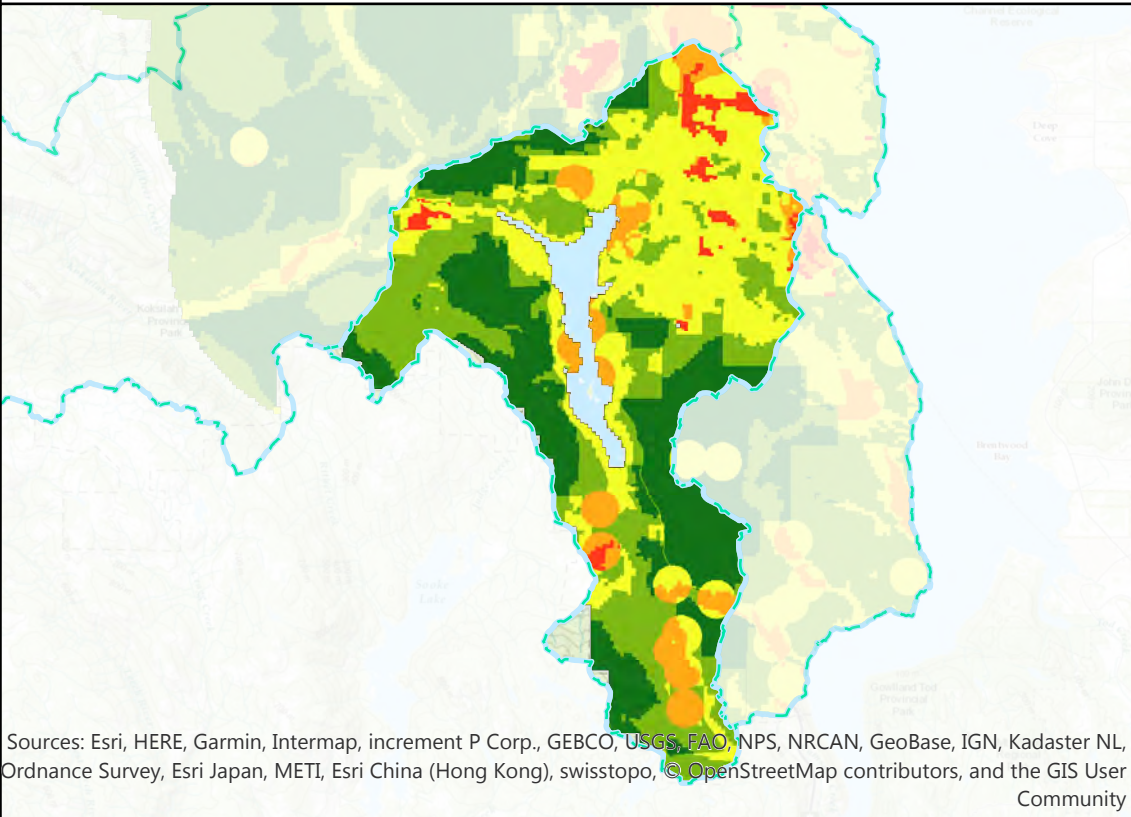


CONSEQUENCE



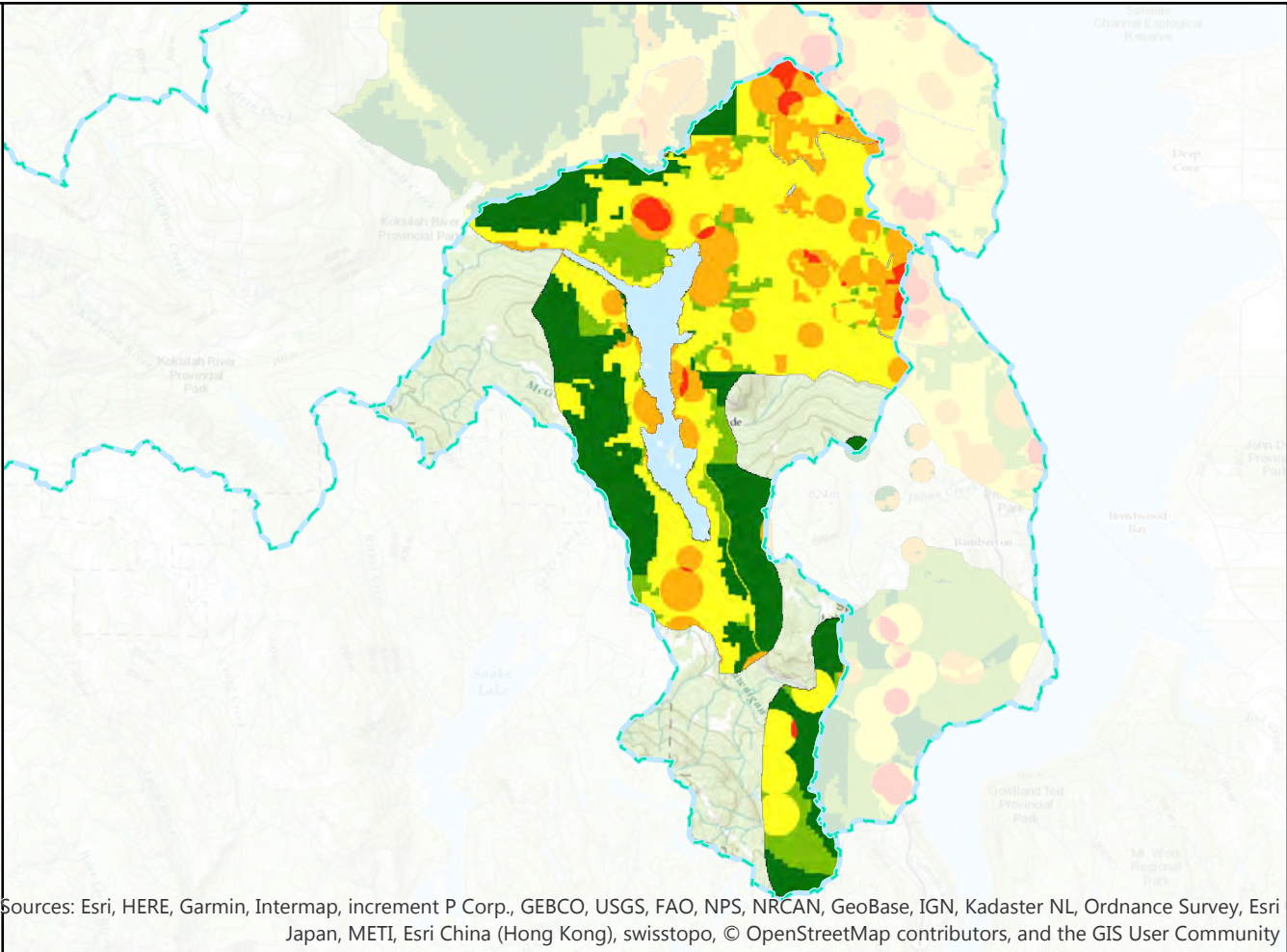
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

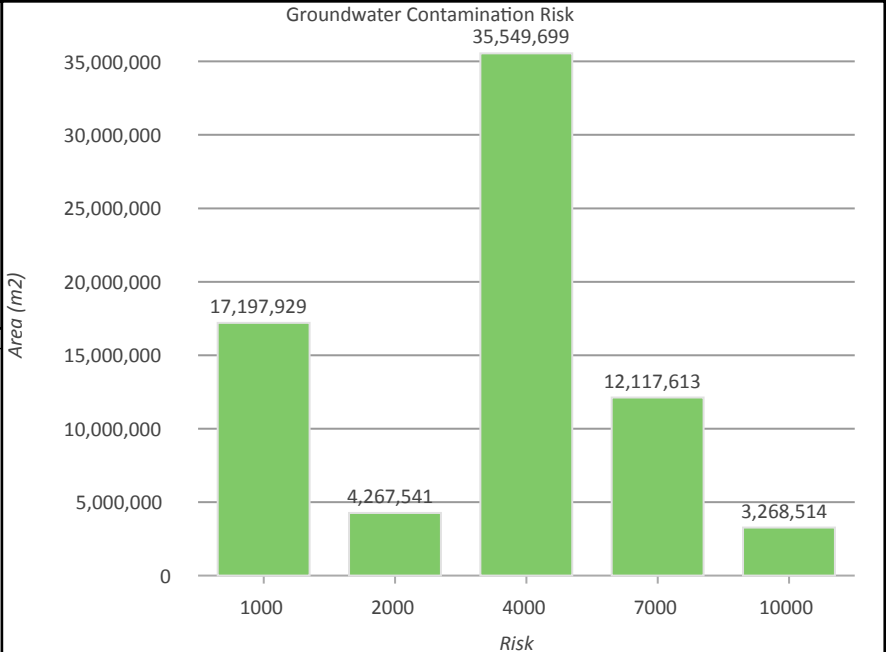
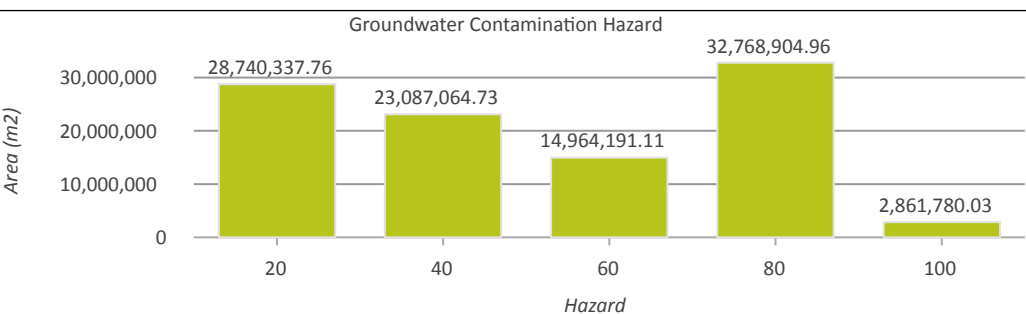
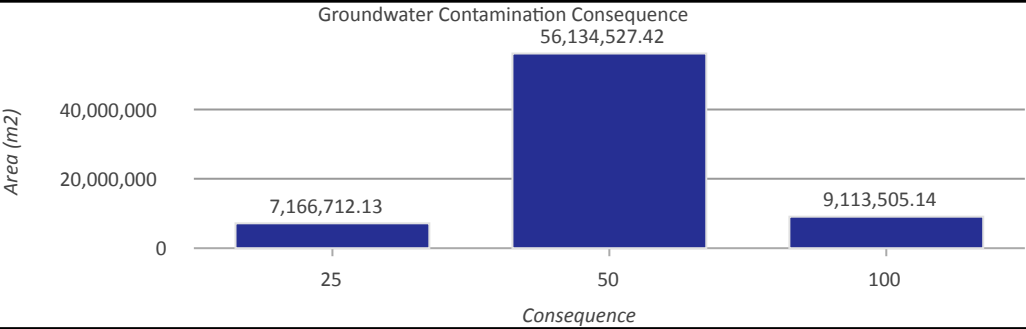


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Shawnigan Creek Watershed



Groundwater Contamination Risk Assessment - Shawnigan Creek

BY: CJW

SCALE CONS: 1:167,469

DATE: 2019/01/08

REF No:

REV: 0

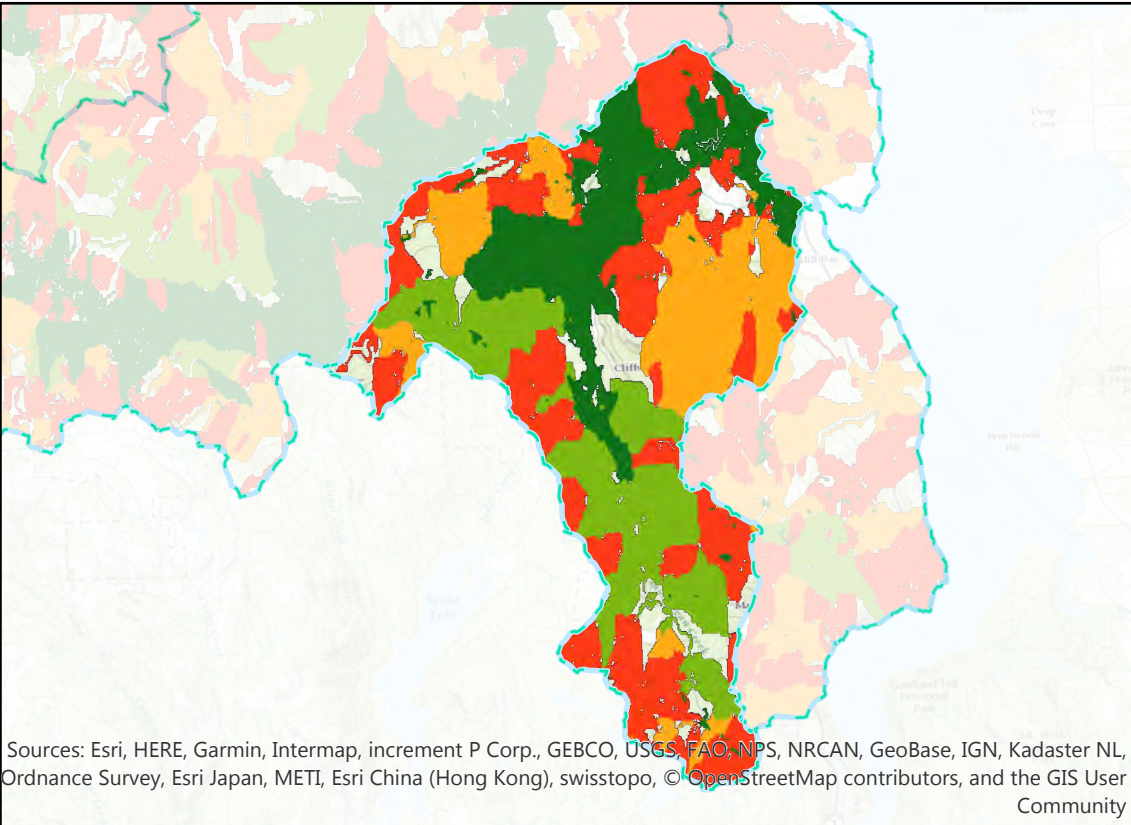
CHK'D: DK

Proj Coord Sys: NAD 1983 UTM Zone 10N

651957-103-SHAWN

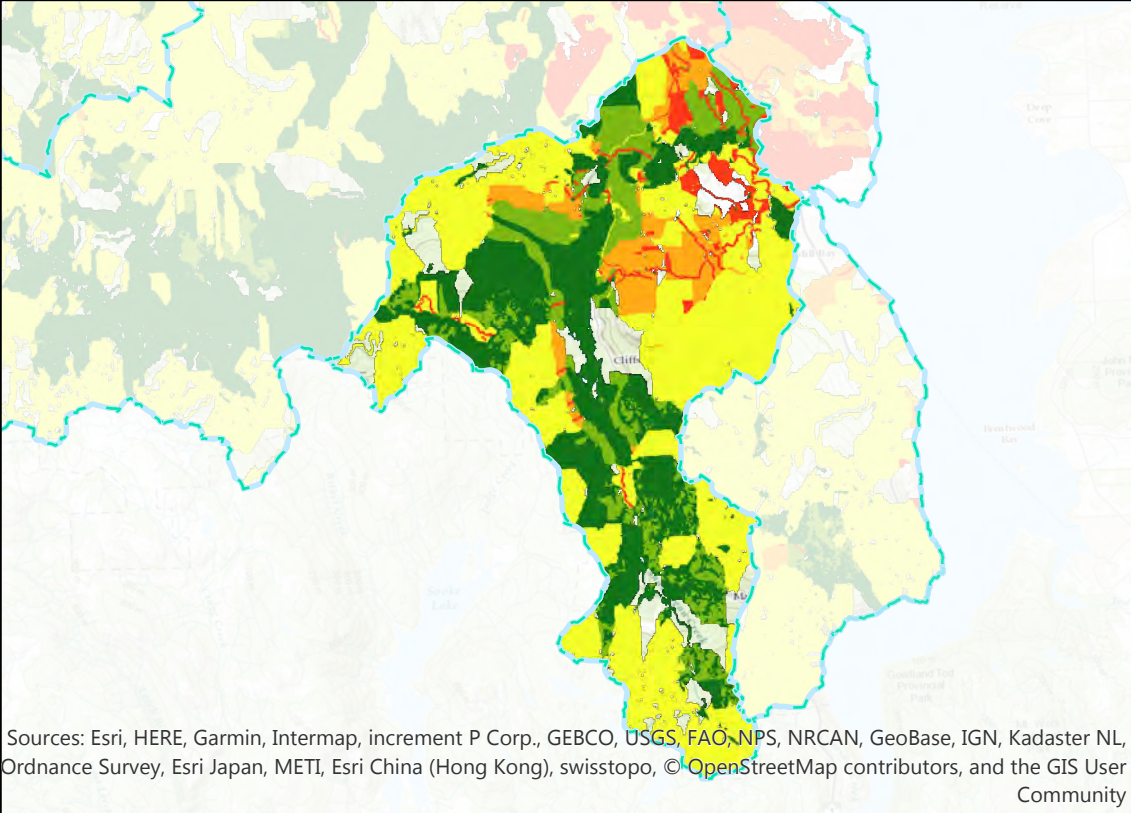


CONSEQUENCE



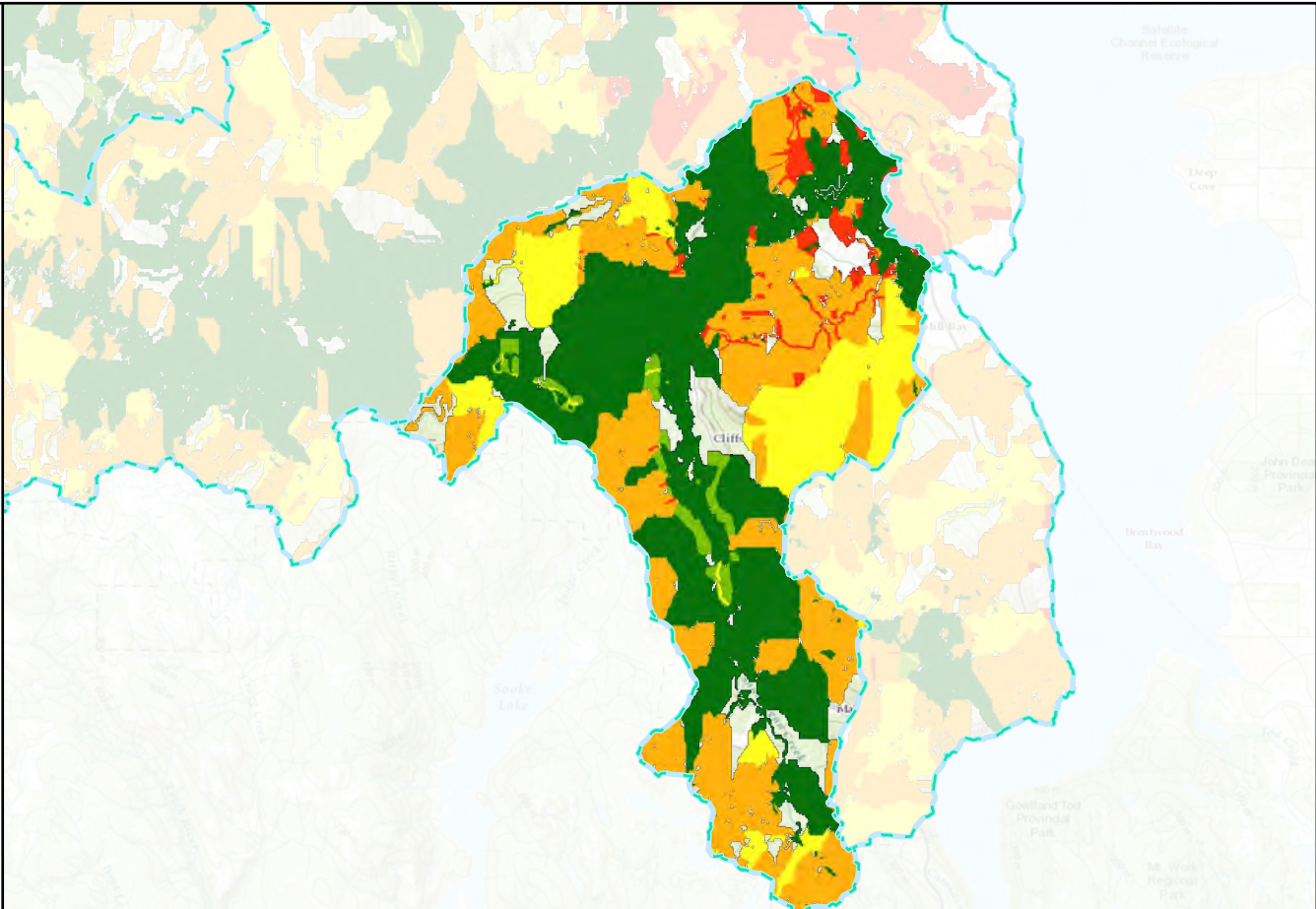
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HAZARD

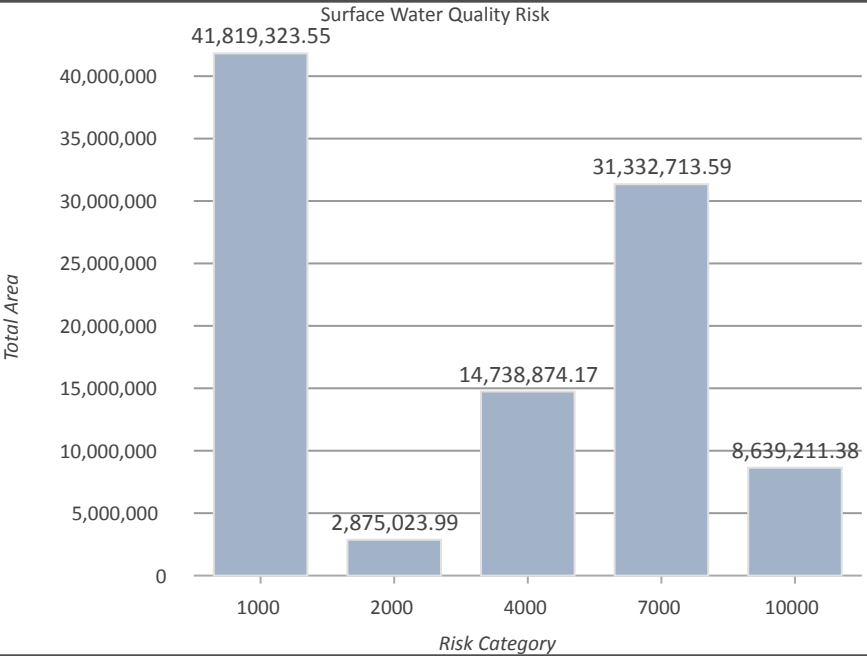
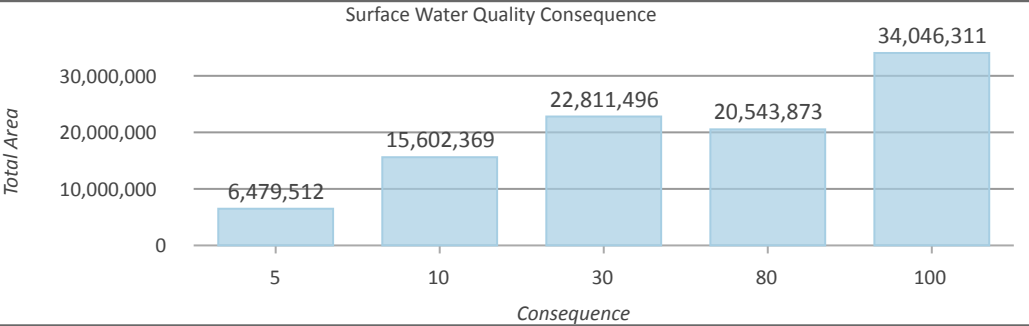
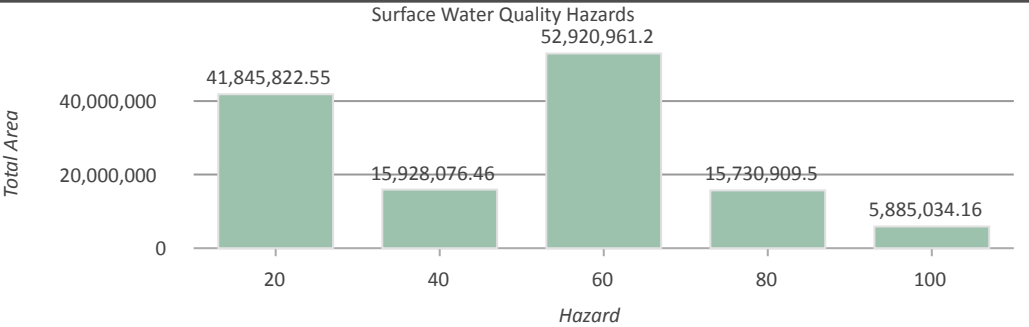


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional DistrictShawnigan
Creek Watershed



Surface Water Quality Risk Assessment - Shawnigan Creek

BY:

SCALE: 1:172,352

DATE: 2019/01/08

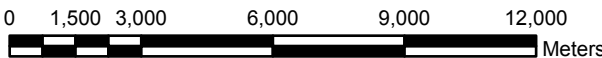
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REV: 0

