TSOLUM RIVER AGRICULTURAL WATERSHED PLAN
Phase Two

MAY 2021

Prepared by:
Elucidate Consulting

Comox Valley
REGIONAL DISTRICT

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A Vision for Collaborative Watershed Management

The Tsolum River watershed lies within the unceded traditional territories of the K'ómoks First Nation (KFN). The KFN have hunted, fished, cultivated crops, and practiced cultural traditions in the watershed since time immemorial. The CVRD acknowledges that it is on the traditional unceded territory of the KFN and is committed to building a relationship with KFN and advancing reconciliation.

The CVRD is committed to aligning its governance, management, and policy development with the BC Declaration of the Rights of Indigenous Peoples (DRIPA). In January of 2021, the CVRD adopted a statement of reconciliation with Indigenous Peoples which focuses on four main themes: self-determination, shared prosperity, protecting cultural heritage and relationship with land and water. The United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) recognizes the right of Indigenous people to connect with, and protect, land and waters in their traditional territories and participate in decision-making that effects their rights.

There is nothing more sacred to the K'ómoks people than water. Access to water is critical for the exercise of traditional rights and necessary for the physical, cultural, and spiritual survival of the K'ómoks Nation. The CVRD recognizes the KFN as an important partner in water management with unique legal status in relation to lands and waters in the Tsolum watershed. The KFN is not a watershed 'stakeholder', but rather one of three levels of government, with rights related to land and water protected through the Canadian Constitution. The Constitution Act, 1982, which sets the rights and freedoms of Canadians, similarly protects the rights of Indigenous peoples. Indigenous rights include the right to fish, hunt, develop economically, and practice one's own culture. KFN espouses the four pillars: authority, jurisdiction, governance, and management over natural resources within the territory.

As part of this project, the CVRD and KFN have opened a dialogue regarding watershed stewardship in the Tsolum River watershed. The KFN has a strong interest in protecting water in their traditional territories and have completed several projects to better understand the watershed and protect watershed health. The KFN has generously shared the results of some of their work to support the technical assessments in this project.

Both the CVRD and the KFN are eager to work together on future watershed stewardship efforts and recognize that supporting watershed health can be best achieved through a respectful, collaborative relationship. While the Province of BC and KFN are currently in the late stages of treaty negotiations, involved in government-to-government discussions regarding land and water management in the Tsolum watershed, there are many ways in which the KFN and CVRD can collaborate to support watershed health.

In the development of the Tsolum River Agricultural Watershed plan, CVRD and KFN representatives discussed a vision for collaborative watershed management. This vision involved collaboration in water governance, co-management, and co-development of policy to protect groundwater and surface water health. This approach respects the Indigenous worldview and aligns with the calls of the Truth and Reconciliation Commission, UNDRIP, and DRIPA. It takes the 'two-eyed seeing approach' and combines Indigenous knowledge with the best available science to improve decision-making about water. It recognizes KFN's spiritual and environmental laws and draws on each organization's respective legal traditions, governance systems, and perspectives for a more effective, and robust approach to watershed stewardship.

While further discussion at the Council, Board, staff, provincial, and community level is needed to investigate and develop a collaborative approach, this dialogue between the KFN and CVRD has shown a promising way forward. A key KFN worldview is that everything is connected. While western science and legal systems tend to compartmentalize land and water management, there is growing recognition that this fragmented and siloed approach has failed to protect watershed health. Protecting water – which is essential to life for all beings - requires us to recognize our connectedness and work together to support watershed health.

Introduction

Tsolum River Watershed

The Tsolum River, located in the Comox Valley Regional District (CVRD), starts on the northeast side of Mount Washington and flows east, then south, down to Courtenay. The Tsolum River watershed is a relatively flat, low lying watershed and covers 248 km^2 of upland forests, low lying rural residential and agricultural land, and suburban areas.

The watershed lies in the heart of the unceded traditional territory of the K'ómoks First Nation (KFN)*. The KFN have hunted, fished, cultivated crops, gathered food and medicines, and recreated throughout the watershed since time immemorial.

Currently, approximately 8,000 people live in the Tsolum River watershed. The watershed and its aquifers provide water that is critical to the health of the agricultural community, residents, business, and environment. There is a long history of food production in the watershed. Agriculture plays an important role in the community, providing nutritious local food, supporting the economy, and building food security.

Challenges in the Tsolum

Like many watersheds on the east coast of Vancouver Island, the Tsolum experiences extreme seasonal variations in precipitation. In the winter, plentiful rain brings high water levels and flooding. In dry summer months, stream flows become very low and water temperatures rise. These seasonal variations bring challenges for producers, aquatic life, and residents.

River flows are lowest in August, when the water is most needed by producers and aquatic life. With climate change, these challenges are likely to grow.

Activities on the land have also impacted the quality of water in the watershed, reducing the quality of water available for bathing, drinking, aquatic life, and agriculture.

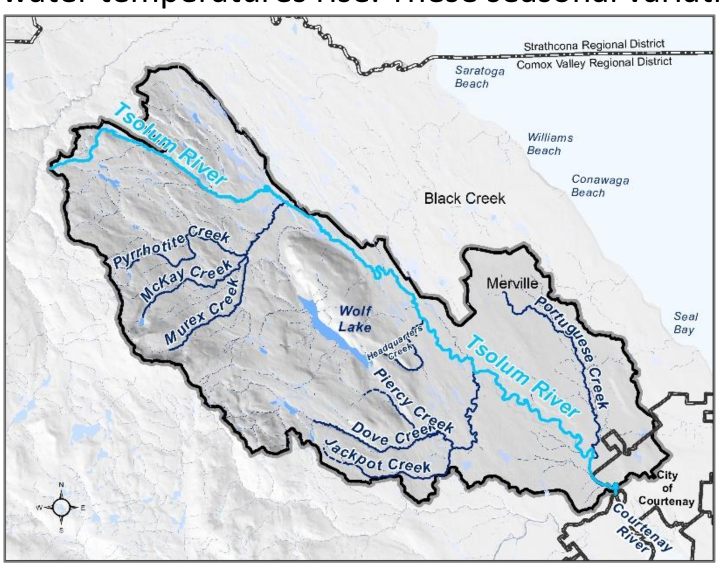


Figure 1: Tsolum River Watershed

** The traditional territories of the Pentlatch people also included the lower Tsolum River watershed.*

Agricultural Watershed Plan

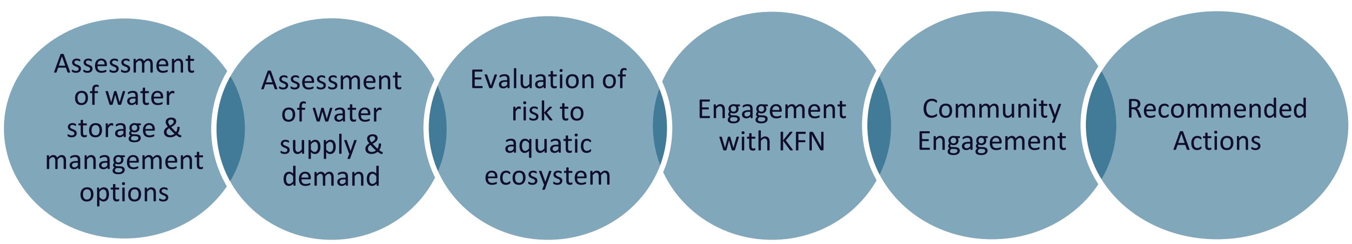
Project Overview

The CVRD has partnered with Investment Agriculture Foundation of British Columbia (IAFBC) on an agricultural watershed plan to address ongoing and future concerns about water availability for agriculture and aquatic health in the Tsolum watershed.

The project is guided by an Agricultural Watershed Planning Advisory Committee with representation from farmers institutes, stewardship groups, forest industry, government, and the KFN. This approach recognizes the multiple sectors and levels of government involved in watershed management in the Tsolum River watershed.

Agriculture watershed planning funded by IAFBC is completed in two phases. Phase One (2018-2019) involved collection and analysis of existing watershed information and community engagement. Phase Two began in 2020 and involved further watershed assessment and community engagement, then the development of recommendations to support agriculture and environmental health in the Tsolum River watershed.

Phase Two activities included:



This document provides a summary of each of these activities and details on the recommended actions. It also includes information to support implementation, including high-level estimates of costs, key players, and next steps for key recommended actions. Full details on the Phase Two activities can be found in Appendices A-D (Appendix A: Water Storage and Management Options, Appendix B: Water Supply and Demand Assessment, Appendix C: Aquatic Risk Assessment, Appendix D: Engagement Activities).

Agricultural Watershed Planning Advisory Committee:

Ministry of Agriculture, Fisheries, and Food (MAFF)
Comox Valley Conservation Partnership (CVCP)
City of Courtenay
Ministry of Forests, Lands & Natural Resource Operations
Mosaic Forest Management
K'ómoks First Nation (KFN)
Comox Valley Farmer's Institute (CVFI)
Mid-Island Farmer's Institute (MIFI)
Tsolum River Restoration Society (TRRS)
Comox Valley Regional District (CVRD)
Fisheries and Oceans Canada (DFO)

Water Storage & Management Options

In Phase One of the project, community members expressed concerns about current and future water supplies and recommended increasing water storage to support agricultural production and ecosystem health. As such, in Phase Two, several options to increase access to irrigation water were evaluated including: water storage, alternate supplies, and demand management. The following options were considered:

1) On-farm storage:
   - Dugouts
   - Cisterns
   - Well-widening
   - Shared storage
2) Large-scale storage: Wolf Lake
3) Alternative sources: reclaimed water
4) Demand management:
   - Improved irrigation management
   - Irrigation system upgrades

Each option was researched and ranked in terms of affordability (based on high-level cost estimates), volume of water that can be made available, ease of implementation, ease of use, and reliability. A summary of the research and rankings is shown in Table 1 on the following page. More details on each option can be found in Appendix A.

Overall, dugouts were the highest ranked storage/supply option. Demand management also scored highly, but was able to provide only minimal volumes of water.

Figure 2: Dugout. Source: https://www.bcagclimateaction.ca/wp/wp-content/media/FarmPractices-WaterStorage.pdf

Table 1: Summary of Water Storage and Management Options: Ranked Low/Medium/High (1-3). For the average score: Low = 0 - 1.33, Medium = 1.34 - 2.16, High = 2.17 – 3.

	Option	Volume of Water that Could be Made Available	Affordability	Adoptability (Ease of Implementation)	Ease of Use	Reliability	Average Score
On-Farm Storage	**Dugout**	**Medium-High (2.5/3)** Common dugout size: 750m^3 12,021,270m^3 could potentially be stored across the watershed. But not all producers (especially small farms) have space and not all available space is likely to be used.[1]	**Medium (2/3)** $10-20+/m^3 for storage + pump, filter, fence e.g. 1,000m^3 of storage, or, 750m^3 of water supply (after , dead storage evaporation) approx. $20,000. Limited funding supports available (EFP)	**High (3/3)** If a dugout does not form a dam and only captures overland flow, a license is not needed. Storage license needed if filled by an existing/new well or surface water.	**Medium (2/3)** Dugouts need to be maintained for water quality purposes. Filters and pumps need maintenance. Dugouts should be fenced.	**Medium (2/3)** Dugouts reliably filled over the winter months. Reliability as a summer supply varies with precipitation, dugout size, and supplementary sources.	**High (2.3/3)**
	Cisterns	**Low (1/3)** Typical cistern size: 2-6.5m^3 Unlikely to provide large volumes due to high cost per m^3.	**Medium (2/3)** $375-$500+/m^3 for storage + pump, filter, etc. e.g. 3m^3/$1,325	**High (3/3)**	**Medium-High (2.5/3)** Cisterns need cleaning. Filters and pumps need maintenance, but fewer water quality concerns than dugouts.	**Medium (2/3)** Rainwater not reliably available in the summer. A cistern can also be filled by water from a well or truck.	**Medium (2.1/3)**
	Well widening (shallow dug wells only)	**Low (1/3)** Limited. Only applies to shallow dug wells. Max storage approx. 7m^3/well.	**Low-Medium (1.5/3)** $700+/m^3 e.g. $3,500 for 4.7m^3 (20' well, 48" well rings - 39" inside diameter)	**High (3/3)**	**High (3/3)**	**Low (1/3)** Shallow aquifers are generally less reliable.	**Medium (1.9/3)**
	Shared Storage (e.g. dugout/dam)	**Medium-High (2.5/3)** Volume of water varies based on site conditions and interest. Potentially, 12,000,000m^3+ of water could be made available.	**Medium (2/3)** Cost varies with size of dugout/dam and site conditions.	**Low-Medium (1.5/3)** Need a joint use agreement and water licenses. Dam safety regulations may apply.	**Medium (2/3)** Co-management may take effort. But maintenance may be easier if pre-scheduled and financed by a group.	**Medium (2/3)** Depends on source. Reliably filled over the winter, but summer inflows variable.	**Medium (2/3)**

[1] Considering land on farm properties that is not currently in use (not farmed and not a farm building or house) with a depth to bedrock depth >6m and slope < 5%.

	Option	Volume of Water that Could be Made Available	Affordability	Adoptability (Ease of Implementation)	Ease of Use	Reliability	Average Score
Large-Scale Storage	Wolf Lake Storage	**Medium-High (2.5/3)** 1,600,000-3,500,000m^3	**Low (1/3)** Cost TBD. Potentially \$20+/m^3 (if storage \$35 million, distribution is \$20 million) plus operation/maintenance.	**Very Low (0.5/3)** Not wanted by dam owner (DFO[2]) and landowner (Mosaic). It would be a high-risk dam. Requires creation of a water service area.	**Medium (2/3)** While it would be easy for producers to use water, water system maintenance and operation required; also dam maintenance and inspections.	**Medium-High (2.5/3)** Volume of water collected may be low as it is a small basin. May vary with climate change. Volume available for agriculture may vary with drought, ecological flow needs.	**Medium (1.7/3)**
Alternate Sources	Reclaimed Water	**Medium-High (2.5/3)** 2,002,000m^3+ (May-September)	**Low (1/3)** Cost TBD. Potentially \$15+/m^3 (if treatment is \$5-6 million, distribution is \$20 million, plus operation and maintenance).	**Low-Medium (1.5/3)** Not in CVRD's plans but aligns with goals. Community concerns re: aquifer impacts (e.g., CECs). Water service area required.	**Medium (2/3)** While it would be easy for producers to use water, water system maintenance and operation required.	**High (3/3)** The water source is reliable and increases with growth.	**Medium (2/3)**
Demand Management	Irrigation Management	**Low (1/3)** On average, across watershed, about a 2.5% decrease in water use. With current crops, 71,837m^3 of water could be made available.	**Very High (3/3)** Free or very low cost.	**High (3/3)**	**High (3/3)**	**High (3/3)**	**High (2.6/3)**
Demand Management	Irrigation Upgrades	**Low-Medium (1.5/3)** On average, about a 15-20% decrease in water use. With current crops, 418,065m^3 of water could be made available.	**High (3/3)** \$/m^3 variable. e.g., fruit/veg operation upgrading to a drip system would cost \$9/m^3.	**High (3/3)**	**High (3/3)**	**High (3/3)**	**High (2.7/3)**

[2] The DFO currently owns the dam and holds a water license for Conservation purpose (which is non-consumptive).
*Contaminants of emerging concern.

Assessing Watershed Health

Estimating Water Supply and Demand

To better understand the health of the Tsolum River watershed, a study was completed, estimating the volume of water that is estimated to enter and leave each subwatershed for each month of the year. This high-level assessment was based on available data and provides insight on areas that may be stressed to help focus further study. This work can be refined as more data becomes available.

While the term ‘water budget’ was first used to describe this work, it has been updated to ‘watershed health’ to acknowledge the KFN worldview that water is not a commodity. Rather a watershed is sacred living system that we rely on, and care for.

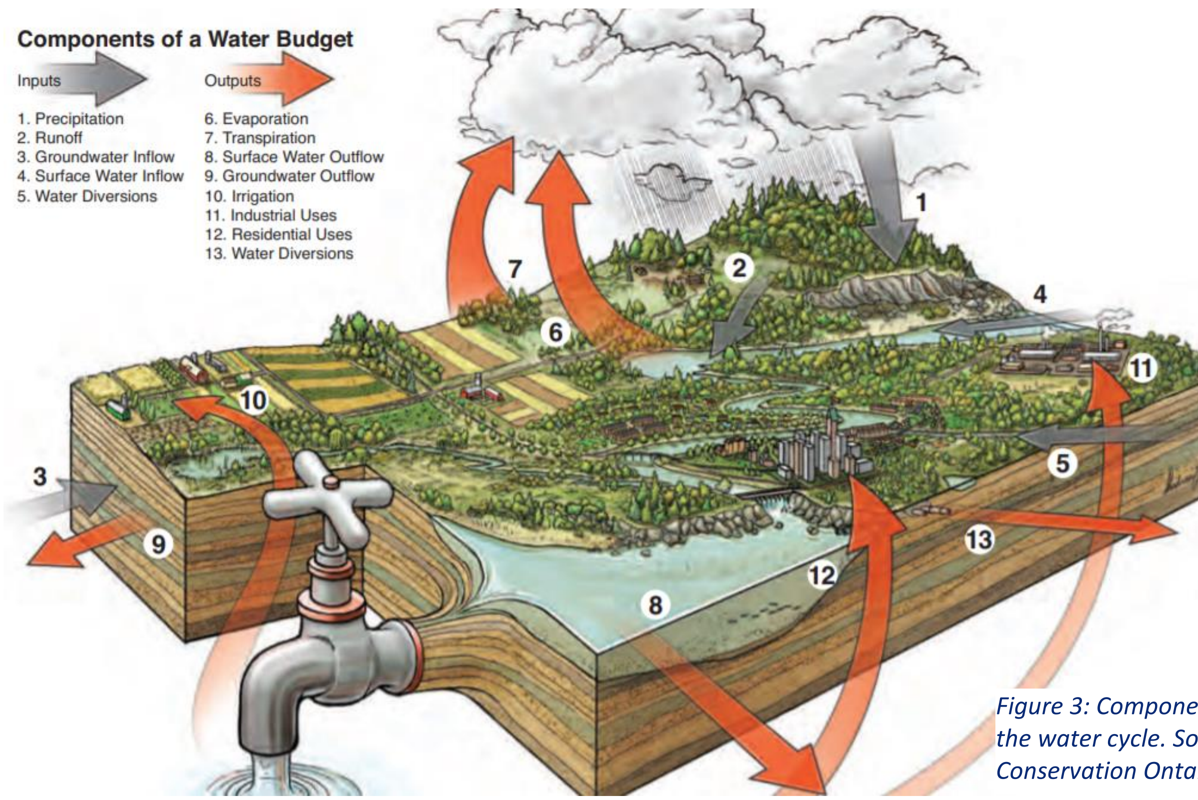


Figure 3: Components of the water cycle. Source: Conservation Ontario.

Water cycle: Water enters the watershed as rain or snow (***Precipitation***) and leaves through:

- **Evapotranspiration**: includes evaporation and water that gets used by vegetation (transpiration)
- **Surface Water: i**ncludes water that flows over land into streams, rivers, and lakes when it rains (***runoff) and*** water that enters streams from underground aquifers (***base flow***)
- **Recharge**: water that goes down into groundwater aquifers. Some of this becomes **base flow**.
- **Surface Water Use:** water taken by humans from lakes, rivers, streams, and springs.
- **Groundwater Use:** water taken by humans from groundwater wells.

Estimating Water Supply and Demand

The water supply and demand assessment for the Tsolum River watershed found that:

- There is a very strong contrast between the wet period and the dry period of the year.
- In the low flows months of July through October, demand is highest, stream flows are lowest, and groundwater (baseflow) is a key contributor to stream flows.
- Of the precipitation that enters the system, approximately 18% - 30% leaves through evapotranspiration (ET) and 30% - 39% goes to groundwater recharge.
- Aquifers play a very important role in water supply, as approximately 76% of the total water demand is provided by groundwater, the remaining 24% is from surface water.

Figure 4, below, provides an overview of the water supply and demand assessment for the whole Tsolum River watershed (values shown are estimated monthly averages).

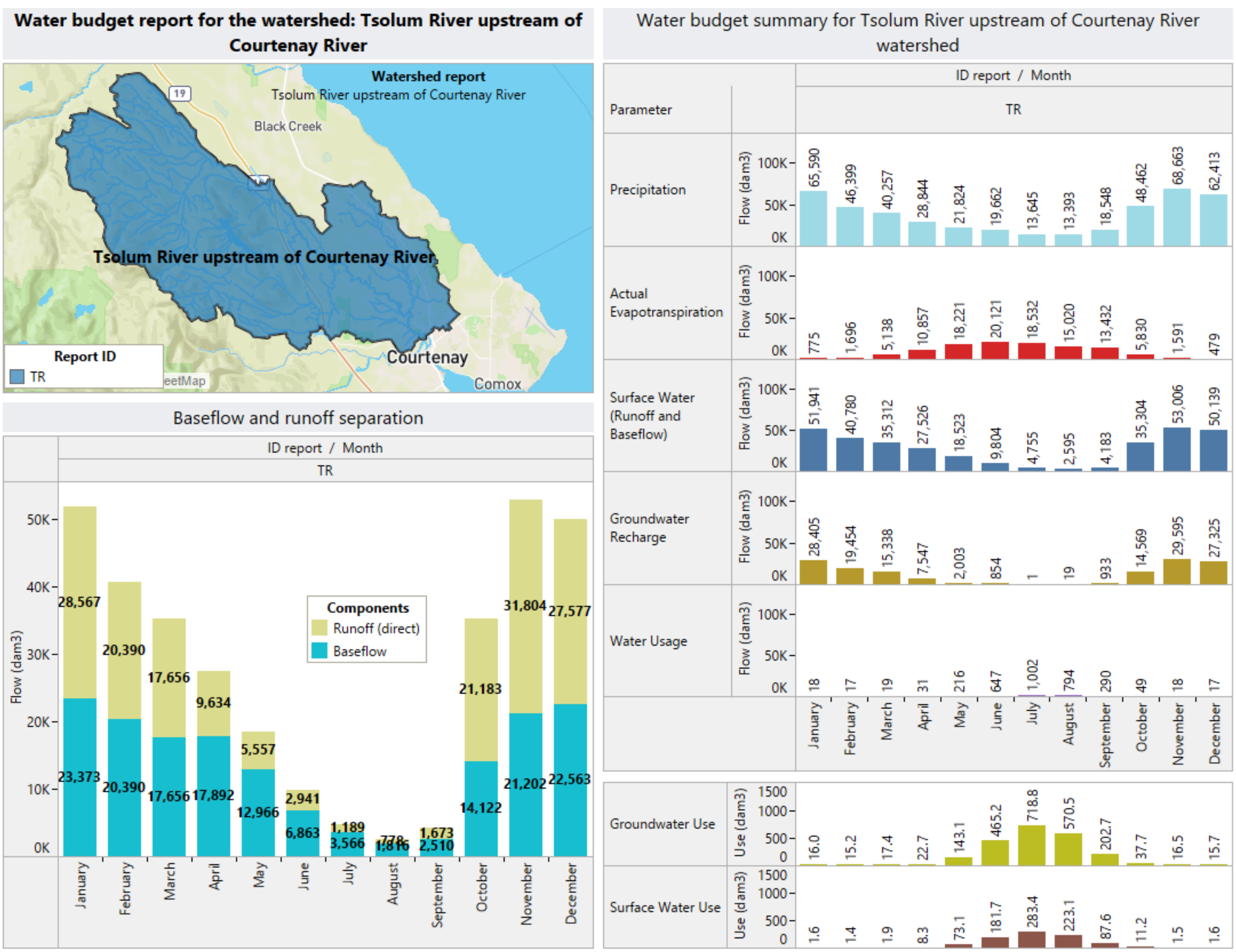


Figure 4: Overview of Water Supply and Demand for the Tsolum Watershed

Results of Water Supply and Demand Assessment

Identifying Areas of Stress

The water supply and demand assessment was completed on a subwatershed basis, to help identify subwatersheds that are experiencing greater stress. A full description of the supply and demand assessment methodology and results for each subwatershed is provided in Appendix B. Portuguese Creek was identified as the subwatershed experiencing the greatest stress in the Tsolum.

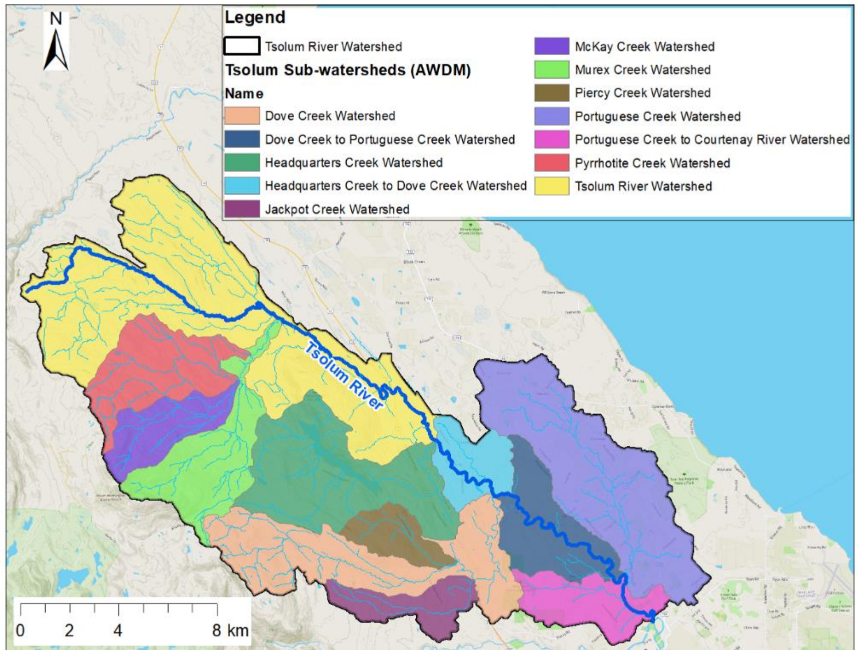


Figure 5: Subwatersheds in the Tsolum River Watershed

Assessing Sustainability of Current Groundwater Use

A common question asked by community members in this project was '*Is our groundwater use sustainable?*'

One way to assess the sustainability of groundwater use is to compare the volume of water entering aquifers (groundwater recharge) to the volume of water taken from aquifers (groundwater use), as shown in Table 2.

Table 2: Percentage of Groundwater Use Compared to Recharge in the Tsolum River Watershed

Subwatershed	%
Jackpot Creek	0.00%
Dove Creek Watershed (Mainstem)	0.01%
Piercy Creek	0.00%
Portuguese Creek	9.35%
Headquarters Creek	0.00%
Murex Creek	0.00%
McKay Creek	0.00%
Pyrrhotite Creek	0.00%
Tsolum River - Headwaters	0.00%
Tsolum River – Headquarters Cr to Dove Cr	2.3%
Tsolum River – Dove Cr to Portuguese Cr	4.51%
Tsolum River – Portuguese Cr to Courtenay R	1.01%
Average: Tsolum River Watershed	**1.53%**

While there is no clear rule regarding the percent of recharge that is sustainable to use, in the Portuguese Creek subwatershed (and to a lesser degree, in three lower mainstem sub watersheds), a higher percentage of groundwater recharge is used. Further data gathering, and caution, is advised in Portuguese Creek, as well as the other subwatersheds.

Agricultural Water Needs

Estimating Current and Future Agricultural Water Use

The Comox Valley has one of the most favorable growing climates in the country. While many areas of the Province have exhausted their available agricultural land, in the Tsolum watershed, there is still a relatively large amount of farmland available. However, access to water currently limits production and is likely to in the future.

Figure 6: Agricultural areas on Dove Creek Road

Consumers are increasingly aware of the benefits of eating locally and it is expected that investment in agriculture will grow. Increased production will result in additional demand for water for agricultural use.

With climate change, it is also likely that the water needs of existing producers will increase. With longer and drier summers, many producers who did not irrigate in the past, have recently discovered they need to begin irrigating their crops. This trend is expected to continue as climate changes.

To better understand current and future agricultural water use, the Agricultural Water Demand Model (AWDM) was used to model agricultural water demand. Table 3 shows a summary of the modelling results.

Table 3: Current and Future Agricultural Water Use in the Tsolum River Watershed

Scenario	Water Use (m^3/year)	Percent Increase
Current climate + amount of farming + current irrigation systems	2,919,539	0%
Current climate + amount of farming + everyone irrigates (due to drier summers)	9,543,400	227%
Climate change (2050s) + current amount of farming (with everyone irrigating)	11,890,153	307%
Current climate + increased amount of farming + irrigation (various types of production)	15,352,345 – 17,937,517	426-514%
Climate change (2050s) + increased amount of farming (assuming current distribution of crops) + irrigation	23,372,272	701%

Climate change effects modelled by using climate data available from the Pacific Climate Impacts Consortium. The climate models used were access1 rcp85, canESM2 rcp85, and cnrm-cm5 rcp85. The were run for the years: 2053, 2056, 2059.

The AWDM estimates water use, based on an inventory (Agricultural Land Use Inventory) of crop and irrigation system types, completed in 2013. Crops and irrigation systems may have changed since that time. Updating the inventory was beyond the scope of this project.

Estimating Future Agricultural Water Demand

To better understand how agricultural use may change in the future, the CVRD used the AWDM to estimate agricultural use under the following possible current and future scenarios:

1. Current crops, more people irrigate (using efficient irrigation practices)
2. Increased production scenario A: assumes significantly increased fruit and vegetable production, much less forage and pasture. Total crop distribution: 38% forage, 10% pasture, 11% berries, 11% grapes, 30% veg.[3]
3. Increased production scenario B: assumes increased fruit and vegetable production. Total crop distribution: 50% forage, 10% pasture, 20% grapes, 20% veg.[3]
4. Increased production C: Assumes the current distribution of crops. Total crop distribution: 60% forage, 25% pasture, 5% berries, 6% veg, 4% grapes. [3]
5. Current conditions plus climate change
6. Increased production A plus climate change
7. Increased production B plus climate change
8. Increased production C plus climate change

The demand estimates were then used to assess environmental risk in each scenario.

Figure 7: Agricultural land in the Tsolum River watershed

[3] Assumes additional land is placed into production, using the MAFF 'buildout' rules (land is available, in ALR, and with proper agricultural capability, meaning soil class). Assume all current and future fruit and vegetable crops are irrigated with drip systems, and centre pivots on forage parcels of more than 10 hectares (no change in irrigation system types on forage parcels less than 10 hectares). Assume good irrigation management.

Assessing Risk to Aquatic Ecosystem Health

Environmental Flow Needs Risk Assessment

An environmental flow needs (EFN) risk assessment was done to evaluate how current water demand and potential future agricultural demand may affect aquatic health.

The assessment followed the Provincial EFN Policy - Environmental Risk Management Framework, which describes a coarse screen for assessing EFN risk and identifies areas where cautionary measures could be taken, or additional analysis may be needed.

The EFN assessment evaluated risk at nine '*points of assessment*' (POAs). Each POA was at the most downstream point of a sub watershed. Figure 8 shows an example of a POA for the Tsolum River upstream of Portuguese Creek.

Risk for each month was assessed as High (3), Moderate (2), or Low (2), considering:

- stream size (small streams are more sensitive to variations in flow)
- fish presence (streams with fish are more sensitive to variations in flow)
- flow sensitivity (or variability, monthly flow as a percent of mean annual flow)
- water use (% of average monthly flow that is licensed).

Because streams and aquifers are connected in the Tsolum, two approaches were taken to assessing water use. The first considered surface water use only. The second considered total water demand (groundwater + surface water use). The second is a more conservative approach, as not all groundwater use will directly affect the river.

Risk was assessed under eleven different water use scenarios, including:

- Licensed demand (considering only 'official' water license volumes): This is less than actual use, as many users, especially well owners, do not have licenses, yet.
- Estimated current use (from AWDM results, Island Health records, and estimates of demand based on land use)
- Eight future agricultural water demand (AWDM) scenarios (as described on last page).

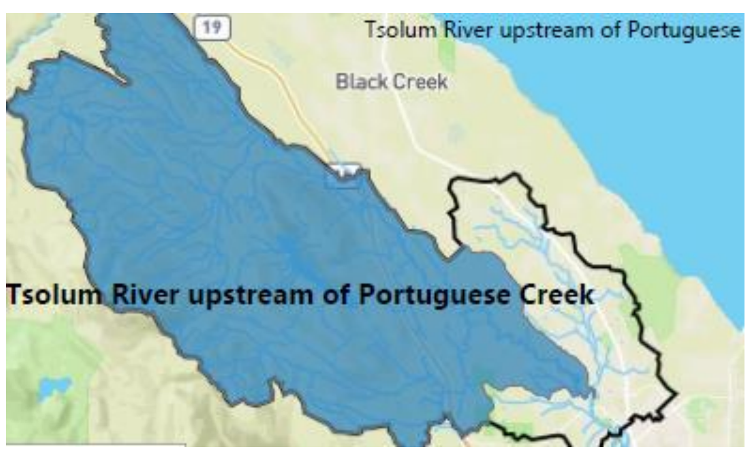


Figure 8: Example of a 'point of assessment' (purple star)

Results of EFN Risk Assessment

The EFN risk assessment found that August is the month with the greatest flow sensitivity. Table 4 shows the risk assessment for August considering surface water use *only*, at nine locations (POAs), under eleven scenarios. Under current conditions, Risk Management Level 2 (Moderate) was assigned for all locations. With increased production, Level 3 was assigned.

Location	Mean Monthly Discharge (m^3/s)	Mean Annual Discharge (m^3/s)	% of Mean Annual Discharge	Stream Size	Flow Sensitivity	Risk Management Level										
						Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate (efficiently)	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Tsolum River upstream of Courtenay River	0.969	10.580	9%	med-large	high	2	2	2	3	3	3	3	3	3	3	3
Tsolum River upstream of Portuguese Creek	0.854	8.791	10%	small	high	2	2	2	2	3	3	3	2	3	3	3
Tsolum River upstream of Dove Creek	0.694	6.454	11%	small	moderate	2	2	2	2	3	3	3	2	3	3	3
Tsolum River upstream of Headquarters Creek	0.583	4.861	12%	small	moderate	2	2	2	2	2	3	3	2	3	3	3
Portuguese Creek upstream of Tsolum River	0.087	1.371	6%	small	high	2	2	2	3	3	3	3	2	3	3	3
Dove Creek upstream of Tsolum River	0.121	1.782	7%	small	high	2	2	2	2	3	3	3	2	3	3	3
Jackpot Creek upstream of Dove Creek	0.018	0.271	7%	small	high	2	2	2	2	3	3	3	2	3	3	3
Piercy Creek upstream of Dove Creek	0.010	0.250	4%	small	high	2	2	2	2	3	3	3	2	3	3	3
Headquarters Creek upstream of Tsolum River	0.086	1.238	7%	small	high	2	2	2	2	3	3	3	2	3	3	3

Table 4: Risk assessment for the month of August considering surface water demand in the Tsolum River Watershed

If total water demand is considered (Table 5), current use in August was assessed at Level 3 in Tsolum River from Dove Creek to the Courtenay River confluence, and within Portuguese Creek. At all POAs, increased production was assessed at Level 3.

Location	Mean Monthly Discharge (m^3/s)	Mean Annual Discharge (m^3/s)	% of Mean Annual Discharge	Stream Size	Flow Sensitivity	Risk Management Level										
						Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate (efficiently)	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Tsolum River upstream of Courtenay River	0.969	10.580	9%	med-large	high	2	3	3	3	3	3	3	3	3	3	3
Tsolum River upstream of Portuguese Creek	0.854	8.791	10%	small	high	2	3	3	3	3	3	3	3	3	3	3
Tsolum River upstream of Dove Creek	0.694	6.454	11%	small	moderate	2	2	2	2	3	3	3	2	3	3	3
Tsolum River upstream of Headquarters Creek	0.583	4.861	12%	small	moderate	2	2	2	2	3	3	3	2	3	3	3
Portuguese Creek upstream of Tsolum River	0.087	1.371	6%	small	high	2	3	3	3	3	3	3	3	3	3	3
Dove Creek upstream of Tsolum River	0.121	1.782	7%	small	high	2	2	2	3	3	3	3	2	3	3	3
Jackpot Creek upstream of Dove Creek	0.018	0.271	7%	small	high	2	2	2	2	3	3	3	2	3	3	3
Piercy Creek upstream of Dove Creek	0.010	0.250	4%	small	high	2	2	2	2	3	3	3	2	3	3	3
Headquarters Creek upstream of Tsolum River	0.086	1.238	7%	small	high	2	2	2	2	3	3	3	2	3	3	3

Table 5: Risk assessment for the month of August considering total water demand (groundwater and surface water use) in the Tsolum River Watershed

Additional Considerations with EFN Risk Assessment

A full description of the EFN risk assessment, including the methodology and all results, is in Appendix B: EFN Report.

It is important to note that this EFN risk assessment is an initial step toward understanding current and future environmental risk. Based on the screening-level assessment, recommendations for future work have been provided (in full in Appendix B, and in the Recommendations portion of this report). Further work and decisions around water use should consider:

- ***Risk during low flow periods:*** *The EFN risk assessment compares estimated average monthly water use (demand) to estimated* ***average*** *monthly flows – not low flows. There are typically days in July and August where flows are much lower than the monthly average. During this period, if flows are too low, fish cannot survive for hours, let alone days. An assessment of risk during low flow periods was beyond the scope of this project. However, because low flow periods are not considered, the current risk assessment under-estimates risk during low flow windows.*
- ***Recent trends in water use and streamflow:*** *The risk assessment used as input* ***modelled*** *monthly flows, developed using 'climate normals', or historical climate data from the years 1981-2010 (the most recent climate dataset). In recent years, measured flows in the summer months are lower than historical flows. Flows are likely to continue to decrease with climate change and increased use. Because this EFN risk assessment is based on historical data, it may under-estimate current and future risk to aquatic life.*
- ***Climate change:*** *While the impact of climate change on water demand was considered, the impact of climate change on* ***stream flows*** *was beyond the scope of this project. Therefore, the risk assessment does not consider future increased risk due to climate change.*
- ***Watershed size:*** *The Provincial EFN policy identifies small streams as being more sensitive than large streams. The Tsolum River watershed is on the border of the small/medium-large stream classification and officially is classified as a medium-large stream. If the Tsolum was classified as a small stream, this would increase its risk-level. Examples of this are shown in Appendix C.*

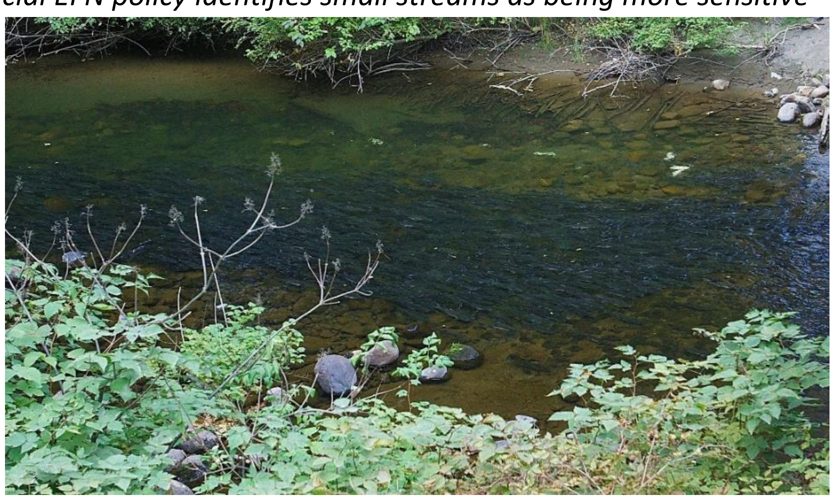


Figure 9: Record 2015 Pink Salmon return on the Tsolum after years of restoration and enhancement. Photo taken by Father Charles Brandt, friend of the Tsolum.

Plan Development: Engagement

The CVRD utilized several approaches to engage with watershed stakeholders and other levels of government to better understand watershed issues and develop solutions. Approaches included nine Agricultural Watershed Planning Advisory Committee meetings (2018 - 2021) and direct engagement with farmer's institutes and the stewardship community via email, phone calls, social media, a survey, a news release, and meetings.

The CVRD also engaged with the KFN, who are leading concurrent watershed stewardship efforts, to better understand their perspective and gain input so that the project does not infringe on the exercise of aboriginal rights.

An overview of the Phase Two engagement activities is shown below. Generally, the community engagement proceeded the technical assessments, so that the results could be presented and considered in developing recommendations.

Table 6: Timeline of Phase Two Engagement Activities

	2020 Jan	Feb	Mar	Apr	May-Aug	Sep	Oct	Nov	Dec	2021 Jan	Feb	Mar	Apr	May
Technical kick-off meeting	Jan 13			COVID-19 Strategy Update	Engagement with producers paused over growing season									
Advisory Committee			Mar 3, 2020				Oct 29, 2020		Dec 14, 2020					May 20
Producer Engagement Emails, social media, meetings, phone calls											Feb 9: CVFI Feb 10: MIFI			
Stewardship Engagement										Jan 7: TRRS	Feb 10: CVCP & TRRS			
KFN Engagement					July 7			Nov 2	Dec 7		Feb 11, 25		Apr 21	May 10: Chief & Council
Interviews														

Technical team meeting included representatives from the KFN, CVRD, TRRS, and consulting team. Dates identify 'official' meeting events.

Community Input

In the community engagement activities, community members, including members of the Farmer's Institutes and stewardship community, shared many concerns and potential solutions. Key themes included:

Take a holistic approach	• Take a whole watershed approach, considering the impact of all activities in the watershed, including upstream forestry. Take a Regional approach, as aquifers may cross surface water boundaries, and other watersheds also require protection. Also, work with neighboring local governments, as watersheds can cross government boundaries.
Agricultural water use should be a priority on ALR land	• Most farmers already experience water scarcity and are very conservative with water use. There are serious concerns that increased (and unregulated) residential development on ALR land and unregulated domestic use will further reduce water availability and cause a 'death by a thousand cuts' to agriculture. For ALR land to be available for farming, land and water use policies must prioritize agricultural water use on ALR land.
Understand the impacts of forest practices on low flows and recharge	• The majority of the land in the watershed is privately managed forest. Changes in land cover and drainage in the upper watershed influence the hydrologic regime, impacting groundwater recharge, evapotranspiration rates, drainage, and influencing low and high flows. The community noticed correlations between forestry activities and hydrologic impacts and emphasized recent research identifying a relationship between harvesting and low flows. The community is interested in seeing this relationship investigated in the Tsolum watershed and the development of recommendations for mitigative actions. They requested this work be paid for by government, not industry, to reduce conflict of interest.
Take a roundtable approach to governance	• A collaborative approach to watershed management is highly supported. There is signficant local knowledge and experience within the community and a local roundtable approach is much more suitable than a 'one-size-fits-all' approach from the Province. A stakeholder mapping exercise would be needed, to carefully and transparently identify who should be at the table.
Concerns regarding climate change	• All groups raised concerns about the role that climate change will play in altering the hydrologic regime and recommended better understanding the impacts of climate change. There were also concerns about the cumulative effects of climate change and forestry practices on the hydrologic regime and a request that this be investigated.
Supply and demand assessment not a low flow risk assessment	• The EFN risk assessment in this project, is an initial assessment of average risk and does not specifically assess risk during low flow periods. It is based on historical data and does not consider how risk may vary under changing climate (as described in the EFN risk assessment section). A cautious approach was recommended.
Restore hydrologic function and health of the watershed	• Pursue opportunities to restore hydrologic function and health, including wetland restoration, restoration of riparian areas, increased water storage in forested uplands, and habitat improvements. Creating incentives for landowners to increase environmental stewardship on their properties was highly recommended.
Support producers in storage and stewardship	• Farming is very hard work. Local producers increasingly experience barriers in their business and reduced supports. Given that the second largest land use in the watershed is agriculture, yet many producers operate with very small financial margins, it was recommended to provide incentives for water storage and environmental stewardship on farmlands.
Remove disincentives for storage and stewardship	• Currently, the Province charges a fee for water storage. While the fee is small, it acts as a disincentive for storage and it was suggested it be removed. In addition, there is uncertainty regarding provincial requirements (e.g. a producer won't know if the dugout they want to dig is connected to an aquifer until they start digging). Reducing uncertainty would help.

Input from KFN

In meetings with KFN, representatives shared the following key themes regarding the relationship of the KFN people with the Tsolum River watershed:

Water and a healthy environment are essential to rights	•There is nothing more sacred to life and as important to the K'ómoks people as water. For thousands of years, the KFN people hunted, fished, recreated, travelled, gathered medicines, grew food, practiced their culture and spirituallity (e.g. spiritual bathing), travelled, and socialized with family and community in the watershed. •KFN's culture and exercise of rights (and the continued opportunity to express culture and rights) is totally dependent on the environment. The two cannot be separated.
Water is sacred	•To the KFN people, water is sacred. KFN respect all living and non-living things and water is not just a commodity but a living system. KFN believe that it is their inherent responsibilty to steward the lands and waters in their traditional territories.
Support respectful collaboration	•The KFN has a strong interest in stewarding watershed health and is open to building on as many synergies as possible with the CVRD to protect the Tsolum River watershed. It is essential that any collaboration does not compromise rights and is in alignment with United Nations Declaration of the Rights of Inigenous People (UNDRIP), B.C. Declaration on the Rights of Indigenous Peoples Act (DRIPA), and the Calls to Action of the Truth and Reconciliation Commission of Canada (CATRCC).
Respect for Indigenous worldviews and knowledge	•Any collaborative approach between the CVRD and KFN must recognize and respect the Indigenous worldview and knowledge base. Harmonizing the western and Indigenous views - or the concept of 'two eyed seeing', was encouraged. •Indigenous worldviews include concepts such as the idea that everything is connected (see below), and approaches such as the seven generations principle: whereby you look back seven generations to understand your current state, and use that information to make decisions to protect seven generations into the future.
Everything is connected	•A core K'ómoks principle is everything is connected. KFN recognizes the interconnectedness of the land and water and living things and views a healthy functioning watershed as essential to community health.
Need to better understand watershed	•KFN encourages actions to better understand the watershed system in order to support watershed health. •KFN believe that the Province currently does not know enough about water in the Tsolum to continue licensing at this time and that a better understanding of the watershed is needed before discussing further demand. Licensing should be within natural limits and a healthy watershed should have a suitability quality and quantity of water and timing of flow so that environmental flow needs can be met.
Current water protection intiatives	•KFN is leading several watershed stewardship projects, including an assessment of groundwater vulnerability. In that work, KFN is identifying areas of the aquifer that are intrinsicly more vulnerable to contamination and comparing this to current and future land uses (based on zoning) . This will support groundwater stewardship. •KFN is also investing in better understanding groundwater-surface water interactions. •KFN has developed a groundwater vision statement, to support strategic management. • KFN holds community focus groups on water. There is signficant community interest in these sessions.

Input from KFN

KFN representatives also shared the following concerns and suggestions for action:

Prioritize actions to support watershed health	• KFN encourages actions that support watershed stewardship. Given the wide range of actions that could be taken, KFN recommends a strategic approach, whereby possible investments in the watershed are prioritized for effectiveness.
Concerns re: licensing	• KFN believes there shouldn't be any increases in demand until there is a better undestanding of supply and rationalization of the demand. KFN has issues with colonialization of access to groundwater and surface water through licensing. There is a lot of colonial pain left over from the previous licensing of water. In some areas, so much water has been licensed that it may compromise KFN's access to water.
Concerns re: impact of forest activities on hydrology	• There are concerns about the desynchronization of water and the impacts of forest harvesting on groundwater recharge. With road development, new drainage, and forest harvesting on hills, surface water now moves very quickly through ditch systems rather than through the ground into streams. Because water is spending less time on the land, there is a loss of groundwater recharge.There needs to be more opportunity for recharging water in upper watersheds and across the landscape.
Concerns regarding water quality	• There are also concerns regarding chemicals entering the river and endangering fish with rapid runoff. Sources of concern include vehicles (car tires and chemicals such as hydrocarbons), agriculture (manure application and storage and herbicides), and other activities on the land. Monitoring of water quality is recommended.
Indigenous knowledge sharing	• While KFN is interested in sharing some Indigenous knowledge to support watershed protection, knowledge sharing should follow the principles of OCAP (Ownership, Control, Access, and Protection of Indigenous knowledge). Some knowledge is confidential, with very strong cultural roots and protections and some may be owned by individuals, families or collectively as a Nation.
Roundtable Approach Recommended	• A collaborative approach to watershed management is recommended over a top-down approach from the Province of BC. There is a lot of knowledge and passion for agriculture and watershed stewardship in the area. Bringing people together to solve problems mobilizes this knowledge and enables the local agricultural community, stewardship community, residents, CVRD, and KFN to collaborate in supporting watershed health. A co-governance approach between the CVRD, KFN was encouraged.
Capacity is limited	• KFN's current efforts in this project are suppported through treaty funds, but that will be gone soon. Further funding/capacity is required to support ongoing work.
Restore hydrologic function and health of the watershed	• On agriculture and residential lands, wetland drainage has reduced groundwater recharge and altered the hydrologic regime - likely contributing to low flows and flooding. KFN encouraged the CVRD to pursue opportunities to restore hydrologic function and health, including wetland restoration and restoration of riparian areas. A strategic approach was recommended, that considers the inter-connectedness of all things (similar to the Western concept of 'cumulative effects') and benefits.
Promote BMPs on farm so support soil health	• To support sustainabilty of agriculture and watershed health, it was recommended that the CVRD, MAFF, and FI's collaborate to identify and then promote/support practices that can be used in the Tsolum to enhance soil health and productivity without additional water. As many producers are not currently irrigating, and as less water is available in the summer with climate change, it may be more financially sound to invest in practices that improve productivity of soil, rather than expensive irrigation systems (some of which may not be suitable for properties in the Tsolum).

Recommendations

Supporting a Healthy Future for Agricultural and the Environment in the Tsolum Watershed

The water budget, EFN risk assessment, and community engagement made it clear that it is important to plan ahead to ensure there is sufficient water available for food production and aquatic health – especially with a changing climate.

The following groups contributed to the development and review of recommendations for the Tsolum River watershed:

- The technical teams that conducted the water budget and EFN assessment
- Comox Valley Farmers Institute (CVFI) and Mid-Island Farmer's Institute (MIFI)
- Tsolum River Restoration Society (TRRS) and the Comox Valley Conservation Partnership (CVCP)
- K'ómoks First Nation (KFN)
- Agricultural Watershed Planning Advisory Committee (AC)

The recommendations are provided on the following pages. This is followed by high-level implementation details, including relative costs, next steps, and key players.

Recommendation #1: Collaborative Watershed Management

Actions	Details
1A. Establish a local government service to support watershed stewardship efforts	The CVRD currently has limited resources and capacity available to support water stewardship efforts in the Tsolum River watershed. A watershed stewardship service could provide the resources needed to move ahead the following recommended actions (e.g., water quality and quantity monitoring, agricultural land stewardship) to support watershed health and the sustainability of agricultural water use. A watershed stewardship service could also support the CVRD in using water resource information to enhance land use planning. The KFN should be approached as a partner in this initiative. KFN also currently has limited capacity, as well, but is very interested in watershed stewardship and supportive of collaboration to protect the resource. A Regional-District wide approach to watershed stewardship is highly encouraged. Aquifers in the Tsolum watershed extend beyond the watershed boundaries and there are likely other areas of the CVRD where greater attention to water is warranted. CVRD should build on existing relationships with neighboring governments, to collaborate in watershed stewardship, as watershed and aquifer boundaries may not align with administrative boundaries. If this approach is pursued, organizations such as the TRRS, CVCP, CVFI, and MIFI could play an important role in sharing the benefits of a service with the community (e.g., producers, well owners, anglers). It may be appropriate to tie this with the Regional Growth Strategy service, as that work has momentum and is appreciated by many in the community.
1B. Roundtable approach to collaborative management	Future watershed management activities should utilize a roundtable approach that brings to the table people from all backgrounds to solve watershed problems. The use of a roundtable mobilizes available knowledge and enables the local agricultural community, forest industry, stewardship community, residents, CVRD, and KFN to collaborate in watershed stewardship. It also helps people understand each other's perspectives and recognize commonalities. The CVRD can draw on the experience of using a roundtable in the Comox Lake watershed. The Fisheries Management Area 23 Harvest Roundtable is another example of successful collaboration using a roundtable approach. When developing a roundtable approach, care must be taken in developing the governance structure. It is recommended that the CVRD collaborate with KFN in water stewardship (recognizing that KFN is not a stakeholder) as this will support the CVRD, KFN, MFLNRORD in their shared objectives of water stewardship, commitments to UNDRIP, and relationship building. Co-governance can support more effective watershed stewardship, by drawing on the strengths of both communities' knowledge, authority, legal traditions, and perspectives. To select roundtable members, a stakeholder mapping is recommended to clearly identify stakeholders and transparently select who is at the table. To ensure that community members can sustainably participate in the roundtables, it is recommended that producers (and other roundtable members, as needed) are enabled to attend meetings remotely.