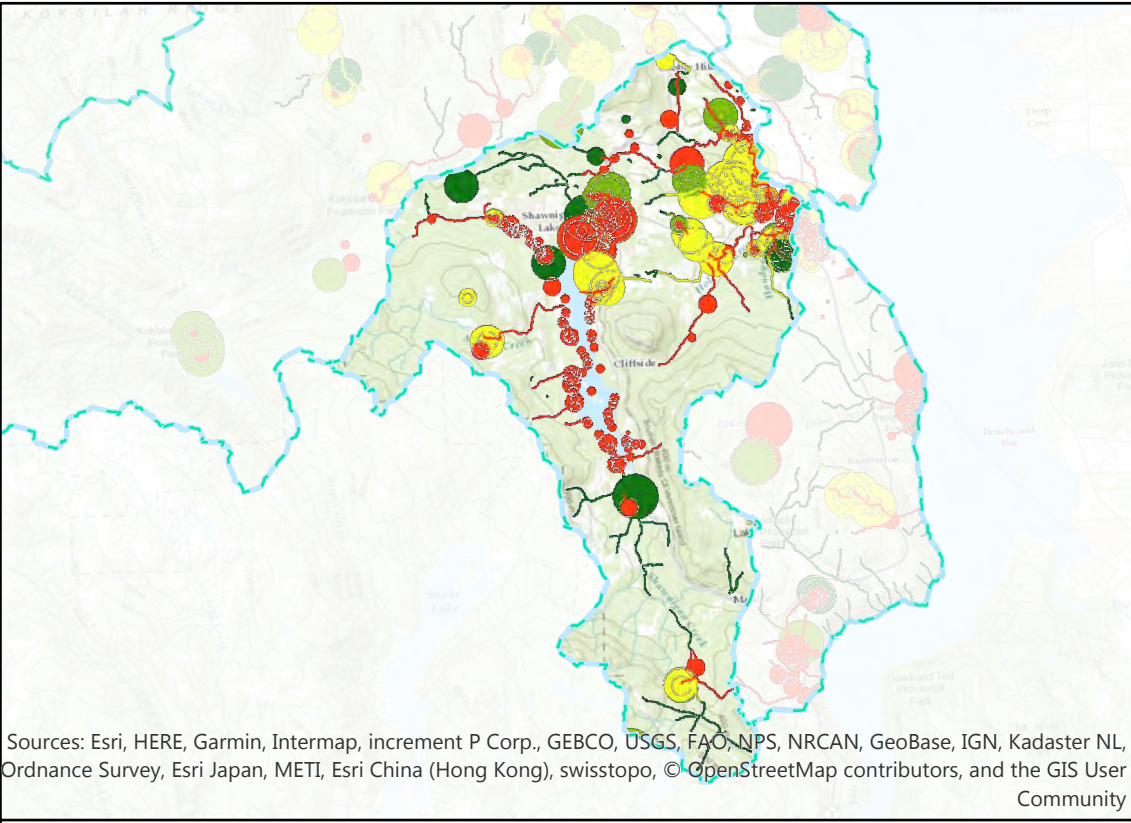
CHK'D:

Proj Coord Sys: PCS Albers

651957-104-SHAWN

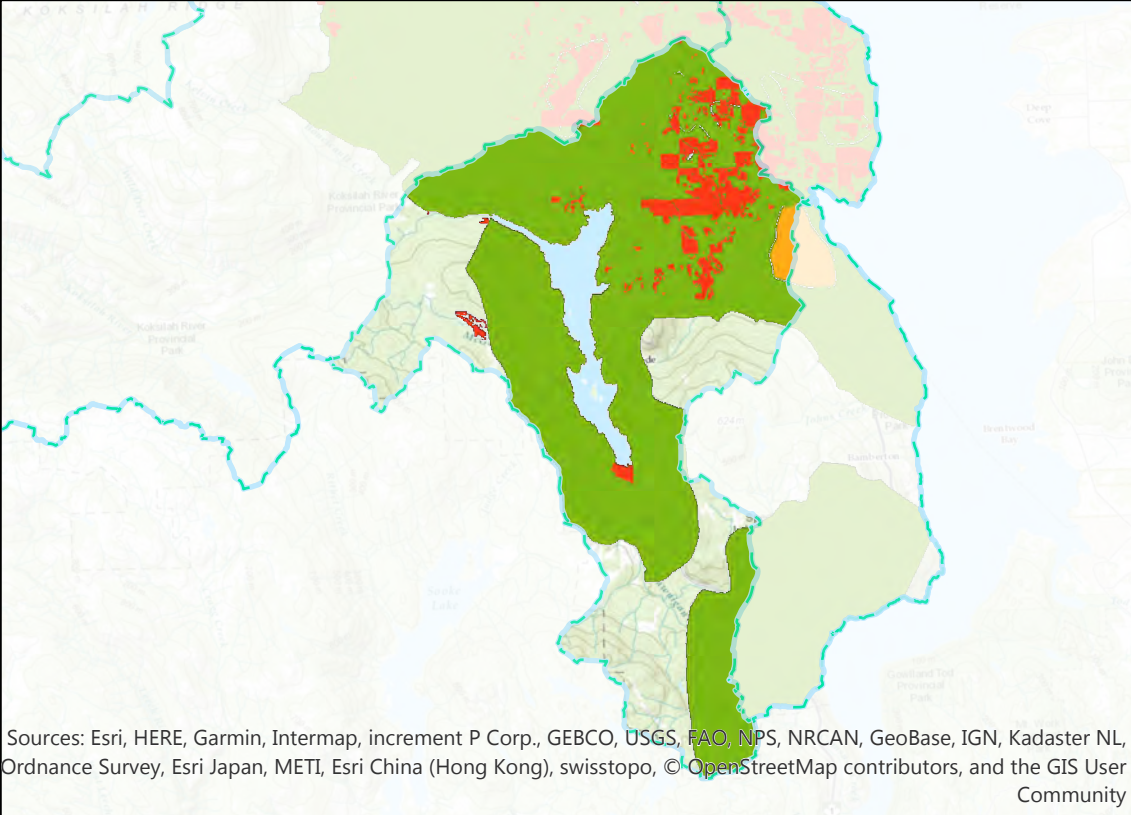


CONSEQUENCE



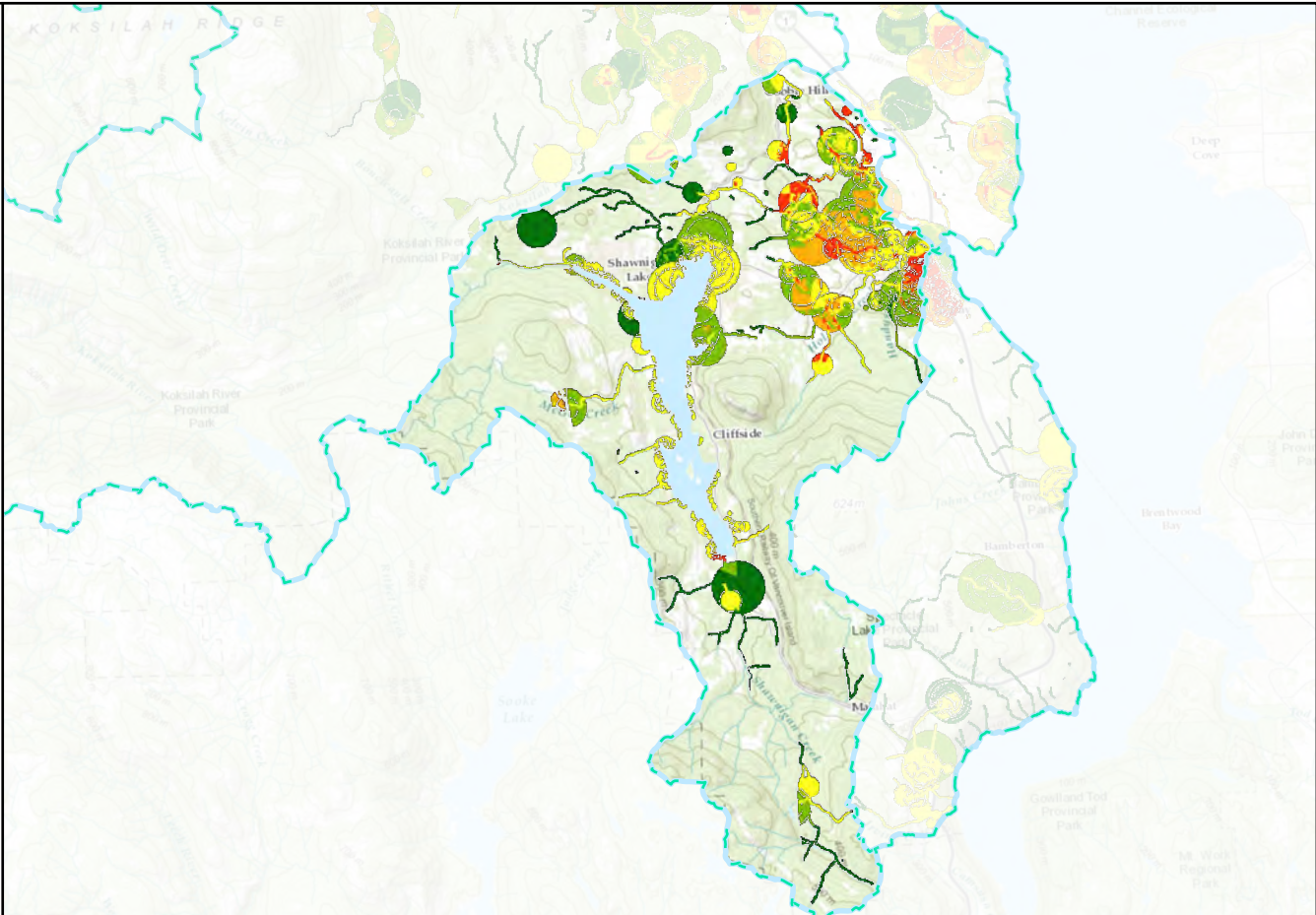
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HAZARD

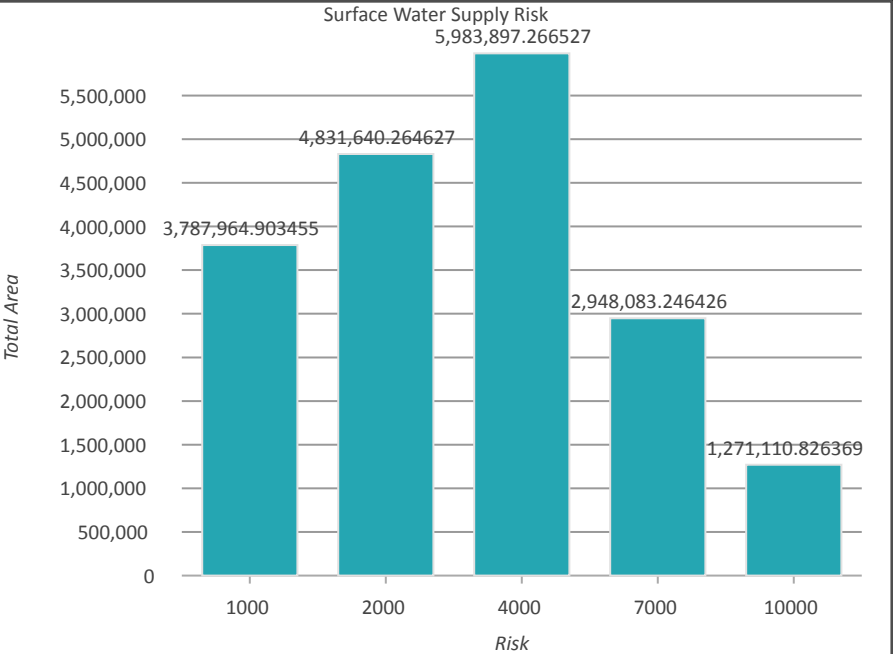
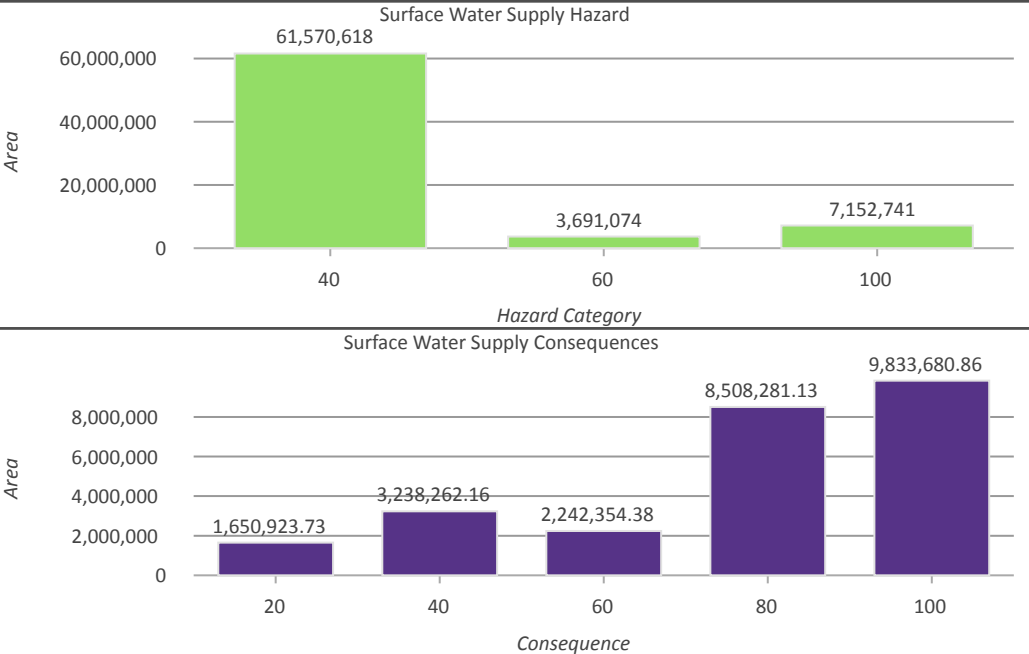


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

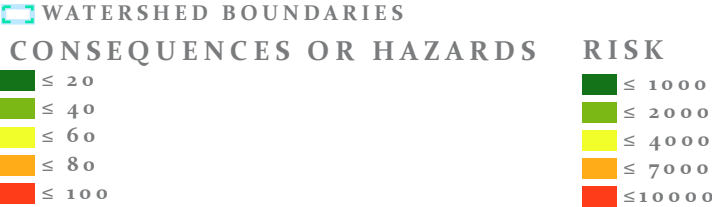
RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend



REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

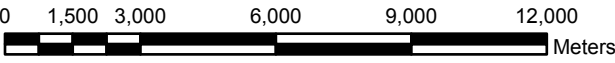
CLIENT:
Cowichan Valley Regional District

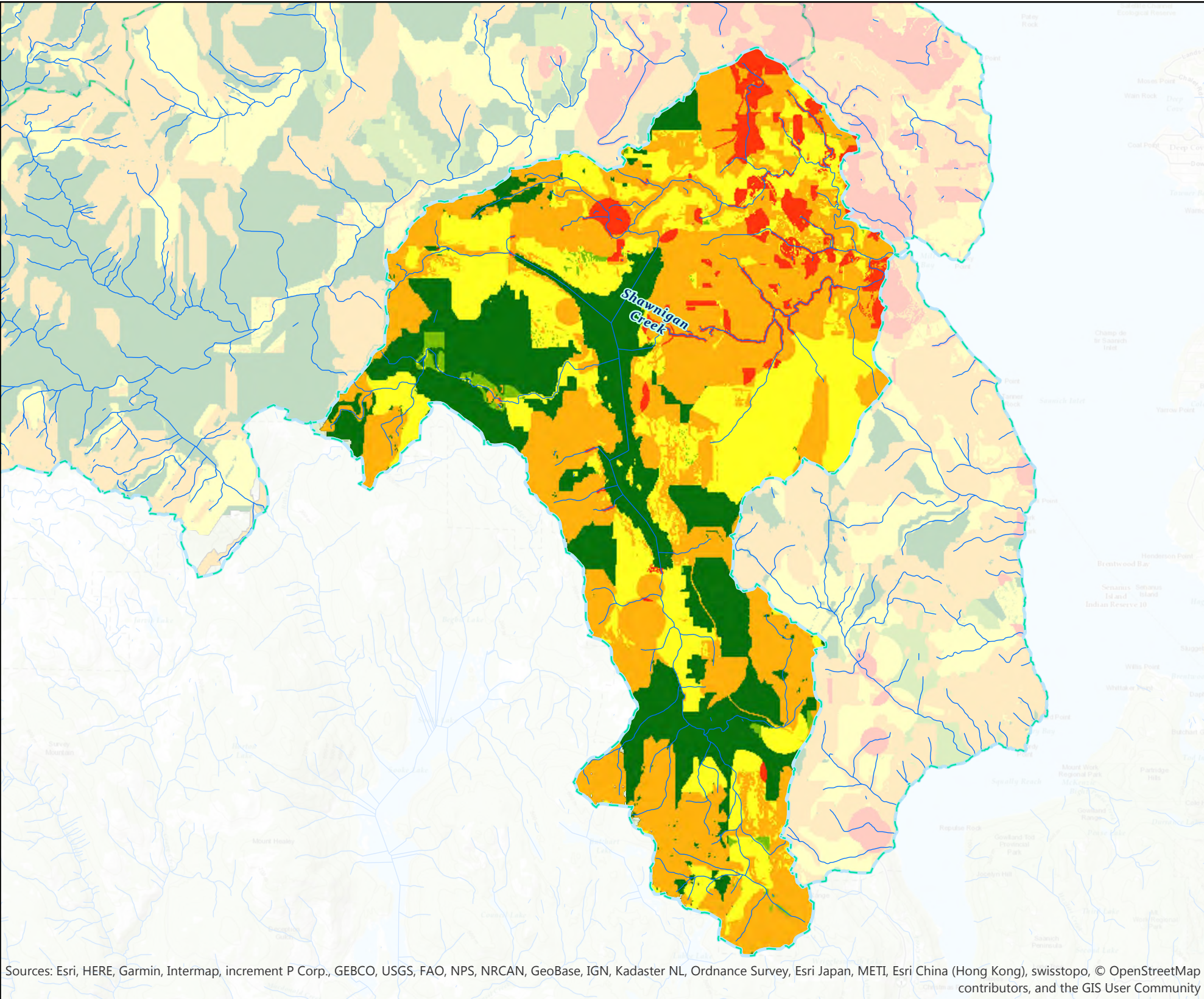
PROJECT LOCATION:
Cowichan Valley Regional DistrictShawnigan Creek Watershed



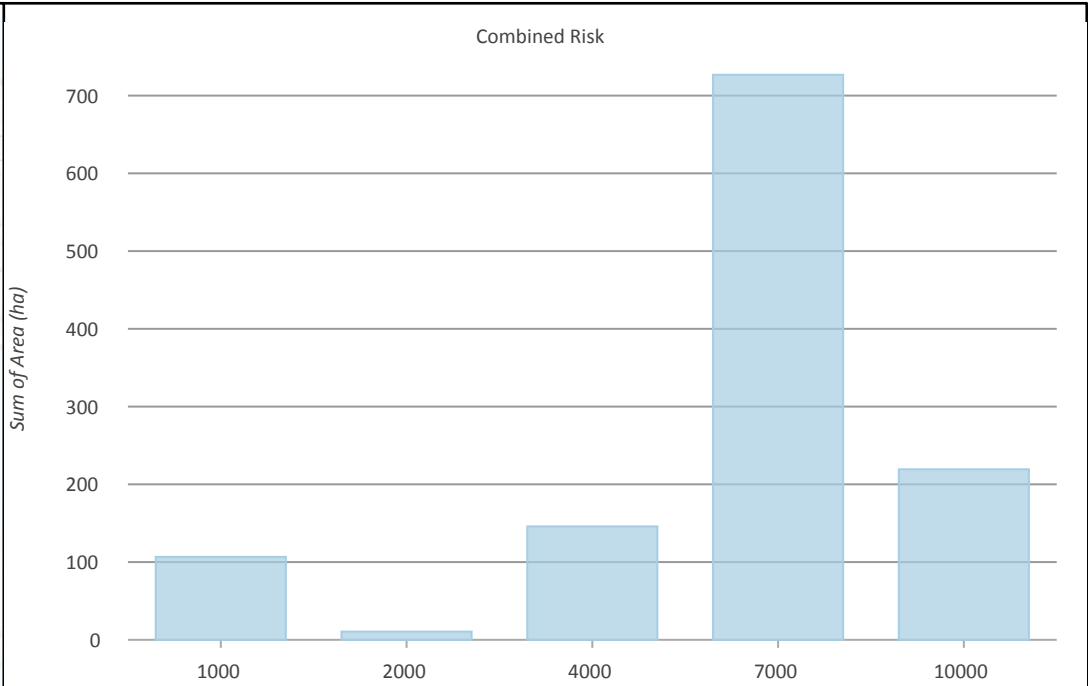
Surface Water Supply Risk Assessment - Shawnigan Creek

BY:	SCALE: 1:167,469	DATE: 2019/01/08	REF No:	REV: 0
CHK'D:	Proj Coord Sys: PCS Albers		651957-105-SHAWN	





Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



NAME	Risk	POP ₂₀₂₁	POP ₂₀₂₆	POP ₂₀₃₁	POP ₂₀₃₆
SHAWNIGAN CREEK		10047	10760	11613	12598
BUSH CREEK		0	0	0	0
KOKSILAH RIVER		5463	5851	6315	6850
HOLLAND CREEK		1302	1368	1446	1537
BONSALL CREEK		934	974	1019	1073
CHEMAINUS RIVER		1490	1461	1439	1421
COWICHAN RIVER		36368	37905	39683	41766
YELLOW POINT BENCHLANDS		2239	2352	2487	2643
LADYSMITH - SALTAIR BENCHLANDS		8410	8834	9342	9929
STOCKING CREEK		1531	1608	1701	1807
CHEMAINUS BENCHLANDS		3663	3818	3997	4207
SATELLITE CHANNEL BENCHLANDS		4390	4701	5074	5504
SANSUM NARROWS - COWICHAN BAY BENCHLANDS		4941	5150	5391	5674
MALAHAT BENCHLANDS		2829	3030	3271	3548

NAME	POP ₂₀₀₁	POP ₂₀₀₆	POP ₂₀₁₁	POP ₂₀₁₆
SHAWNIGAN CREEK	6348	8439	8925	9484
BUSH CREEK	0			
KOKSILAH RIVER	4555	4808	4954	5157
HOLLAND CREEK	1611	1114	1169	1245
BONSALL CREEK	672	830	815	890
CHEMAINUS RIVER	1423	1395	1497	1514
COWICHAN RIVER	29779	32673	34075	34647
YELLOW POINT BENCHLANDS	1167	1958	2021	2141
LADYSMITH - SALTAIR BENCHLANDS	5275	7488	7541	8042
STOCKING CREEK	1332	1003	1354	1464
CHEMAINUS BENCHLANDS	3177	3129	3085	3490
SATELLITE CHANNEL BENCHLANDS	5425	3902	3989	4144
SANSUM NARROWS - COWICHAN BAY BENCHLANDS	5993	4221	4500	4707
MALAHAT BENCHLANDS	1673	2472	2548	2671

Legend

WATERSHED BOUNDARIES

RISK

≤ 1000

≤ 2000

≤ 4000

≤ 7000

≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

NOTES:

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REVISIONS:

0 - CJW - 2018-11-30 - Issued - DK

CLIENT:

Cowichan Valley Regional District

PROJECT LOCATION:

Cowichan Valley Regional District

Shawnigan Creek Watershed

Combined Risk Assessment - Shawnigan Creek

BY: CJW

SCALE CONS: 1:98,000

DATE: 2019/01/08

REF No:

CHK'D: DK

Proj Coord Sys: NAD 1983 UTM Zone 10N

651957-106-SHAWN

REV: 0

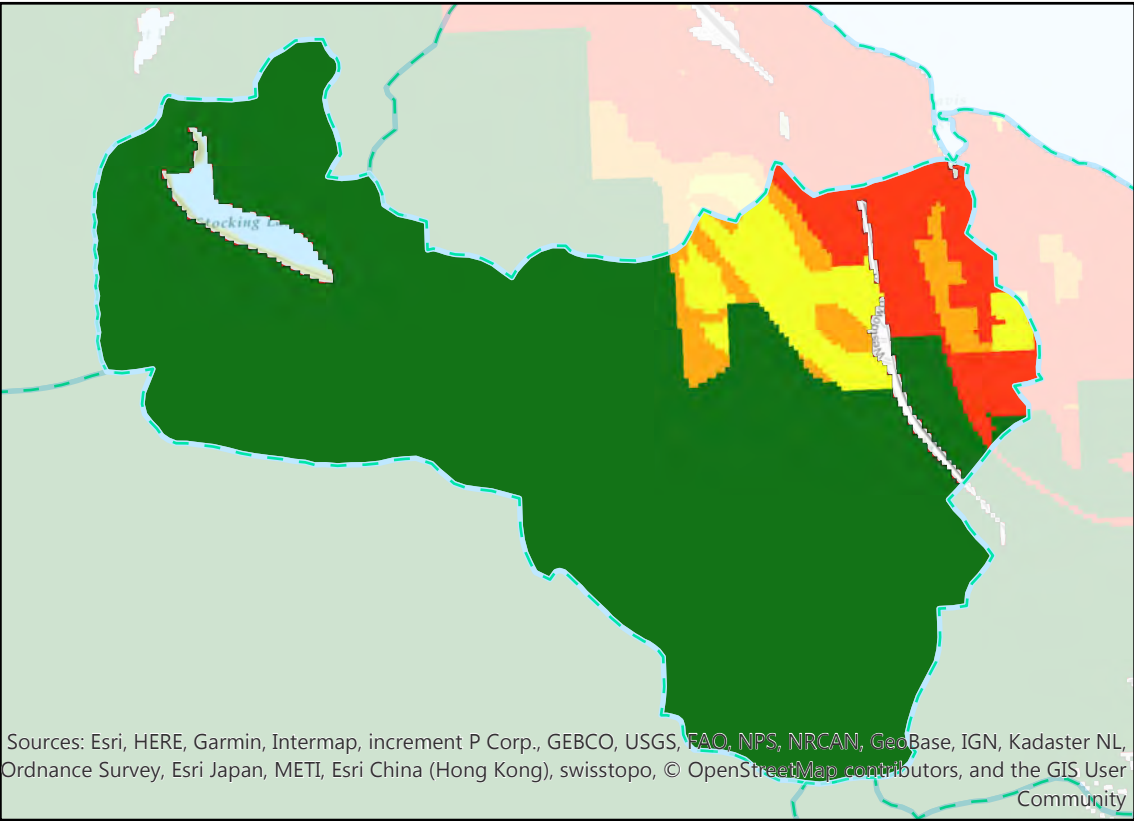
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Project Path: P:\Current Projects\CVRD\651957\

P: 12 - 6

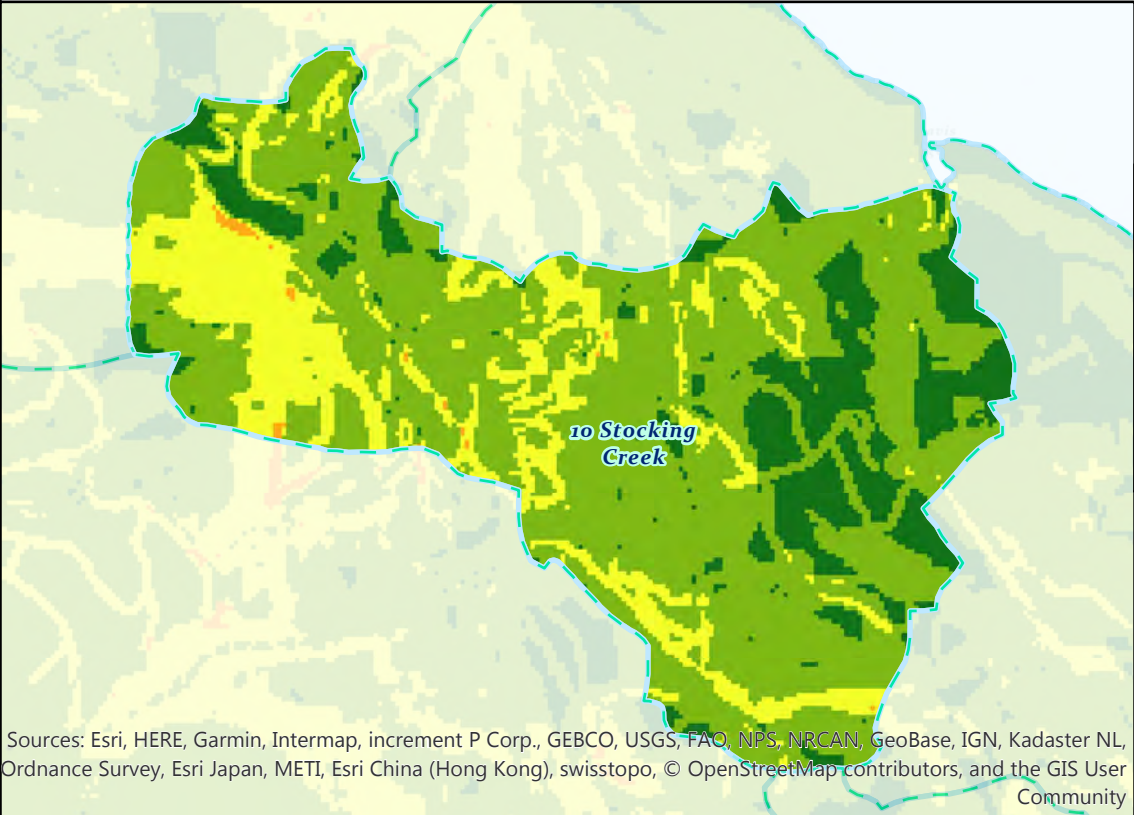
13. Stocking Creek	
Topic	Discussion
Slope Failure	<p>Hazard was determined qualitatively at a high level to describe areas based on the degree to which they may be prone to landslides and other mass movements using terrain characteristics. Hazard classifications were generated to show relative comparisons between terrain units within the CVRD watershed study area. Risk ratings derived from this analysis are relative, and should be used to guide prioritization of further detailed studies.</p> <p>Hazard is generally low throughout the watershed. Hazard is greatest on the relatively steep slopes near Stocking Lake at the western edge of the watershed. Consequence is considered moderate to high through the populated areas near the northeast corner of the watershed. Risk is considered moderate in this populated area.</p>
Flooding	<p>Stocking Creek is the only creek within the watershed that drains between two adjacent areas that belong to the Ladysmith-Saltair Benchlands. Consequence and risk are both very low for the majority of the watershed and are greatest along the downstream (east) end of the watershed along the industrial area situated off Highway 1.</p>
Groundwater Contamination	<p>Likelihood is greatest to the eastern side of the watershed although consequence for this region is considered very low. Therefore, risk is considered low for the area of the watershed where data sources were available.</p>
Surface Water Quality	<p>Hazard is greatest surrounding Highway 1 where residential and industrial areas are located. Consequence is greatest surrounding Stocking Lake and several areas along the watershed boundary where lower order streams are present and therefore are more susceptible to water quality issues. Risk is considered greatest along the industrial lots adjacent to Highway 1. Population is projected to steadily increase at a relatively slow rate. Depending on the changes in land use, development, and impervious surface cover to accommodate the increase in population, and where a growing population will reside, higher risk areas may or may not extend in coverage throughout the watershed.</p>
Surface Water Supply	<p>Hazard is greatest in small isolated zones at the east side of the watershed. Consequence in the watershed is localized around surface water points of diversion, the greatest at the southeast end of Stocking Lake, and moderate to high consequence at the east end of the watershed, northwest of Saltair. Risk is moderate across the east end of the watershed. Projected population increase for the watershed is expected to add pressures on groundwater sources concentrated at the east end of the watershed, may increase the level of hazard and risk.</p>
General Data Notes	<p>Further work to identify and map aquifers in the upper watershed could identify water resources available to support projected population growth as the risk is currently greatest in the main aquifer at the east end of the watershed. Surface water quality risk is one of the major contributors, with flood, slope failure, surface water supply, and groundwater contamination all being focused in the areas around the highway and into Saltair.</p>

CONSEQUENCE



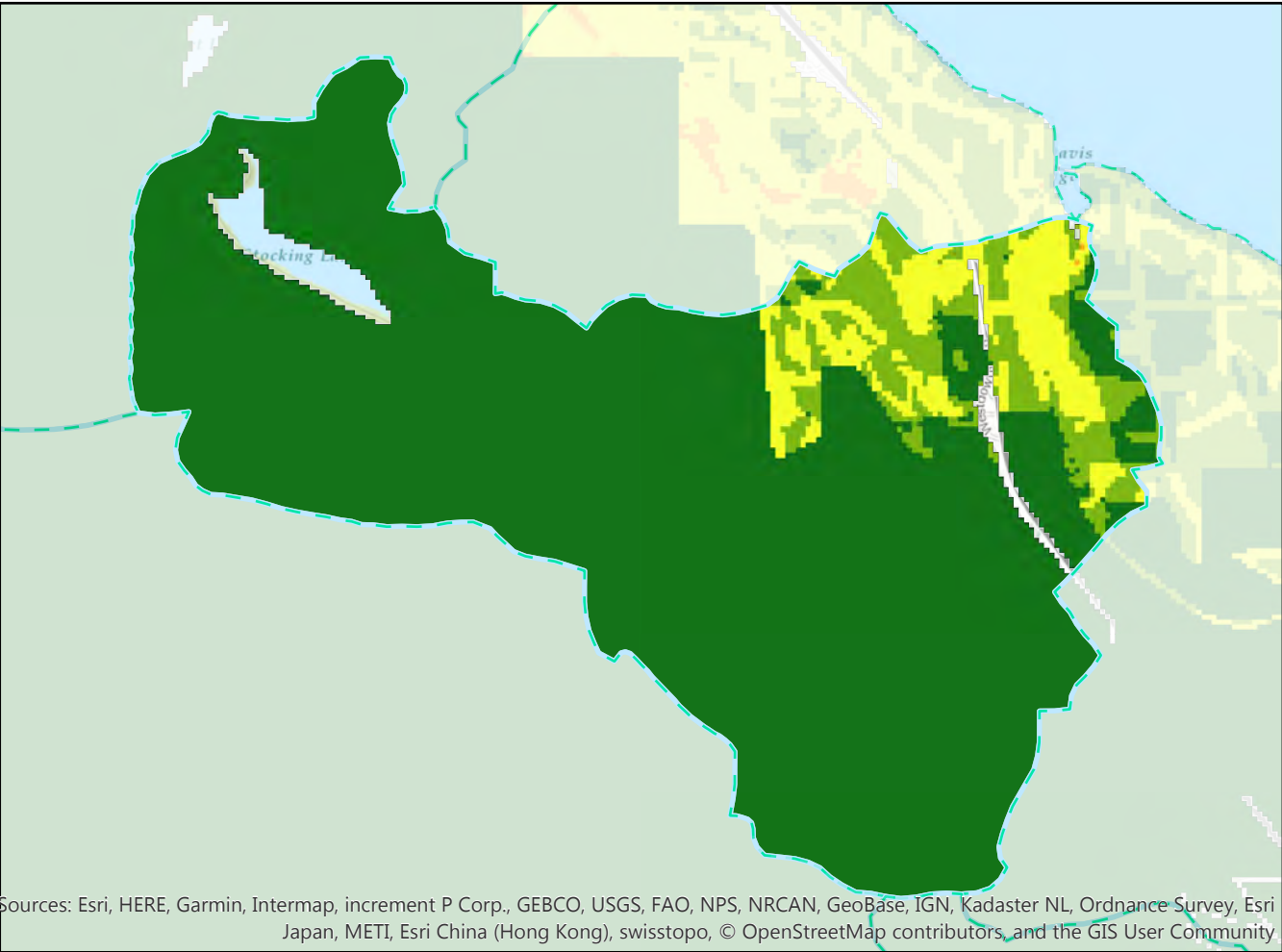
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

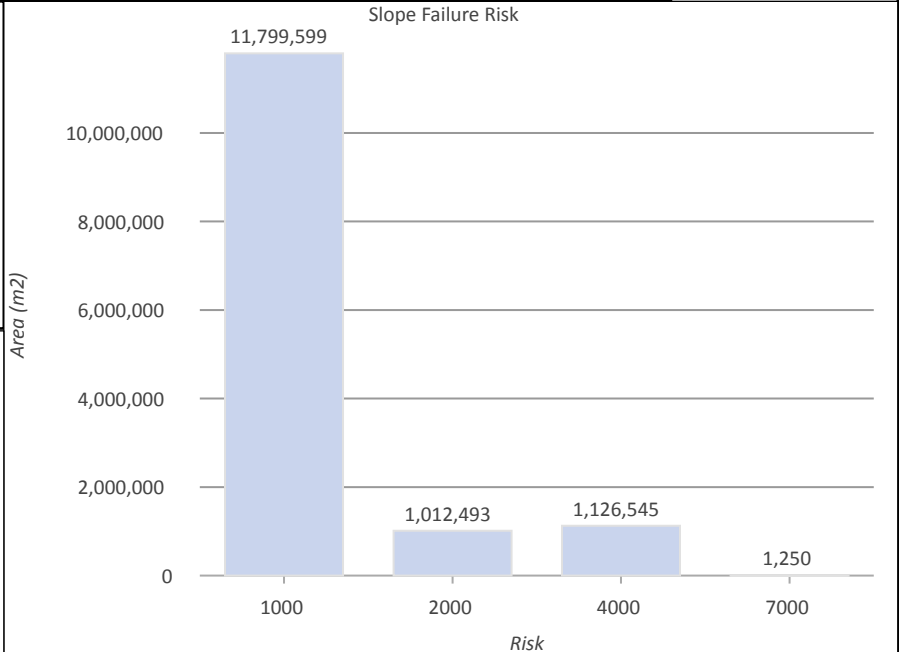
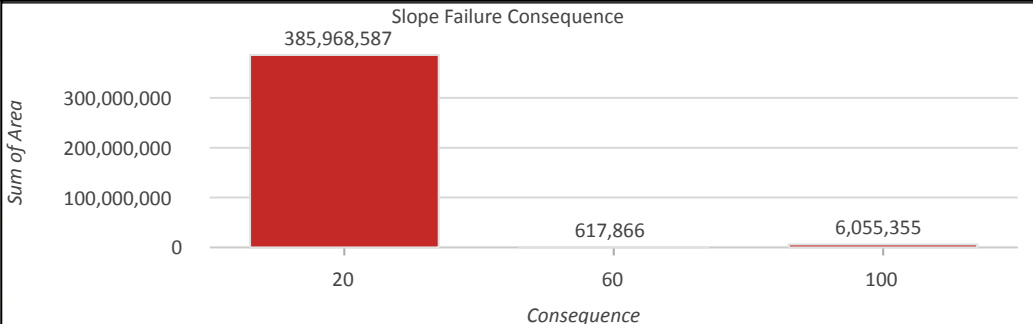


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

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NOTES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

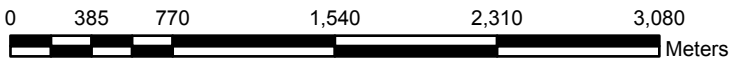
CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Stocking Creek Watershed

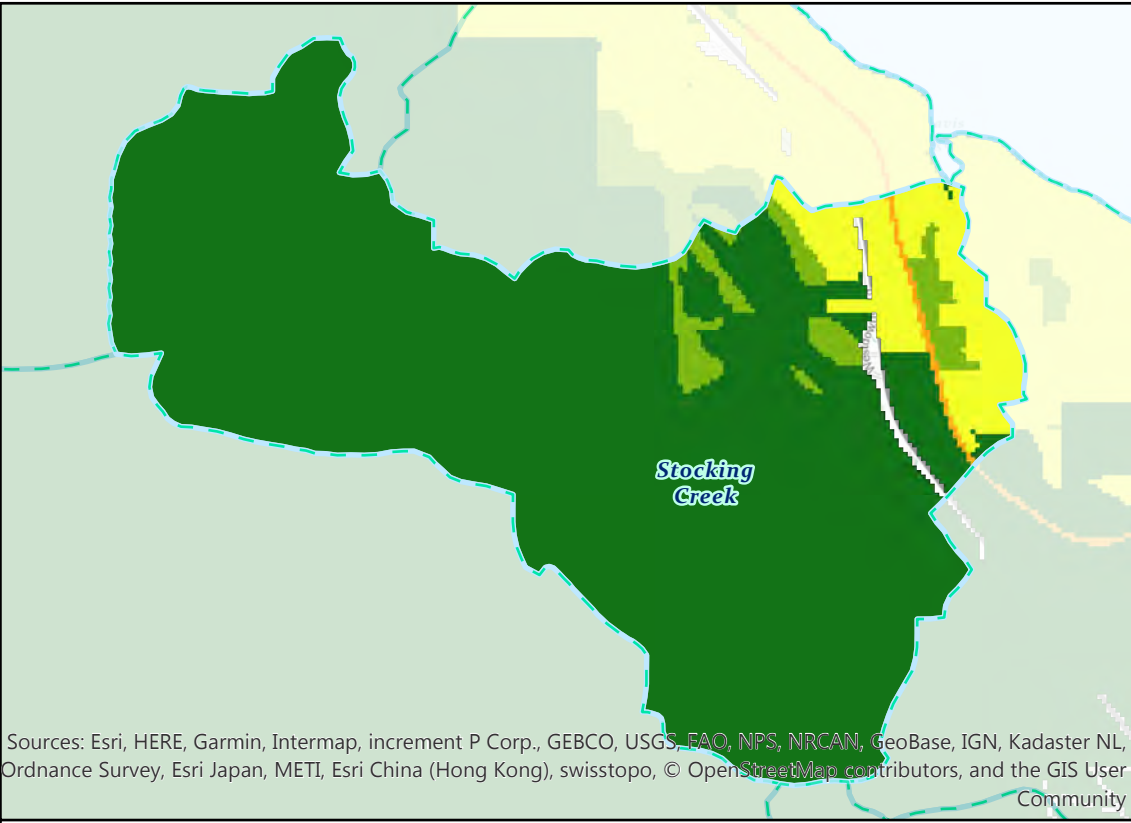


Slope Failure Risk Assessment - Stocking Creek

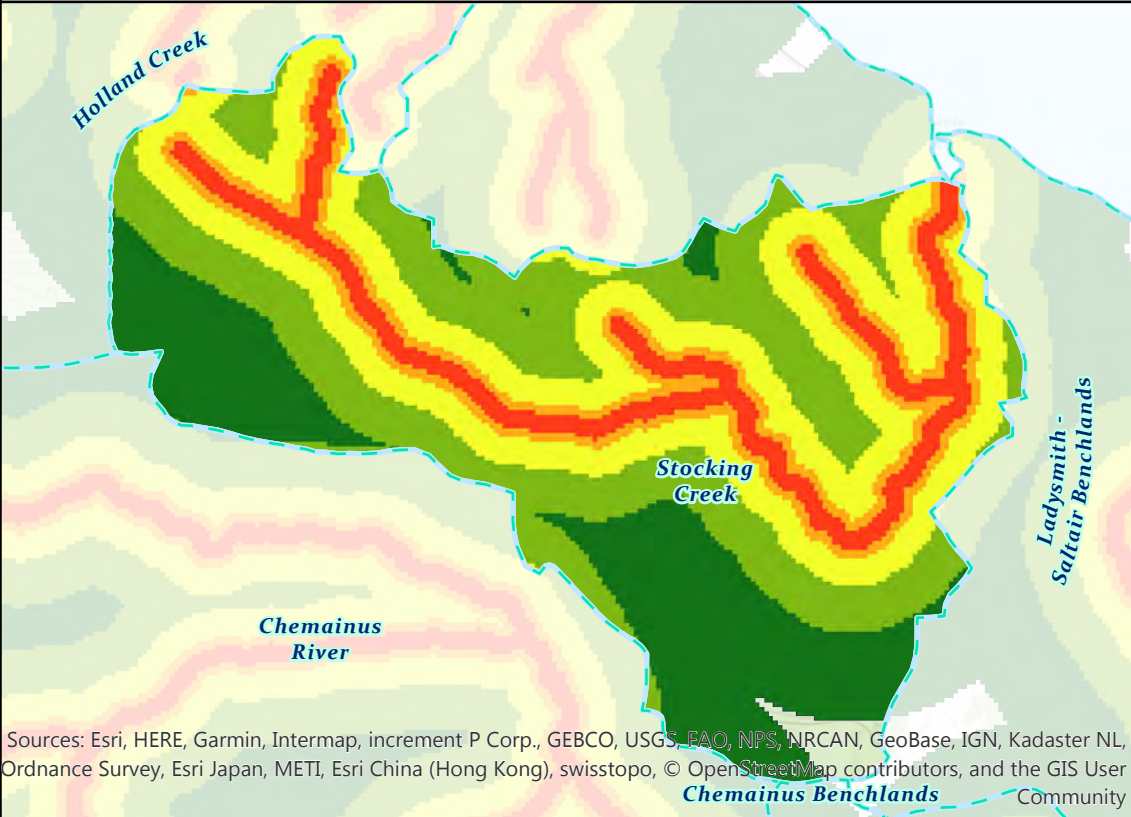
BY: CJW	SCALE CONS: 1:35,892	DATE: 2019/01/07	REF No:	REV: 0
CHK'D: DK	Proj Coord Sys: PCS Albers	651957-101-STOCK		



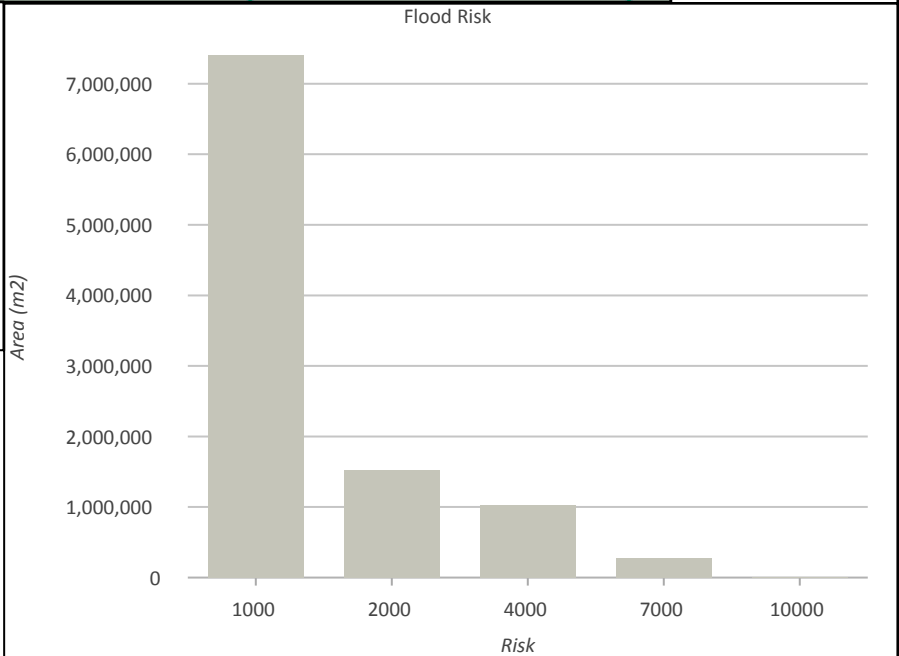
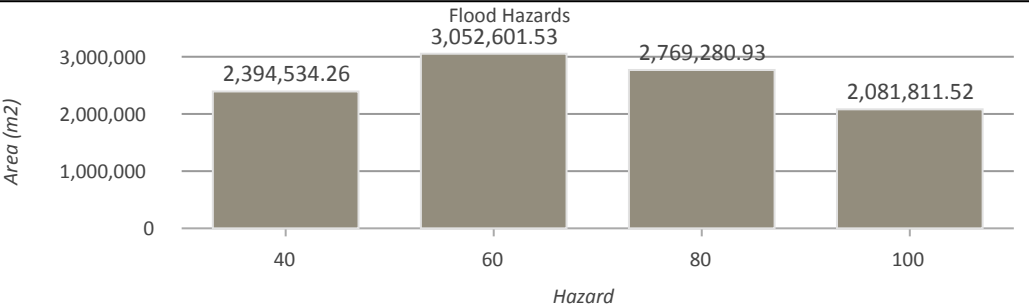
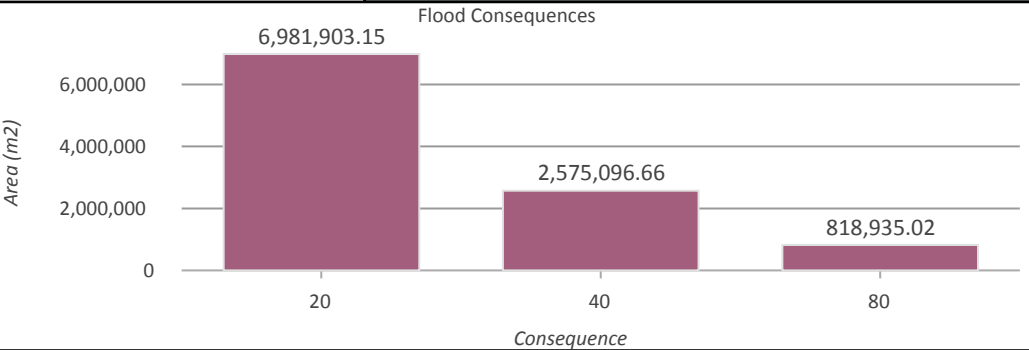
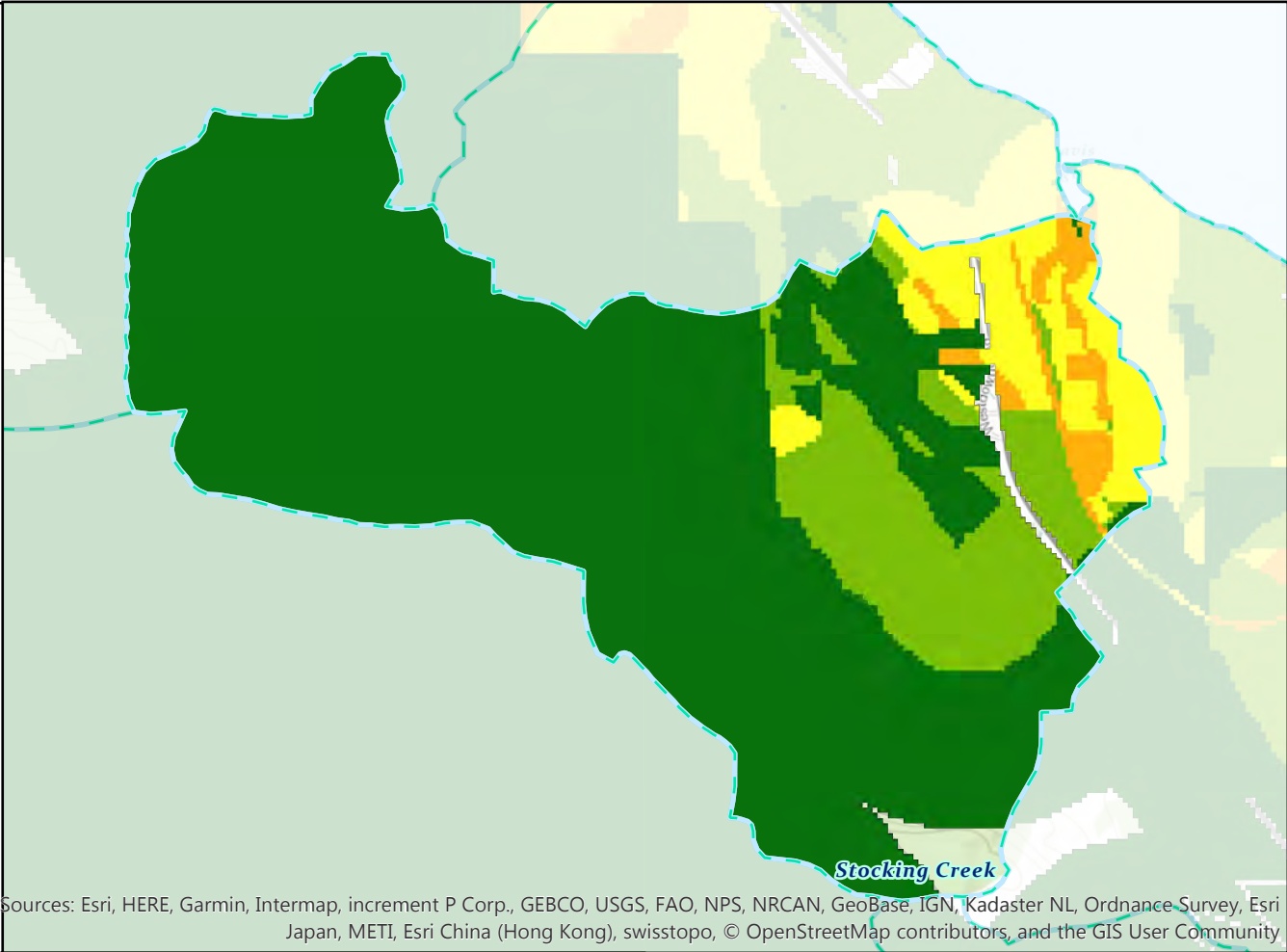
CONSEQUENCE