Recommendation #2: Enhance Land Use Planning to Protect Watershed Health and Agricultural Water Supplies

<table>
<tr><th>Actions</th><th>Details</th></tr>
<tr><td>2A. Align planning and development policy with watershed stewardship and vision for the watershed</td><td>There is a need to align land use zoning and planning with water stewardship. It is recommended to utilize planning tools and policy to prioritize agricultural use of ALR land, support food production and food security in the CVRD, and prevent future development from impacting watershed health and reducing the volume of water available for existing users.
There are several tools that can be used including development permit areas (DPAs), zoning, policies, and bylaws.
The CVRD has a Regional Growth Strategy service which may be an option for implementing some of the recommended actions – particularly related to agricultural climate change adaptation.
Relationship with KFN
To move forward in watershed stewardship and reconciliation, it is recommended that any actions to align planning and development tools with the vision for the watershed consider Indigenous knowledge and co-development of policies.
The Province of BC has delegated land use planning authorities to local governments. The ways in which the CVRD manages land use has the potential to impact the rights of the KFN. While the KFN is not in agreement with the delegation of decision-making on unceded land, the KFN recognizes that working collaboratively with the CVRD can assist both in stewarding the lands and waters.
Recommended Actions:
Conduct a review of the CVRD planning tools and policies through a watershed stewardship and agriculture lens. As part of this review, identify gaps in current bylaws and policies, opportunities to address those gaps (e.g., upcoming zoning bylaw updates, etc.), draft language for policies/bylaws, a timeline for implementation (considering the current workplans of the Planning Department), and potential costs. This would be best done through collaboration with the watershed stewardship roundtable/advisory committee and the KFN. The following are potential areas for application of planning tools and policy:
Collaborate with the KFN to consider the groundwater vulnerability mapping in land use planning. The KFN has initiated a project to map groundwater vulnerability (susceptibility to groundwater contamination) throughout the KFN territory. The KFN will also compare groundwater vulnerability to land use zoning to identify areas at risk of aquifer contamination. It is anticipated that the results of this work will include recommendations to protect groundwater quality. The CVRD should utilize planning tools to address recommendations and protect groundwater in areas that have been identified as high-risk. In areas that are highly vulnerable (also likely to be significant recharge areas), land uses that have the potential to contaminate groundwater or significantly reduce recharge should either not be supported or managed in a way that does not negatively impact the aquifer.</td></tr>
</table>

	• Utilize land use planning tools and policy to ensure that agricultural use is prioritized on ALR land. The Agricultural Land Commission (ALC) is involved in land use decisions on ALR land and may permit several non-farm uses on ALR land which have the potential to be significant water uses.[4] Some of the permitted non-farm uses can be prohibited by local governments or subject to conditions, thresholds, or other requirements. It is likely appropriate to reduce some of the permitted non-farm uses in the Tsolum River watershed. There are several ways in which the CVRD could take action to reduce pressures related to residential or commercial/industrial development on ALR land (e.g., update the zoning bylaw to further inhibit non-farm uses on ALR land, update the OCP policies to ensure that any non-farm use on ALR land does not reduce the *volume* of water available, develop Board policy to only support re-zoning applications and water license referrals in ALR or agricultural-zoned land if they are supportive of food production and/or improve the health of the watershed, etc.). Currently, the CVRD's Regional Growth Strategy includes supportive policy language. However, further restrictions could help protect water for agricultural and watershed health. • Given the relatively higher water use in Portuguese Creek, the CVRD may want to use tools to further protect water quantities in this area. Tools such as a Water Conservation Development Permit Area could be used to require, with any new development/re-development, an assessment of impacts on existing water users and/or the use of alternate supplies (e.g., rainwater harvesting). An example of this type of DPA is the RDN Yellow Point DPA. • Given the value of wetlands for maintaining the hydrologic regime and aquatic health, the CVRD may want to utilize planning tools to enhance existing protection of wetlands in new development and re-development (e.g., Aquatic Development Permit Area). • The CVRD may want to require the use of rainwater management practices that increase retention and recharge (e.g., vegetated swales). • The CVRD may want to require further actions to reduce water demand in areas that are currently experiencing water scarcity (e.g., water conservation bylaws, etc.). ***Relevant concurrent activities*:** CVRD planning staff are participants in the development and implementation of the Regional Adaptation Strategies Vancouver Island under the BC Agriculture Climate Action Initiative (BACAI). There are several areas of overlap between this strategy, and recommendations proposed in this report, particularly in the areas of water storage, irrigation management, watershed planning, and riparian area restoration. At time of publishing, there may funding available for partnership in implementation. CVRD planning is also looking to update the Comox Valley agricultural plan (originally developed in 2002). This will unfold over approximately 3-years, and will be informed by an advisory committee, and supported by a contracted coordinator.

[4] https://www.alc.gov.bc.ca/alc/content/alr-maps/living-in-the-alr/permitted-uses-in-the-alr

Recommendation #3: Advocate for the Use of Provincial Water Management Tools to Protect Watershed Health and Agricultural Water Supplies

Actions	Details
3A. Advocate for Use of strong provincial water management tools	Under the Water Sustainability Act, there are several tools that can be utilized to protect watershed health in areas that are experiencing water challenges, including Water Objectives, Water Sustainability Plans (WSP) (which can include the development of an Agricultural Water Reserve), the regulation of domestic use in areas of water scarcity, and the consideration of Environmental Flow Needs.* It is likely that the development of a Water Sustainability Plan (with an Agricultural Water Reserve [AWR] and other actions, as identified in the planning process), and regulation of domestic use would be of value in addressing the current and likely issues related to water scarcity in the Tsolum River watershed.** The Province has indicated that they are more supportive of utilizing tools in areas where there is alignment between local government and First Nations (Jennifer Vigano, personal communication). It is recommended that the CVRD and KFN have a discussion to determine the willingness of both parties to enter into agreement in watershed stewardship efforts. If there is the willingness on the part of both parties, then both parties could approach the Province of BC, identifying the problems that exist in the watershed (both now, and with potential future water use) and how the use of the tools available under the Water Sustainability Act could address those. This work is closely tied to Recommendation #1, as the Province may look for local capacity and alignment with FN priorities when considering where a WSP can work. A more detailed EFN assessment would help inform the development of a WSP or be a recommended action. ** While a full description of these tools is beyond the scope of this project, there are several resources that can provide further details on how they may be used to support water management in places like the Tsolum River watershed.* *** An AWR can reserve water for the future by including water both currently allocated to agricultural properties and water for lands in the ALR that do not currently have water rights. Unlike a water license, where a license holder must use the water or lose rights to it, an AWR reserves water for the future. An AWR provides some incentive for conservation because if water demand is reduced through water conservation, the water saved will be available for agriculture in the future. An AWR can only be created through a Water Sustainability Planning (WSP) process. A WSP is powerful water management tool that must be supported/approved by the Province. A WSP is a new tool, and it is expected that to develop a plan is a lengthy (and likely costly) process. If an AWR was created, it is recommended that the volumes of water required by agriculture, identified in Table 3 of this report, are used.*

Recommendation #4: Support Producers and the Community in Water Management and Watershed Stewardship

Actions	Details
4A. Develop and implement watershed communications and outreach	While local organizations currently provide watershed-education in schools (e.g. the CVRD's Connected by Water campaign for the Comox Lake watershed), there are many ways in which further watershed education can help adults (and children) develop a deeper understanding of the watershed and better understand how to protect it. Recommended communications topics include rural land stewardship, the value of agriculture, the importance of beneficial management practices, the relationship between agriculture and the environment, the value of wetlands and wetland restoration, the inter-relationship of people, place, and ecology in the watershed (e.g., archeological sites on farms). Communications materials could be shared through print and online communications materials, in-person engagement, watershed tours, farm tours, watershed signage, private well owner workshops (e.g. WellSmart).
4B: Support producers in developing on-farm water storage options	On-farm storage can help many producers meet irrigation needs throughout the summer, by modulating flows from low producing wells and/or storing early season rainfall. The CVRD could investigate ways to further support producers in developing on-farm storage. Three main barriers to development of on-farm storage are the cost of construction, land availability, site feasibility, and lost revenue. By converting an area of the crop to storage, a producer may lose 10% of their farm income (approximately 10% of the cropped area needs to be converted to storage). If a watershed stewardship service was in place, the CVRD could potentially provide incentives (e.g. rebates) that would help offset the considerable opportunity costs of water storage and support the retention of water and stream augmentation during low flows. However, there are restrictions on the ways in which local governments can support businesses and these would need to be considered. [5] It is important to note that while the Tsolum River has better physical conditions than in many areas for dugout construction, due to the relatively high clay content in soils (to help seal the dugout and allow steeper sides), sufficient depth to bedrock, more available land, and a water table that is often low enough that the dugout is not connected to the aquifer, there are still many sites where a dugout may not be feasible - or may be more expensive - because these conditions are not present. For example, a small 5-acre farm simply would not have sufficient space to create a dugout. Any incentive program that is developed should recognize that water storage solutions (and costs/incentives required) vary by farm. A large farm would require a larger dugout (costing \$100,000-\$500,000) a medium-sized farm would require a medium-sized dugout (costing \$20,000-\$100,000), and a small 5-acre vegetable farm may only have room for a few cisterns (costing \$2,000-\$10,000). The Province recently created an update Water Storage Factsheet, that will be a valuable resource for producers considering storage (MAFF, 2021).

4C: Variety Trials	It is recommended that the CVRD, CVFI, MAFF, and BACAI collaborate to identify crop varieties (especially forage crops) that require less water and may be suitable for the Tsolum watershed, to help producers adapt to changing climate. Collaboration with the BC Cattlemen's Association is recommended.
4D. Assist existing users in licensing their wells	The results of the technical studies suggest that it will likely be challenging to obtain a water license in the Tsolum River watershed in the future – particularly in the Portuguese Creek subwatershed. There is a limited window in which existing users can apply for a license (an existing use application has a greater chance of approval than a new license application). It is highly recommended that existing users apply for a license ASAP to secure water access on their property. There is already significant messaging encouraging producers to license their wells, but some well owners are hesitant. As the deadline approaches, there will likely be producers who want to apply for a license but need support with the application process. MAFF staff have offered to lead a workshop. As the deadline approaches, it is recommended that the CVRD/MFLNRORD/MAFF collaborate to assist producers in completing their applications (as was done in Phase One).
4E. Support home and business practices that protect watershed health	There are many ways in which residents and industrial, commercial and institutional (ICI) property owners can protect water quality and quantity. It is recommended that practices to improve watershed health are promoted, supported, and incentivized. Home and business practices may include water conservation, rainwater harvesting, septic system maintenance, appropriate hazardous materials disposal and storage, etc. The groundwater vulnerability mapping developed by the KFN can be used to identify areas at greater risk of groundwater contamination. Then a water stewardship program staff could work with landowners in highly vulnerable areas to implement improvements that protect groundwater quality.
4F. Support additional beneficial management practices (BMPs) on farms that improve	There are a range of beneficial management practices (BMPs) that can be used on farms to support both watershed health and agricultural production. Examples of BMPs include riparian area management, water storage, off-stream watering, vegetative buffers, drainage management, irrigation improvements, manure management improvements, etc. The Environmental Farm Plan (EFP) process, delivered by the Agriculture Research & Development Corporation (ARDCorp), helps producers identify both environmental strengths and potential risks on their farms and provides guidance on the most appropriate BMPs for their property. Producers who develop an EFP can apply for funding to complete a range of more specific management plans on their farms (e.g., water management plan, nutrient management plan, riparian management plan, etc.). These plans provide further guidance for each farm.

[5] The Local Government Action, Section 273 states that a Board "must not provide assistance to an industrial, commercial or business undertaking."(Local Government Act, RSBC 2015, c. 1.) While at times this has been interpreted that local governments can provide assistance, as long as the assistance is offered fairly to all businesses and there are clear eligibility criteria, so that no one business is favored over the other, the CVRD would need to speak with a lawyer to better understand limitations. It may be possible to administer such a grant program (if desired) through a community organization (e.g. Farmer's Institute). However, the funding for grants would have to have a source, and as a local government, the source would be through taxation (Joshua Craig, personal communication).

watershed health	Every year BMP funding is released to encourage producers to implement BMPs identified in their EFP. The funding is highly competitive and there are some BMPs for which the available funding is small compared to the cost of the BMP (e.g., In the 2021 BMP program, the funding to support dugout construction covers 50% up to $10,000, a relatively small amount compared to the $150,000-$500,000 it may cost to construct a dugout for a large property) (BC ARDCorp, 2021). In Ontario, several local governments, through a 'Rural Water Quality Program' provide 'top-up' funding to the EFP BMP program, to help further incentivize improvements that support water quality (GRCA, 2021). If the CVRD was to support producers in implementing BMPs, it would make sense to follow a similar approach and support selected BMPs that were identified in a farm's EFP and/or related management plan and that are of benefit in the Tsolum watershed. Support for BMPs could take both the form of financial incentives and extension activities. The following provides information on BMPs that were identified in this planning process as particularly relevant for the Tsolum watershed: **Water Storage:** This BMP is a top priority in the Tsolum River watershed and for this reason, is a separate recommended action (**4B**). **Soil Health Enhancement:** Much of the soil in the Tsolum watershed requires some form of enhancement to support production. With increased drought, it will be increasingly important to maintain and enhance soil health to support production with the same or less water. Opportunities to enhance soil health and increase soil water holding capacity should be explored. Enhancing soil health can be beneficial to the environment and make sense economically. Some practices that improve soil moisture holding capacity require less inputs and improve production. Many producers are not currently irrigating, and as less water is available in the summer with climate change, it may be more financially sound to invest in practices that improve soil productivity, than irrigation systems. A compendium of BMPs to improve soil health could be developed and practices shared with producers and/or piloted in the Tsolum River watershed. There are producers in the Tsolum who are very experienced with managing soil health in the watershed, and so an approach that involves collaboration and sharing between producers is recommended. It is important to ensure that soil enhancement practices are not detrimental to water quality (e.g., increase herbicide use). **Accessing Soil Amendments:** In the watershed, nutrients get washed away in winter/spring, and the acidic soil needs constant inputs. Many larger producers use soil amendments to support productivity with limited water but are having increasing difficulty accessing soil amendments (such as lime). Support in accessing soil amendments could help increase production without increasing the need for more water supplies. **Drainage management and water reuse:** Drainage management can play a significant role in improving productivity without adding additional water. Improved drainage management enhances plant health, reduces the need for inputs, and can lengthen the growing season, so that producers are able to get on the fields while there is still precipitation to

	water plants. Tile drains have been effectively used in the Tsolum to create some of the most productive ground in the valley. While tile draining lowers the level at which water is stored in the soil, it only lowers it a small amount, and in return, it causes roots to grow deeper, and makes plants stronger, healthier, and live longer. It prevents plants from dying every year and reduces the need for reseeding and plowing. By combining tile drains with storage and reuse (in a way, water recycling), producers can significantly increase the volume of water available. While water recycling can be challenging and costly, several local producers in the Tsolum have used it very effectively as their dominant water supply source in summer. **Irrigation system upgrades:** Opportunities to provide additional support to producers to assist with inspecting and upgrading irrigation systems should be explored. While the Environmental Farm Plan program currently provides some funding for irrigation system upgrades, if a CVRD watershed stewardship service were in place, the CVRD could provide top-up funds, which would, for a very low cost, provide a significant incentive for water conservation enhancement. *Note: Large-scale producers in the watershed already use the most efficient irrigation systems possible on their property. Many forage producers are unable to use central pivots, as local properties are long and narrow, and pivots are not possible. The use of drip systems is not appropriate on forage and pasture. As the landscape is not intensively irrigated (e.g. approximately only 10 large-scale producers irrigate, plus smaller fruit-veg producers with much lower water requirements) this was seen as a lower priority action than the others.* Note: Agricultural Environmental Management (AEM Code): On February 28, 2019, a new regulation called the Code of Practice for came into effect. The core applies to all agricultural operations in BC and sets requirements to reduce impacts of agriculture on aquifers and watercourses. Regional agrologists and industry associations are working to inform producers of the requirements. Conforming to these requirements will support improved watershed stewardship.
4G: Restoration of hydrologic function: riparian areas and wetlands	**Riparian areas: Increase tree cover and habitat in riparian areas and ditches:** Tree cover can reduce stream temperatures, reduce nutrients, turbidity, stability of streambanks. It is recommended that farmers institutes, the MAFF, TRRS, DFO, Mosaic, and CVRD collaborate to support the addition and maintenance of tree cover in riparian areas. There are several examples of collaboration between local government and producers to enhance riparian cover on rural land (GRCA, 2021). Supporting natural vegetation in ditch areas is also recommended. Many ditches have been manicured and trimmed, reducing the natural vegetation, habitat, and wildlife populations. This has reduced the complexity and diversity in the environment and altered the hydrologic regime, reducing the sustainability of the watershed and its ecosystem. In the Indigenous understanding, biodiversity and complexity lead to sustainability (Ron Frank, personal communication). **Wetland preservation and restoration:** Wetlands support groundwater recharge, slow/filter surface water runoff, support migratory birds, and provide wildlife and aquatic habitat. It is recommended that the CVRD, CVFI, MIFI, MAFF,

	TRRS, Mosaic, and KFN work together to identify priority areas and the best way to restore wetlands to support the hydrologic regime and watershed health. One way to identify potential wetland areas for restoration is to reach out to producers and ask them to identify areas on farms that are low lying, almost permanently wet, and unproductive. In areas that are under-productive, there is likely a good financial case to be made for taking them out of production and protecting them if a tax credit or incentive was available. It may be helpful to work with a conservation organization to arrange/cover the cost of a covenant. **Slowing runoff:** There are many structures that have been created throughout the watershed to collect and transport surface water runoff and reduce groundwater recharge (e.g. roads, ditches). The CVRD should work internally through Planning, and with large landowners (e.g., Mosaic), MoTI, etc. to identify and pursue opportunities to slow surface water runoff. **Other practices to increase retention and storage of water in the landscape:** There are a range of other actions that can be taken to increase storage and retention of water in the landscape to support recharge. Examples include vegetation and forest management to increase storage, fragile land retirement (where key areas of land such as groundwater recharge areas, steep slopes, areas of standing water, floodplains, etc. are taken out of agricultural or forestry production to enhance recharge), etc. These could be explored in collaboration with technical experts, KFN, and the roundtable. **Approach:** There are a range of restoration activities that can be taken to protect water quality, quantity, and timing of flow. It will be important to identify and prioritize investments, to understand which investments of time, capacity, and money will be most effective in protecting groundwater quantity, quality, and timing of flow. A KFN principle is that everything is connected. Human activities on the landscape create webs of interaction – some positive and some negative. In the western science tradition, this is viewed as cumulative effects. Restoration should be tackled by working with the roundtable to understand webs of interaction and identify the best place to invest restoration efforts. The TRRS has created a new sub-group, called TWIG – the Tsolum Wetland Interest Group that would be interested in collaboration. One additional recommendation that was made was to incentivize environmental stewardship by providing producers who take good environmental stewardship actions with greater access to water. While this may be a challenge to bring into practice, it would be an interesting way to support improved environmental health and the sustainability of agriculture in the watershed.

Recommendation #5: Improve Understanding of the Watershed

Actions	Details
5A. Monitor groundwater levels	Currently there is no monitoring of groundwater levels in the Tsolum River watershed. Groundwater levels in aquifers should be actively monitored and the monitoring data should be regularly updated and analyzed to determine the cumulative impacts of extraction and use. The location of monitoring wells should consider present and potential future needs as well as proximity to streams to monitor impact on EFNs. It would be ideal if the CVRD and MFLNRORD could work together to expand the provincial observation well network to include an observation well in the Tsolum River watershed. There may be opportunities to collaborate on this, For example, through a watershed stewardship service, the CVRD could apply for infrastructure funding to drill an observation well. The CVRD could connect with MFLNRORD and ask if a well in the Tsolum would be a desired addition to the provincial observation well network. If so, the CVRD could work with MFLNRORD staff to identify a suitable well location(s). This could be advantageous for both organizations, as the CVRD could assist by providing a dedicated monitoring well in a suitable location and the MFLNRORD could assist by collecting and reviewing data. A 'B-level' network could also be developed to obtain more detailed information on groundwater levels within the CVRD. The CVRD and KFN could work with volunteer private well owners to monitor groundwater levels by installing water level loggers in unused wells or volunteer domestic wells. If a watershed stewardship service were established, this work could be led by the CVRD (other organizations have limited authority/funding for more localized monitoring). The provincial government has developed a tool to store and share water data, called the Real-time Water Data Tool, which should be used to store data, if possible. If possible, groundwater level monitoring should occur throughout the CVRD, as the aquifers in the Tsolum extend outside watershed boundaries and there is value in monitoring groundwater levels throughout the Regional District. Potential partners include the KFN (through the KFN stewardship programs), TRRS, CVCP, MIFI, and CVFI.

5B. Monitor surface water levels	Discontinued river gauges should be reactivated. New gauges should be installed immediately upstream of the confluence of major tributaries and at the discharge point of any areas of interest. Gauges should utilize continuous monitoring. Monitoring should be done using equipment and methods that are suited for measuring low flows. Portuguese Creek is a priority tributary for a new gauge. It is different from other branches of the Tsolum in that it is a larger, seasonal stream, uniquely located on the east side of the Tsolum River watershed with no snow storage and has high water use. It is more difficult to develop a synthetic hydrologic record for Portuguese Creek, so actual data is helpful. Flow monitoring data should be stored in the Real-time Water Data Tool. It will be important to work with Water Survey of Canada and Province on surface water monitoring to ensure that the data is of a suitable quality and can be useful in provincial water management. The MFLNRORD has supported stewardship groups in other areas to monitor streamflow and should be contacted to identify partnership potential. TRRS has been working with BCCF since 2012 collecting water flow data that is analyzed by BCCF and forwarded to FLNRO. Where appropriate, a lower-cost citizen science approach could be utilized so that stewardship groups (TRRS, CVCP) and community members can get involved. It will be particularly important to work with MFLNRORD and Environment Canada staff (or a consulting hydrologist) on this to ensure that the data gathered is of sufficient quality to be used in further analysis and support decision-making. For example, the TRRS purchased a FlowTracker 2 ($20,000) to measure flows, after learning that instruments used previously did not collect data that was of sufficient quality. On a more qualitative level, the KFN has used and is considering annual low flow photographic monitoring to develop a baseline understanding of flows, by stream and identify trends over time. So far, they have done a couple photo collections for the whole territory and have found it indicates the effect of upstream land use on flows. ***Update:*** *In light of the findings of this project (the Risk Management Level 3 identified in the EFN assessment), the MFLNRORD will begin monitoring flows in the Portuguese Creek and lower Tsolum in 2021. The duration of monitoring is TBD and is currently estimated to be approximately five years. One objective of the monitoring is to obtain better precision with low flow data on the Tsolum River and Portuguese Creek. The results will be used to develop a rating curve (which relates water levels to discharge) for low flow periods and will allow for easier monitoring in the future.*

5C. Better understand water consumption	Collecting data on water consumption could help validate the water demand estimates, improve the understanding of water consumption, and inform management strategies. There is significant value in better understanding water demand. There was also significant discussion in the development of this plan regarding the value of metering water use and the challenges of obtaining and managing water use data. Many community members shared that there is an incredibly low likelihood of water users (especially larger water users) volunteering to allowing metering of their wells. This has been confirmed through practical experience in other areas. Provincial staff also noted that they currently do not have the resources to collect, store, and analyze large volumes of water use data. While the Province may begin requiring metering with water licenses, the details are yet to be determined. The Province is likely to have greater success in obtaining support, due to its role in licensing, regulation, and compliance. Although the value of obtaining water use data is extremely high, given the practical limitations to implementation and maintenance, and potential for similar action by other levels of government, this recommendation is recommended for implementation after more urgent and achievable recommendations (e.g., groundwater level monitoring).

5D. Understand the impact of forest management on the hydrologic regime (esp. low flows and groundwater recharge)	There is significant interest within the community in better understanding the role of forest management practices on the hydrologic regime. In particular there is significant interest in exploring the relationship between forest harvesting and low flows and groundwater levels. The relationship between forest harvesting and low flows is a growing area of research, particularly with climate change. The impact of forestry activities on watersheds is complex and varies significantly with watershed characteristics (Zhang & Wei, 2021). Research to-date suggests that in rain-dominated watersheds in the PNW, forest disturbance has the potential to increase the severity of summer low flows, due to the high ET rates from rapidly regenerating vegetation, and variation in the volume and timing of snow melt (Segura et. al, 2020; Moore, Gronsdahl, & McCleary, 2020; Coble et al, 2020; Goeking & Tarboton, 2020). These effects are most clearly noted in small catchments with consistent stand ages and a single instance of disturbance (e.g. harvest or fire). The hydrologic response is more complex in larger watersheds, and the low flow response may attenuate downstream, due to a broad range of stand ages in multiple phases of hydrologic recovery (Moore, Gronsdahl, & McCleary, 2020; Coble et al, 2020). Community members expressed a strong interest in better understanding the relationship between forest activities in the Tsolum, in particular, and (if they exist) the ways in which forest management practices can be enhanced to increase groundwater recharge and reduce low flow impacts. The community recognizes the importance of working with private forest managers in this work and requested that Mosaic collaborates in this, but that the research is funded by government to reduce any perceived conflict of interest. The community also expressed an interest in exploring the relationship between forestry activities and high flows in the Tsolum. This has been explored in the past, but there is room for further analysis. If it is possible to evaluate the relationship between forestry and high and low flows, without reducing the quality of the low flow investigation that would be good. However, given the significant interest in understanding the connection with low flows, particularly as climate changes, if funds are limited or focused expertise is required, it is recommended to begin with an investigation of low flows and then further assess the relationship with high flows as a second step.
5E. Monitor surface water and groundwater quality	There is currently no groundwater quality data available in the watershed. The MOE recently completed a draft baseline surface water quality monitoring report that will be available as part of the Environmental Quality Series, once finalized. The results indicate agricultural & residential impacts to surface water in Portuguese Creek. In the future, surface water and groundwater quality should be tested to identify water quality impacts from residents (e.g. septic systems), agriculture (e.g, manure, herbicides), vehicles and transportation (e.g. car tires, hydrocarbons), industrial, commercial and institutional (ICI) use, and other activities on the land. This work could take the form of a water quality survey (e.g., RDN Cassidy-South Wellington groundwater survey), an ongoing community stream monitoring effort (e.g., RDN Community Monitoring Network), and/or the voluntary sharing of water well test results (e.g. RDN private well testing program).

5F. Synthesize existing data: Indigenous Knowledge, Western science, and observational knowledge	The TRRS has led numerous studies and observations of fish and fish habitat in the Tsolum River watershed, covering decades of assessment. In addition, the KFN has knowledge of the watershed that goes back thousands of years. Gathering this information can help create a better picture of the watershed and aquatic environment. **TRRS data**: To identify critical habitats and inform a detailed EFN assessment (if initiated as part of a water license application, Water Sustainability Planning process, etc.), these data should be integrated into a single spatially-referenced dataset including fish and redd observations, locations of potential and confirmed barriers, key habitats, locations of potential thermal refugia, and key restoration sections (as recommended by Remillard and Clough, 2015). This data would allow the development of a map of fish and habitat distribution in the Tsolum River watershed as well as a fish periodicity table. Further details on this recommendation are included in the EFN Report. **Indigenous Knowledge:** To gather information from Indigenous sources, the first step is to work with the KFN to develop a protocol for data sharing and confidentiality. The principles of OCAP (Ownership, Control, Access and Possession) should be used, as some of the data is related to spiritual practices and will be confidential.[6] There is also knowledge of the landscape that can be shared (e.g., swimming holes and fishing areas also have significant cold-water contribution from groundwater). Some of the knowledge is in stories from many years of learning by Indigenous people.
5G. Habitat Surveys	Based on the outcome of the synthesis of existing data (5F), there may be a need to conduct further habitat assessment. Future efforts to survey habitat should be concentrated on areas identified as a priority in the synthesis and follow recommendations in the 'FHAP' section of the EFN Report, incorporating Indigenous knowledge, where possible.
5H. Document flow-related issues	There are anecdotal reports of constraints to fish passage within the Tsolum River mainstem and from its tributaries to the Tsolum River during low flows (provided by TRRS and communities members). However, the extent of these issues and the magnitude of their affect to fish productivity is currently unknown. It would be helpful to document fish isolation and migration issues using a systemic data collection process (e.g. pictures taken with dates and times – if possible, at defined intervals) to assess the magnitude of the problem and support future work. There may be links between this, and the flow monitoring tasks in 5B. See EFN Report for details.
5I. Aquifer characterization and refinement of supply and demand assessment	Further work to better understand the aquifers in the Tsolum River watershed, including groundwater and surface water interactions is recommended. In Phase One of this project, a new aquifer was identified in the Tsolum and this was a big step forward in understanding the watershed. As more information becomes available (e.g., through groundwater monitoring, stream flow monitoring, collection and synthesis of data such as pump tests potentially required as part of a Water Conservation DPA, etc.), it will be possible to refine the understanding of the aquifer including groundwater surface connections, water availability, aquifer stress (through a more refined supply and demand assessment), etc.