HAZARD



RISK



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

	≤ 20
	≤ 40
	≤ 60
	≤ 80
	≤ 100

RISK

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	≤ 2000
	≤ 4000
	≤ 7000
	≤ 10000

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

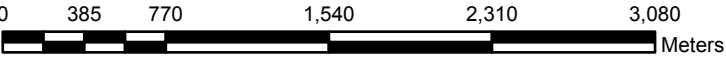
PROJECT LOCATION:
Cowichan Valley Regional District
Stocking Creek Watershed

Flood Risk Assessment - Stocking Creek

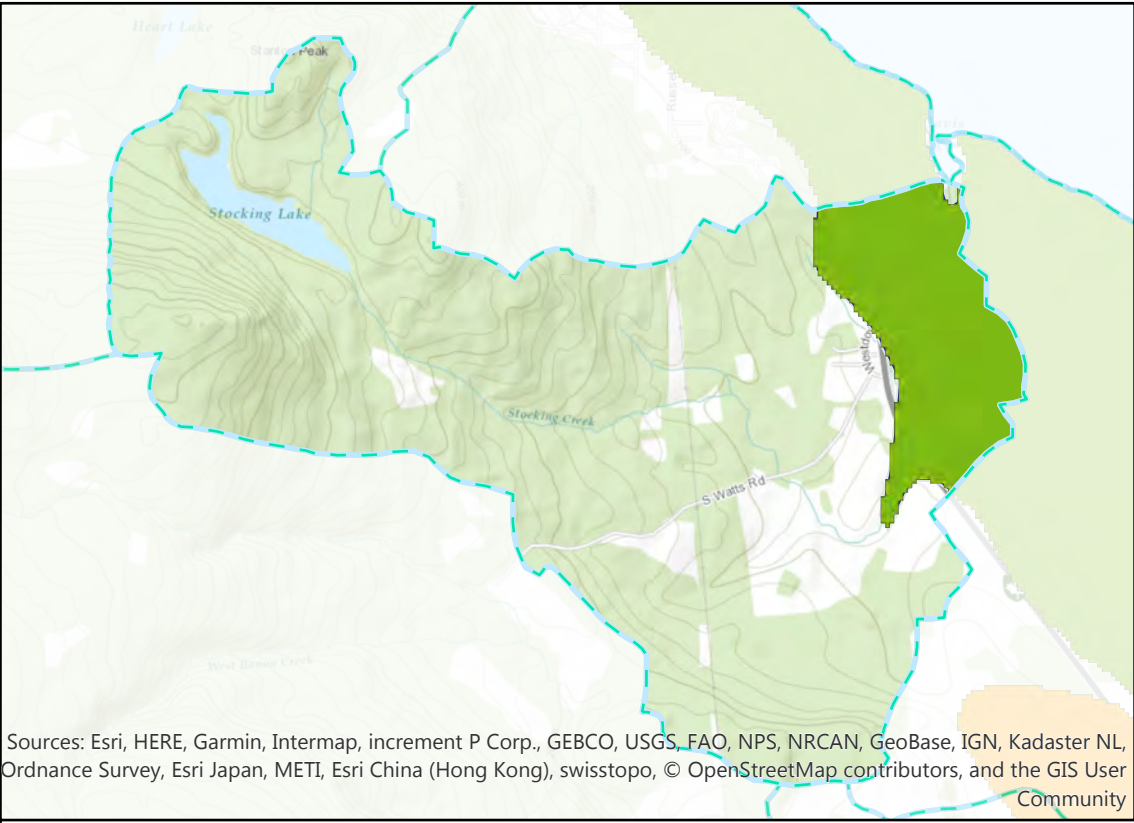
BY: CJW SCALE CONS: 1:35,704 DATE: 2019/01/08 REF No: REV: 0

CHK'D: DK Proj Coord Sys: NAD 1983 UTM Zone 10N **651957-102-STOCK**

SNC • LAVALIN

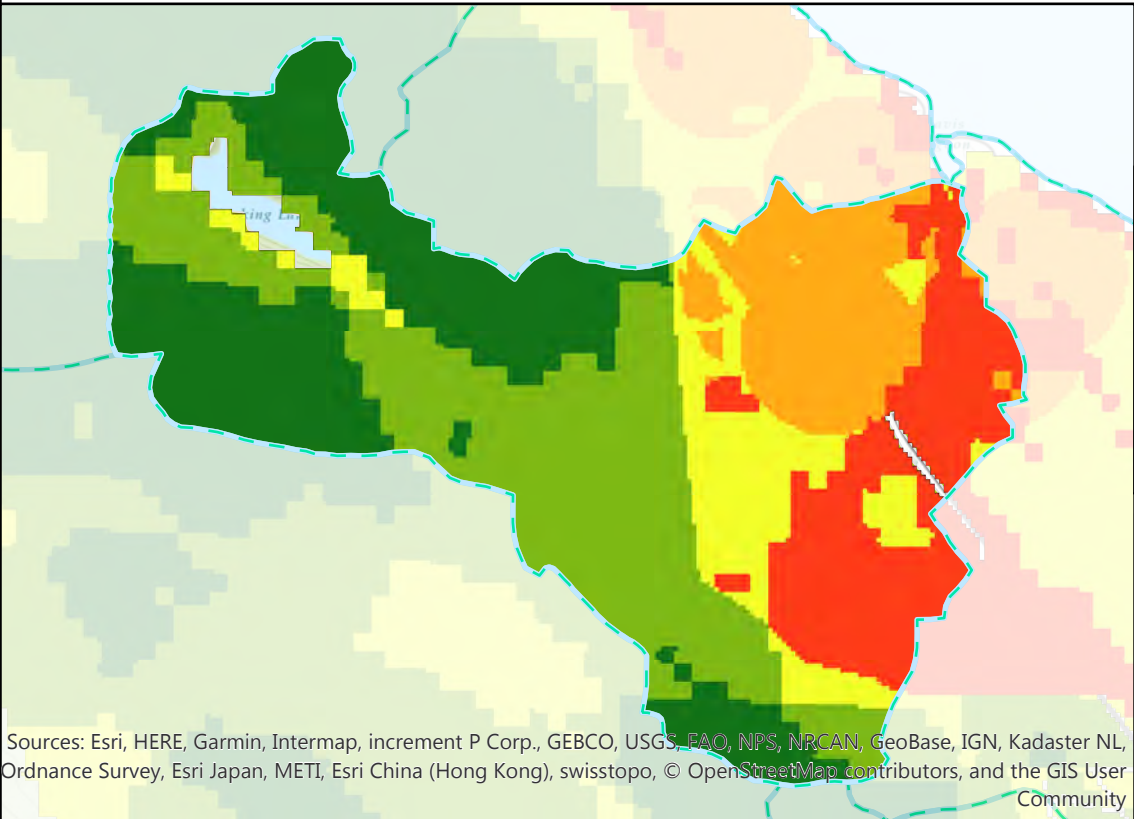


CONSEQUENCE



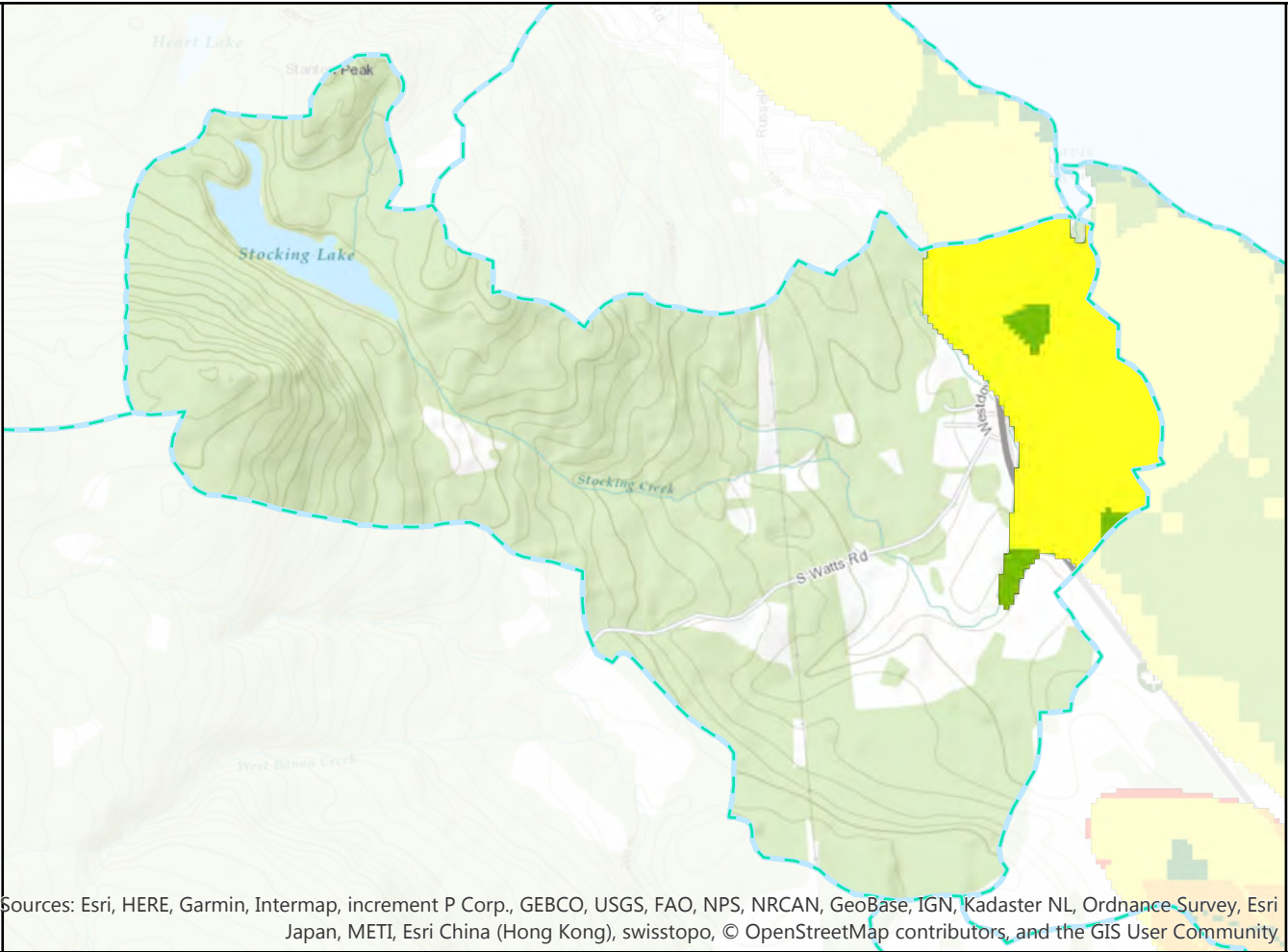
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

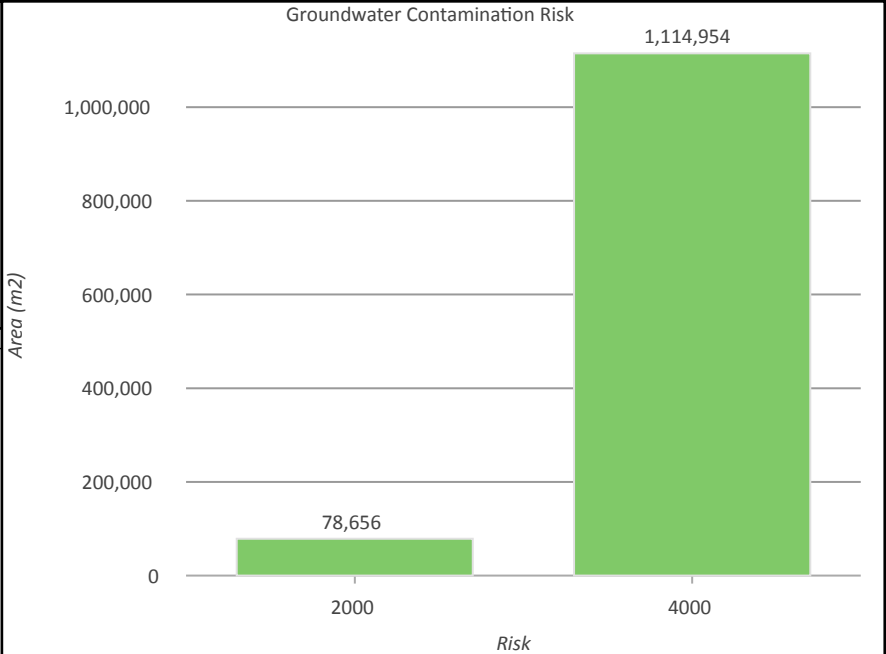
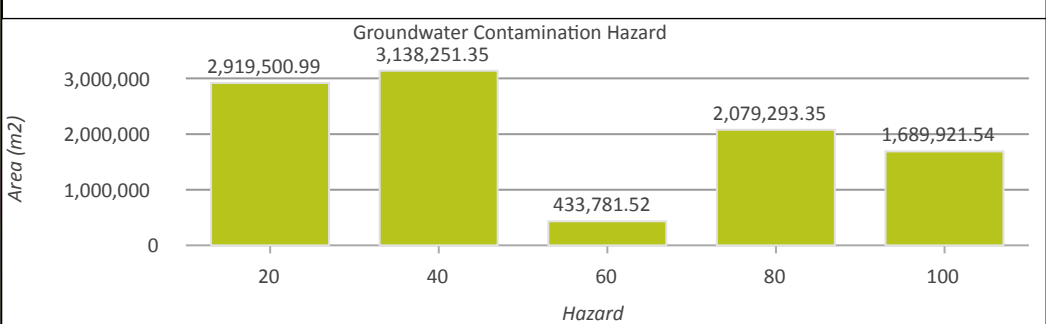
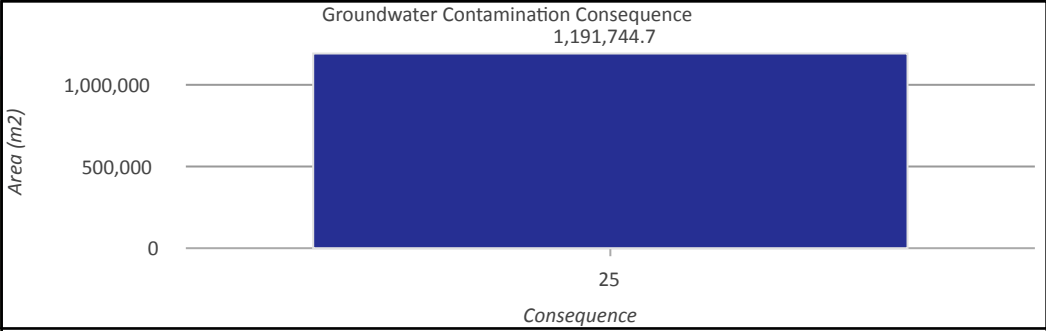


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Stocking Creek Watershed



Groundwater Contamination Risk Assessment - Stocking Creek

BY: CJW

SCALE CONS: 1:35,704

DATE: 2019/01/08

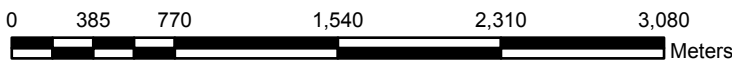
REF No:

REV: 0

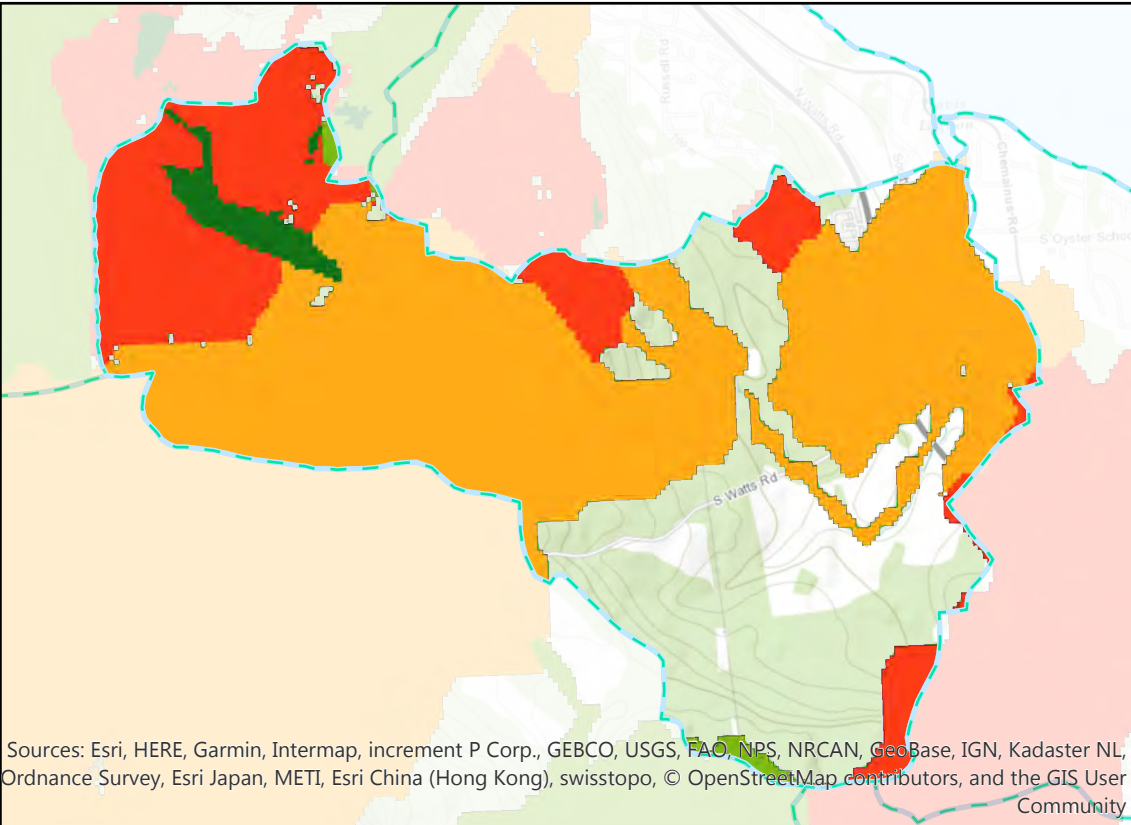
CHK'D: DK

Proj Coord Sys: NAD 1983 UTM Zone 10N

651957-103-STOCK

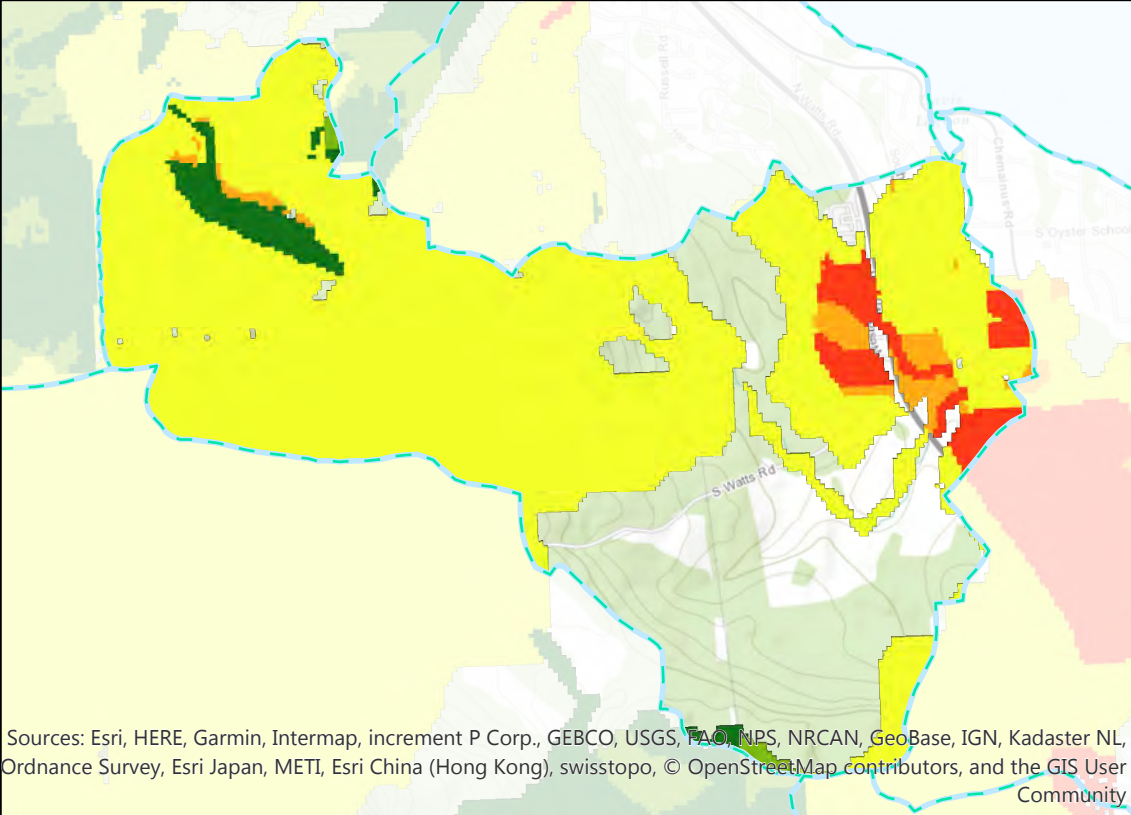


CONSEQUENCE



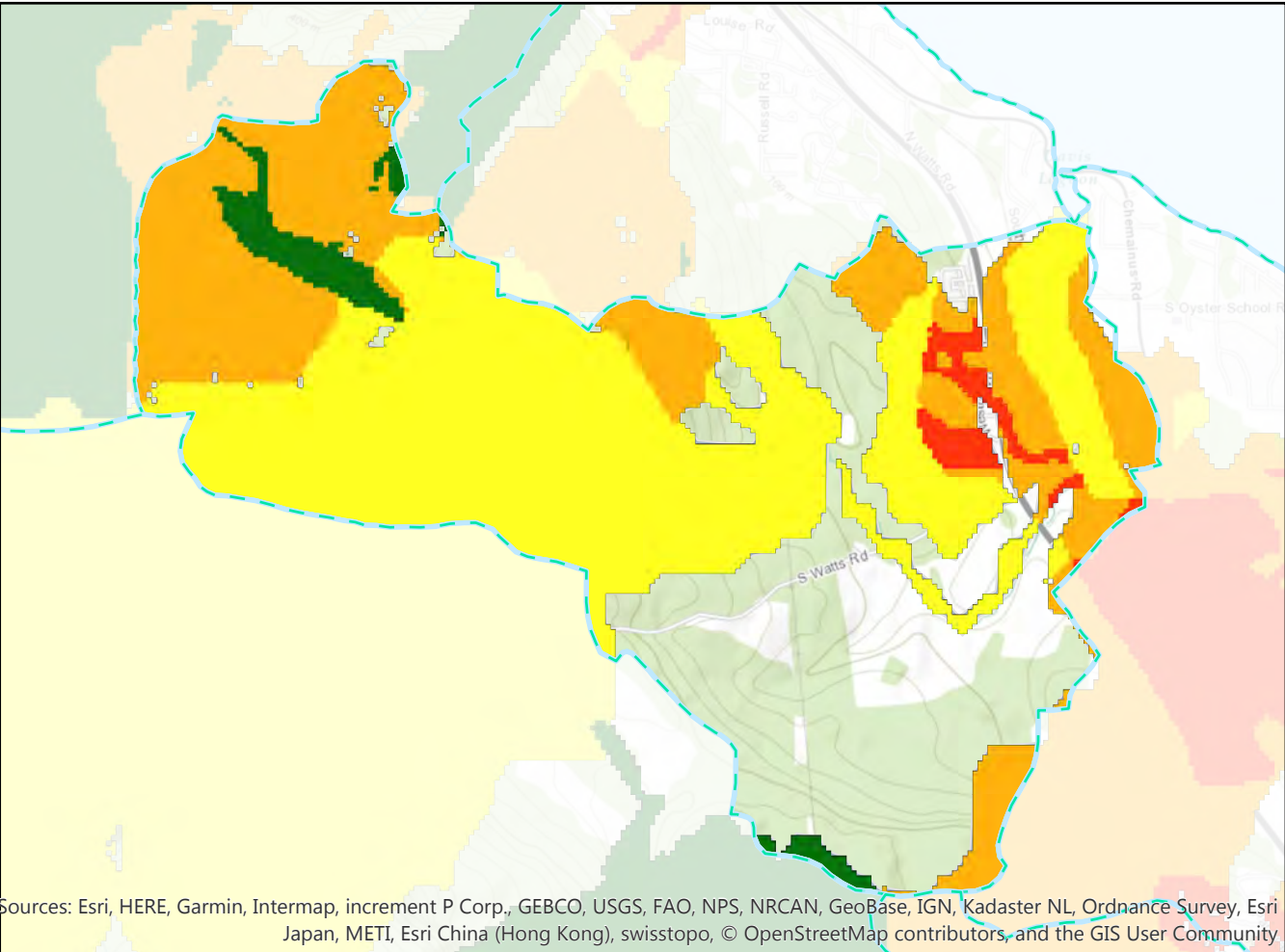
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

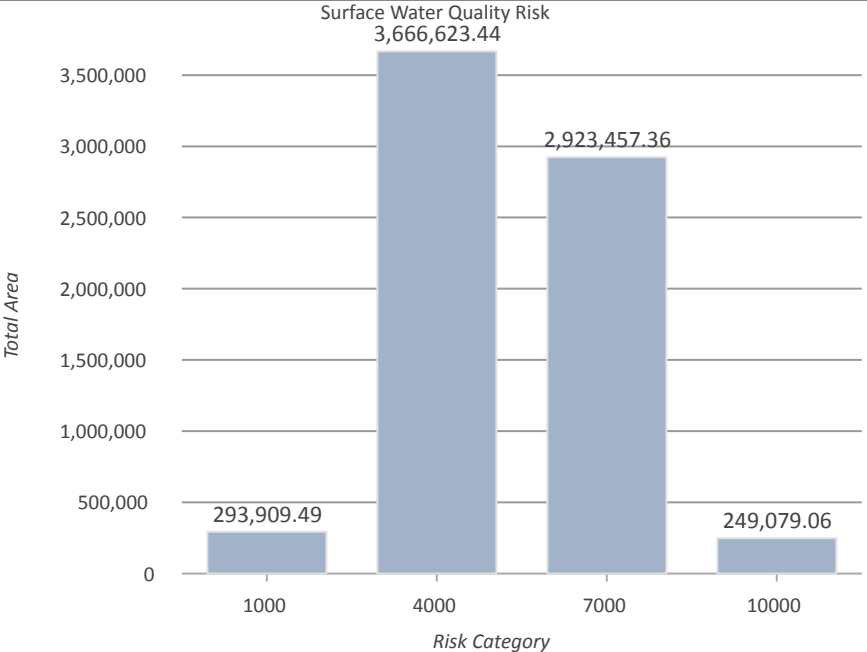
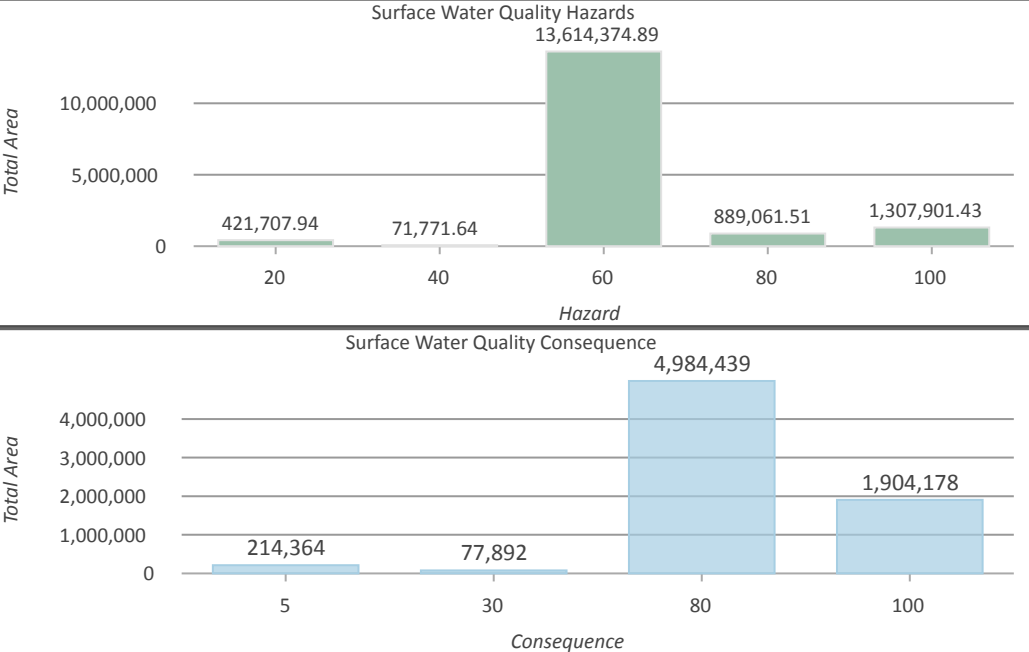


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

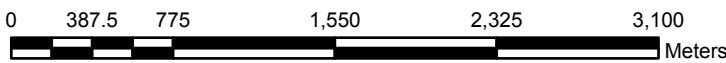
CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District Stocking Creek Watershed

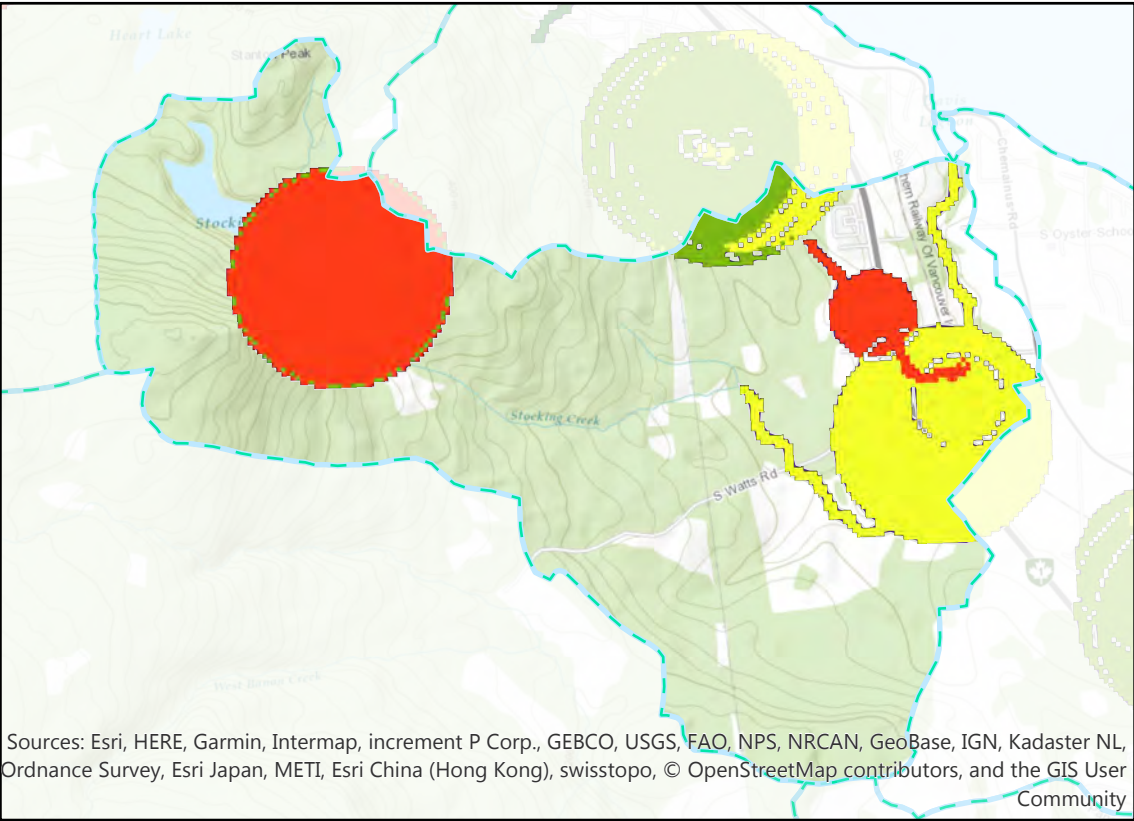


Surface Water Quality Risk Assessment - Stocking Creek

BY: SCALE: 1:36,216 DATE: 2019/01/08 REF No: REV: 0
CHK'D: Proj Coord Sys: PCS Albers 651957-104-STOCK

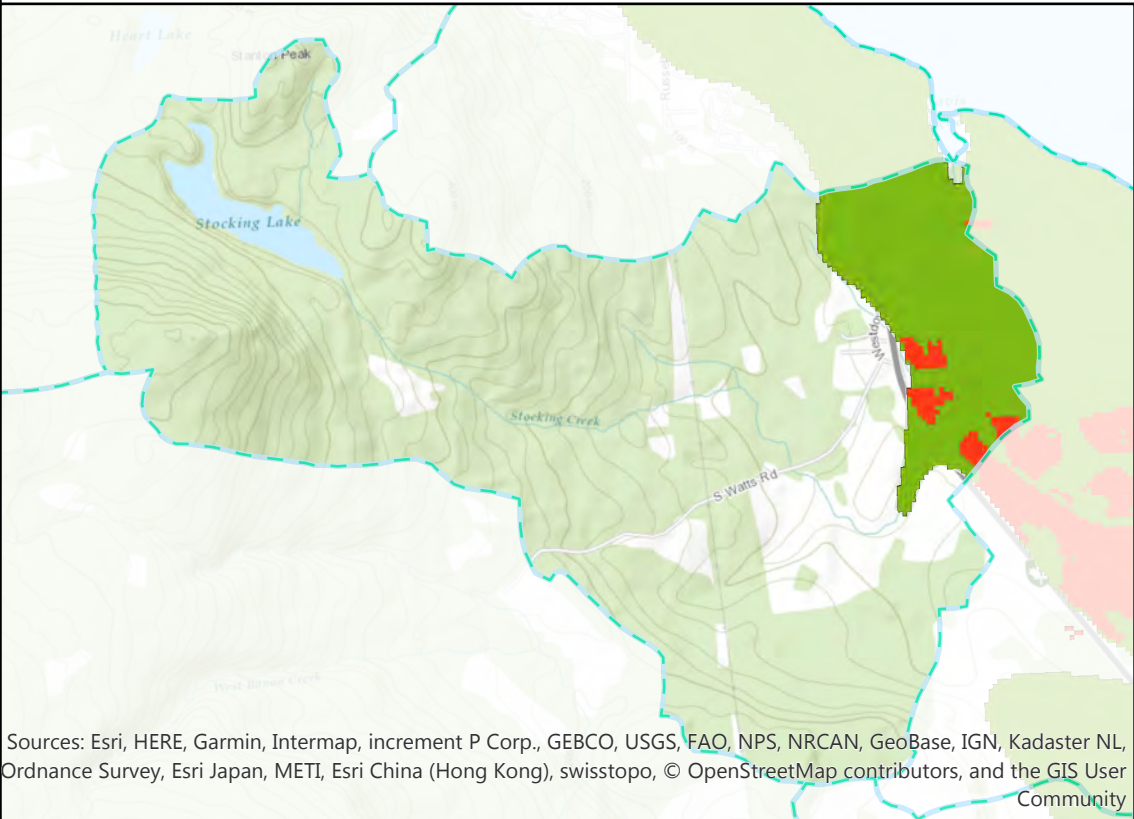


CONSEQUENCE



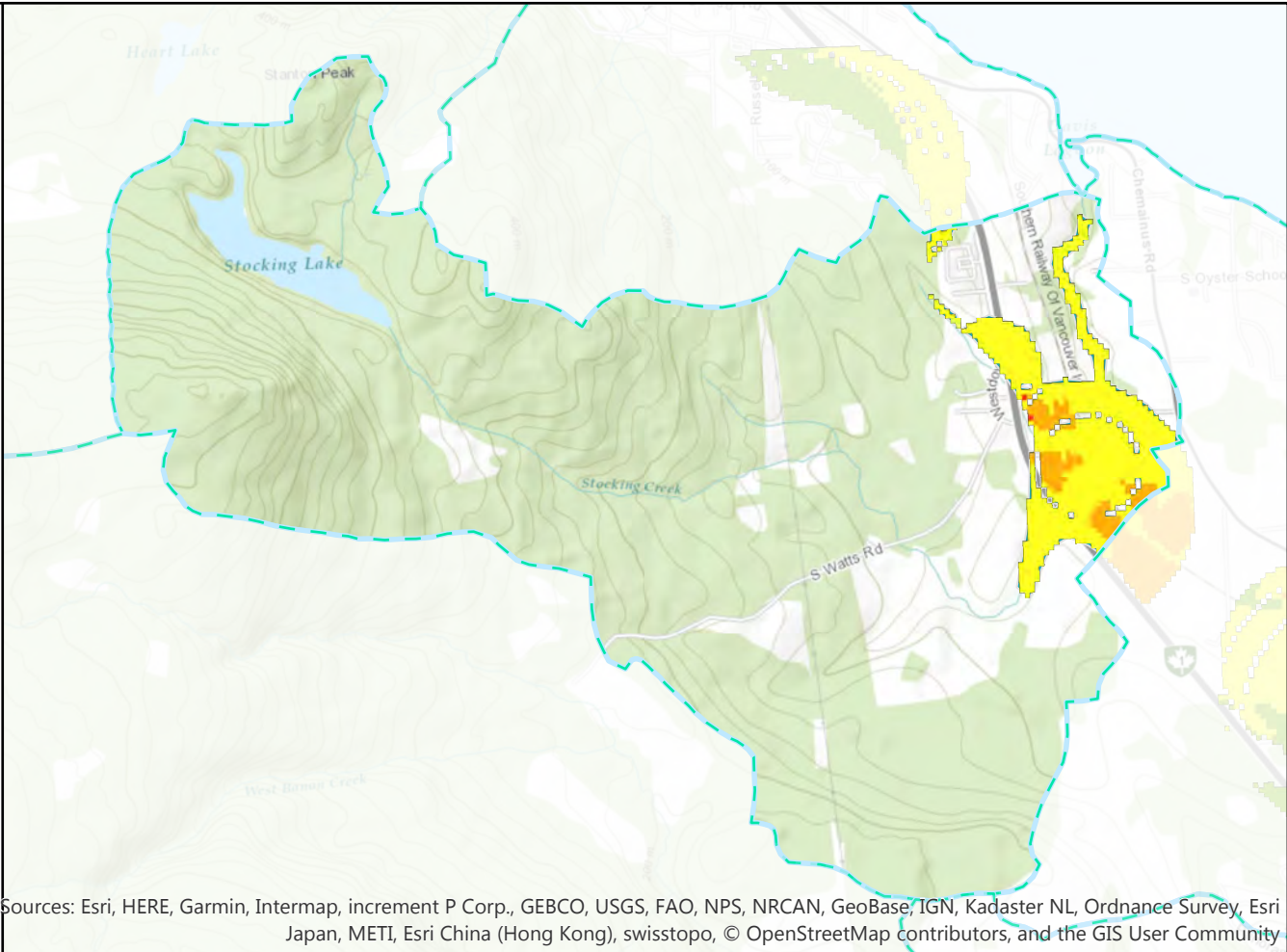
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

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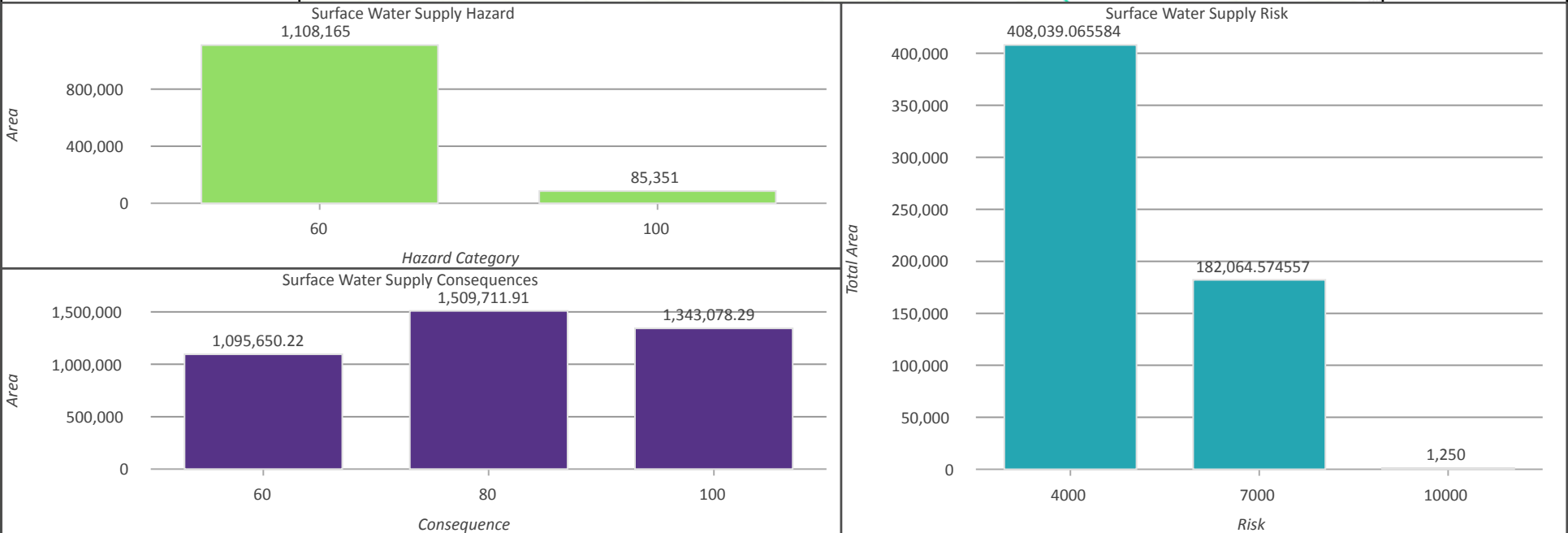


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

	≤ 20
	≤ 40
	≤ 60
	≤ 80
	≤ 100

RISK

	≤ 1000
	≤ 2000
	≤ 4000
	≤ 7000
	≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

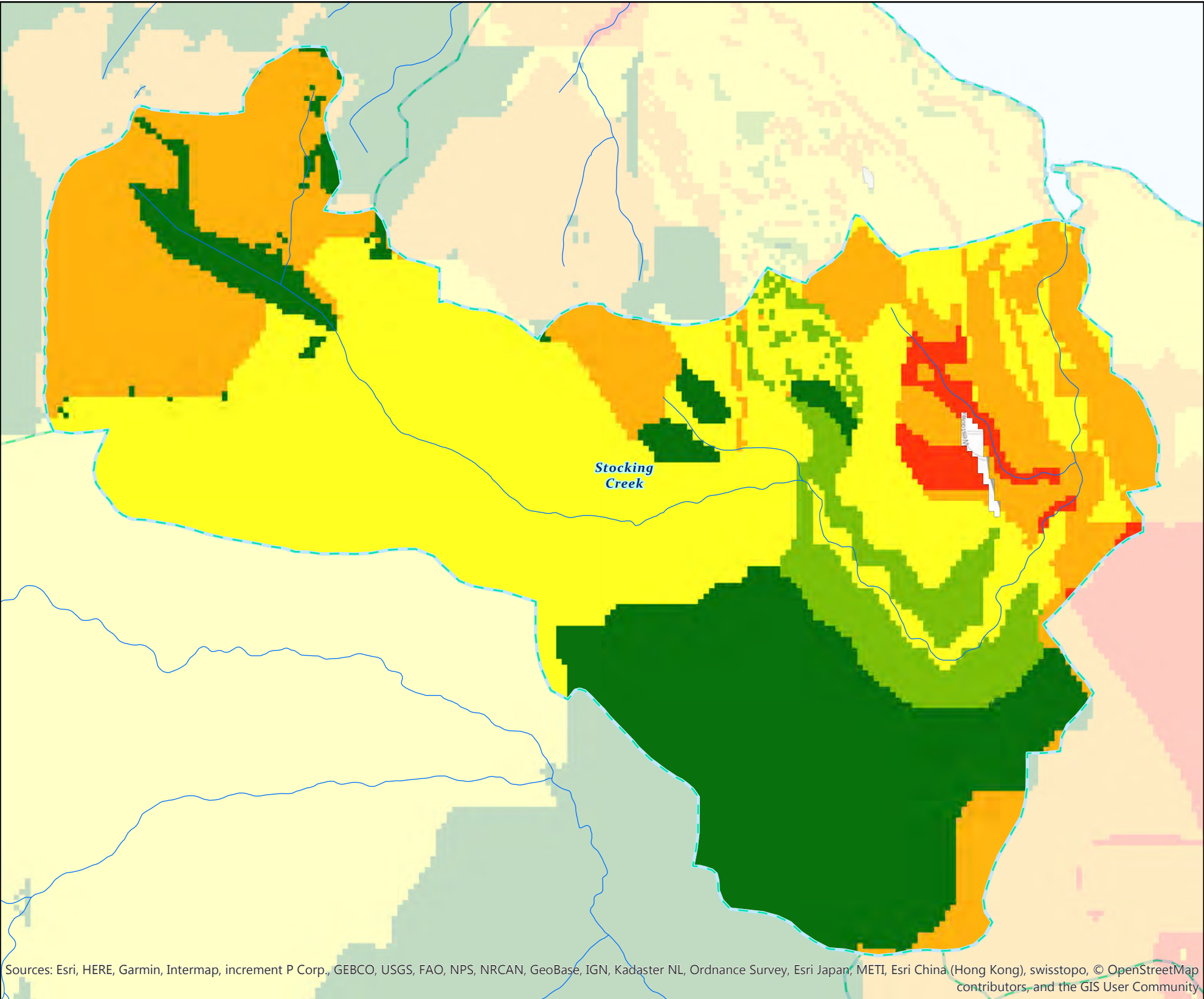
PROJECT LOCATION:
Cowichan Valley Regional District Stocking Creek Watershed

Surface Water Supply Risk Assessment - Stocking Creek

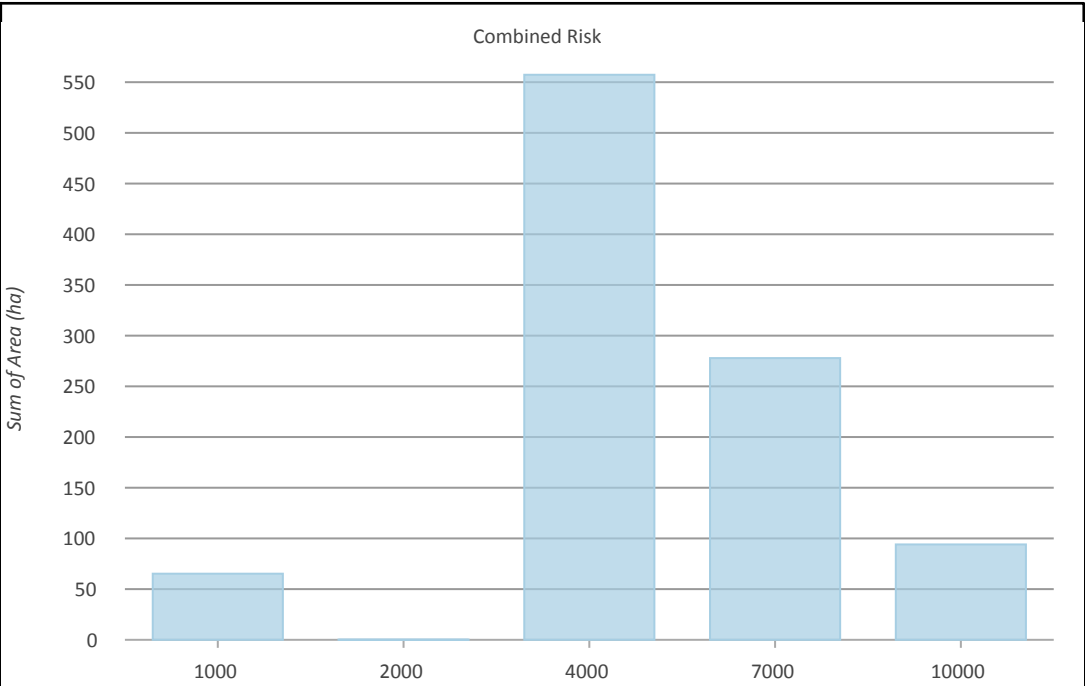
BY: _____ SCALE: 1:34,854 DATE: 2019/01/08 REF No: _____ REV: **0**

CHK'D: _____ Proj Coord Sys: PCS Albers **651957-105-STOCK**

0 375 750 1,500 2,250 3,000 Meters



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



NAME	Risk	POP ₂₀₂₁	POP ₂₀₂₆	POP ₂₀₃₁	POP ₂₀₃₆
SHAWNIGAN CREEK		10047	10760	11613	12598
BUSH CREEK		0	0	0	0
KOKSILAH RIVER		5463	5851	6315	6850
HOLLAND CREEK		1302	1368	1446	1537
BONSALL CREEK		934	974	1019	1073
CHEMAINUS RIVER		1490	1461	1439	1421
COWICHAN RIVER		36368	37905	39683	41766
YELLOW POINT BENCHLANDS		2239	2352	2487	2643
LADYSMITH - SALT AIR BENCHLANDS		8410	8834	9342	9929
STOCKING CREEK		1531	1608	1701	1807
CHEMAINUS BENCHLANDS		3663	3818	3997	4207
SATELLITE CHANNEL BENCHLANDS		4390	4701	5074	5504
SANSUM NARROWS - COWICHAN BAY BENCHLANDS		4941	5150	5391	5674
MALAHAT BENCHLANDS		2829	3030	3271	3548

NAME	POP ₂₀₀₁	POP ₂₀₀₆	POP ₂₀₁₁	POP ₂₀₁₆
SHAWNIGAN CREEK	6348	8439	8925	9484
BUSH CREEK	0			
KOKSILAH RIVER	4555	4808	4954	5157
HOLLAND CREEK	1611	1114	1169	1245
BONSALL CREEK	672	830	815	890
CHEMAINUS RIVER	1423	1395	1497	1514
COWICHAN RIVER	29779	32673	34075	34647
YELLOW POINT BENCHLANDS	1167	1958	2021	2141
LADYSMITH - SALT AIR BENCHLANDS	5275	7488	7541	8042
STOCKING CREEK	1332	1003	1354	1464
CHEMAINUS BENCHLANDS	3177	3129	3085	3490
SATELLITE CHANNEL BENCHLANDS	5425	3902	3989	4144
SANSUM NARROWS - COWICHAN BAY BENCHLANDS	5993	4221	4500	4707
MALAHAT BENCHLANDS	1673	2472	2548	2671

Legend

WATERSHED BOUNDARIES

RISK

- ≤ 1000
- ≤ 2000
- ≤ 4000
- ≤ 7000
- ≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-30 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Stocking Creek Watershed

Combined Risk Assessment - Stocking Creek

BY: CJW

CHK'D: DK

SCALE CONS: 1:21,000

Proj Coord Sys: NAD 1983 UTM Zone 10N

DATE: 2019/01/08

REF No:

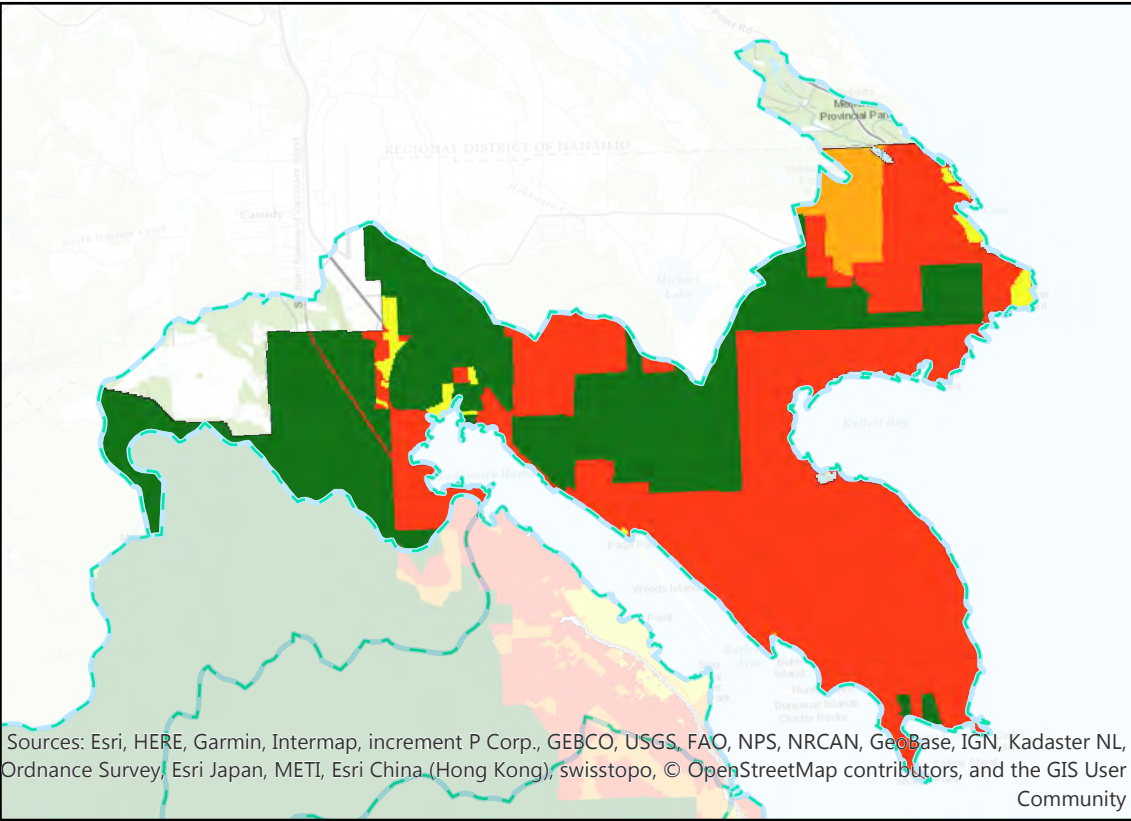
REV: 0

651957-106-STOCK

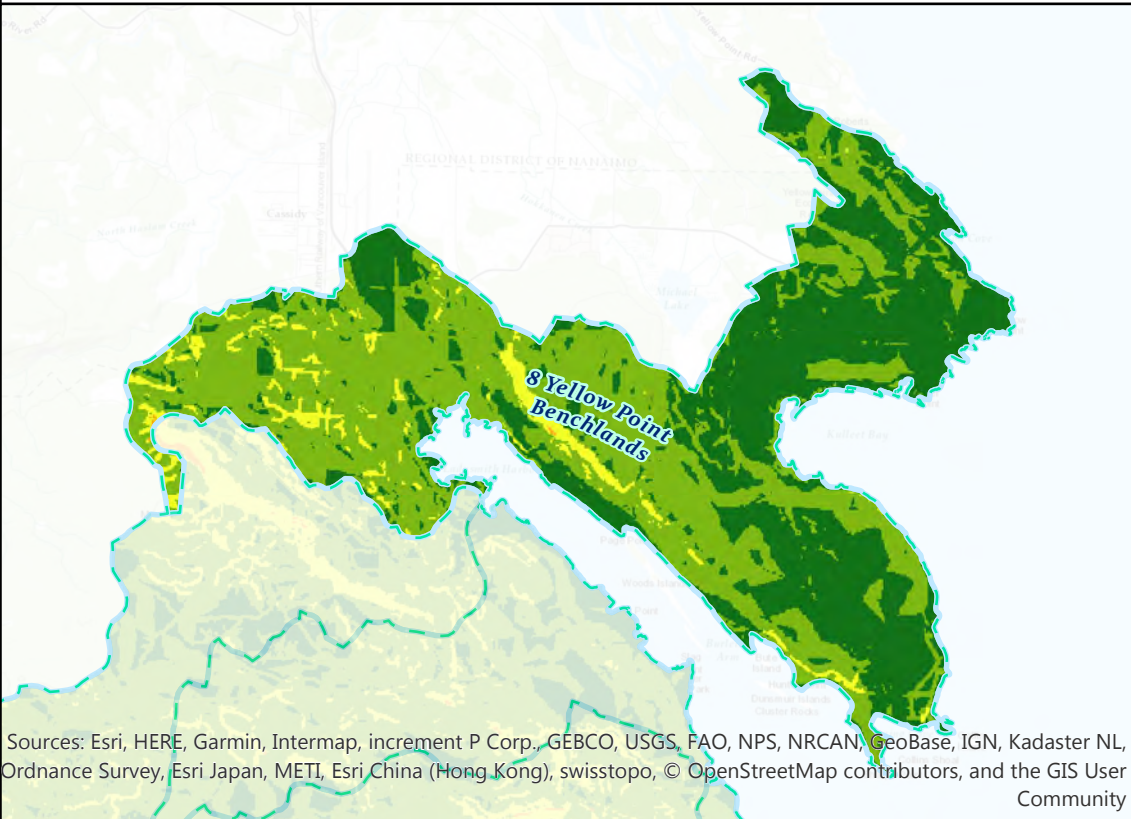
Project Path: P:\Current Projects\CVRD\651957\ P: 13 - 6

14. Yellow Point Benchlands	
Topic	Discussion
Slope Failure	<p>Hazard was determined qualitatively at a high level to describe areas based on the degree to which they may be prone to landslides and other mass movements using terrain characteristics. Hazard classifications were generated to show relative comparisons between terrain units within the CVRD watershed study area. Risk ratings derived from this analysis are relative, and should be used to guide prioritization of further detailed studies.</p> <p>Hazard is generally low throughout the watershed. Hazard is greatest on the isolated and relatively steep slopes near the Woodley Range Ecological Reserve. Consequence is considered moderate to high through the populated areas which cover much of the watershed area. Risk is considered moderate in these populated areas and is highest where slopes encroach on populated areas downslope from the Woodley Range Ecological Reserve.</p>
Flooding	Consequence and risk are relatively low. Consequence is greatest along Highway 1. For the most part, the greatest risk is focused at the downstream end of rivers near their outlets to the bays.
Groundwater Contamination	Likelihood is greatest, for the most part, in the north-western region of the watershed where the airport and Highway 1 are located. A series of municipal water supply wells enhance consequence in isolated zones throughout the watershed. As such, areas of highest risk are situated in pockets where higher likelihood levels overlap areas surrounding municipal water supply wells, and are situated near the most inland areas of the Ladysmith inlet.
Surface Water Quality	Hazard is greatest in areas that have seen development such as the agricultural and industrial area along Highway 1. Consequence is considered relatively high throughout much of the watershed due to the presence of lower order streams that are more susceptible to water quality issues than larger (higher order) streams. Risk is greatest in areas that have seen logging, mining, agriculture, and industrial development. The area of higher risk is expected to increase as populations are projected to continually grow.
Surface Water Supply	Hazard is greatest in zones south of Cassidy and east of Michael Lake, in agricultural zones. Consequence is considered low for the majority of the watershed and is greatest in a zone north of Ladysmith, along the stream draining into the north end of Ladysmith Harbour, south of Micheal Lake, and in isolated locations south of Priest Lake. Risk is greatest around the north end of Ladysmith Harbor and in the drainage through the agricultural zone west of Kulleet Bay, occupying a very small proportion of the watershed. Projected population increase for the watershed is expected to add pressures on groundwater sources that may increase the level of hazard and risk.
General Data Notes	As the most northern of the watersheds Yellow point is projected to grow in population by approximately 24% in the next 20 years.

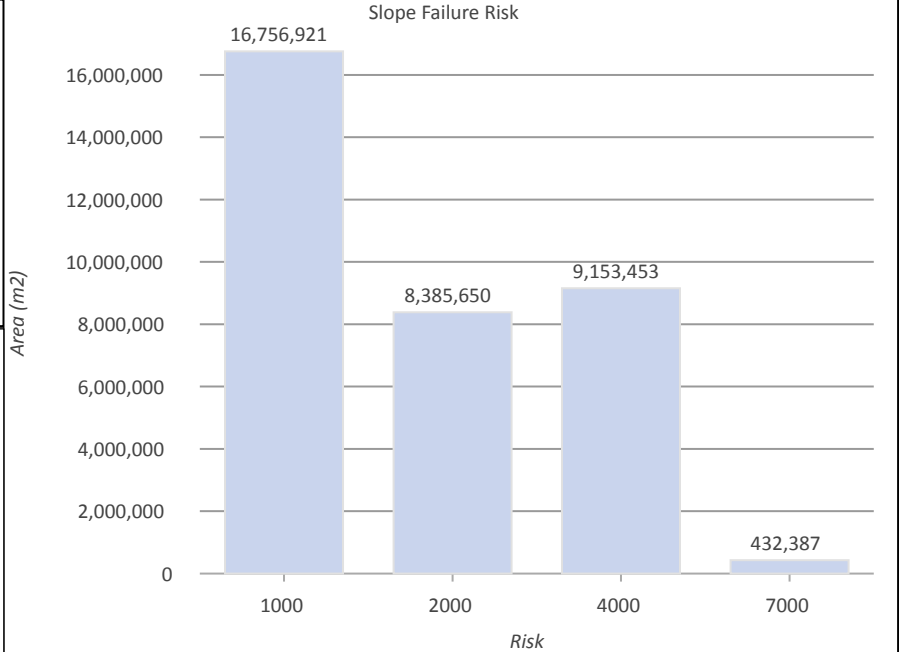
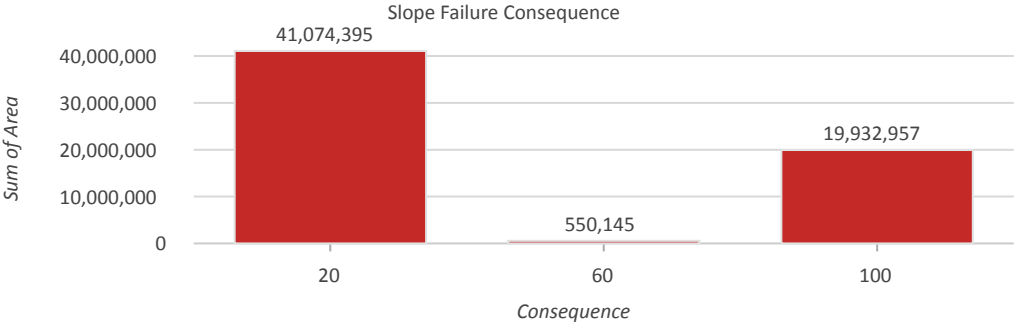
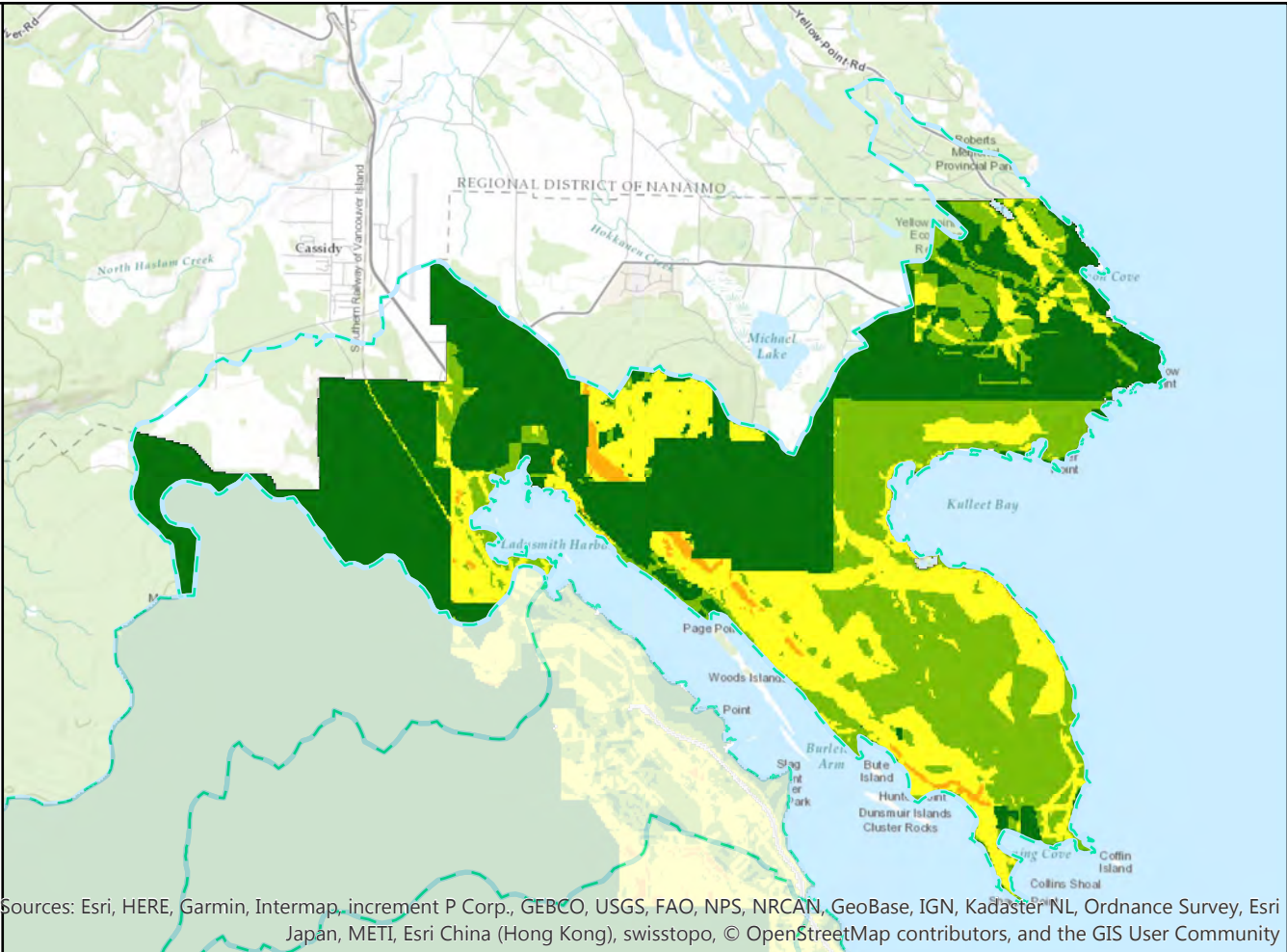
CONSEQUENCE



HAZARD



RISK



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Yellow Point Benchlands Watershed



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Slope Failure Risk Assessment - Yellow Point

BY:

CJW

SCALE CONS: 1:87,531

DATE: 2019/01/07

REF No:

REV: 0

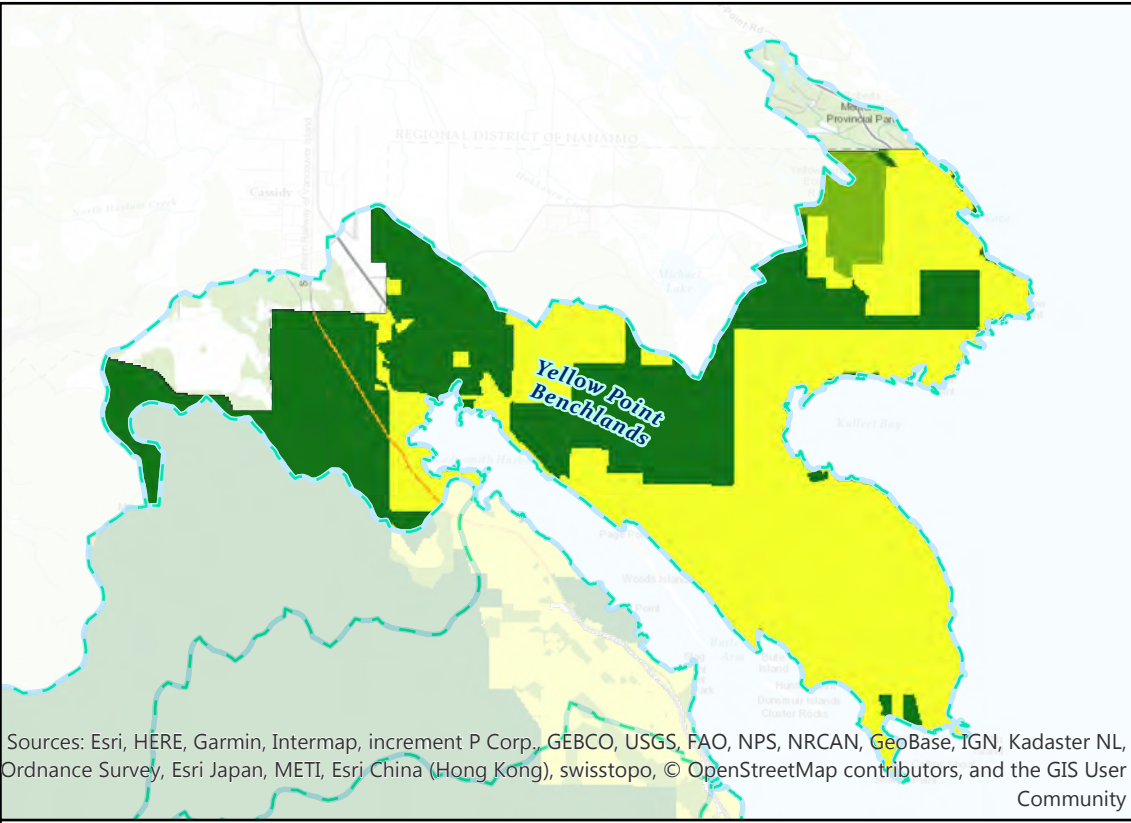
CHK'D: DK

Proj Coord Sys: PCS Albers

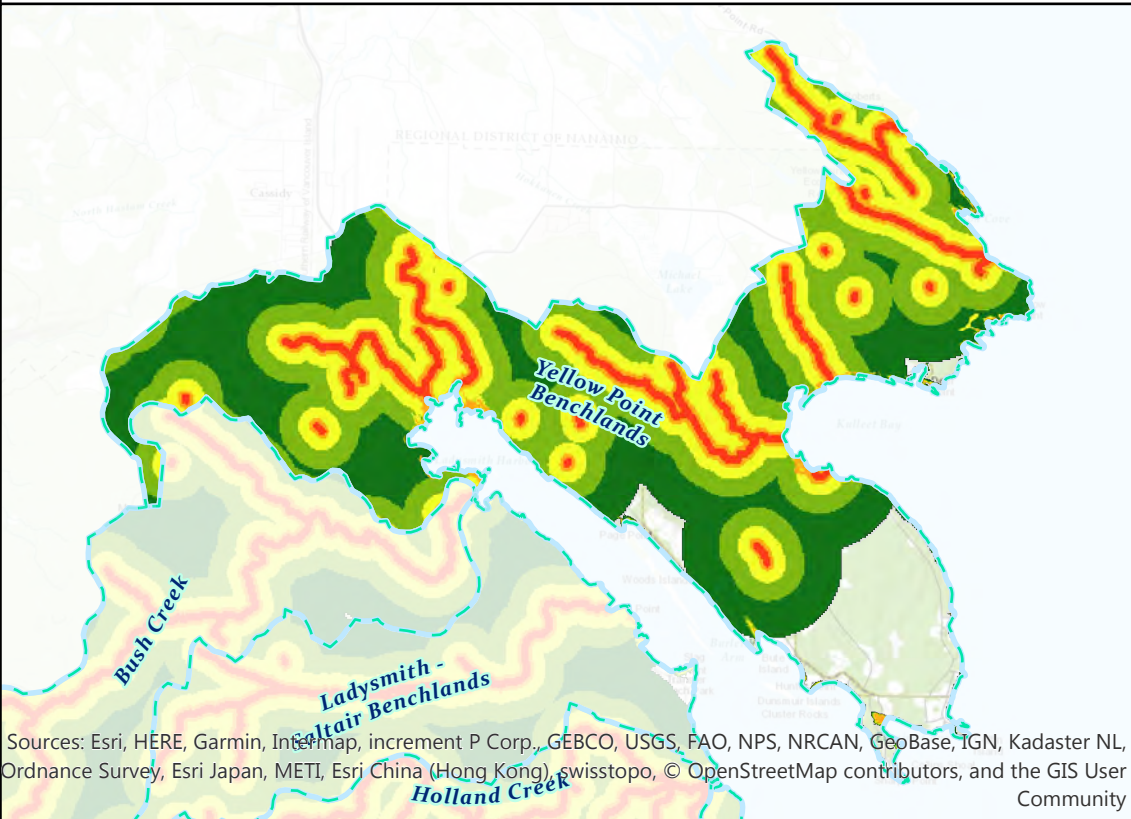
651957-101-YELL



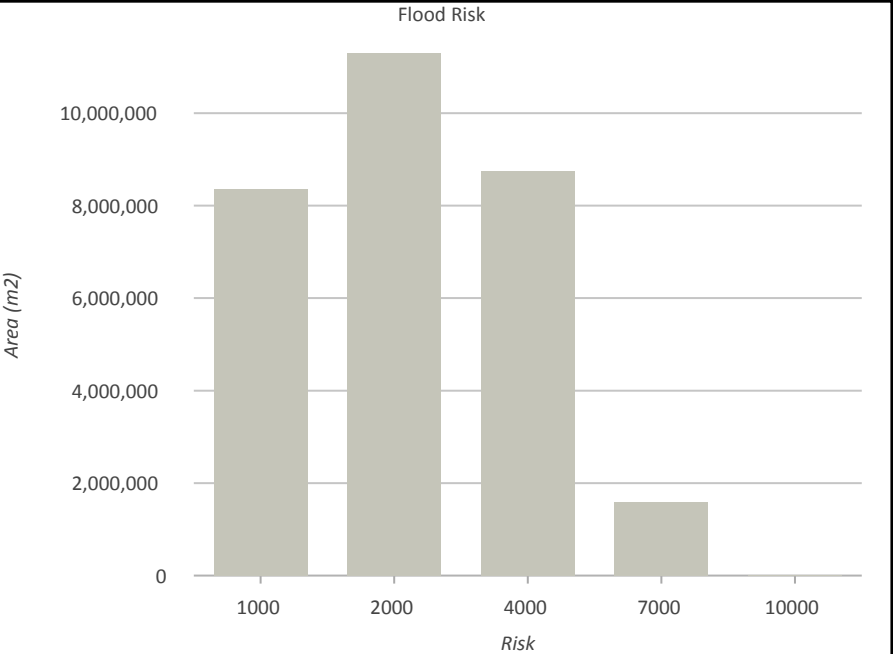
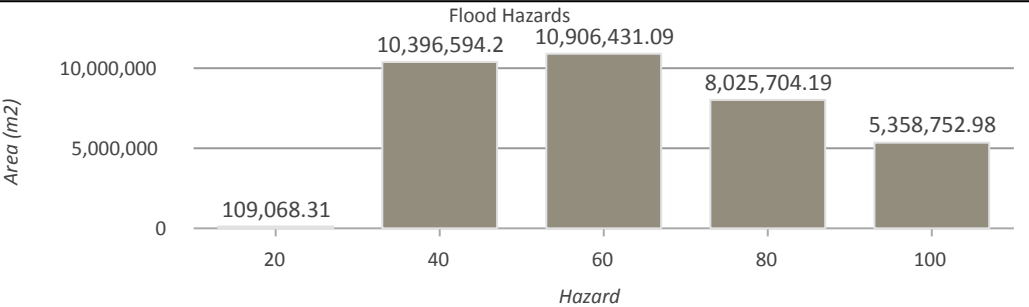
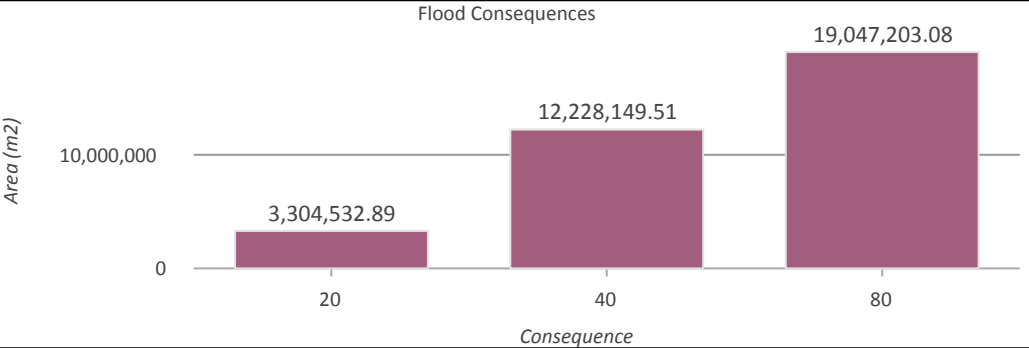
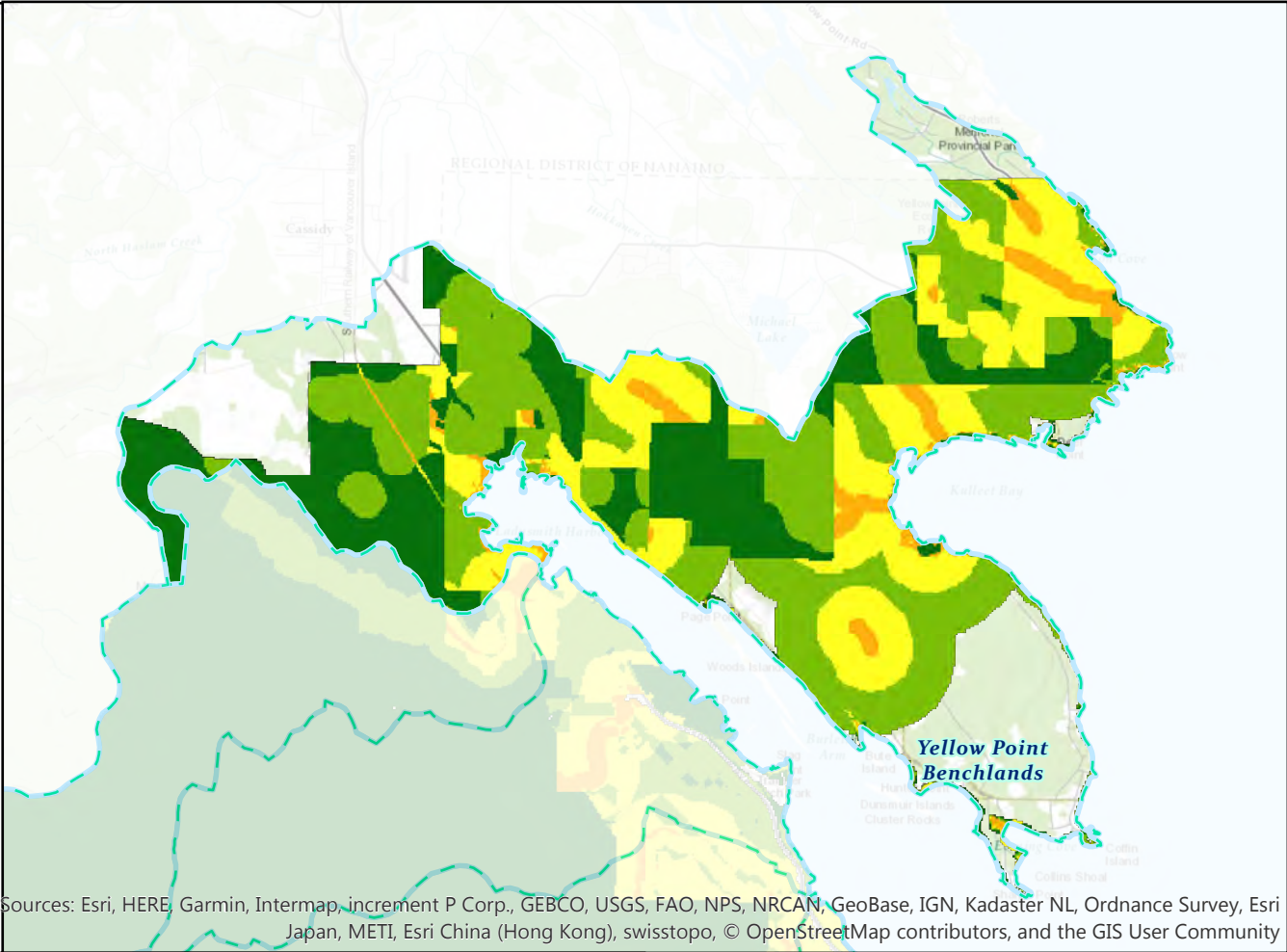
CONSEQUENCE



HAZARD



RISK



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

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≤ 10000

REFERENCES:

1. Risk data compiled from various data sources provided by the Cowichan Valley Regional District. Presentation of data is intended to provide a general guidance on potential issues, rather than a definitive study.