[6] https://fnigc.ca/wp-content/uploads/2020/09/5776c4ee9387f966e6771aa93a04f389_ocap_path_to_fn_information_governance_en_final.pdf

Recommendation #6: Improve Understanding of Impacts of Climate Change on the Watershed

Actions	Details
6A. Assess climate change impacts	A quantitative analysis of the potential impact of climate change to the supply side of water cycle and stream hydrology should be completed. Climate change is already affecting hydrology and the effects of climate change have been well-documented on eastern Vancouver Island, with increased summer precipitation, reduced low flows in rivers, and reduced summer precipitation. An assessment of climate change impacts should consider both the impact on low flows and high flows. It is important to consider both low and high flows because high peak flows impact fish as well. High peak flows in the winter cause significant negative impacts, through sediment and bedload transport, bank erosion, infilling of pools in lower watershed (which may not reduce water, but reduces water availability), etc. KFN has some climate change impact assessment information that should be considered and there has been some recent climate modelling work for the Comox Lake watershed by BC Hydro that may be of value.
6B. Investigate combined impact of climate change and forest disturbance on hydrology	An assessment of the combined impact of climate change and forest hydrology should be conducted. This may be appropriate to pair with action 6A. The community recognizes that it is important for Mosaic to be a partner in this work but requested that the study is funded publicly to reduce any perception of bias due to funding sources.
6C. Identify ways in which land use planning and potentially water use should be modified to address climate impacts	Once actions 6A (and potentially 6B) are completed, it is suggested that an assessment of the ways in which land use planning and water allocation policies, as well as other watershed stewardship activities, will need to be updated to consider climate change impacts.

Recommendation #7: Take a Conservative Approach with Future Water Use

If additional water use is proposed, the following recommendations are provided as a consideration for regulators:

Actions	Details
If additional water use is proposed, the following recommendations are provided as a consideration for regulators:	
7A. Consider climate impacts	Consider the impact of climate change on water availability and demand when assessing water license and use approval applications.
7B. Long-term hydrologic records	If additional water use is proposed in areas with EFN Risk level 3, a long-term baseline hydrological record is required according to the EFN Policy. Where sufficient surface water level data is not available (e.g. 20+ years), a synthetic long-term hydrological data time series may be created. For example, historical data exists in the Tsolum watershed but not for the Portuguese Creek subwatershed (and most other subwatersheds).
7C. Hydrological Assessment	If additional water use is proposed in areas with EFN Risk level 3, an intermediate-level assessment of the effects of water use could be used (e.g. the Indicators of Hydrologic Alteration method, Richter et al. 1996). These methods include calculation of ecologically-relevant flow statistics (e.g., low flow statistics) that describe how water use affects streamflow and may affect the aquatic ecosystem.
7D. Detailed habitat assessment	A detailed habitat assessment could be used to quantify the effects of current and potential future water use on aquatic habitat, to inform critical environmental flow thresholds specific to this watershed, and to identify minimum instream flow requirements for incorporation into future licensing decisions.
7E. Set limits on extraction as a percentage of recharge. Adjust limit over time as more data is available	It is recommended to only rely on a certain percentage of the recharge rate as a safe extraction rate and adjust the extraction rates over time as surface water and groundwater is monitored and reviewed. An approach like that presented in the Draft BC Water Science Series: Estimating Groundwater Availability for Allocation in BC should be considered. While the net extraction of groundwater from the Tsolum is a small fraction of recharge, this does not ensure sustainability.
7F. Consider adverse impacts on surface water, aquatic environment, other users	Groundwater extraction from a given source may adversely impact surface water, environmental flow needs or other users. Current or future groundwater extraction should be designed considering these potential impacts. This study was conducted at the watershed scale and does not include the level of detail required to address the potential impacts of individual groundwater users.

7G: Consider Indigenous knowledge	When reviewing water license applications, consider Indigenous knowledge (including Indigenous knowledge around cumulative effects) to ensure there is a sufficient understanding of the resource prior to approving additional licenses.
7H. Revisit unused licenses	There are some licenses in the watershed that are no longer in use. The results of the water demand estimate (e.g. discrepancy between licensed and estimated demand in the lower Tsolum) suggest that unutilized licenses may represent large water volumes. Given that the watershed is already stressed without these uses, it would be helpful to revisit those licenses (as described under Section 94 of the Water Sustainability Act). While it is not recommended that those licenses are revoked, as those licenses are on some of the most productive land in the area, it is important to consider that they are unused and could potentially be updated to consider how much water is needed, using the most efficient equipment that could be utilized on that property.
7I. Ensure compliance with use periods	Ensure new and existing water license holders are not using water outside of allowed windows (e.g. during low flow periods).

Implementation

This plan is a strategic document and further work is needed to guide the implementation of next steps. The following table provides high-level details on the recommended next steps, players, and a very high-level estimate of costs and effort.

The cost of specific recommendations has not been developed in detail. To provide some guidance to the relative costs of the actions, Table 2 includes a cost category estimate. The categories for cost are:

- Very low, less than $20,000
- Low, less than $75,000
- Medium, $75,000 to $250,000
- High, more than $250,000

Some actions would require ongoing funding for several years, whereas others would involve a one-time cost. Actions with annual costs are noted with an (A) after the cost category. When annual budgets are developed and considered, more precise costing of the recommended actions should be undertaken.

An estimated timeframe is also provided. While all the recommended actions are high priority - and in an ideal world, would already be implemented - an approximate timeframe provides guidance on actions that should be taken in advance of others because they provide resources for other actions, are more urgent, or easier to implement. Recommended timeframes include:

- ASAP (ideally, 2021-2022)
- Short-term (2021-2024)
- Medium-Term (2024-2028)

Recommended Action	Next Steps	Primary (P) and Secondary (S) Responsibility	Costs	Timeframe
1A. Establish a local government service to support watershed stewardship efforts	There are several ways in which this could be accomplished. Prior to initiation of any approach, CVRD staff should engage with KFN and municipalities to identify their level of interest in collaboration. One approach could be: 1) Board to direct staff to create a report outlining the pros and cons of a watershed stewardship service. 2) Staff present the report and recommendations pursuing service for CVRD Board consideration. 3) Pending Board approval, CVRD staff initiate development of an Action Plan, developed in collaboration with an advisory committee that identifies what would be covered by the service and how much it would cost. The membership of the advisory committee would need to be carefully considered. If the CVRD and KFN are moving forward with co-governance, this would need to be reflect in the structure and function of the advisory committee. 4) Board directs staff to engage with the community on the concept. Plan is updated, as needed. 5) Staff presents results of community engagement to the Board and recommend proposed method for establishing and funding the service. 6) Confirm method of participating area approval (assent voting, or alternative approval process). 7) Introduce the service establishment bylaw for three readings. 8) Provincial review and approval by Inspector of Municipalities 9) Complete the participating area approval based on chosen method. 10) Adopt bylaw once participating area approval is gained. A full description of the approaches used by other governments to develop and adopt watershed stewardship programs can be found in the Regional District of Central Kootenay Regional Watershed Governance Initiative Report (Metherall, 2020) and is a recommended resource.	P: CVRD S: KFN, TRRS, CVFI, MIFI	Medium. E.g., $150,000 (including staff time and referendum).	ASAP
1B. Roundtable approach to management	The approach taken for the development of a roundtable will depend on the resources that are available and the specific actions that are going to be addressed through the roundtable (e.g. is the roundtable provide ongoing advice on the delivery of a watershed stewardship service? Supporting the	P: CVRD, KFN S: FLNRORD, TRRS, CVFI, MIFI, DFO, etc.	Low (Annual, or 'A')	ASAP

Recommended Action	Next Steps	Primary (P) and Secondary (S) Responsibility	Costs	Timeframe
	development of a water sustainability plan?). As noted in recommendations, prior CVRD experience with Comox Lake watershed and lessons learned from the Area 23 Harvest Roundtable can inform roundtable development. The following steps are common to developing an advisory group. 1) Engage with KFN 2) Conduct stakeholder mapping exercise 3) Develop Terms of Reference 4) Invite membership	Roundtable labelled as AC in this table.		
2A. Align planning and development policy with water stewardship and vision for the watershed	1) Conduct a review of CVRD planning tools and policies considering watershed stewardship and agricultural land and develop an implementation plan. See details in the recommendation for suggested actions.	P: CVRD, KFN	Low-Medium	Short-term
3A. Provincial Tools	1) CVRD and KFN to identify and confirm interest in collaboration. 2) Develop 'problem statement', identifying challenges, and the need for the use of provincial tools. 3) Engage with the Province. 4) Move forward assessing suitability of tools.	P: CVRD, KFN, MFLNRORD	Medium	ASAP
4A. Communications and Outreach	1) Develop capacity and partnerships. 2) Develop and deliver communications and engagement materials and activities. 3) Assess effectiveness and outcomes.	P: CVRD S: KFN, CVFI, MIFI, CVCP, TRRS, MAFF	Low (A)	ASAP
4B. Support producers in developing on-farm water storage	1) Develop funding/capacity 2) Identify suitable allocation and pilot and then deliver incentive program. Note: While a medium amount of funding would be preferable, a Low amount of funding for this action would be more beneficial than none.	P: CVRD S: CVFI, MIFI, MAFF, CAI	Medium (A), potentially Low (see note in Next Steps)	Short-term
4C. Variety Trials	1) Develop funding/capacity. Suggest collaborating with the CAI and BC Cattleman's Association. 2) Develop and deliver program.	P: CVFI, MIFI S: CAI, CVRD, MAFF, BC Cattleman's Association	Very low - low	Short-term

Recommended Action	Next Steps	Primary (P) and Secondary (S) Responsibility	Costs	Timeframe
4D. Assist existing users with the application for a license on their wells	License applications for existing uses are due in March 2022. A workshop prior would assist existing users to apply for a license for the existing use. Contact Stephanie Tam to set up a webinar for producers in the off-season.	P: CVRD, MFLNRORD S: CVFI, MIFI, MAFF, CAI	Very low	ASAP
4E. Support home and business practices that protect watershed health	1) Develop funding/capacity 2) Identify priority areas 3) Develop and deliver program.	P: CVRD S: KFN, residents and property owners, TRRS, CVFI, MIFI	Very low – Moderate (A)	Medium-term
4F. Support additional beneficial management practices on farms that improve watershed health	1) Develop funding/capacity 2) Work with FIs, CAI, and MAFF to understand needs and target audience 3) Develop materials (e.g. workshops, brochure, etc.) in partnership with FIs, MAFF, and industry or academic specialists.	P: CVRD S: CVFI, MIFI, MAFF, KFN, CAI	Very low (A) (outreach) - medium (incentives)	Short-term
4G: Restoration of hydrologic function: riparian areas and wetlands	1) Develop funding/capacity 2) Identify priority areas 3) Develop and deliver program.	P: CVRD, KFN S: CVFI, MIFI, MAFF, CAI, TRRS, private land owners (e.g. Mosaic), MoTI	Low-Medium (A)	Medium-term
5A. Monitor groundwater levels	1) Identify funding source (preferably, through watershed stewardship service) 2) Identify preferred monitoring locations (hire a consulting firm, and/or collaboration between CVRD and MFLNRORD staff). Suggest considering whole CVRD area. 3) Identify suitable (used or unused) wells (or new well drilling locations). 4) Equip/drill wells 5) Upload data to the Real-time Water Data Tool 6) Conduct a review of data every 2-3 years.	P: CVRD, MFLNRORD S: KFN, volunteer private well owners, TRRS, CVCP, CVFI, MIFI	Very low (A); Medium if new wells drilled	ASAP
5B. Monitor surface water levels	1) Identify funding source and potential partners in monitoring (surface water monitoring equipment is typically more costly to install than groundwater monitoring equipment and requires more frequent site visits). Collaborating with TRRS and the KFN is recommended for site work. 2) Identify preferred locations. Portuguese Creek is a priority location.	P: CVRD, MFLNRORD, WSC, KFN, TRRS, CVCP	Low-Medium (A)	Short-term

Recommended Action	Next Steps	Primary (P) and Secondary (S) Responsibility	Costs	Timeframe
	3) Install equipment. 4) Share data via the Real-time Water Data Tool 5) Ongoing maintenance, monitoring, and analysis			
5C. Better understand water consumption	1) Obtain funding source. 2) Meet with MFLNRORD the level of effort the province is investing in this and if monitoring will be required with licensing. 3) Identify priority areas and types of demands to better understand 4) Determine if there are volunteers in those areas with those types of use who are interested in volunteering to have a meter on their well. 5) Implement. While this could be done on an ongoing basis, it is likely that obtain that this effort would involve collecting data for a year or two to use to validate estimates of demand. Note: due to the low likelihood of success of #4, it is recommended that this action is taken after item 5A and several others. (The earlier that groundwater monitoring can begin, the better).	P: CVRD S: volunteer water users, MFLNRORD	Low (potentially annually, A)	Medium-term
5D. Understand the impact of forest management on the hydrologic regime, especially, low flows and groundwater recharge	1)Engage with potential partners (e.g. Mosaic, KFN, MFLNRORD) to determine their commitment to collaboration, funding opportunities, and data sharing. 2) Engage with potential partners (e.g. Mosaic, KFN, MFLNRORD). 3) Move forwards with study.	P: CVRD, Mosaic S: KFN, MFLNRORD, and potentially community groups (e.g TRRS, CVCP, MIFI, CVFI)	Low-Medium	Short-term
5E. Monitor surface water and groundwater quality	This could take the form of a water quality survey (e.g. RDN Cassidy-South Wellington groundwater survey), an ongoing community stream monitoring effort (e.g. RDN Community Monitoring Network), and/or the voluntary sharing of water well test results (e.g. RDN program). Obtain funding and engage with potential partners to determine the preferred approach and next steps.	P: CVRD S: MOE, KFN, Island Health, testing laboratories, CVCP, TRRS, MFLNRORD, Mosaic, CVFI, MIFI, etc.	Low (one water quality survey) - medium (if doing multiple surveys)	Medium-term
5F. Synthesize existing data: Indigenous Knowledge, Western science, and	1) Compile TRRS data 2) Develop protocol for sharing of Indigenous knowledge 3) Engage with the community and FI reps	P: CVRD, TRRS, KFN S: FIs.	TRRS data - Very low; KFN – Low (A)	Short-term

Recommended Action	Next Steps	Primary (P) and Secondary (S) Responsibility	Costs	Timeframe
observation knowledge				
5G. Habitat Surveys	As noted in the recommendation, this work would move forward based on the outcome of 5F, following the recommendations in the FHAP section of the EFN report.	P: CVRD S: TRRS, KFN	Low-Medium	Medium-term
5H. Document flow-related issues	1) TRRS to EFN Report for details.	P: TRRS	Very low	Short-term
5I. Aquifer characterization	1) Engage with MFLNRORD staff (e.g. Regional Hydrogeologist) and KFN to refine project scope. 2) Hire consultant.	P: CVRD, MFLNRORD, KFN	Medium	Medium-term
6A. Assess climate change impacts	Hire consultant	P: CVRD S: KFN, MFLNRORD	Low	Short-term
6B. Investigate combined impact of climate change and forest disturbance on hydrology	Hire consultant	P: CVRD S: Mosaic, KFN, MFLNRORD, potentially TRRS, CVCP, MIFI, CVFI	Low	Short-term
6C. Identify ways in which land use planning and potentially water use should be modified to address climate impacts	Once actions 5E (and potentially 5F) are completed, assess ways in which land use planning and water allocation policies, as well as other watershed stewardship activities, may need to be updated to consider climate change impacts. This would be done by hiring a consultant or through staff investigation.	P: CVRD S: KFN, MFLNRORD, potentially TRRS, CVCP, MIFI, CVFI and broader community	Low	Short-term
Recommendations 7A-7I	These recommendations are for regulators and are encouraged to be considered in future budgeting of monitoring and assessment effort and licensing decisions in the Tsolum.	P: MFLNRORD, water license applicants	Very low – moderate (A)	Ongoing

Conclusion

This document provides guidance on how to better manage water in the Tsolum River watershed so that adequate supplies of clean water will be available today and in the future. This plan is intended to be a living document. By working together - and enhancing the understanding of the watershed through western science, Indigenous knowledge, and local experience – we will develop a better understanding of the watershed and ways in which to support community and watershed health.

References

Agricultural Land Commission. (2019). Information Bulletin 07: Soil or Fill uses in the ALR. Retrieved from: https://www.alc.gov.bc.ca/assets/alc/assets/legislation-and-regulation/information-bulletins/information_bulletin_07_-_soil_or_fill_uses_in_the_alr.pdf

Agricultural Land Commission. (2021). Permitted Uses in the ALR . Retrieved from: https://www.alc.gov.bc.ca/alc/content/alr-maps/living-in-the-alr/permitted-uses-in-the-alr

Associated Engineering Services Ltd. (1976). Wolf Lake Study. For the Department of the Environment Fisheries and Marin Service. Provided by the Tsolum River Restoration Society.

Bank of Canada. (2021). Inflation Calculator. Retrieved from: https://www.bankofcanada.ca/rates/related/inflation-calculator/

BC Agricultural Research & Development Corporation (BC ARDCORP). (2021). Canadian Agricultural Partnership: Beneficial Management Practices 2020/21. Retrieved from: https://ardcorp.ca/wp-content/uploads/2020/03/BMP-List-2020-21-March-2020-1.pdf

BC Assessment. (2018). Land Use Data compiled by the CVRD.

Brandes, O.M., Simms, R., O'Riordan, J., & Bridge, G. (2020). Towards Watershed Security—The Role of Water in Modernized Land Use Planning in British Columbia. Victoria, Canada: POLIS Project on Ecological Governance, Centre for Global Studies,
University of Victoria. Retrieved from: https://poliswaterproject.org/polis-research-publication/towards-watershed-security/

Climate & Agriculture Initiative BC. Vancouver Island. Retrieved from: https://www.bcagclimateaction.ca/regional-project/cw08/

Climate Adaptation Strategies. (2017). Economics of Supplemental Irrigation. Retrieved from: https://www.cattlemen.bc.ca/docs/irrigation_fact_sheet_3_economics_2017-10-17.pdf

Comox Valley Regional District. The Comox Lake Watershed – Connected By Water. Retrieved from: https://www.comoxvalleyrd.ca/watershed#:~:text=Connected%20by%20Water%20is%20a,protection%20and%20water%20conservation%20efforts

Comox Valley Regional District. Comox Valley Sewer Service Liquid Waste Management Plan. Retrieved from: https://www.comoxvalleyrd.ca/projects-initiatives/past-current-projects/comox-valley-sewer-service-liquid-waste-management-plan

Goeking, S.A., Tarboton, D.G., 2020. Forests and Water Yield: A Synthesis of Disturbance Effects on Streamflow and Snowpack in Western Coniferous Forests, Journal of Forestry, Volume 118, Issue 2, March 2020, Pages 172–192, https://doi.org/10.1093/jofore/fvz069

Grand River Conservation Authority. (2021). Rural Water Quality Program. Retrieved from: https://www.grandriver.ca/en/our-watershed/Rural-Water-Quality-Program.aspx

Grand River Conservation Authority. (2021). Forest Management. Retrieved from: https://www.grandriver.ca/en/our-watershed/Forest-management.aspx

Hatchet n Seed. (2018). Water Sources Advantages and Disadvantages. Retrieved from: https://hatchetnseed.ca/wp-content/uploads/2018/08/water-sources-da.png

Kerr Wood Leidal Associates Ltd. (2016). Evaluation of Irrigation Potential in the BC Peace Region. Retrieved from: https://www.climateagriculturebc.ca/app/uploads/PC05-Evaluation-Irrigation-Potential-Peace-report.pdf

KFN. (2020). Depth to Bedrock Mapping in the Tsolum River Watershed. Provided by GW Solutions (with permission from KFN).

Local Government Act, RSBC 2015, c. 1. Province of British Columbia. Retrieved from: https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/r15001_00

Metherall, C. (2019). Tsolum River Agricultural Watershed Plan: Phase 1. Retrieved from: https://www.comoxvalleyrd.ca/sites/default/files/docs/Projects-Initiatives/tsolum_river_agricultural_watershed_plan_-_phase_one_report.pdf

Metherall, C. (2020). Regional District of Central Kootenay Regional Watershed Governance Initiative. Retrieved from: https://rdck.ca/EN/main/services/sustainability-environmental-initiatives/water.html

Ministry of Agriculture. (2013). Agricultural Land Use Inventory for the CVRD. Provided by the CVRD.

Ministry of Agriculture, Fisheries, and Food. (2021). Water Supply Fact Sheet: Guidance on Farm Water Storage. Retrieved from: https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/agricultural-land-and-environment/water/water-supply-conservation/510100-1_farm_water_storage.pdf

Ministry of Community Services. (2006). Improvement District Governance: Policy Statement. Retrieved from: https://www2.gov.bc.ca/assets/gov/british-columbians-our-governments/local-governments/governance-powers/improvement_district_governance_policy.pdf

Ministry of Forests, Lands, Natural Resource Operations, and Rural Development. (2016). Environmental Flow Needs Policy. Retrieved from: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/water-rights/efn_policy_mar-2016_signed.pdf

Moore, R. D., Gronsdahl, S., & McCleary, R. (2020). Effects of Forest Harvesting on Warm-Season Low Flows in the Pacific Northwest: A Review. The Confluence Vol 4 No 1 (2020). doi: 10.22230/jwsm.2020v4n1a35.

Province of BC. (2019). B.C. Declaration on the Rights of Indigenous Peoples Act. Retrieved from: https://www2.gov.bc.ca/gov/content/governments/indigenous-people/new-relationship/united-nations-declaration-on-the-rights-of-indigenous-peoples

Province of BC. (2020). Natural Resource Online Services: Existing Use Groundwater License. Retrieved from: https://portal.nrs.gov.bc.ca/web/client/-/existing-use-groundwater-licence-application

Rain Farmers. (2021). Rainwater Storage Solutions. Retrieved from: http://www.rainfarmerscanada.ca/carat-s-rainwater-storage-tanks/

Regional District of Nanaimo. (2021). Drinking water and Watershed Protection Program. Retrieved from: https://www.rdn.bc.ca/drinking-water-and-watershed-protection

Segura, C., Bladon, K. D., Hatten, J. A., Jones, J. A., Hale, V. C., & Ice, G. G. (2020). Long-term effects of forest harvesting on summer low flow deficits in the Coast Range of Oregon. Journal of Hydrology, Volume 585 (2020). [Online] Available at: http://fews.forestry.oregonstate.edu/publications/Segura_JoH_2020.pdf

Truth and Reconciliation Commission of Canada. (2012). Truth and Reconciliation Commission of Canada: Calls to Action. Winnipeg, Manitoba. Retrieved from: http://trc.ca/assets/pdf/Calls_to_Action_English2.pdf

United Nations. (2007). *United Nations Declaration on the Rights of Indigenous Peoples*. Retrieved from: https://www.un.org/development/desa/indigenouspeoples/declaration-on-the-rights-of-indigenous-peoples.html

Vancouver Island Precast. (2021). Miscellaneous Concrete Products. Retrieved from: https://vancouverislandprecast.com/products/concrete-products/category/23-miscellaneous-concrete-products

Water Investigations Branch, BC Water Resources Service. Hydrology Division Report: Tsolum River – Wolf Lake Near Courtenay. Retrieved from: https://www.for.gov.bc.ca/hfd/library/documents/bib97077.pdf

Zhang, M. & Wei, X. (2021). Deforestation, forestation, and water supply. Science 371 (6533), 990-991. Washington, DC. Doi: 10.1126/science.abe7821

Appendices: Tsolum River Agricultural Watershed Plan Phase Two

Appendix A: Water Storage and Management Options
Appendix B: Water Budget Study for Tsolum River Watershed
Appendix C: Environmental Flow Needs Screening Assessment
Appendix D: Engagement Events

Appendix A: Water Storage and Management Options

On-Farm Water Storage

On-farm storage generally takes the form of a dugout (or dam) or cistern.

In some areas of the Province, producers use shared storage to store water in large dugouts or dams.

In areas of the Tsolum River watershed, some producers have expanded the dimensions of their dug well to create storage and modulate low flows.

Dugouts

Volume of water that could be made available	Medium
Affordability	Medium
Ease of implementation	High
Ease of use	Medium
Reliability	Medium

A dugout is a reservoir or impoundment constructed by excavating into the ground and/or by building an embankment or other modification to the land to collect and store water. Dugouts can be filled with groundwater, surface water, snow melt, rainwater, runoff, or a combination of these. They are used to store water for livestock watering and/or irrigation.

Dugouts in the Tsolum River Watershed

Many producers in the Tsolum River watershed already use dugouts to store water. Ponds in the area are typically dug to a depth of 18-20 feet deep, and vary in width, based on the producer's space and water needs.

Deeper ponds are more desirable than shallow ponds because less water is lost to evaporation, water is better retained at depth where the clay is heavily compacted and there is less growth of cattails and organic matter.

In the Tsolum River watershed, ponds tend to be dug to ~18 feet, as it is the most practical depth for the excavation equipment used locally and most bedrock is at least 20 or 30 feet below the ground in the ALR.[1]

Not all the depth of a pond is usable water. Some water is lost to evaporation (approx. 16" over the growing season) and the water at the very bottom of the dugout will be of such poor quality that it is rated as dead storage and unavailable for use.

Figure 1: Dugout. Source: https://www.bcagclimateaction.ca/wp/wp-content/media/FarmPractices-WaterStorage.pdf

[1] Sources: 1) Personal communications, Trevor Stevenson, Boondock Contracting; 2) Bedrock mapping from Tsolum River Agricultural Watershed Plan: Phase One.

Potential Volumes of Water that Could be Made Available

In the Tsolum River watershed it is estimated that there is approximately 600 ha of land on farmed properties that is currently not in production.[2]

If all this land was converted to medium sized dugouts (16m16mx6m with steep side slopes), it is estimated that 12,000,000m^3 of storage could be made available. More storage (e.g. 97,000,000m^3) could be made available by land clearing.

However, not all farm properties have unused space available for storage. And it is unlikely that all available space would be converted to dugouts.

Financial Considerations

Potential Costs

Construction

The costs to dig a dugout vary significantly because they depend on site conditions. Typically, dugout storage costs approximately \$10-\$20/m^3.

A large cost of dugout construction is related to fill disposal. When a dugout is created, a significant volume of soil and clay needs to be disposed of. It is cheapest if that can be used on the property (or by a nearby producer who needs fill and is interested in paying part of the cost).

Several producers in the Tsolum have installed a dugout that is 16mx16mx6m for approximately \$10,000, by sharing the costs of fill removal and \$20,000 without sharing costs. With steep side slopes[3], that provides approx. 1,000m^3 of storage (or 750m^3 of water, if removing 1m for evaporation and dead storage) at a cost of \$10/m^3-\$20/m^3 of storage or \$13-\$27/m^3 of water.

If the fill costs are not shared, the dugout could cost twice as much, but there may be other benefits. For example, one producer in the Tsolum used the fill from the dugout to elevate their field. They stripped the field of topsoil, put 2' of fill down over the field, and put the topsoil back on. This improved field drainage and directed water to the dugout. But, the additional excavating doubled the cost.

In all cases, it is important that the rules regarding soil or fill use in the ALR are followed.[4]

Equipment

A pump and pipes will likely be needed to transport water from the dugout. The cost varies with application (e.g. how far the water needs to be pumped and the type of irrigation system).

Water Treatment (if required)

Many producers need to filter water to prevent sediment or algae from affecting pumps and irrigation equipment. Dugout water used for drip irrigation must be filtered (a disk filter with a 120 mesh is recommended. Estimated cost: \$250-\$600).[5]

Fencing

Dugouts should be enclosed by a tall (e.g. 8') fence for safety and to reduce liability. The cost to fence a 15m dugout would be approximately \$1,200.[1]

Permits

Depending on the water source (see Administrative and Legal Considerations on the following page), permits may be needed. They would cost: [6]

- Irrigation licence: Irrigation application fee \$150.00, Irrigation licence - \$30 - \$50
- Storage licence: Application fees \$150.00, Annual storage fee \$25 - \$50

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[2] While it is unlikely that all available land on farmed properties would be converted to storage, this shows the maximum amount of available storage on farmed properties if available un-treed land on properties that are currently farmed. This estimate considered all land that is:
-On a 'farm property' (according to BC Assessment)
-Described as 'Available for Farming' (according to the Agricultural Land Use Inventory, 2013), but not currently used for farming, farm purposes (e.g. accessory buildings) or house.
- Bedrock is more than 6m below the surface
-Slope is less than 5%
- Land that is not water
More water could be made available, it properties that are currently not farmed are considered.

[3] Assuming the sides of the dugout have a slope of 2.

[4] https://www.alc.gov.bc.ca/assets/alc/assets/legislation-and-regulation/information-bulletins/information_bulletin_07_-_soil_or_fill_uses_in_the_alr.pdf

[5] Source: Personal communication, customer service representative, Southern Irrigation

[6] https://www.bcagclimateaction.ca/regional-project/cw08/

Liner

Generally, clay holds water well and in the Comox Valley, there is sufficient clay beneath the soil, so ponds are not lined. If a liner was needed, it would increase the cost considerably (e.g. $100,000 for a 1,000$m^3$ dugout). Liners need to be replaced every 10 years (approx.).[1]

Cover

It is not common to cover ponds in the Comox Valley, but a cover could help reduce evaporative losses. Costs vary. It may be cheaper to dig a deeper dugout.

Funding Mechanisms

Current approaches to funding dugouts include:

- Loans
- Assistance through the Environmental Farm Plan (EFP). The 2020/2021 BMP (now fully allocated) includes the following funding supports and caps[7]:
  - Construction of new agricultural water storage dams (30% up to $10,000)
  - Construction of new farm dugouts for water use (50% up to $10,000)
  - Alternative watering systems to manage livestock (60% up to 30,000) and fencing

While it was suggested that the CVRD assist producers by funding small-scale storage through grants or lost-interest loans, the Local Government Act limits the CVRD from providing assistance to businesses.[8]

Administrative and Legal Considerations

There are three main legal considerations when building a dugout:

- Dam Safety Regulation
- Water Sustainability Act (water licenses)
- Liability

"Don't build up the side of your dugout– it just builds up the bureaucracy – and that extra meter just leaks out."[1]

Dam Safety Regulation

Anytime water is stored above grade, it is considered a dam. **It is recommended that producers avoid building a dam, to avoid costly requirements for engineering,**

Water Storage Example #1: 5-acre vegetable with sprinkler irrigation and a 5gpm well*

The BC Agriculture Water Calculator website shows that the annual water requirements for the property are 5,112m^3.

A well produces 5gpm and supplies 2,800m^3 during the growing season (after 1m^3/day household use).

An additional 2,300m^3 is needed. A 15mx30mx6m (2,700m^3) dugout would provide this, assuming that the dugout is filled with water from runoff prior to the irrigation season (and 1m of depth is lost to dead storage and evaporation losses). It would cost approximately $20,000-$40,000.

Question: Could they avoid building a dugout by installing drip irrigation?

No. But it is still a good idea. According to the BC Agriculture Water Calculator, only 3,999m^3 is needed with drip irrigation and so if they installed drip irrigation, they could install a smaller dugout (1,200m^3). This would save money ($10,000 to upgrade to drip, and $11,000-$20,000 for a smaller dugout) and leave more land in production. Plus, they would have lower water needs in the event there is less water available in the future.

**Example provided by Ted van der Gulik at the Cowichan Water Storage and Management workshop (Feb 2016)*

[7] https://ardcorp.ca/wp-content/uploads/2020/03/BMP-List-2020-21-March-2020-1.pdf

[8] The Local Government Action, Section 273 states that a Board "must not provide assistance to an industrial, commercial or business undertaking." While at times this has been interpreted that local governments can provide assistance, as long as the assistance is offered fairly to all businesses and there are clear eligibility criteria, so that no one business is favored over the other, the CVRD would need to speak with a lawyer to better understand limitations. It may be possible to administer such a grant program (if desired) through a community organization (e.g. Farmer's Institute). However, the funding for grants would have to have a source, and as a local government, the source would be through taxation. It is unclear if there is support within the community for a new local government service with taxation authority, that provides grants to producers to implement water storage. It is not recommended that local governments participate in lending, as they are not designed for that purpose (Joshua Craig, personal communications, Sept 21, 2020).

maintenance, construction, inspections, and maintenance under the Dam Safety Regulation.[9]

If a dam is the best or only option on the property, consult provincial water licensing and dam safety staff for guidance. It is simplest if the dam is classed as a 'minor dam' (storing less than 10,000m^3 of water, with a side less than 7.5m, and limited/no downstream consequences if it fails).

Water Sustainability Act

Dugouts do not require a licence if water is collected from runoff on the property.

If the water in the dugout comes from the ground (e.g. the bottom of the dugout or a well) or a surface water source (e.g. pond, river, spring), then a water license is needed for the volume removed from the source. A water license is also needed for storage.

For example, if building a dugout and topping up with groundwater, a producer would need to be have a water license for irrigation on the well (if the producer does not yet have a license, complete an existing use groundwater license application) and apply for storage license.

THE EASIEST WATER TO GET PERMISSION TO USE IS THE WATER THAT YOU CURRENTLY USE.

Producers have until March 1, 2022 to complete an Existing Use Groundwater License Application. After the deadline, it may be difficult to get a license for irrigation in the Tsolum watershed.[10] Well owners are encouraged to apply ASAP.[11]

Liability

Dugouts create a safety risk on the property. Children and livestock should be kept out of the dugout area by reliable, high fencing. A flotation device should be in the pond.

Operational and Maintenance Considerations

For a full list of operational and maintenance concerns, consult the BC Farm Dugout Manual. Key issues and concerns include:

Pump and Filter: A dugout generally requires the use of a filter and pump system with ongoing maintenance needs.

Maintenance: Dugout should be maintained to support water quality and reduce algae growth. Supplemental flows (e.g. from a well) can help improve aeration. If dugout is sealed (not recommended), the seal will need maintenance.

Table 1: Dugout Pros and Cons[12]

Pros	Cons
Improves water security on property	Reduces funds available for other farm projects
Fire control	Liability and safety issues
Can modulate flows from a low yielding well	Removes land from production
Warmer, biologically active water	Some water evaporates (more if shallow)
Adds value to property	Requires maintenance
Enhances habitat for predatory insects	If pond leaks (rare in area), it can be very costly to fix
If used for stock watering, can protect riparian areas	Limited by volume of water available on property
Can assist with flood control	
Creates wildlife habitat	

Water Storage Example #2: 5-acre grape with drip irrigation and a 10gpm well**

The BC Agriculture Water Calculator website shows that the annual water requirements for the property is 3,700m^3. A 10gpm well supplies 5,454m^3 over the 120-day growing season.

Question: Do they have enough water?

No. While the well produces 10gpm, the BC Agriculture Water Calculator shows that the grape farm needs **14gpm at peak season**. To make up for this shortfall in peak season, a dugout can be constructed to provide one month's supply at 4gpm. The dugout should store 700m^3 (e.g. 8mx15mx6m). This would cost approximately $5,000-$10,000.

***Example provided by Ted van der Gulik at the Cowichan Water Storage and Management workshop (Feb 2016)*

[9] Source: Personal communications, David Skarbo, MFLNRORD Dam Safety Officer; Personal communications, Trevor Stevenson, Boondock Contracting

[10] Due to limited surface water supplies and connections between groundwater and surface water.

[11] https://portal.nrs.gov.bc.ca/web/client/-/existing-use-groundwater-licence-application

[12] https://hatchetnseed.ca/wp-content/uploads/2018/08/water-sources-da.png

Cisterns

Volume of water that could be made available	Low
Affordability	Medium
Ease of implementation	High
Ease of use	Med-High
Reliability	Medium

Some producers need a smaller volume of water for production and can support their water needs by collecting rainwater and storing it in a cistern. Other producers may use a cistern to help modulate flows from a low producing well (as in Water Storage Example #1).

Potential Volumes of Water that Could be Made Available

Cisterns vary in size, with some of the largest available cisterns holding 6.5 m^3 of water.[13] Some people install multiple cisterns on their property. Water storage in cisterns is costly (per m^3), so the volume of water stored across the watershed would be limited by cost and by fact that it is does not hold enough water for many farm operations.

Financial Considerations

Potential Costs

The cost of a cistern depends on the volume of water stored and site conditions. On average, water storage in a cistern costs from $375-$500+/m^3. For example, a larger, 1,722-gallon (6.5 m^3) cistern costs $2,450.[13]

Funding Mechanisms

Current approaches to funding cisterns include:

- Loans
- EFP Program 2020-2021[14]: Installation of roof rainwater harvesting systems for farm water use (30% up to $5,000).

Administrative and Legal Considerations

There are no permits or authorizations required to install a cistern that collects rainwater. If the cistern is used to collect groundwater for irrigation purposes, then a water license should be held for the groundwater.

Operational and Maintenance Considerations

The cistern does need to be maintained with occasional cleaning.

Water treatment and maintenance will vary based on application. It is important to make sure that the water is of sufficient quality for its intended use (e.g. it should be potable water quality if it is used for fruit/vegetable washing or for irrigating edible parts of plants).

One of the additional benefits of owning a cistern is that it can be used for emergency purposes on property, to store trucked water if needed due to well failure or drought.

Figure 2: Dual tank with aeration, seasonal irrigation pumps, well top-up, and potable water emergency pump. Source: https://eco-sense.ca/tag/rainwater-harvesting/

[13] http://www.rainfarmerscanada.ca/carat-s-rainwater-storage-tanks/

[14] https://ardcorp.ca/wp-content/uploads/2020/03/BMP-List-2020-21-March-2020-1.pdf

Well widening

Volume of water that could be made available	Low
Affordability	Low-Med
Ease of implementation	High
Ease of use	High
Reliability	Low

Some producers in the Tsolum have expanded the diameter of their shallow dug well to create additional storage and modulate flows.

While this is not a conventional approach to on-farm storage, in some areas of the Tsolum (e.g. Merville), the aquifer is composed of shallow unconsolidated deposits with no underlying quadra sand outwash (e.g. till sitting over very low yielding bedrock) and well widening may be a suitable option.

To do this, one would buy larger well rings and excavate the ground around the well. Some well owners also add drain rock around the outside of the well (sealed from the ground surface with clay/bentonite), to increase porosity near the casing.

It is **ESSENTIAL** that any work on a well be done according to the Groundwater Protection Regulation to protect the aquifer and drinking water sources.

Potential Volumes of Water that Could be Made Available

A very limited volume of storage capacity is created when widening a well. For example, if a 20' well was expanded using 72" diameter rings (48" is the max size available locally), it would create 7m^3 of storage.

Financial Considerations

Potential Costs

The cost to expand well size will vary based on well depth and conditions. For example, if widening a 20' deep well as follows it could cost approx. $3,500.

- 48" well rings (39" inside diameter 48" high) cost $425 each[15]
- concrete lid with riser: $420
- cost for excavator, drain rock: variable

Potential Funding

There are no known funding sources for this work. Previously, funding was available from the Water Supply Expansion Program.

Legal and Administrative Considerations

This approach is only appropriate for shallow dug wells. Any modifications to a well should meet the Groundwater Protection Regulation and ensure proper well components (e.g. a surface seal, secure covering) are included. It is necessary to make sure the surface is sealed (using bentonite, clay, etc.) to prevent surface water from entering the aquifer.

If the well becomes wide enough, it could be considered a dugout. But there is no clear guidance on how to distinguish between a dugout and a well.

If the well is close to a stream, it may be connected to that stream and could be considered a surface water source (needing a license), potentially impacting stream health.

Operation and Maintenance Considerations

Water quality is a concern, as any user that obtains water from a shallow well is tapping into a shallow water table that likely has total coliforms.

It is not recommended that producers invest significantly in expanding wells, because shallow dug wells can be unreliable water sources and water levels and quality are highly impacted by precipitation, climate change, surrounding uses, etc.

Figure 3: 48" well casings. Source: https://vancouverislandprecast.com

[15] Source: Personal communication, Colin Rogers, Vancouver Island Precast.

Shared Storage

Volume of water that could be made available	Medium
Affordability	Medium
Ease of implementation	Medium
Ease of use	Medium
Reliability	Medium

Some producers may want to share a larger dugout. This is common in many areas of the province and could be a helpful solution for producers that do not have sufficient room on their own properties for storage. There would be two main ways to organize shared storage:

1) One user would apply for a waterworks license and sell the water to the other users,
2) Each user could each have their own a water license for irrigation (or livestock water) on the source and they could share the 'works' (dugout/dam, pipe, etc.). This is the more common approach.

When a group of producers is sharing the cost of storage, there may be more of a rationale for building a larger storage that is classified as a dam, because the additional costs for engineering, maintenance, and inspections would be shared.

Potential Volumes of Water that Could be Made Available

The volume of water that could be made available would depend on the group's interests and site conditions.

Financial Considerations

Potential Costs

The potential costs would vary based on dugout size and site conditions.

Potential Funding

The EFP funding sources identified in the dugout section may apply to shared works. Contact an EFP advisor for more information.

Legal and Administrative Considerations

Waterworks

If one user ran a waterworks, they would need to adhere to provincial and regional health authority legislation around waterworks. This approach is not recommended due to the liability involved in running a waterworks.

Six or more users in a group:

If there are 6 or more members each with their own water license, the group could form a Water Users Community (WUC) to coordinate the use and maintenance of the storage. There are no costs associated with setting up a WUC.

A WUC can help people organize to share works like a dugout. To help WUCs, the Province provides guidance on procedures and practices and can help address challenges that may arise (e.g. if the group voted to have a fee every year for maintenance and one user stops contributing to maintenance costs, while everyone else is paying, the WUC tools outline the way in which the group can legally intervene and prevent a user from obtaining water).

WUCs are commonly developed in parts of the province where a group of producers want to obtain water from a stream that is a distance away, and want to share the costs of the pipe and storage for transporting water closer to their properties and storing water for summer use.

Five or few users in a group

If there are less than six users, the group would not qualify as WUC, but would ideally work with their lawyers to develop a shared use agreement, outlining how shared works are to be operated, the costs associated with creating and maintaining the shared works, how the costs are going to be divided between the users, etc.

If a group of water users is developing a joint use agreement, they can use the WUC resources as guidance.

They all still need their own water licenses.

Large-Scale Storage

Volume of water that could be made available	Med-High
Affordability	Low
Ease of implementation	Very Low
Ease of use	High
Reliability	Med-High

It may be possible to create large-scale water storage in the Tsolum watershed. However, there are considerable costs and liabilities associated with building a dam to store a large volume of water.

Background

In 1976, a study assessed the feasibility of using Wolf Lake to store water for agriculture and fisheries. The study found that it would be very costly and the work did not move ahead.

In 2007, the Tsolum River Restoration Society (TRRS) conducted a study to identify the potential volumes of water that could be stored by creating dams on lakes in the watershed. The study considered lake area, angle of the surrounding slopes, outlet size, and catchment area (water capture potential).

The study found Wolf Lake to be the most cost-effective option for water. However, there was no work done to assess feasibility (e.g. see if the lake would reliably fill with water to the max dam height), identify costs, or determine if it would be permitted.

Water Body	Volume Stored
Wolf Lake	1,600,000 - 5,100,000
Hell Diver lake	90,000-190,000
Little Lost Lake	450,000-750,000
Lost Lake	360,000-1,200,000
Regan Lake	200,000-650,000
Blue Grouse Lake	650,000-1,750,000
Blue Gr-Regan Confluence	900,000-2,000,000

Table 2: Theoretical volumes of water that could be stored in lakes in the Tsolum watershed

The project did not move ahead because raising the dam would create a high-risk dam and the dam owner did not want the liability.

Wolf Lake

The current dam on Wolf Lake is owned by the Department of Fisheries and Oceans (DFO) and operated by the hatchery. The role of the dam is to store and release water in the late summer and fall to meet minimum flows for fish passage and spawning. The DFO has a license to draw down 9' in Wolf Lake, but only draws down 3-6', because it is required to leave water to protect shoal habitat.

Increasing the size of the dam is not part of the DFO's plan. Increasing storage at Wolf Lake would turn the dam into a 'high risk' dam by both Provincial and potentially international standards. Under the BC Dam Safety Regulation, there are significant costs associated with designing, constructing, operating, and maintaining a high-risk dam.

Mosaic is the landowner around the dam. While they understand the need for water for agriculture and are open to the idea of a dam if it is the best option, they prefer to avoid dam infrastructure due to concerns about worker safety and liability. [16]

The only way that the dam could be raised is if a separate organization was interested in developing a dam and taking on the liability and cost of land acquisition, engineering, construction, operation, maintenance, and inspections of the dam.

The organization would need to gain the support of the DFO (the dam owner), the landowner (Mosaic), and the Province (water licensing and dam safety).

For the DFO to support co-management of the dam, there would need to be a portion of the storage reserved for supporting fish in low flows.[17]

Potential Volumes of Water that Could be Made Available

Table 3 shows the theoretical volumes of water that would be stored in lakes in the watershed.

Increasing the height of the Wolf Lake dam could create the following increased amounts of water

[16] Source: Personal communication, David Beleznay, Manager of Hydrology and Terrain, Mosaic Forest Management.

[17] Source: Personal communication, Nick Leone, DFO; Personal communication, Brian Epps, MFLNRORD; Personal communication, Wayne White, TRRS.

storage: 1m: 1,600,000m^3, 2m: 3,200,000m^3, 3m: 5,100,000.[18] (It is unlikely that 5,000,000m^3 would reliably be stored in the lake, as the lake drainage is relatively small and climate change may alter rainfall.)

However, if the dam at Wolf Lake was built higher, the full volume of increased storage would not be available for agriculture, as a portion would likely be reserved so that the DFO could use its current licensed amount[19] and for environmental flow needs.

Financial Considerations

Potential Costs

An engineering study would need to be conducted to determine the costs. High-level cost estimates were made in 1976 but are very dated (e.g. land costs were $500/acre) and dam regulations are now stricter.

Storage

The costs provided in 1976 ranged from $to 800,000 $15,100,000. Considering inflation alone, the costs would range between $3,600,000 to $69,000,000, or $2.28-$14/m^3.[20] It is likely that costs would actually be higher**,** due to the greater regulatory requirements now and cost of land.

Distribution

The cost for conveyance infrastructure also need to be estimated in an engineering study. It could be ***very roughly*** estimated that the cost for distribution infrastructure would be at least $21,500,000.[21] This would increase unit costs to $16-$18/m^3.

Funding Mechanisms

If the community expressed a strong interest in the CVRD providing an irrigation service and the CVRD Board was supportive of exploring this option, the CVRD could allocate funding (e.g. Gas Tax funds) to

Establishing a New Local Government Service

The following are theoretical steps that would be taken to establish a CVRD irrigation service:

- Community provides a very clear indication that they want the service and are willing to pay the associated costs.
- Board directs staff to conduct a feasibility study. This would include an engineering study that identifies the cost of initiating the service (e.g. building a dam at Wolf Lake and the associated distribution infrastructure), ongoing operations costs (e.g. water service delivery, dam inspections), properties that would benefit, impacts, etc.
- The results of the engineering study should be presented to any affected stakeholders (e.g. DFO, Province, MOTI, Mosaic, etc.) and K'omoks First Nation to obtain their input on the proposed project.
- Present feasibility report and results of stakeholder engagement to the Board and ask the Board if they would like to continue with the concept. If supported, obtain direction to move ahead with community engagement.
- Share information with the community, identifying the costs and benefits of an agricultural irrigation service.
- Report community engagement results to the Board. If supportive, bring forward a proposed service area bylaw.
- Obtain a Board resolution giving first three readings to the financing and service area bylaws and directing staff to proceed with elector approval (either by referendum or alternate approval process).
- Send bylaws and referendum question to the Province for approval
- Hold referendum or alternate approval process.
- On successful completion of the referendum (certified by the Province) hold the final reading of the financing and service area bylaws. A majority vote is needed.
- Move ahead with hiring staff and initiating project and service.

[18] Source: Tsolum River Flooding, Erosion, and Irrigation Investigation, BC Water Investigations Branch, April 1968.
[19] It is estimated that approximately 1,600,000 of the DFO's existing license is unused.
[20] https://www.bankofcanada.ca/rates/related/inflation-calculator/
[21] Assuming 5km of major pipeline @ $244/foot, 15km of arterial pipeline @ $122/foot, 30km of distribution pipeline @ $7/foot, plus pump, power, and other infrastructure for $8 million, with a 15% contingency. Source for cost estimates: https://www.climateagriculturebc.ca/app/uploads/PC05-Evaluation-Irrigation-Potential-Peace-report.pdf

conduct a feasibility assessment. [22] See 'Establishing a New Local Government Service' for further details.

Capital, operating and maintenance costs for a potential irrigation service would be funded through taxes and/or user fees collected from property owners within the service area. Capital costs could be financed through a long-term loan.

If the irrigation service was provided by the CVRD, it may be able to apply for grants from other levels of government.

Administrative and Legal Considerations

Many permits would be needed for the dam and distribution system. Initial considerations include:

Dam Safety Regulation

The dam would be likely be viewed as a high-risk due to the large storage volume and the consequence of a dam failure (to downstream population, fisheries, and properties). There are significant maintenance and inspections requirements for high-risk dams.

If the dam height was increased by 2-3m, the dam may also meet the International Commission on Large Dams (ICOL) criteria (applies to dams greater than 5m high over 3,000,000 m3) and need to be registered and subject to their rules.

Water License

The dam proponent would need to apply for a water license for storage and irrigation and provide a strong rationale for the additional storage.

Water Service Provider

Irrigation districts (aka improvement districts) were once viewed as the type of organization that would be most suited to provide such a service. But the Province now has clear policy against the creation of irrigation districts and has not approved the creation of an improvement district since the 1990's.[23]

The Province views local governments as the organizations best equipped to provide services in rural areas. If supported by the electors and Board, a local government can provide a water service, collect taxes to run the service, borrow money for projects, and apply for grants. At this time, there is no sign that the CVRD should or would take on this role.

Operational and Maintenance Considerations

The operational and maintenance considerations would need to be determined in the feasibility study.

[22] Grant funding for any particular project would be weighed against other CVRD priorities in terms of pursuing grant funding.

[23] https://www2.gov.bc.ca/assets/gov/british-columbians-our-governments/local-governments/governance-powers/improvement_district_governance_policy.pdf

Reclaimed Water

Volume of water that could be made available	Med-High
Affordability	Low
Ease of implementation	Low
Ease of use	High
Reliability	High

Another potential source of water for irrigation is reclaimed water. Reclaimed water from the wastewater treatment plant could be used to provide water for irrigation. Several communities in BC use reclaimed water for irrigation including Kamloops, Spallumcheen Cranbrook, Oliver, communities in the Okanagan, and Dockside Green.

There are two main categories of reclaimed water to can be used for agricultural irrigation:

1) Moderate Exposure Potential (water which the public may come in contact with)
2) Greater Exposure Potential (water that the public is likely to come into contact with).

Currently, water released from the treatment plant is treated to the level of Moderate Exposure Potential and is suitable for irrigation on pastures, nurseries, frost protection, and in orchards and vineyards irrigated with a drip irrigation system.

If the water was treated to a tertiary level (at an approximate cost of $5-$6 million), it would be suitable for use in agricultural crops, frost protection, and crop cooling.

It could be applied by sprinkler irrigation systems, pivots and travelling guns to forage, fibre, nursery, or turf crops, and to crops that will be eaten raw, provided that the water does not contact the fruit or vegetable directly (i.e., drip or trickle irrigation is used) and E. coli is monitored in addition to fecal coliforms.

Potential Volumes of Water that Could be Made Available

Approximately 14,000 m^3/day of water is discharged from the CVRD wastewater treatment plant. This amounts to 2,002,000m^3 over the growing season (May-Sept.). The amount of water available grows as the community grows (e.g. by 2060, could provide 3,388,000m^3 of water over the growing season).

Financial Considerations

Potential Costs

Distribution

Further study is needed to assess the costs of distribution. As with large scale storage conveyance, a high-level estimate would be $20,000,000.[24]

Treatment

If water was treated to a tertiary level, it is estimated that it would cost approximately $5-$6 million.[25]

Funding Mechanisms

This work could be supported through tax dollars and the creation of a new water service (See 'Establishing a New Local Government Service'). Federal and provincial government grants may be available to support a feasibility study and implementation.

Administrative and Legal Considerations

Reclaimed water use must meet the requirements of the Municipal Wastewater Regulation (MWR). A permit would be needed to use water for irrigation purposes. Many permits would be needed for the distribution system (TBD).

There are some restrictions on the use of greater exposure water. Where crops are eaten raw, crop irrigation should be avoided in the short period before harvest. Milking animals must be prohibited from grazing for 6 days after irrigation ceases. Other

[24] It would likely cost a similar amount to distribute water from Wolf Lake. However, with Wolf Lake, there would be the additional cost to build storage with a complex group of stakeholders.

[25] https://www.comoxvalleyrd.ca/projects-initiatives/past-current-projects/comox-valley-sewer-service-liquid-waste-management-plan
2xAWDF is $8 million, but only 1x required.

livestock must be prohibited from grazing for 3 days after irrigation ceases, unless their meat is inspected under the Meat Inspection Act.

The reclaimed water is intended to be used to replace water lost to evapotranspiration (water taken up by plants) and is not intended to recharge groundwater. Because of this, there are limits to the volume of water per area of land that can be used, to ensure that it is not contributing to the aquifer.

Operational and Maintenance Considerations

Operational and maintenance considerations would need to be fully outlined in the feasibility study.

Figure 4: Potential pipeline bringing reclaimed water to Portuguese Creek subwatershed.[25] Image provided by Paul Nash, consultant on the CVRD Liquid Waste Management Plan.

Table 3: Pros and Cons of Reclaimed Water Use

Pros	Cons
Nutrients in reclaimed water proven to increase production.	Not useful for many organic producers.
Reliable water source that grows with population and minimally impacted by climate change.	Groundwater monitoring may be required.
Stream flow augmentation: After peak irrigation use (late Aug-mid Oct), excess water could be released into Portuguese Creek.[26]	Emerging contaminants may be a concern (this is the case for many water sources).
Meets the objectives in the CVRD Sustainability Strategy	
Brings water from the Puntledge to the Tsolum watershed, which may not otherwise not be allowed.	
Makes use of a dam that is already in place (Puntledge).	
Producers would not lose land as they would with on-site storage.	
Golf course could potentially participate.	

[26] Water treatment may be needed to remove nutrients.

Volume of water that could be made available	Low-Med
Affordability	High
Ease of implementation	High
Ease of use	High
Reliability	High

There are several ways in which producers can reduce the volume of water that they need to use on their properties. For this project, two approaches to demand management were considered:

1) Improved management of irrigation systems
2) Irrigation system upgrades:
- Upgrading fruit and vegetable crops to drip
- Irrigating forage parcels > 10 ha with low pressure centre pivots.

Potential Volumes of Water that Could be Made Available

Improved management: Across the Tsolum River watershed, if producers improved their management of irrigation systems by improved scheduling and watering based on weather, soil type, etc., according to the Agricultural Water Demand Model (AWDM), it is estimated that it would result in 2.46% less water needed annually. With current production and irrigation systems, across the watershed, this would amount to 71,837m3 less water being required.

Irrigation System Upgrades: Across the Tsolum River watershed, if irrigation systems were upgraded so that all current fruit and vegetable crops were irrigated with drip systems, and all forage parcels > 10ha were irrigated with low pressure centre pivots, then according to the AWDM, it is estimated that 14.7% less water would be needed annually. With current irrigation systems and crops, that would amount to 418,065 m^3 less of water being required.

Financial Considerations

Potential Costs

Improved management

Many producers can improve their management for free by using irrigation scheduling tools, increased irrigation system inspection and maintenance, etc.

Irrigation maintenance (replacing nozzles) and the use of weather stations and improved irrigation system controls can also reduce demand. Costs vary based on application. An irrigation management plan can also be developed (costs vary).