NOTES:

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3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.

REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Yellow Point Benchlands Watershed



Flood Risk Assessment - Yellow Point Benchlands

BY: CJW

SCALE CONS: 1:85,860

DATE: 2019/01/08

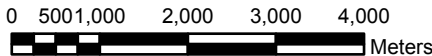
REF No:

REV: 0

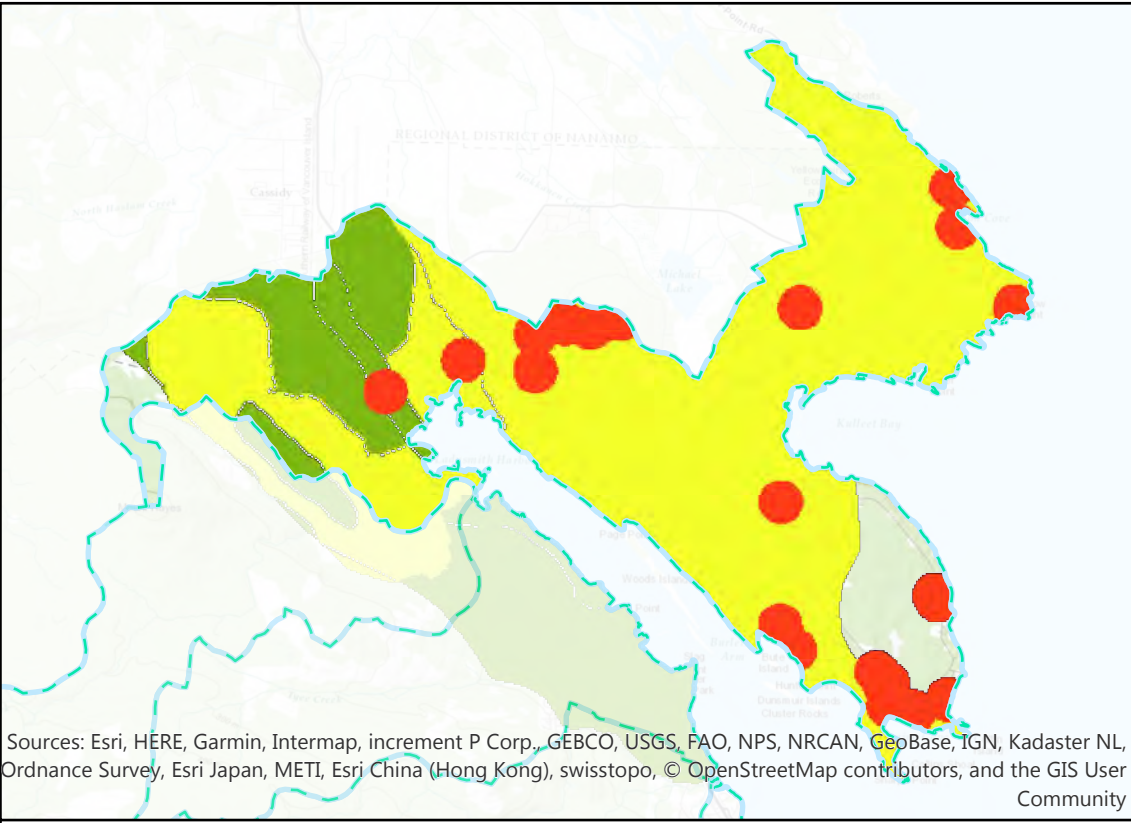
CHK'D: DK

Proj Coord Sys: NAD 1983 UTM Zone 10N

651957-102-YELL

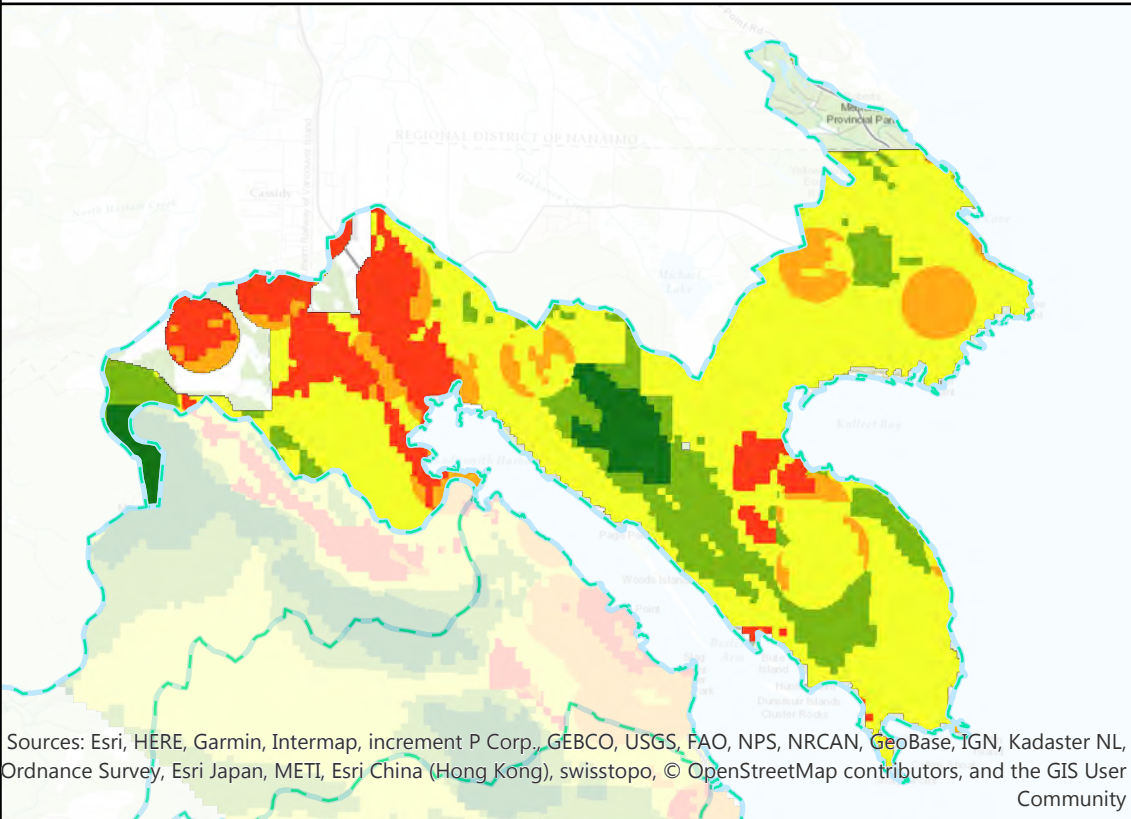


CONSEQUENCE



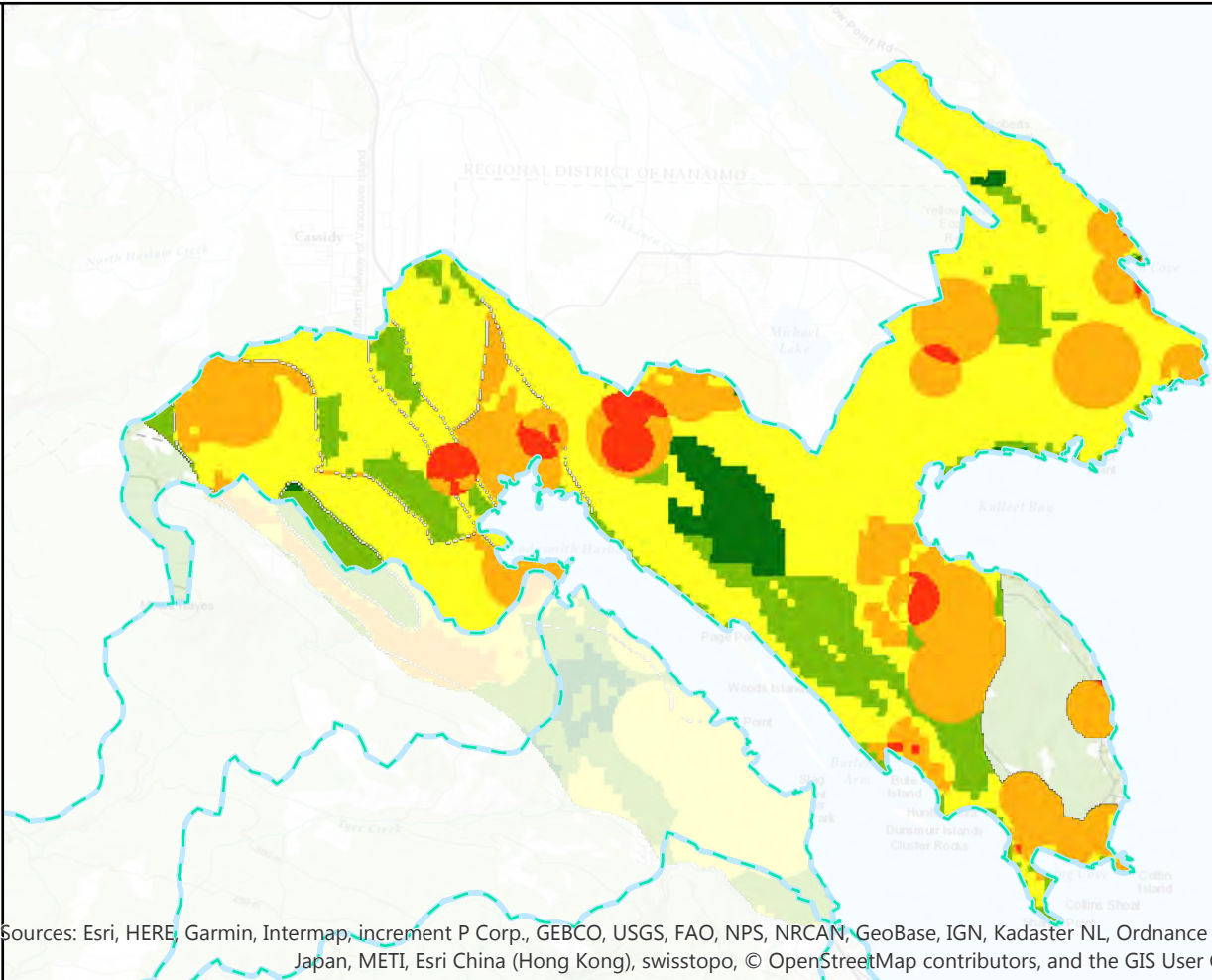
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

HAZARD

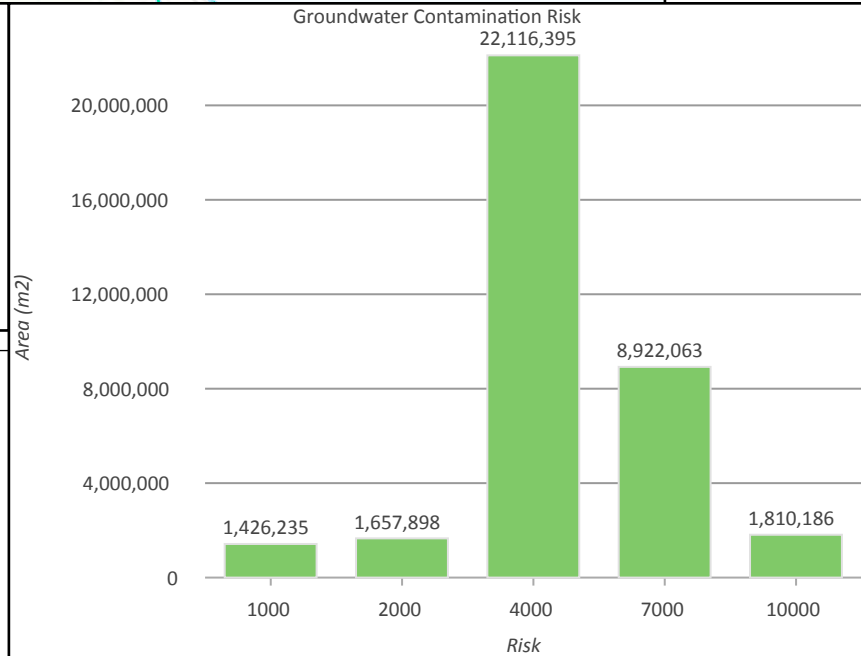
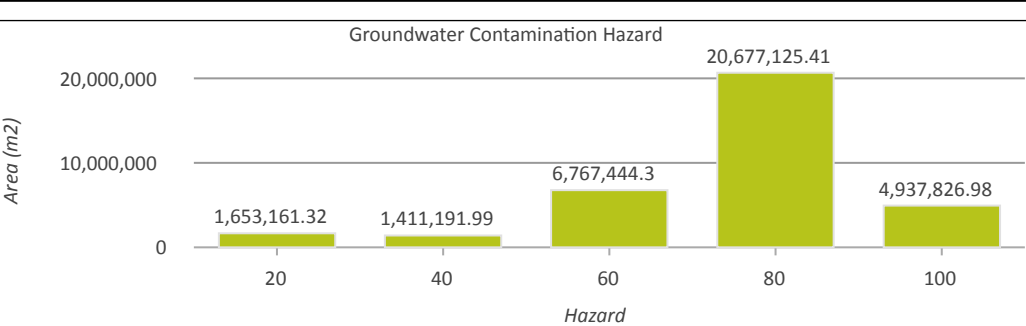
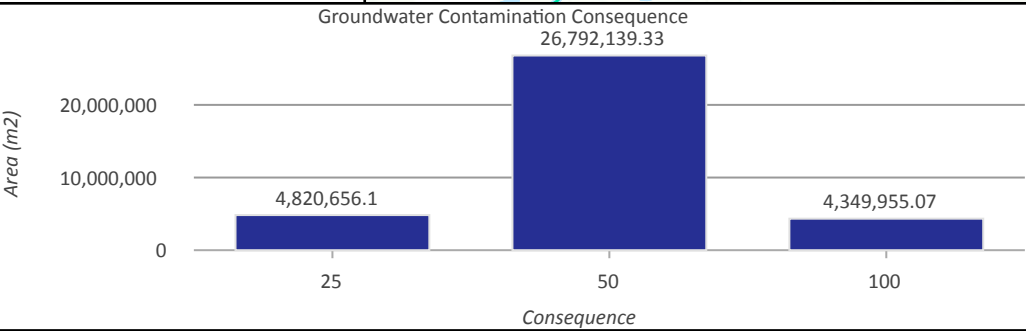


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

RISK



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Yellow Point Benchlands Watershed



Groundwater Contamination Risk Assessment - Yellow Point

BY: CJW

SCALE CONS: 1:85,860

DATE: 2019/01/08

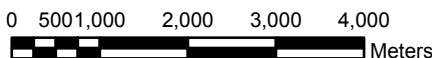
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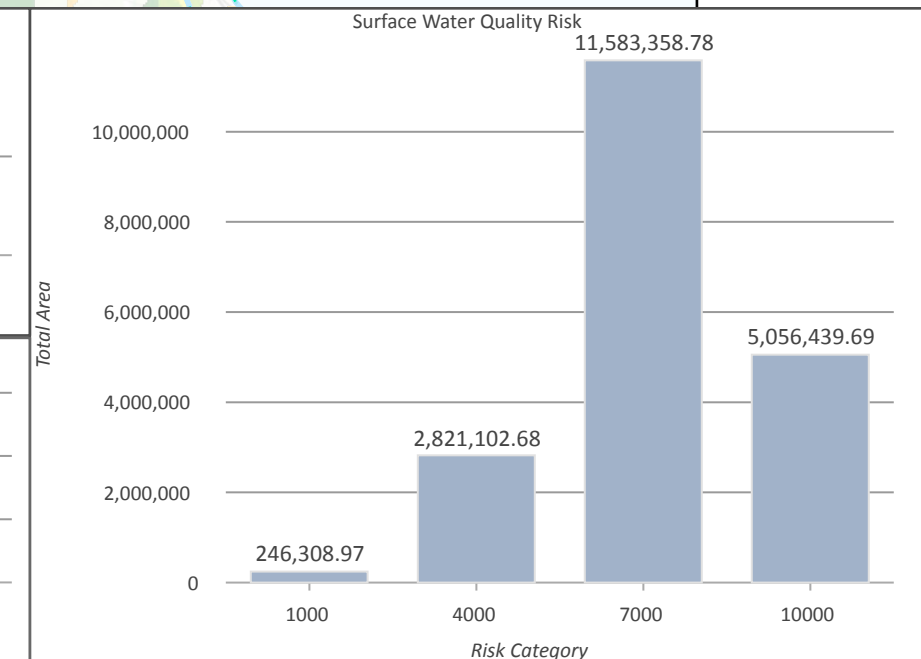
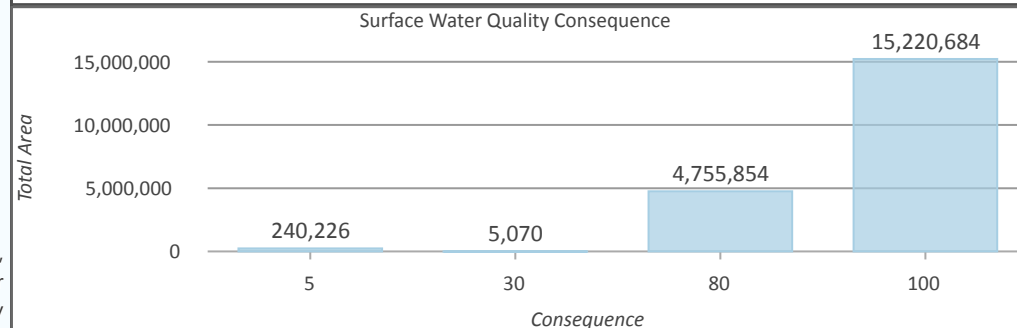
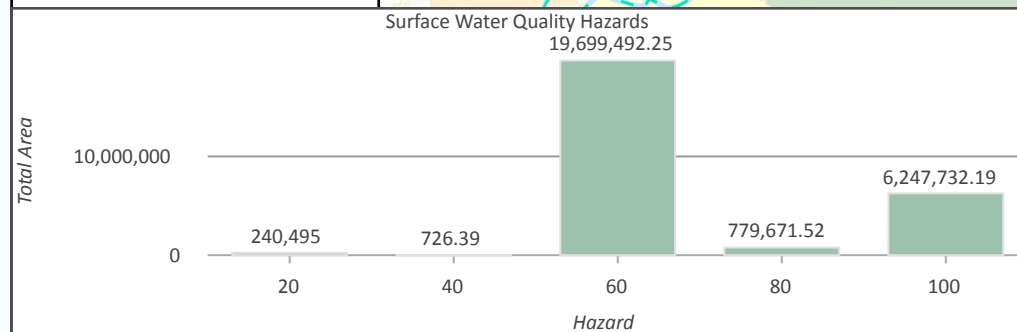
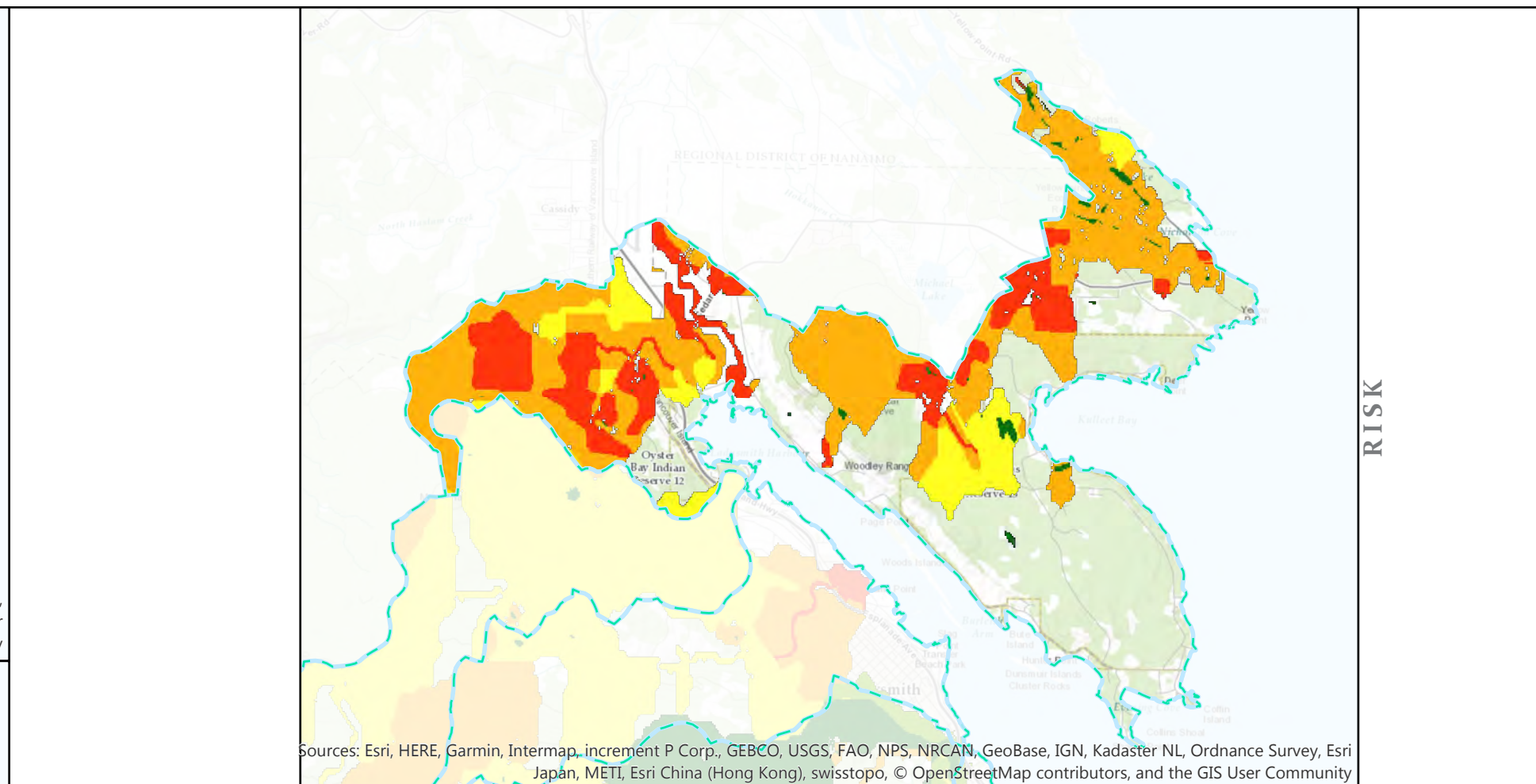
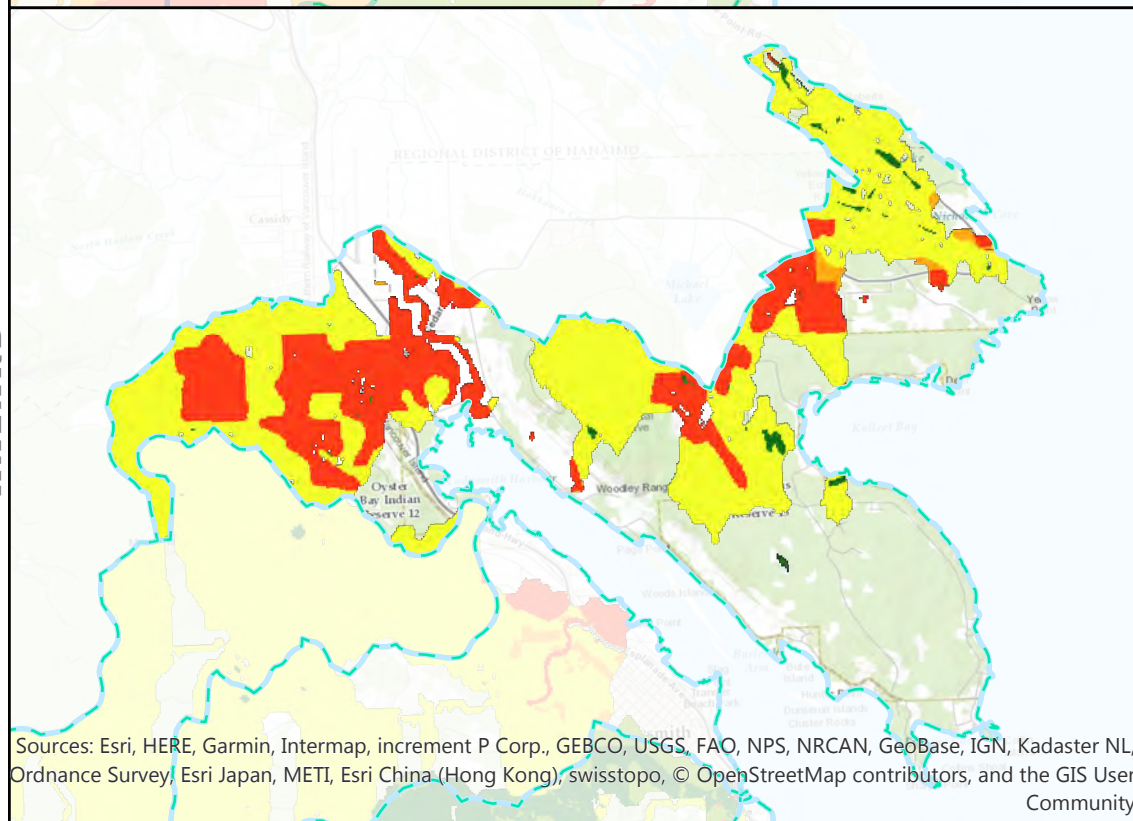
CHK'D: DK