Irrigation system upgrades

Irrigation system upgrades vary based on conditions, crop, irrigation system types, etc.
On average, installation of a drip irrigation system costs approximately $1,500-$2,000 per acre.[27]
Purchasing a center pivots can range in cost from $60,000 to $140,000, depending on age/options.[28]

Funding Mechanisms

- Loans
- EFP:
  - Weather stations or improved irrigation system management control components (50% up to $5,000)
  - Irrigation Infrastructure Improvement (50% up to $12,500)
  - Irrigation System Replacement (30% up to $20,000)
  - Irrigation System Improvement – Conveyance Ditch (50% up to $10,000)
  - Irrigation management planning (100% up to $1,500)

Administrative and Legal Considerations

No permits required.

Operational and Maintenance Considerations

Operations and maintenance concerns vary with irrigation systems. For example, drip systems have higher maintenance needs than sprinkler systems.

[27] This is based on an estimate of a roll of drip tape costing $162/1,000 feet (personal communication, customer service representative, Southern Irrigation), spaced 4 feet apart. A disc filter with a 120 mesh is recommended, which could cost between $250 and $600.

[28] https://www.cattlemen.bc.ca/docs/irrigation_fact_sheet_3_economics_2017-10-17.pdf

Water Budget Study for Tsolum River Watershed

Prepared for:

Elucidate Consulting

Prepared by:

GW Solutions Inc.

December 2020

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APPENDIX 1:

GW Solutions Inc. General Conditions and Limitations

APPENDIX 2:

Water Budget Reports for Sub watersheds (Agricultural Water Demand Model)

APPENDIX 3:

Water Budget Reports for Sub watersheds (Assessment Boundaries)

BACKGROUND AND OBJECTIVES

Background

GW Solutions was retained by Elucidate Consulting to complete a water budget study of the Tsolum River Watershed ('the Tsolum Watershed'). We understand that this study and its conclusions will ultimately be used by the Comox Valley Regional District (CVRD) for developing an agricultural watershed plan for the Tsolum watershed. The watershed plan will aim to address concerns about current and future water availability for agricultural and instream needs.

Objectives

The main objective of this project was to develop a water budget analysis for the Tsolum Watershed.

The project was completed in two phases.

- Phase 1 was completed in 2018 and involved mainly data compilation and preliminary analysis of the available hydrogeology/hydrology data for the Tsolum Watershed and sub-watersheds.
- Phase 2 (this report) develops a water budget for the Tsolum Watershed and sub-watersheds, with input from Phase 1 and the Province's Agricultural Water Demand Model (AWDM).

Figure 1 shows the Tsolum Watershed and its sub-watershed boundaries at the Assessment Boundary level and Figure 2 shows the Tsolum Watershed and its sub-watersheds at the AWDM scale watershed.

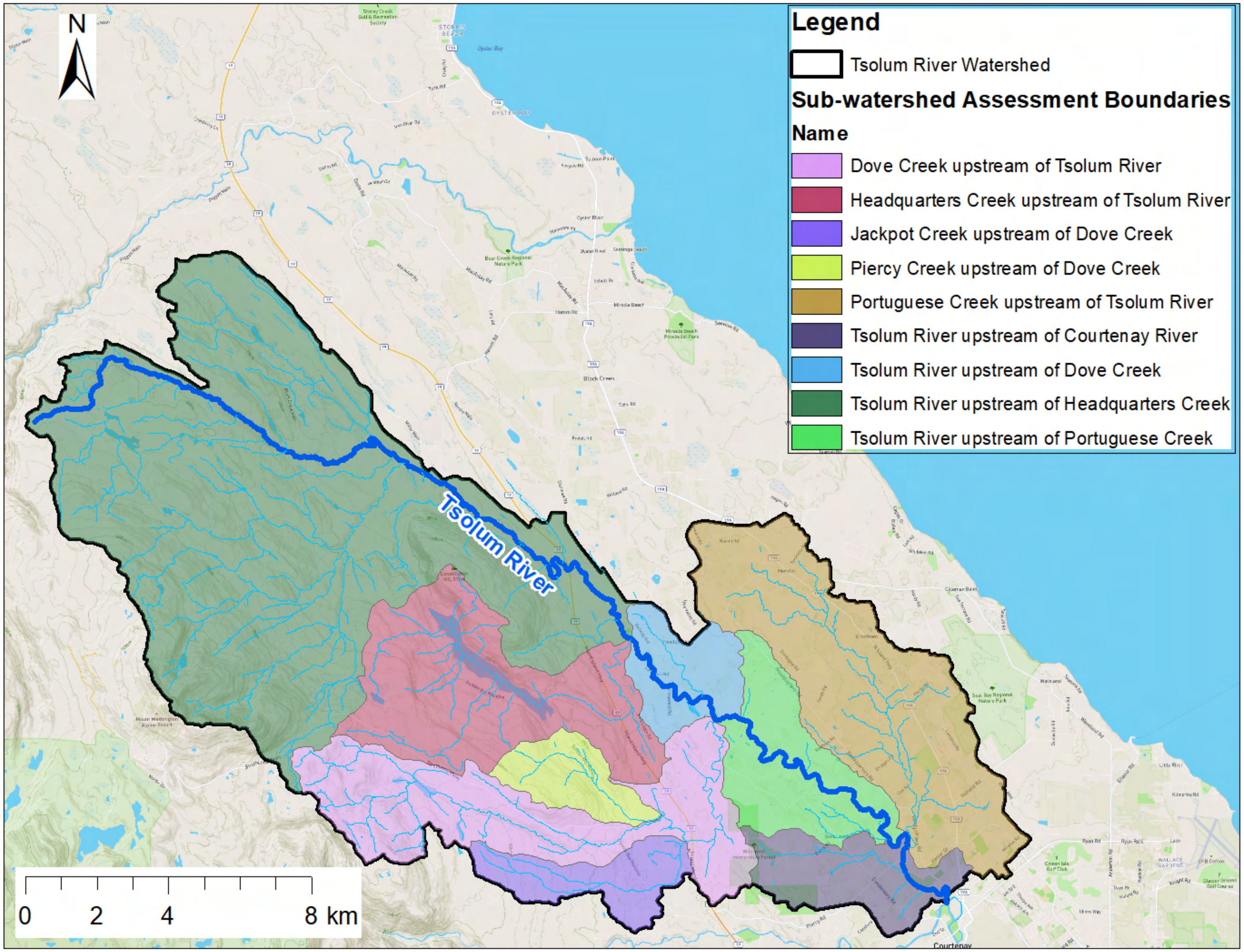


Figure 5: Tsolum River watershed and its sub-watersheds based on the BC Watershed Assessment

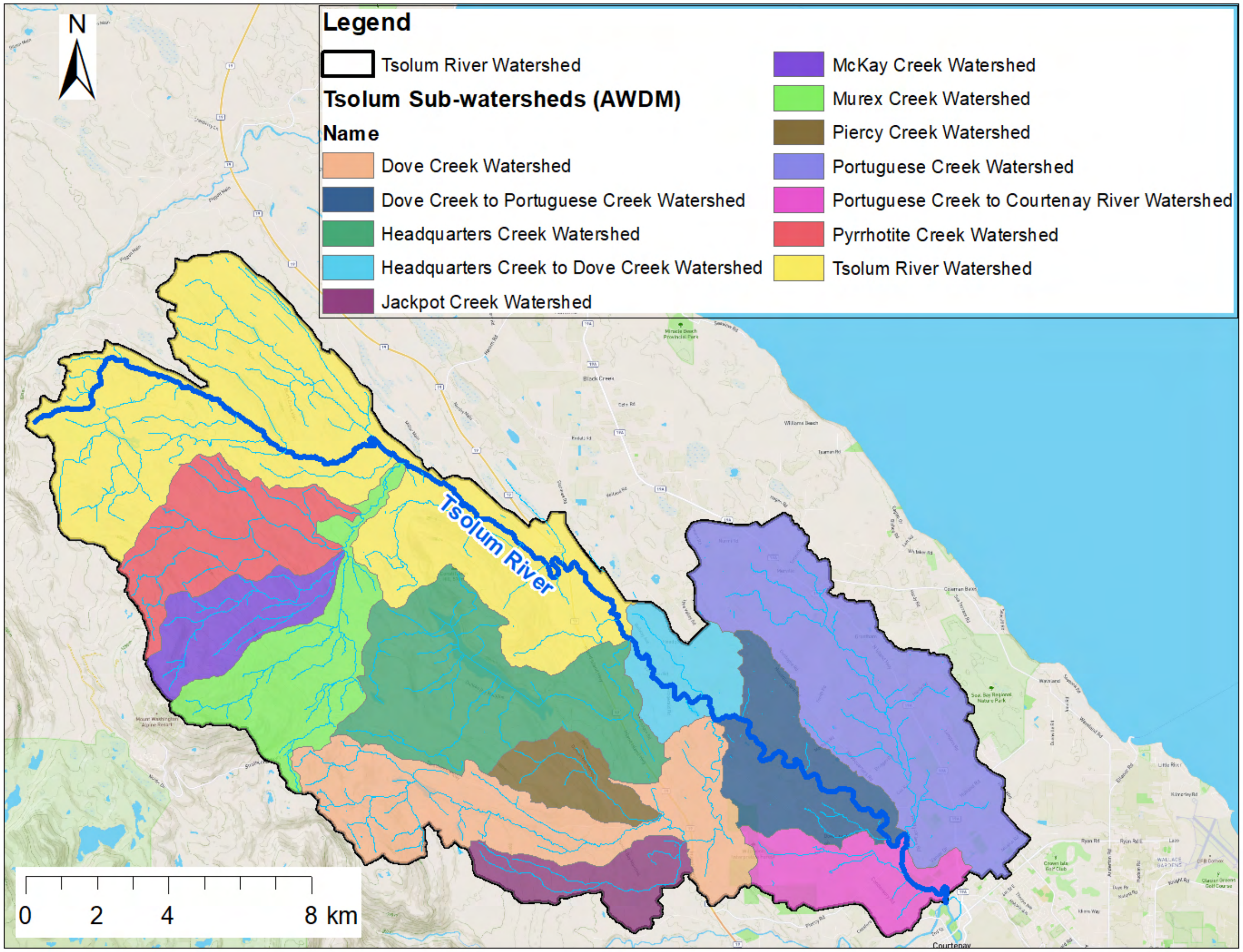


Figure 6: Tsolum River Watershed and its sub-watersheds from AWMD study

Methodology

A water budget methodology has been developed to quantify the monthly amount of water available in the Tsolum Watershed for agriculture and instream flows. The methodology is illustrated with a simplified flow chart in Figure 3.

Data on aquifers properties, water wells, groundwater levels, stream flow and levels, climate variables (e.g. precipitation, temperature), topography, soils, geology, land cover and water demand were collected, reformatted and used for the development of the water budget. These datasets were converted to 20 m x 20 m grids (rasters) for development of a monthly gridded water balance model.

Selection of Water Balance Model

GW Solutions has used an ArcGIS-based water balance model developed by James Dyer from the University of Ohio. The tool estimates monthly potential evapotranspiration using the Turc method, and soil moisture storage, actual evapotranspiration, soil moisture deficit, and soil moisture surplus using the grid-based Thornthwaite-Mather approach.

The main data inputs include a digital elevation model (DEM), soil available water capacity (AWC), monthly temperature (average), precipitation, and solar radiation.

The outputs of the model are described below:

- **Potential evapotranspiration (PE)** represents moisture demand. It is the evaporative water loss from vegetation when water is not a limiting factor. PE depends mainly on temperature and solar radiation.
- **Actual evapotranspiration (AE)** refers to water loss from vegetation given water availability (precipitation and soil moisture storage). If water is not a limiting factor, actual evapotranspiration is equal to potential evapotranspiration.
- **Deficit** represents moisture stress and occurs when the evaporative demand is not met by available water. Water deficit is the difference between potential and actual evapotranspiration.
- **Surplus** is excess water (not evaporated or transpired). Surplus water becomes runoff, or subsurface flow, or a combination of both. Surplus is greater than zero only if soil storage is full.

Methodology

The Thornthwaite-Mather water balance method is used with the following conceptual, logical, and chronological steps:

A. Precipitation – potential evapotranspiration (P-PE):

   a. If supply (P) < demand (PE), plants utilize soil water;

   b. If supply (P) > demand (PE), there is more water than needed by vegetation;

   c. Available water is prioritized as follows:

      i. Plants use what they need (first from precipitation, then from soil storage);

      ii. If there is still excess water, it is used to recharge storage if recharge is not full;

      iii. Any excess water becomes surplus.

B. Calculations begin with soil water storage (ST) assumed to be full (equal to soil available water capacity (AWC)) based on consecutive values of P-PE. It can be assumed that soil storage is fully recharged if the sum of consecutive positive P-PE values exceeds AWC.

C. Change in storage (ΔST) from month to month, resulting from water used by plants (negative change in storage) or excess water (positive change in storage).

D. Actual evapotranspiration (AE) is what plants use. If water is not limited, plants use what they demand (AE=PE).

   a. Whenever storage (ST) = AWC, AE = PE (water is coming from P).

   b. As storage (ST) is depleted, it becomes increasingly difficult for plants to extract the water they need.

   c. When $ST < AWC$, $AE = P + |\Delta ST|$.

E. Deficit (D) = PE - AE.

F. Surplus (S). If ST is full (ST = AWC), there is liable to be “excess precipitation” – plants do not use it all.

   a. If $ST < AWC$, there can be no Surplus.

   b. If ST = AWC, then S = P - AE.

   c. Note that the month when ST reaches AWC, $S = P - AE - \Delta ST$ (excess first went to fill Storage).

G. The balance in water supply and demand at a site can be expressed in two relationships:

   a. PE = AE + D (Moisture demand is equivalent to moisture transpired, plus the “shortfall.”).

b. P = AE + S (Moisture supply equates to moisture transpired plus excess beyond this need).

Note the above logic will hold true for monthly or annual totals (from December to January).

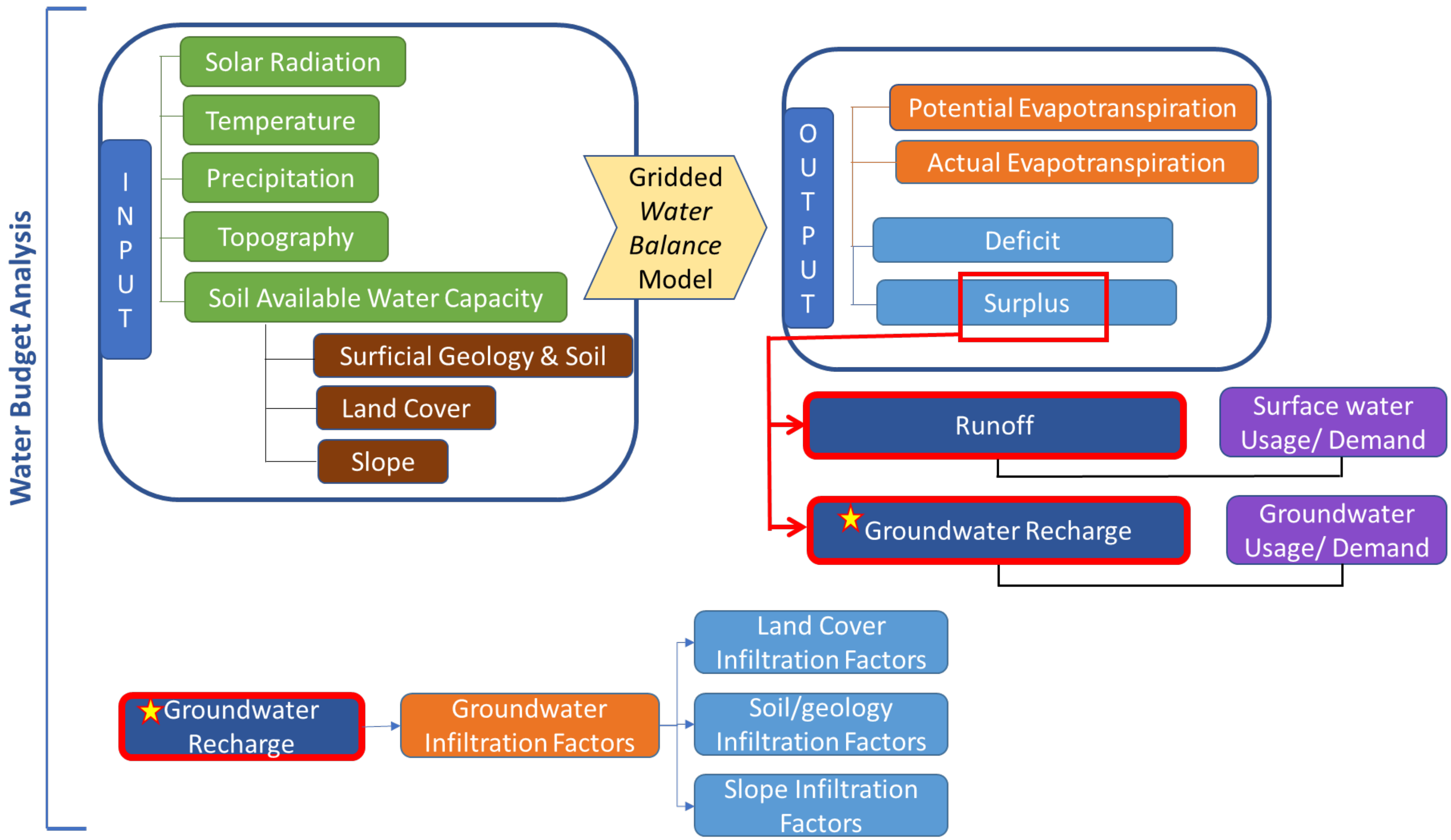


Figure 7: Water Budget methodology

Data collection, review, and integration

Data Type and Sources of Information

GW Solutions compiled the following information sources (Table 1).

Table 4: The data inputs used in the Tsolum Watershed water budget

Data Type	Data Source	Provided by/obtained from
Groundwater levels	Observation Well Network (water levels) from the Province	Ministry of Environment and Climate Change Strategy (PGWOWN Aquarius Database)
Surface water levels and flows	Streamflow and water level data from Water Survey of Canada	Water Survey of Canada (HYDAT database)
	Water level data from Pacfish-Hydromet (sponsored by First Nations, Regional Districts, Provincial and Federal Government)	Hydromet Stations through Pacfish
	BC Hydro	BC Real-time Water Data
Water usage/demand data	BC Cadastral information	BC Province-FLNRORD
	BC Assessment parcel information	BC Province-FLNRORD
	VIHA water supply systems (location, number of connections, use type)	BC Province-FLNRORD
	Spatial map of water service areas	BC Province-FLNRORD
	Ministry of Agriculture 2014 – Agricultural Water Demand Model (conceptual model)	BC Province
Climate	Pacific Climate Impacts Consortium (gridded meteorological information and precipitation data);	Pacific Climate Impacts Consortium
	WorldClim (gridded climate information).	WorldClim
	Current and Historical precipitation and temperature information	Environment and Natural Resources Canada (NRCAN)

Data Type	Data Source	Provided by/obtained from
Elevation	LiDAR data	CVRD
	1:50,000 scale Digital Elevation Model (DEM) available from Natural Resources Canada (NRCAN).	Environment and Natural Resources Canada (NRCAN)
Soil, geology and land cover	Digital surficial geology database for Vancouver Island	BC Province-FLNRORD
	BC Soil Information Tool (regional and local geology and soils information)	British Columbia Soil Information Finder Tool and BC Soil Database
	BC Land Cover, circa 2000-Vector Data	BC Province and Government of Canada
Wells, aquifer properties and mapped aquifers	BC GWELLS database	BC Province
	Aquifer boundaries and map sheets	BC Province

Data Description and Integration

GW Solutions used Tableau and GIS software for data integration. Tableau is a program for data management, analysis and display that can integrate geospatial data as well as time-series information (i.e., water level, water quality monitoring data).

Stream flows and levels

GW Solutions compiled streamflow and stream level information from Water Survey Canada[29] (WSC) and one community (private) station (Figure 4). The WSC data was used to characterize average daily and monthly flows and estimate baseflows. There are two discontinued (08HB089 and 08HB090) and two active (08HB011 and 08HB075) WSC hydrometric stations within the study area. We understand that the community station ("Tsolum1") is active.

The stations were classified based on the available information related to available climate normal data (1981-2010) as shown in Table 2. Information on stream flow and level is limited. One station (08HB011) covers all of the climate normal data period.

Table 5: Hydrometric stations

Area	Station Number	Station Name	Station Data Overlap with Climate Normal Data	Status	Data Range

[29] WSC maintains and operates approximately 213 hydrometric stations on Vancouver Island (59 are active and the remaining 154 are inactive).

Tsolum River	08HB090	Headquarters Creek Above Tsolum River	Less than 50% of 1981-2010 climate normal data	Discontinued	1997-1999
	08HB089	Tsolum River Below Murex Creek	Less than 50% of 1981-2010 climate normal data	Discontinued	1997-2015
	08HB075	Dove Creek Near Mouth	75% to 90% of 1981-2010 climate normal data	Active	1985-2020
	08HB011	Tsolum River Near Courtenay	Complete 1981-2010 climate normal data	Active	1914-2020
	TSOLUM1	Tsolum River Todd Road station	Less than 50% of 1981-2010 climate normal data	Active	2012-2015

Figure 5 to Figure 9 show the historical and average monthly water level and flow in five gauged sub-watersheds. The lowest water level/flow occurs in August and the highest levels are present from November to January.

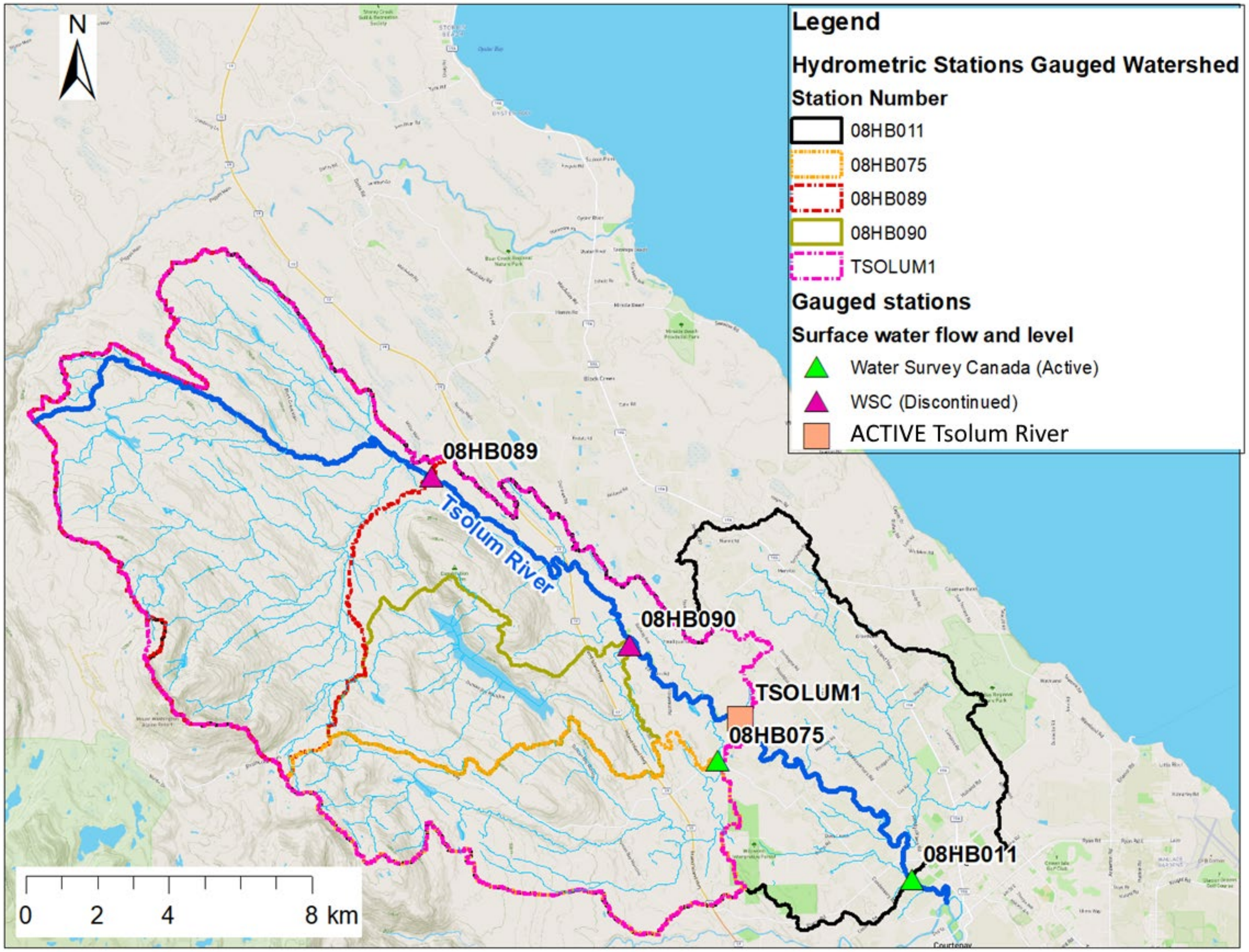


Figure 8. Water Survey Canada gauged hydrometric stations in the Tsolum Watershed

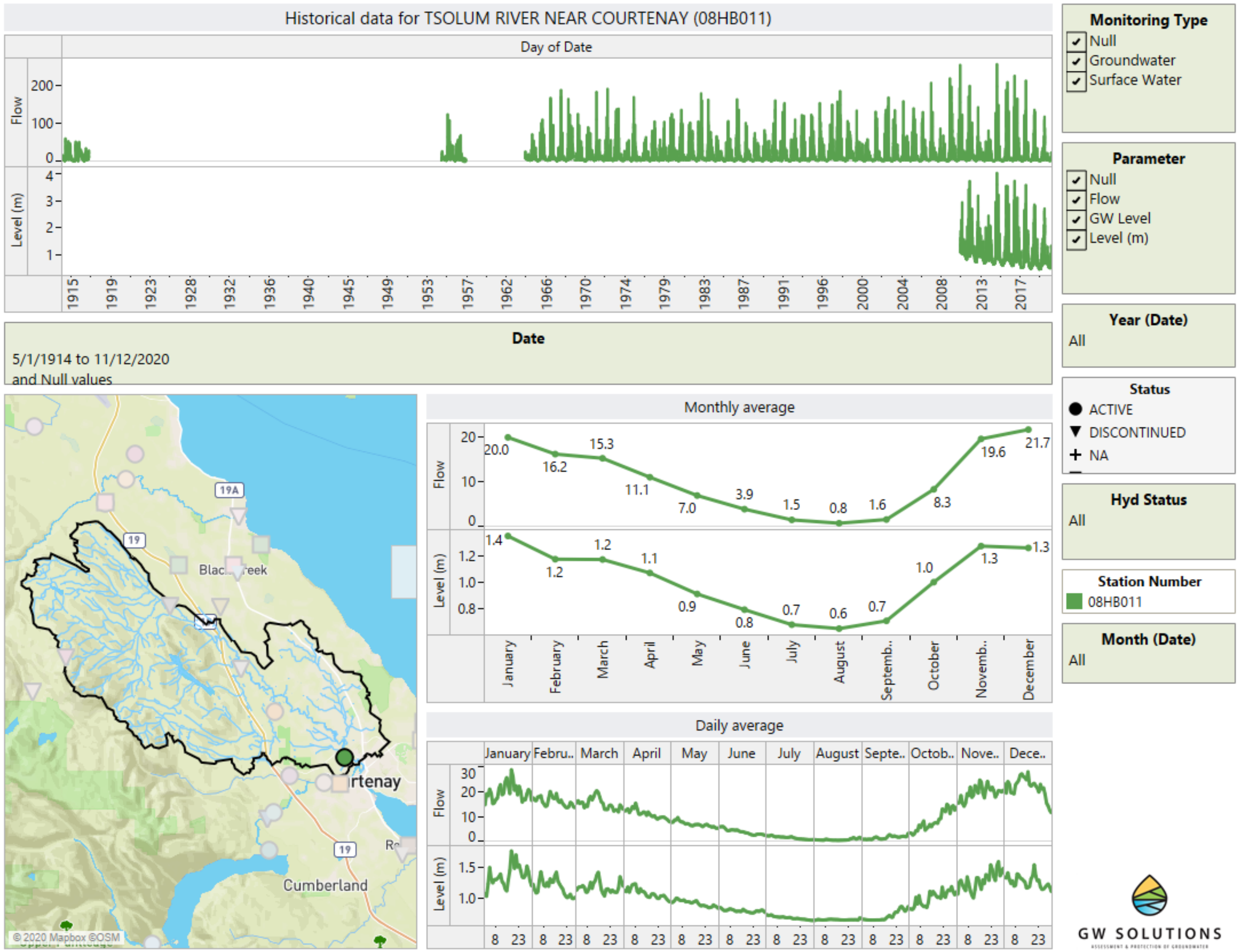


Figure 9. Flow and water level data for Tsolum River near Courtenay Station (08HB011)

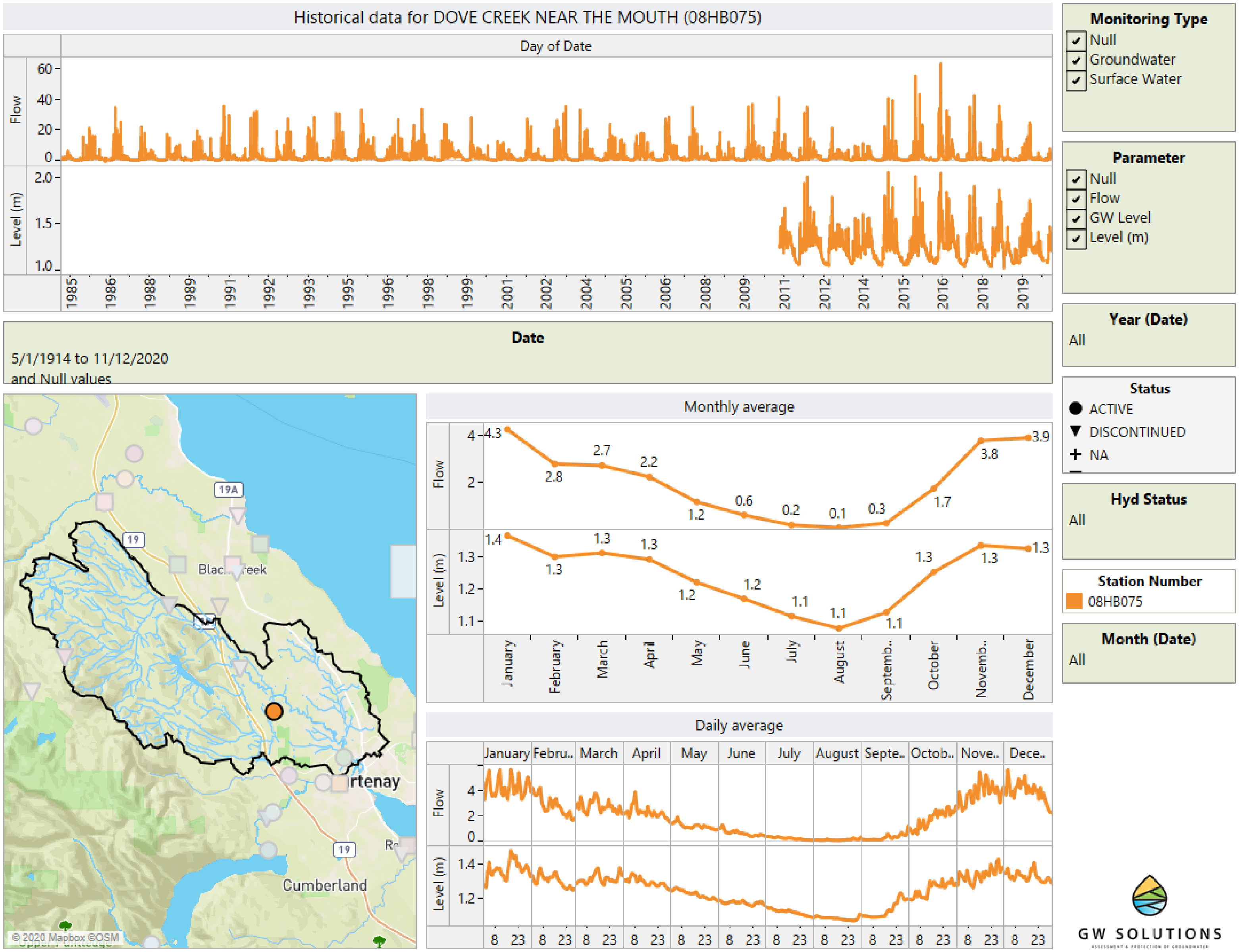


Figure 10. Flow and water level data for Dove Creek near the Mouth Station (08HB075)

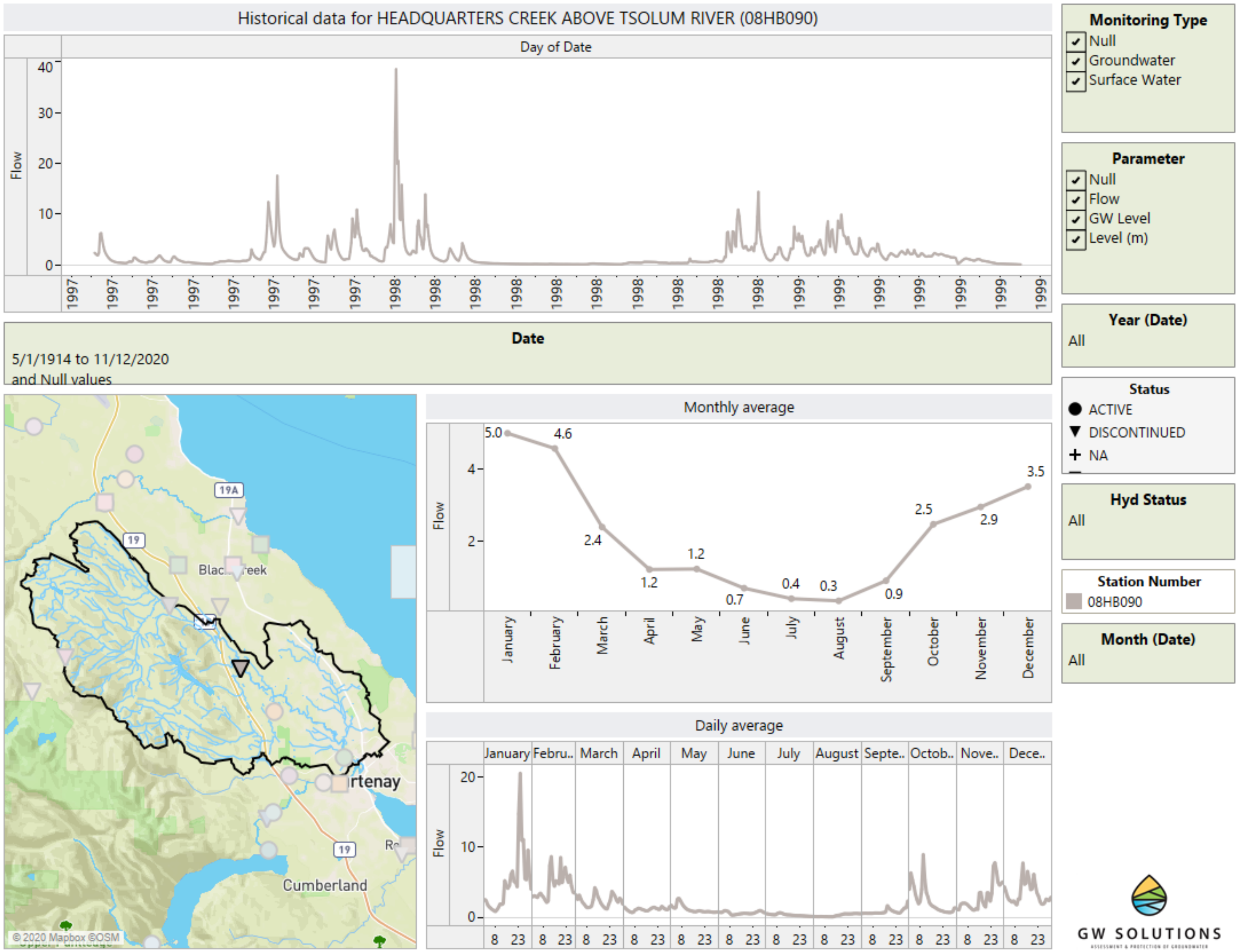


Figure 11 : Flow data for Headquarter Creek above Tsolum River Station (08HB090)

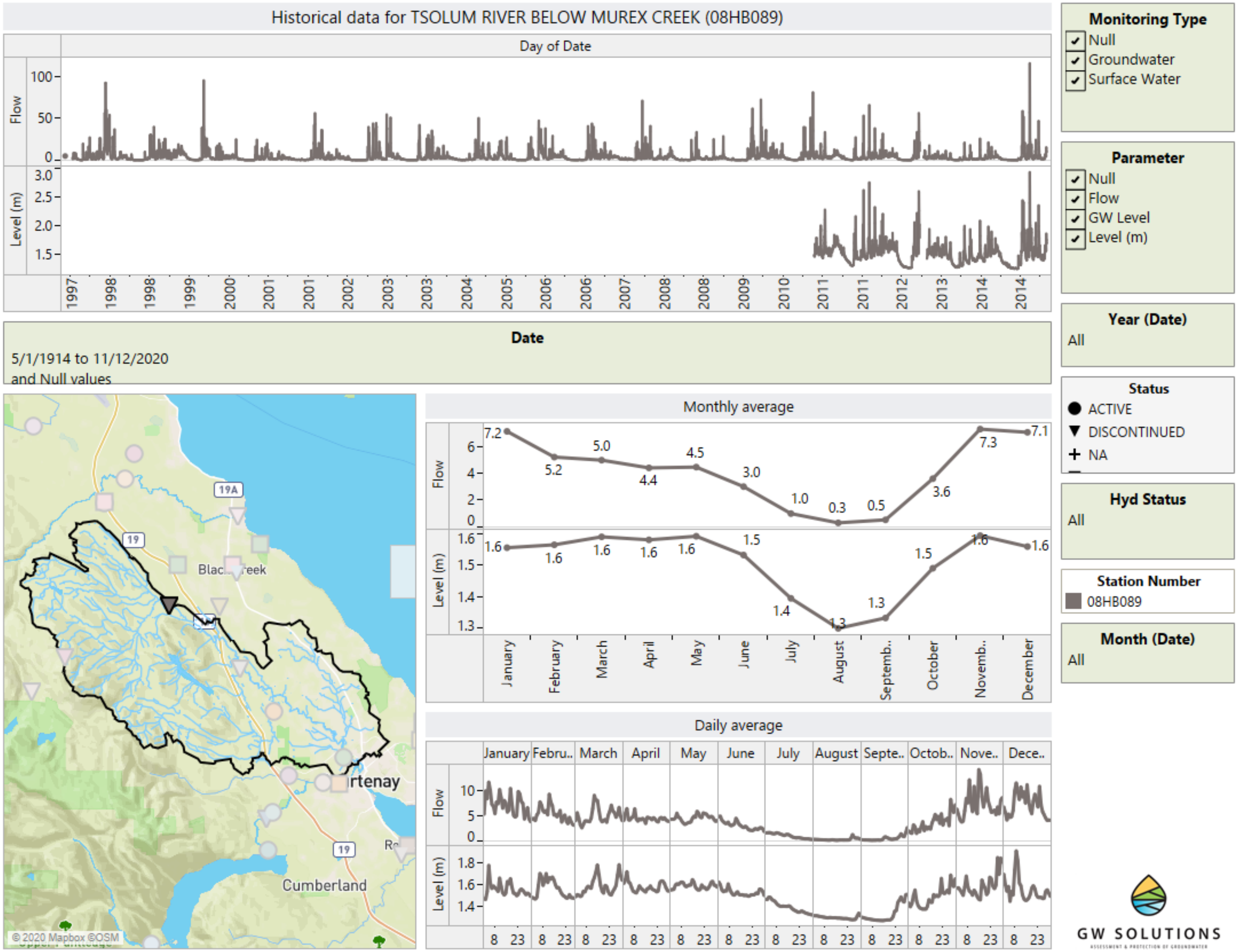


Figure 12: Flow and water level data for Tsolum River below Murex Creek Station (08HB089)

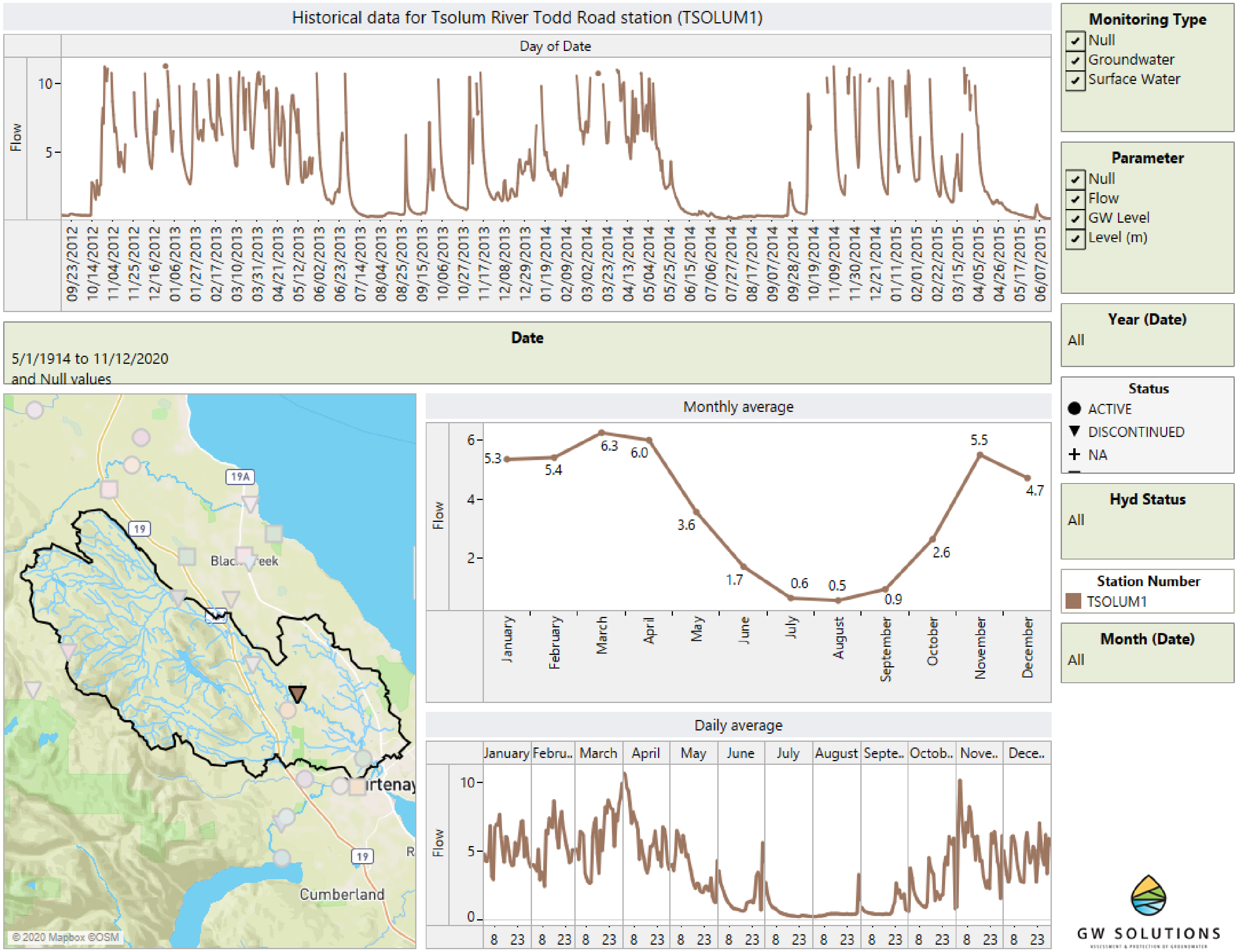


Figure 13: Flow data for Tsolum River Todd Road Station (Tsolum1)

Climate monitoring stations (precipitation, temperature, snow melt, soil moisture, humidity, wind)

The main sources of information for climate monitoring data on Vancouver Island are listed below:

- Environment Canada (EC);
- Agricultural and Rural Development Act Network (ARDA);
- BC Hydro (BCH);
- BC Ministry of Environment - Automated Snow Pillow Network (ENV-ASP);
- BC Ministry of Environment - Air Quality Network (ENV-AQN); and
- BC Ministry of Forests, Lands, and Natural Resource Operations - Wild Fire Management Branch (FLNRO-WMB).

This information has been gathered and standardized by the Pacific Climate Impacts Consortium (PCIC). Climate data for the Tsolum Watershed come predominantly from two sources (EC and ARDA) as shown in Figure 10. Climate monitoring stations mainly record precipitation and temperature (hourly, daily, monthly).

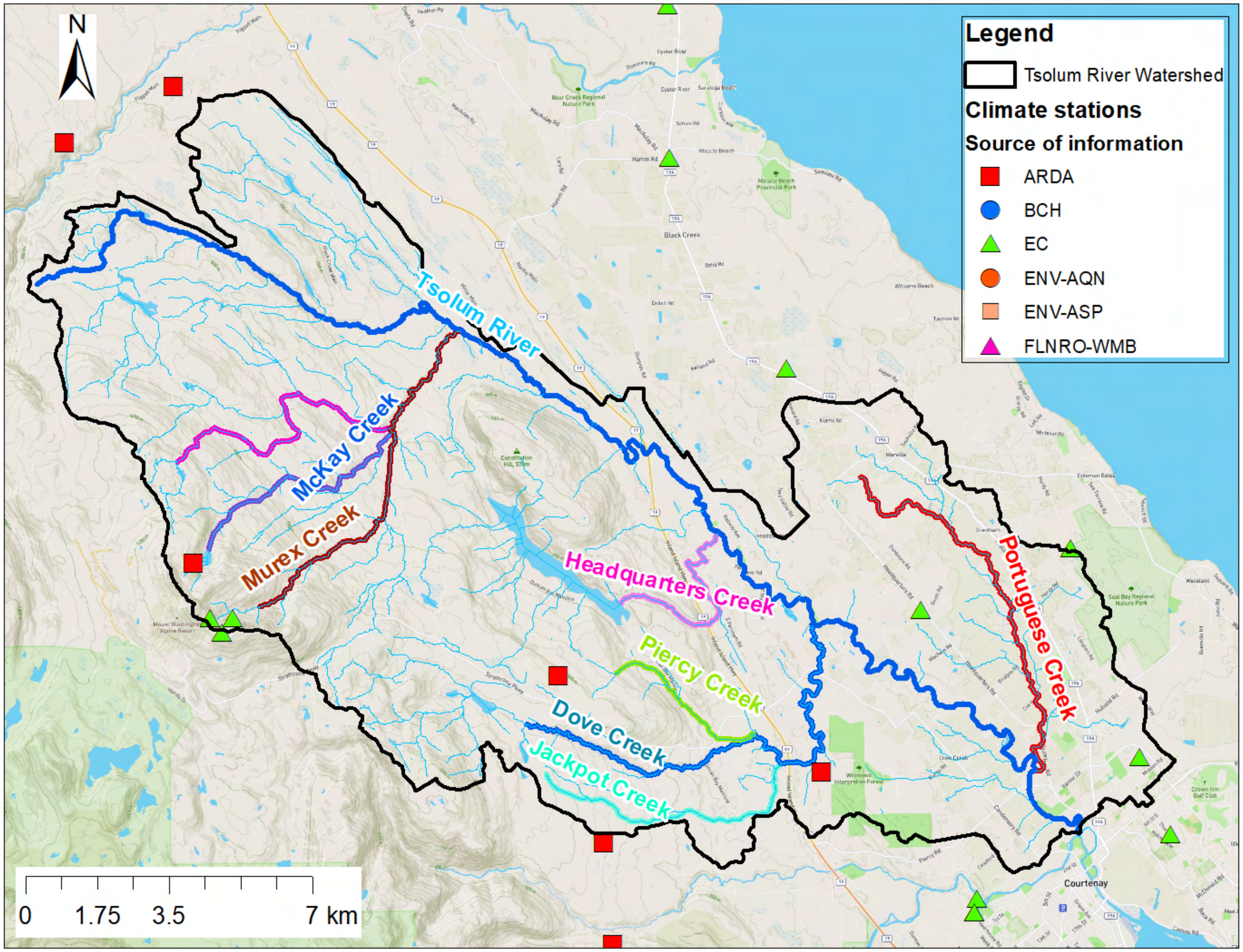


Figure 14. Climate monitoring stations within or near the Tsolum Watershed

Estimation of water demand

The water budget model requires the estimation of monthly and yearly volumes of water withdrawal. GW Solutions developed a methodology to estimate the water demand for the Tsolum Watershed for the Phase 1 (July 2018). Surface water withdrawal rates were taken from the current licensed volumes for both springs and surface water (BC Points of Diversion (POD) database). Groundwater withdrawal rates were estimated using the Cadastral Parcel Map and BC Assessment information (i.e. parcel type), the active wells in GWells database, and water service areas. Also included were groundwater withdrawal rates from small water supply systems that are regulated by Island Health Authority (IHA).

Figure 11 presents the POD locations and types, and water service areas. Some coefficients were estimated based on monthly usage trends for water supply systems on Vancouver Island (i.e. Regional District of Nanaimo, Ecofish Baseline Report, and Rood and Hamilton, (1995) for domestic, industrial and commercial).

Water usage for agricultural purposes including irrigation and livestock was calculated by Elucidate Consulting using the BC Agriculture Water Demand Model (AWDM), and integrated to the water demand component of the monthly water budget.

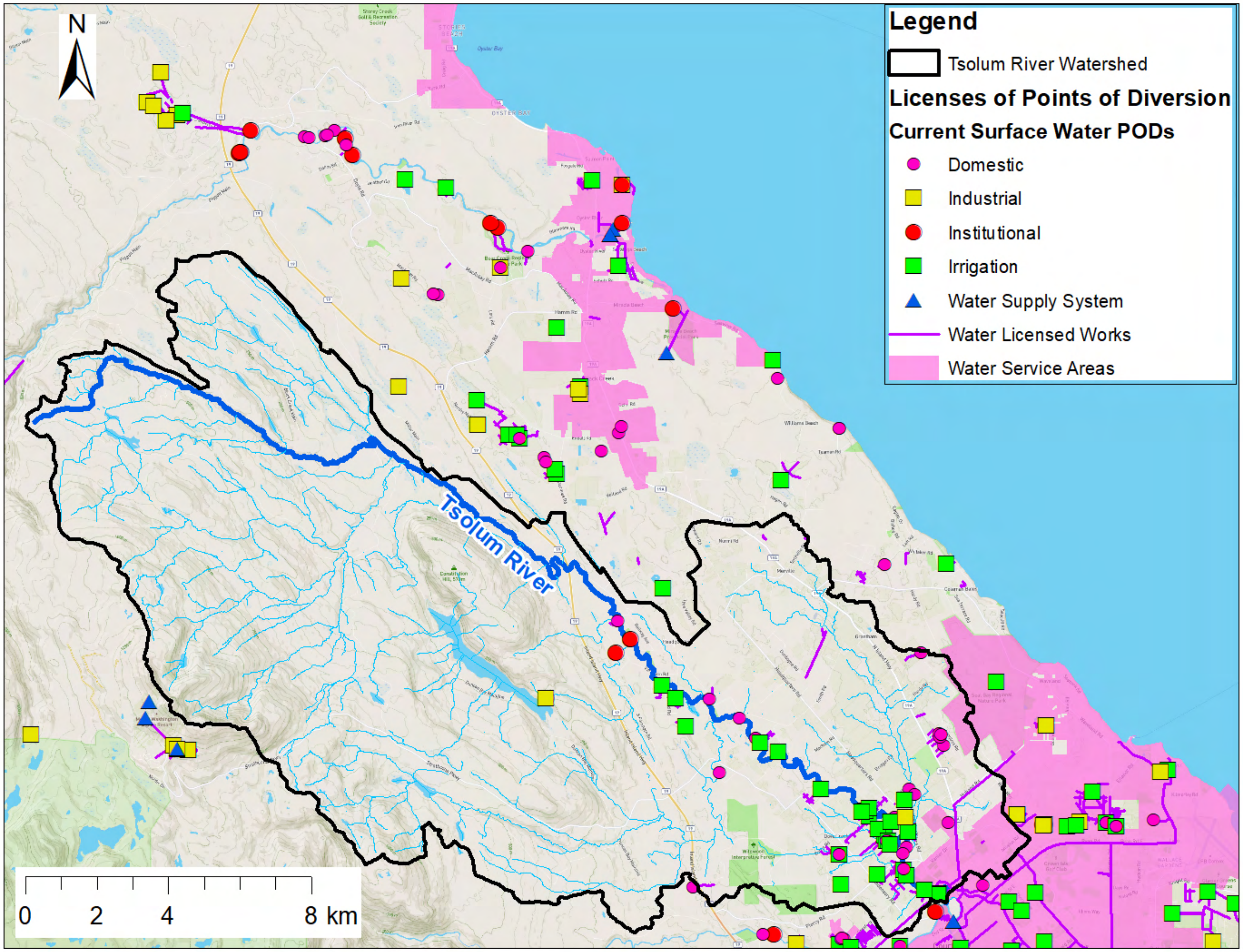


Figure 15. Current Licenses of Points of Diversion, licensed water works and water service areas

Water balance model

Data Inputs

Digital elevation model (DEM), aspect, and slope

Slope (inclination of the ground) and aspect (direction of the slope) were derived from the 1:50,000 scale digital elevation model (DEM) available from Natural Resources Canada (NRCAN). The DEM was scaled to 20 m x 20 m resolution for the water budget gridded model. Figure 12 presents the topography.

Soil Available Water Capacity (AWC)

Soil-related data can be retrieved from the British Columbia Soil Information Finder Tool. The BC Soil database includes soil composition (mineral or organic), soil texture, coarse fragment content, drainage, soil layer thicknesses and characteristics, soil physical and chemical properties, as well as landform and parent material. Soil mapping also includes available water holding capacity at different depths (0.15, 0.30, 0.45, 0.60, 0.75, 0.90, 1.05 and 1.20 m). The model assumes uses the Available Water Capacity at 0.90 m depth. This assumes that 95% of root mass within temperate forests occur within the top 1 m of soil.

Land cover

GW Solutions used Land Cover classification (circa 2000) in vector polygons to derive land cover classes for the water budget model. We have also used updated land cover based on current satellite imagery. Figure 13 presents the land cover for the Tsolum Watershed.

Geology (surficial geology, geomorphology)

The available surficial geology for Vancouver Island was integrated in the model (Figure 13).