Proj Coord Sys: NAD 1983 UTM Zone 10N

651957-103-YELL



HAZARD



- ≤ 1000
- ≤ 2000
- ≤ 4000
- ≤ 7000
- ≤ 10000

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0 - CJW - 2018-11-29 - Issued - DK

CLIENT:
Cowichan Valley Regional District



PROJECT LOCATION:
Cowichan Valley Regional District Yellow Point
Benchlands Watershed

Surface Water Quality Risk Assessment - Yellow Point

BY:	
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SCALE: 1:87,438

DATE: 2019/01/08

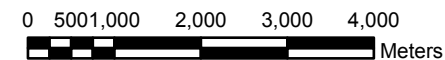
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REV: 0

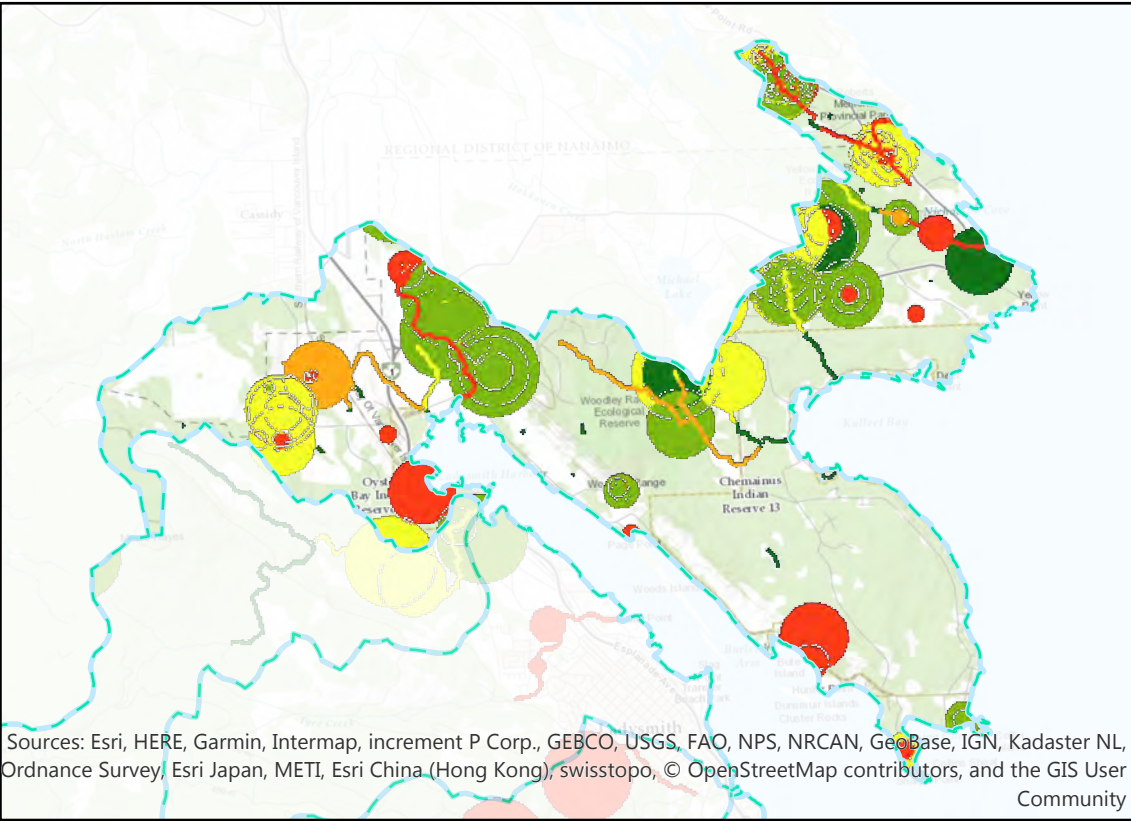
CHK'D

CHK'D:	Proj Coord Sys: PCS Albers
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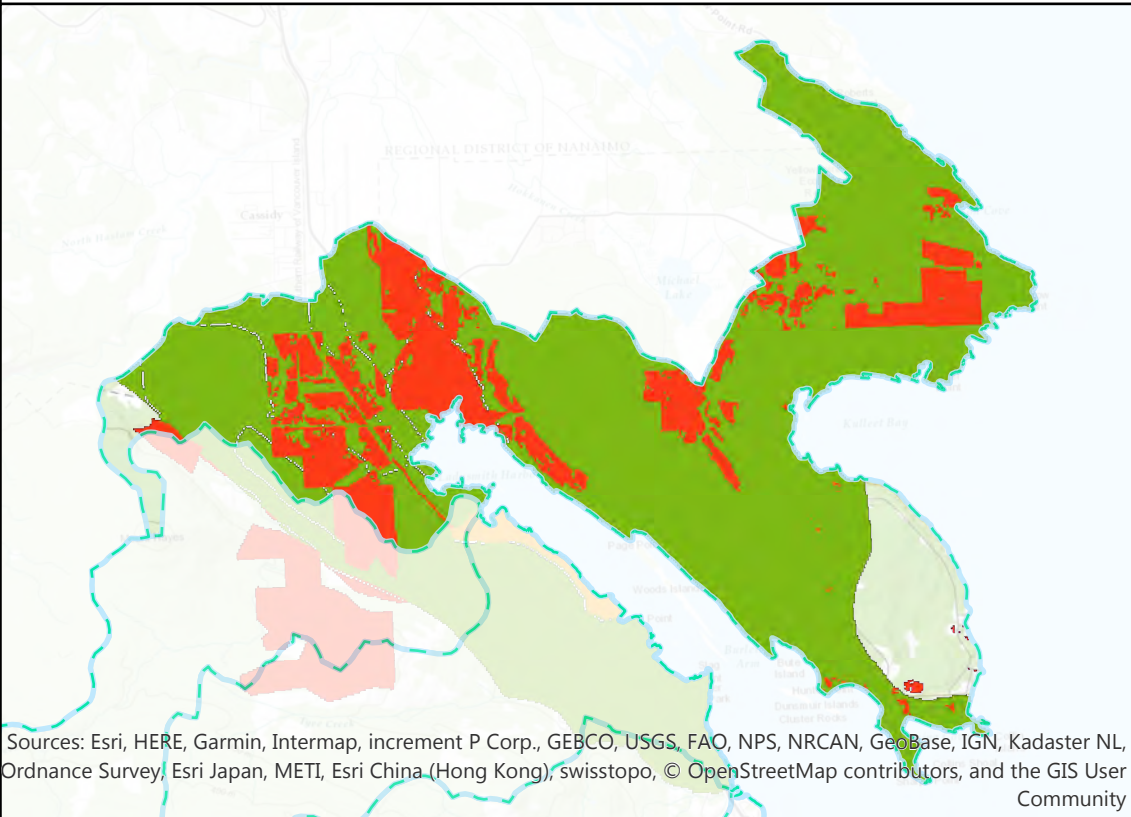
651957-104-YELL



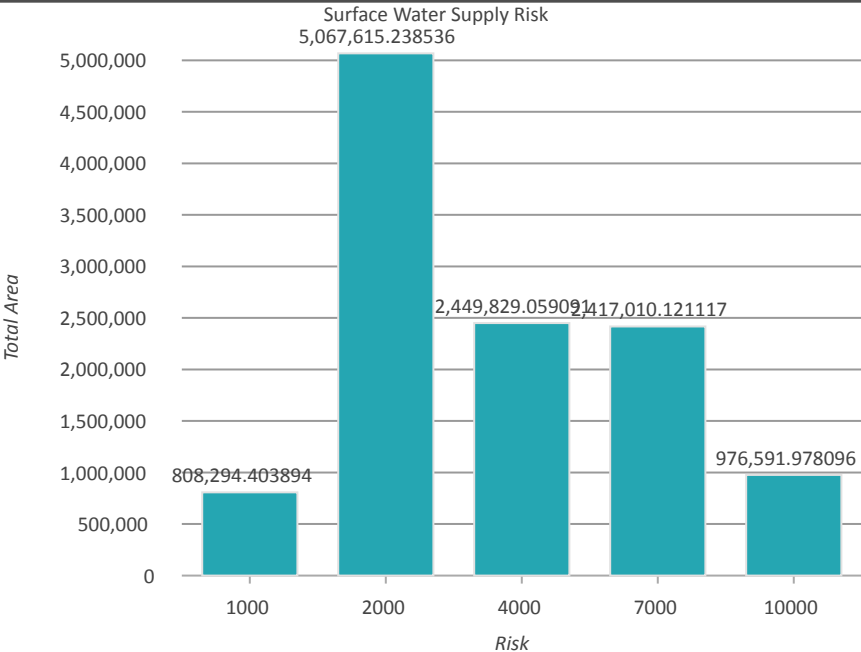
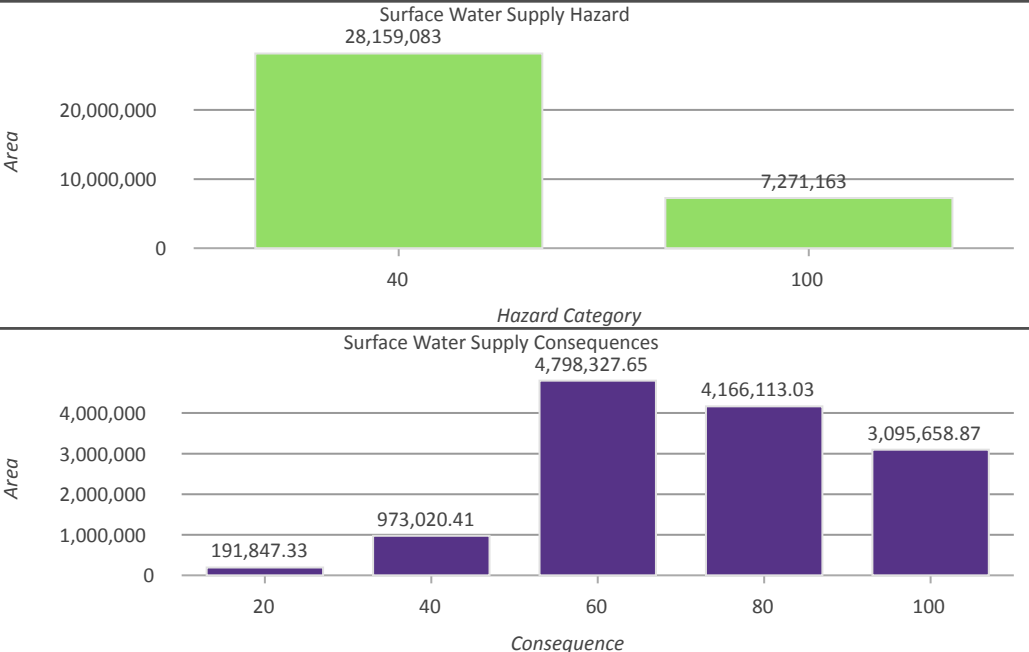
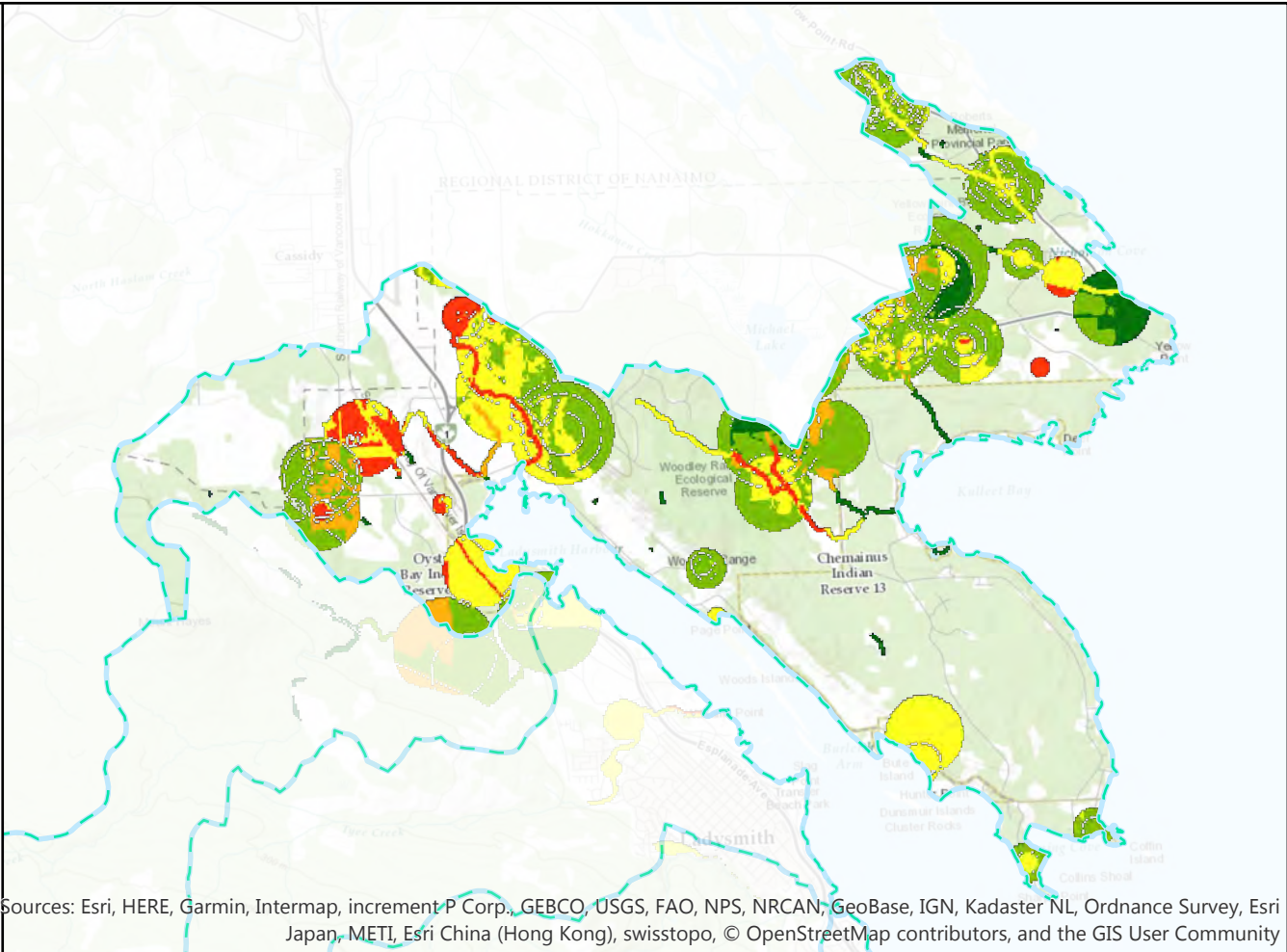
CONSEQUENCE



HAZARD



RISK



Legend

WATERSHED BOUNDARIES

CONSEQUENCES OR HAZARDS

≤ 20
≤ 40
≤ 60
≤ 80
≤ 100

RISK

≤ 1000
≤ 2000
≤ 4000
≤ 7000
≤ 10000

REFERENCES:

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REVISIONS:

0 - CJW - 2018-11-29 - Issued - DK

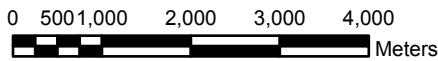
CLIENT:
Cowichan Valley Regional District

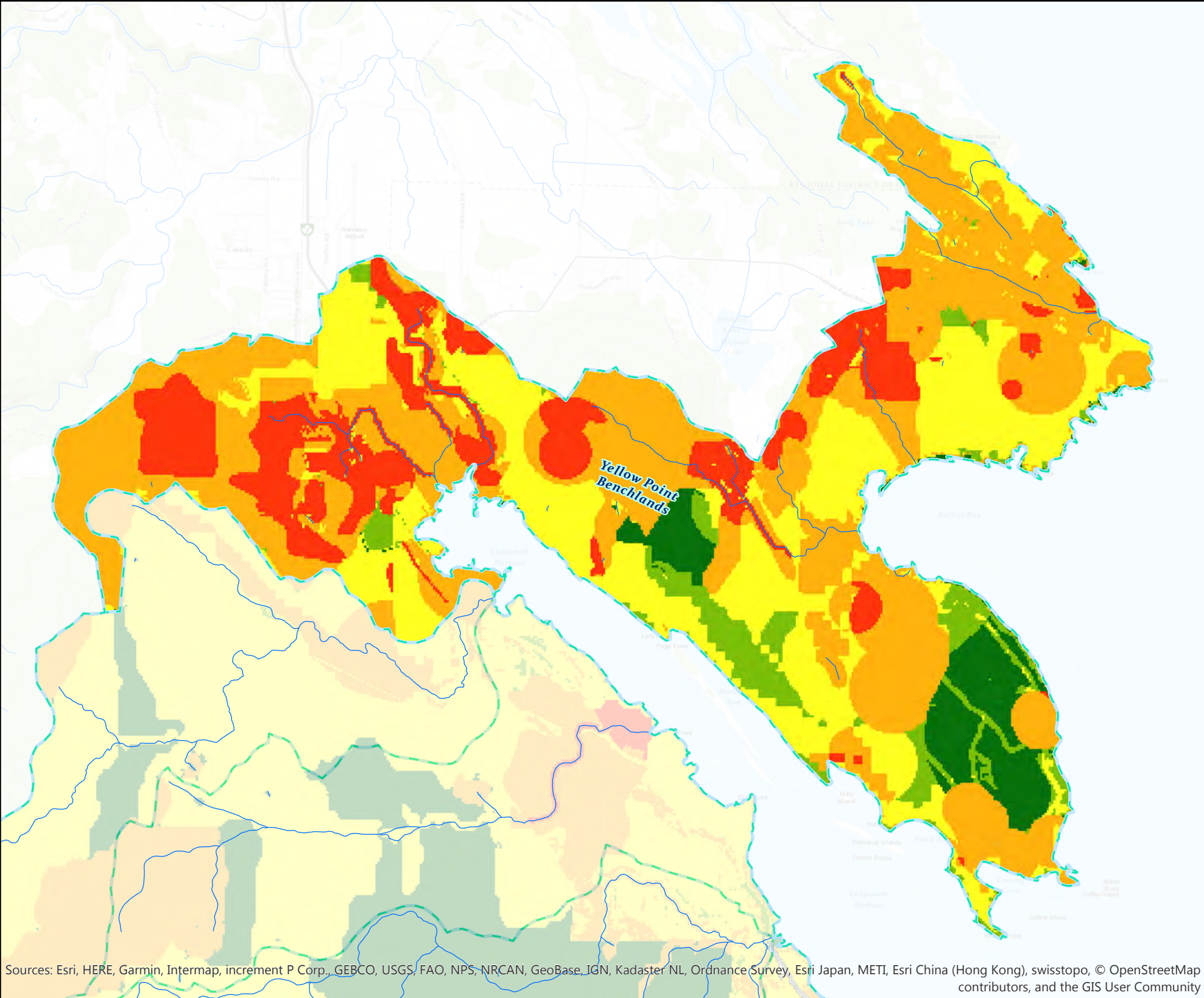
PROJECT LOCATION:
Cowichan Valley Regional District
Yellow Point
Benchlands Watershed



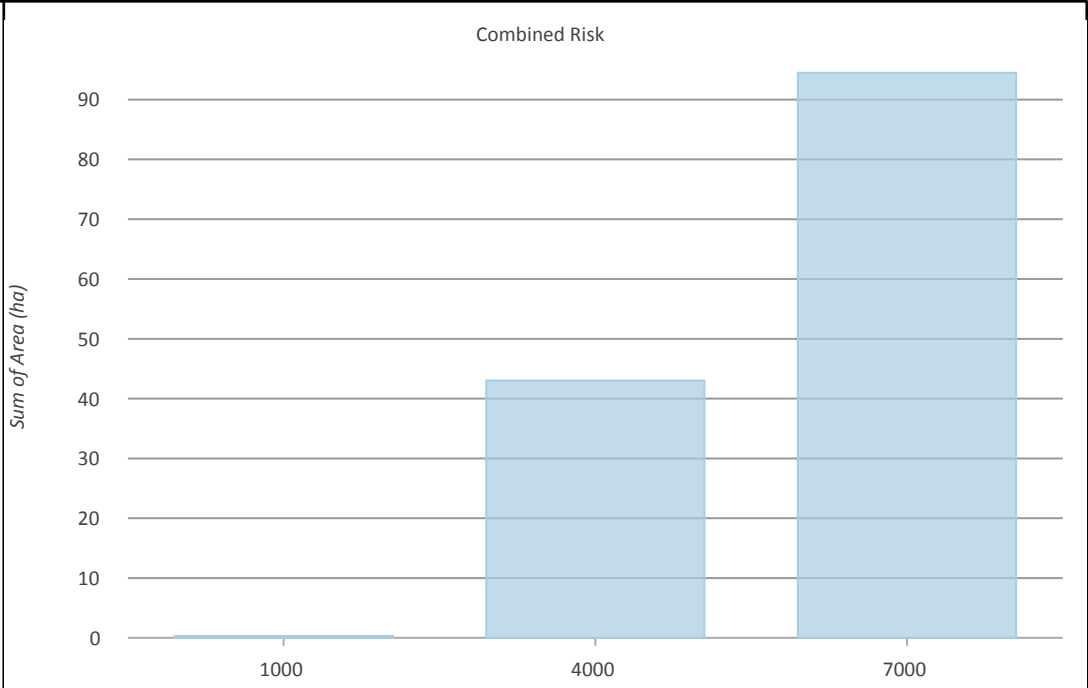
Surface Water Supply Risk Assessment - Yellow Point

BY: SCALE: 1:85,010 DATE: 2019/01/08 REF No: REV: 0
CHK'D: Proj Coord Sys: PCS Albers 651957-105-YELL





Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



NAME	Risk	POP ₂₀₂₁	POP ₂₀₂₆	POP ₂₀₃₁	POP ₂₀₃₆
SHAWNIGAN CREEK		10047	10760	11613	12598
BUSH CREEK		0	0	0	0
KOKSILAH RIVER		5463	5851	6315	6850
HOLLAND CREEK		1302	1368	1446	1537
BONSALL CREEK		934	974	1019	1073
CHEMAINUS RIVER		1490	1461	1439	1421
COWICHAN RIVER		36368	37905	39683	41766
YELLOW POINT BENCHLANDS		2239	2352	2487	2643
LADYSMITH - SALT AIR BENCHLANDS		8410	8834	9342	9929
STOCKING CREEK		1531	1608	1701	1807
CHEMAINUS BENCHLANDS		3663	3818	3997	4207
SATELLITE CHANNEL BENCHLANDS		4390	4701	5074	5504
SANSUM NARROWS - COWICHAN BAY BENCHLANDS		4941	5150	5391	5674
MALAHAT BENCHLANDS		2829	3030	3271	3548

NAME	POP ₂₀₀₁	POP ₂₀₀₆	POP ₂₀₁₁	POP ₂₀₁₆
SHAWNIGAN CREEK	6348	8439	8925	9484
BUSH CREEK	0			
KOKSILAH RIVER	4555	4808	4954	5157
HOLLAND CREEK	1611	1114	1169	1245
BONSALL CREEK	672	830	815	890
CHEMAINUS RIVER	1423	1395	1497	1514
COWICHAN RIVER	29779	32673	34075	34647
YELLOW POINT BENCHLANDS	1167	1958	2021	2141
LADYSMITH - SALT AIR BENCHLANDS	5275	7488	7541	8042
STOCKING CREEK	1332	1003	1354	1464
CHEMAINUS BENCHLANDS	3177	3129	3085	3490
SATELLITE CHANNEL BENCHLANDS	5425	3902	3989	4144
SANSUM NARROWS - COWICHAN BAY BENCHLANDS	5993	4221	4500	4707
MALAHAT BENCHLANDS	1673	2472	2548	2671

Legend

WATERSHED BOUNDARIES

RISK

- ≤ 1000
- ≤ 2000
- ≤ 4000
- ≤ 7000
- ≤ 10000

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REVISIONS:

0 - CJW - 2018-11-30 - Issued - DK

CLIENT:
Cowichan Valley Regional District

PROJECT LOCATION:
Cowichan Valley Regional District
Yellow Point Benchlands Watershed

Combined Risk Assessment - Yellow Point Benchlands

BY: CJW

CHK'D: DK

SCALE CONS: 1:52,000

Proj Coord Sys: NAD 1983 UTM Zone 10N

DATE: 2019/01/08

REF No: 651957-106-YELL

REV: 0