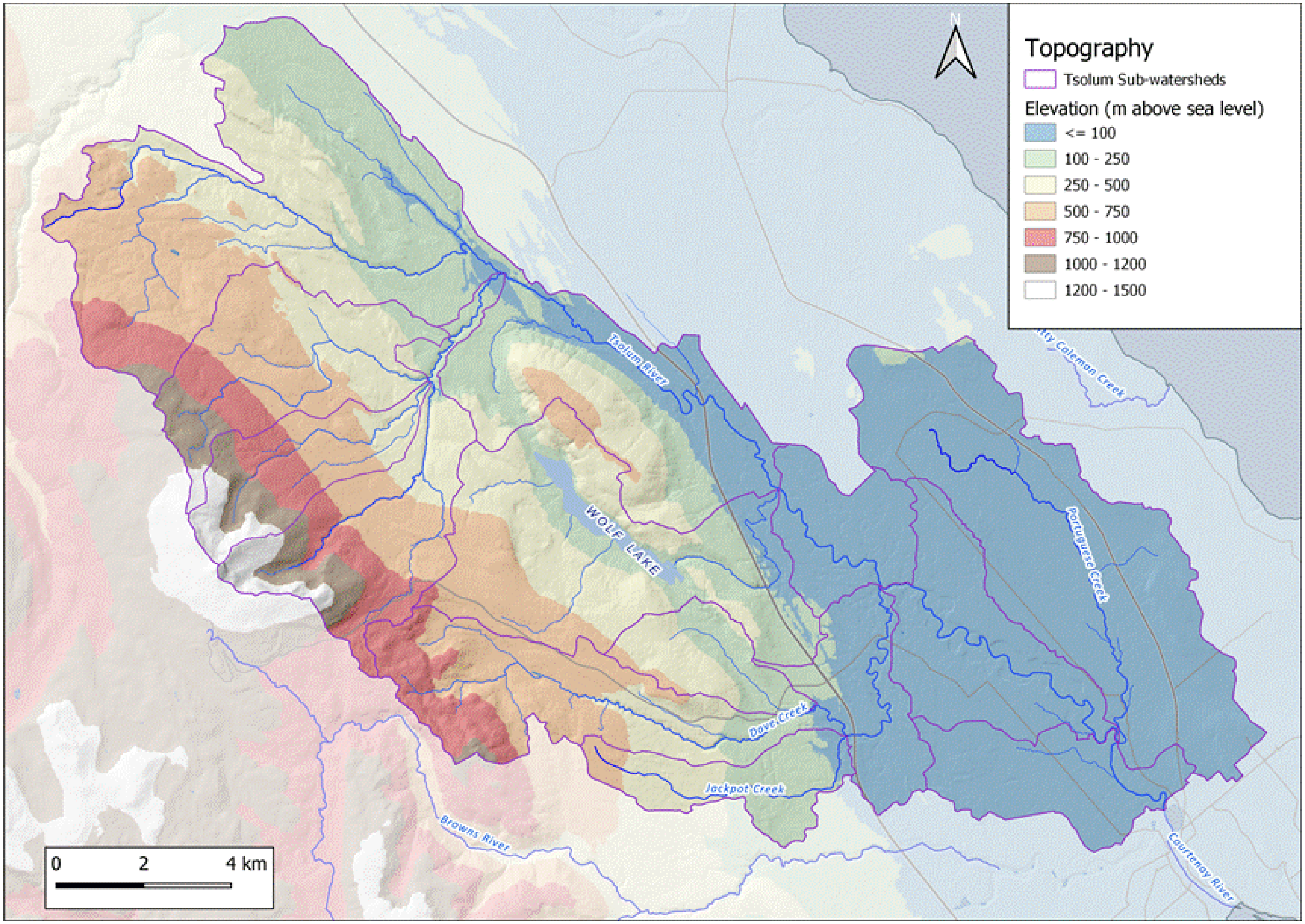


Figure 16. Topography ranges within the Tsolum Watershed

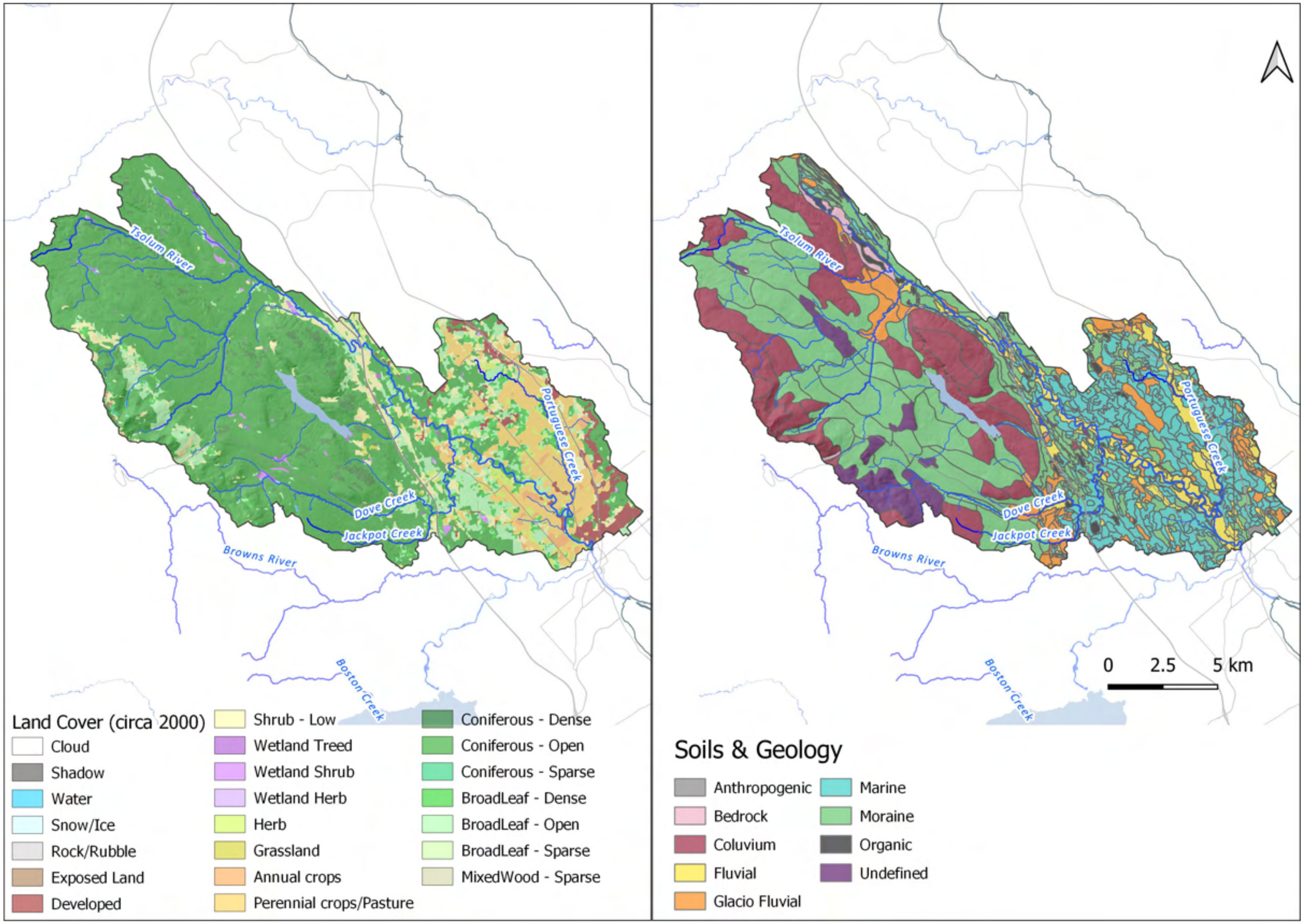


Figure 17: Land cover and soils & surficial geology

Monthly average temperature and total precipitation

Monthly total precipitation and maximum and minimum temperature gridded data were obtained from the Pacific Climate Impact Consortium (PCIC). The information corresponds to climate normal data 1981-2010. The gridded climate datasets have been interpolated from regional climate station data. The Tsolum Watershed station locations are shown in Figure 10.

Like much of eastern Vancouver Island, the Tsolum Watershed experiences a Mediterranean Climate, with warm, dry summers and relatively mild and wet winters. Figure 14 shows the monthly total precipitation in millimeters. The wettest months occur between October to January, and the driest months are usually July and August. The highest precipitation events occur from November to January. Average temperatures for the Tsolum Watershed are shown in Figure 15; warmer months correspond to drier months.

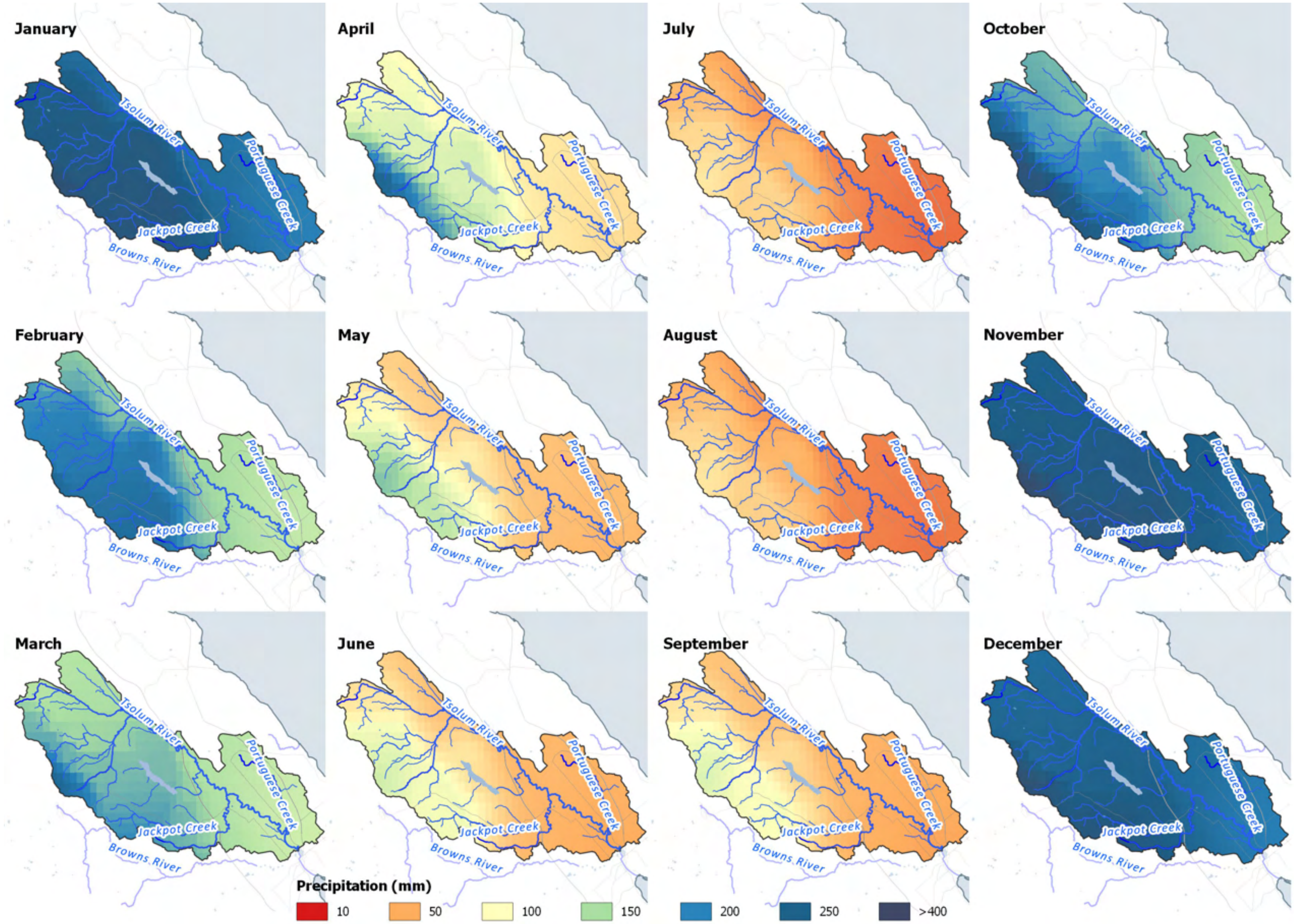


Figure 18. Monthly total precipitation (mm) for the Tsolum Watershed

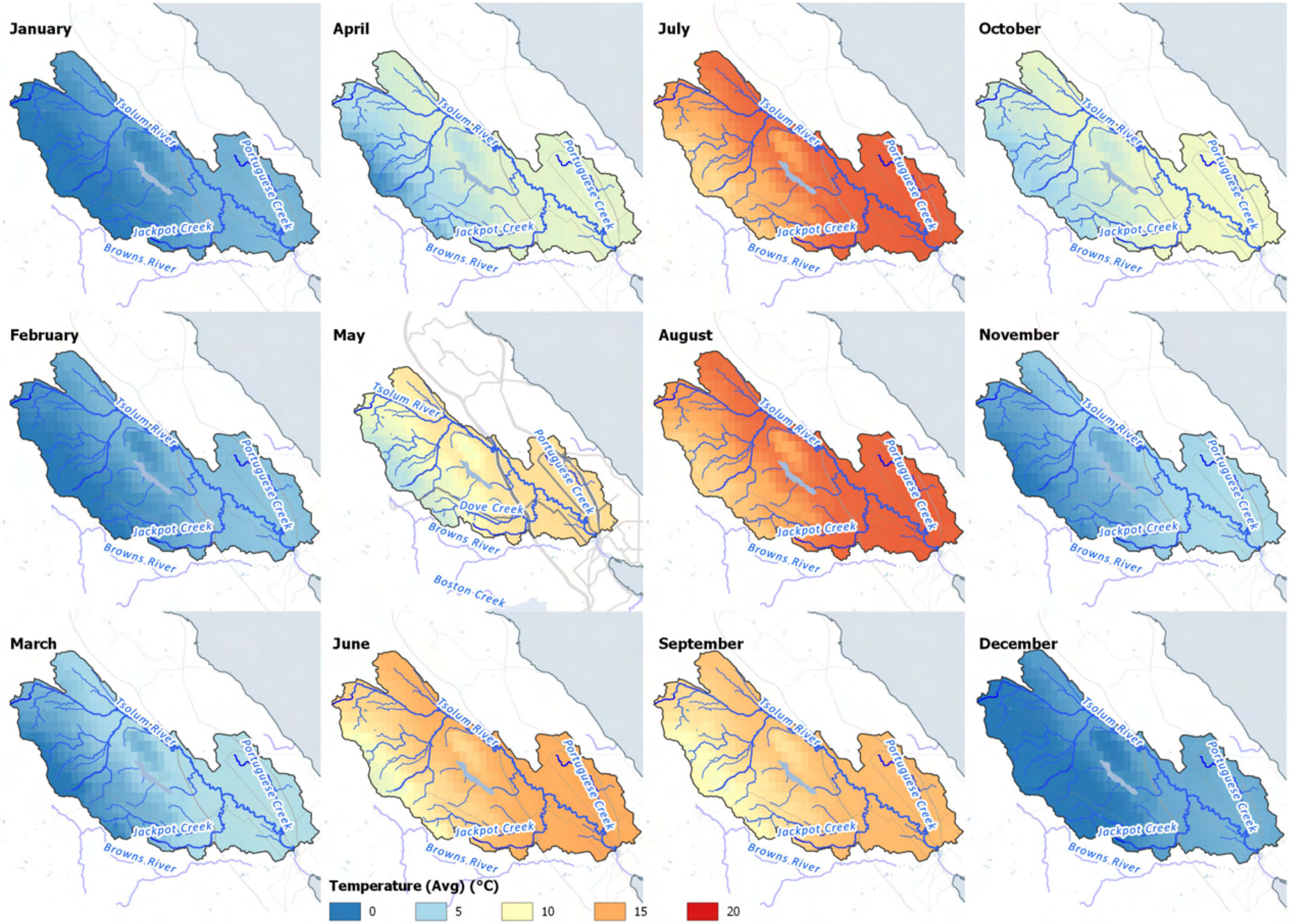


Figure 19. Monthly average temperature (deg. C) for the Tsolum Watershed

Solar Radiation

Solar radiation can be estimated based on topographic surface (DEM), geographic location and time of the year. GW Solutions obtained solar radiation data (kJ m^{-2} day^{-1}) from WorldClim (http://worldclim.org/version2) at a resolution of 30 seconds (~1 km^2). This data was converted to watt-hours per square meter (wh/m^2) per month and scaled to a 20 m grid size for input to the model.

Data Outputs

Estimation of Monthly Actual Evapotranspiration

Actual evapotranspiration was estimated using the GIS-based water balance model. Figure 16 shows the monthly actual evapotranspiration for the Tsolum Watershed. Very little evapotranspiration occurs between November and February. In contrast, May, June, and July correspond to the months with the largest evapotranspiration rate.

Monthly Surplus (runoff and groundwater)

The surplus is the remaining water (not evaporated or transpired). It leaves a site through runoff or subsurface flow, or a combination of both. There can be no surplus if soil storage is not full.

Figure 17 presents the monthly water surplus. May through September are the months with basically no surplus. Therefore, streams are likely fed by storage (groundwater) during these months.

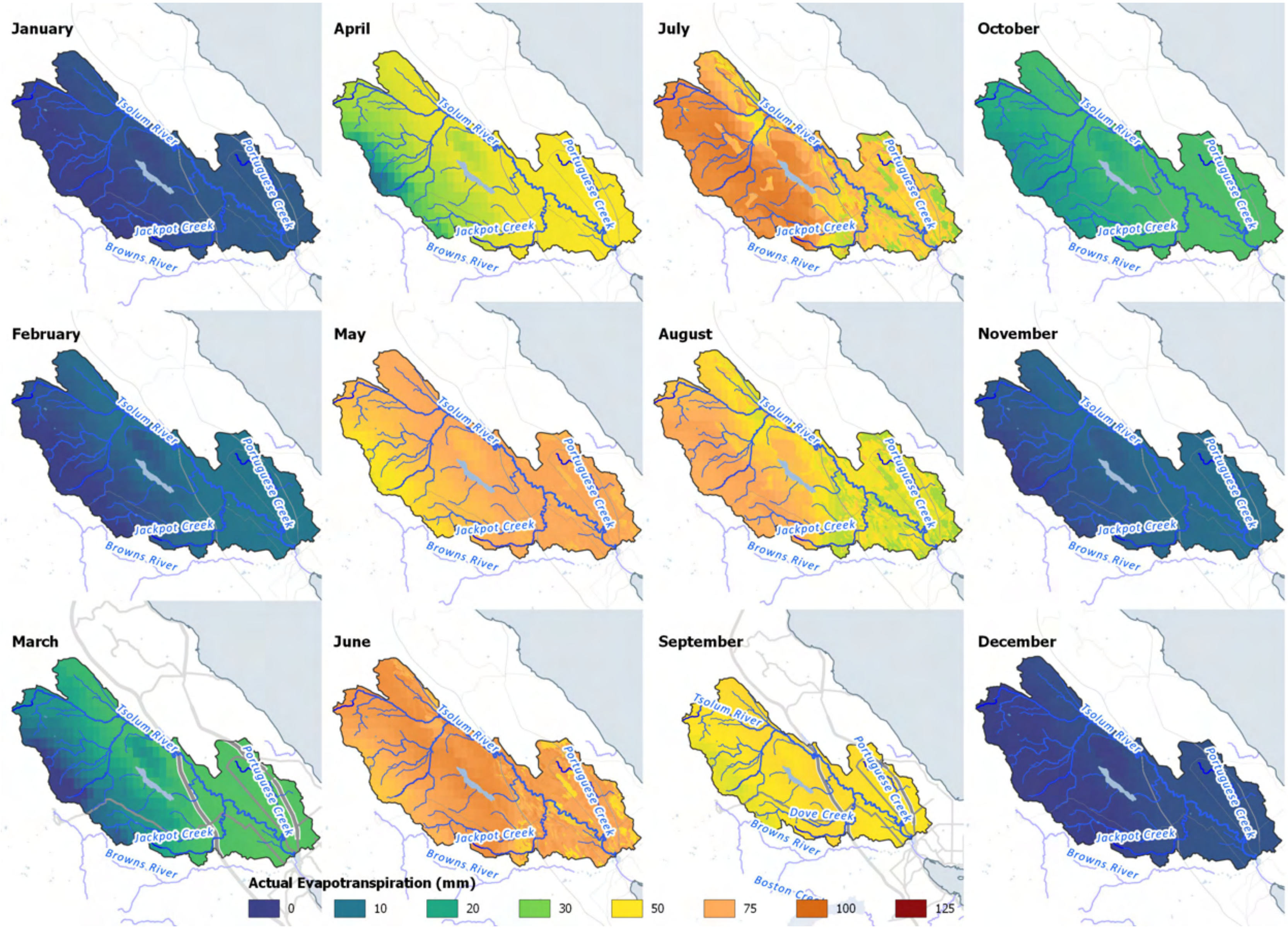


Figure 20. Monthly actual evapotranspiration (mm)

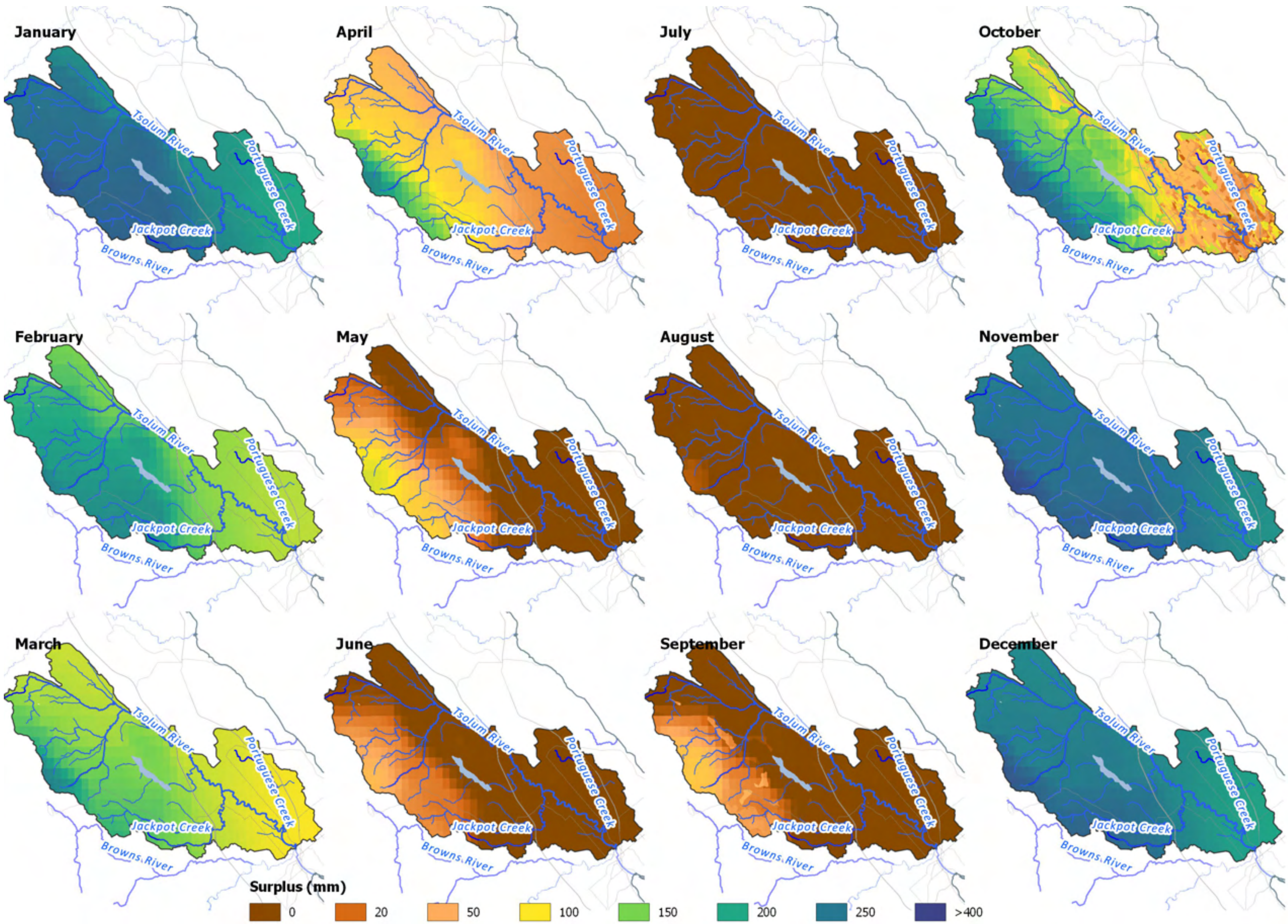


Figure 21. Monthly surplus (runoff and groundwater)

Model Calibration Using Gauged Watersheds

Delineation of up-stream watershed of gauging stations

TauDEM (Terrain Analysis Using Digital Elevation Models) is a set of tools for the extraction and analysis of hydrologic information from topography (DEM). TauDEM was used to delineate catchments for gauged stations. Figure 18 shows the resulting gauged hydrometric sub-watersheds for the Tsolum Watershed. All available hydrometric stations were considered for the analysis.

Water flux model calibration

Water fluxes calculated with the water balance model were compared to measured flow values for the gauged watershed. Figure 19 through Figure 23 show the measured and modeled flows in cubic decameters (1 dm^3 = 1000 m^3) for the gauged watersheds. The figures also show the difference between modeled and measured flows (in percentage). Due to its completeness, WSC Station 08HB011 (Tsolum River near Courtenay) was used to estimate the components of baseflow and runoff within the stream channel.

Table 3 resents the gauged sub watersheds and the statistic analysis[30] results for comparing measured flow and modeled flow values. The average difference for the year (Mean Annual Discharge-MAD) varies depending on the watershed and completeness of the data.

Table 6: Comparison between modelled flow and measured flow for gauged sub-watersheds

Station Number	Station Name	Station Data Overlap with Climate Normal Data	Data Range	RSR	NSE	PBIAS
08HB090	Headquarters Creek Above Tsolum River	Less than 50% of 1981-2010 climate normal data	1997-1999	0.77	0.41	-44.47%
08HB089	Tsolum River Below Murex Creek	Less than 50% of 1981-2010 climate normal data	1997-2015	0.31	0.91	-11.78%

[30] To evaluate the reliability of the water balance model, measured flows were compared to modelled flows using three statistical approaches: Nash-Sutcliffe efficiency (NSE), Percent bias (PBIAS), and the RMSE-observations standard deviation ratio (RSR). In general, NSE varies from negative infinity to 1, where close to 1 is highly satisfactory. RSR varies from 0 (highly satisfactory) to any large number. PBIAS is reported as a percentage where the lower values indicate generally a good match between modelled and measured values. GW Solutions considers it a satisfactory model if NSE > 0.75, RSR < 0.50, and PBIAS < 20%.

08HB075	Dove Creek Near The Mouth	75% to 90% of 1981-2010 climate normal data	1985-2020	0.26	0.93	-15.73%
08HB011	Tsolum River Near Courtenay	Complete 1981-2010 climate normal data	1914-2020	0.14	0.98	-5.16%
TSOLUM1	Tsolum River Todd Road Station	Less than 50% of 1981-2010 climate normal data	2012-2015	2.53	-5.38	123.17%

The difference in flow (modeled vs measured) could also be attributed to the following:

- Monthly Precipitation Grids are interpolated from the available climate normal data. Inaccuracies may result from the uneven distribution of stations, or the altitude correction and downscaling used in the interpretation of the gridded data.
- Water usage might have increased over time (i.e. from 1981 to 2010). Therefore, the changing influence of water usage on the modelled flows is difficult to determine.
- The water balance model does not account for the presence of dams or regulated flows within the watershed.
- The modelled flow values are directly proportional to the estimated area of the upstream watershed. GW Solutions has delineated the upstream watersheds using a 30-meter Digital Elevation Model. Therefore, the delineation will have some discrepancies in flat areas. Although this might influence the modelled values, its effects should be minimal.
- Variability in the completeness of measured values likely strongly correlate with inaccuracies in the model results. Station 08HB011 (Tsolum River near Courtenay) has a complete set of data (1981-2010) and the corresponding error is less than 10%.

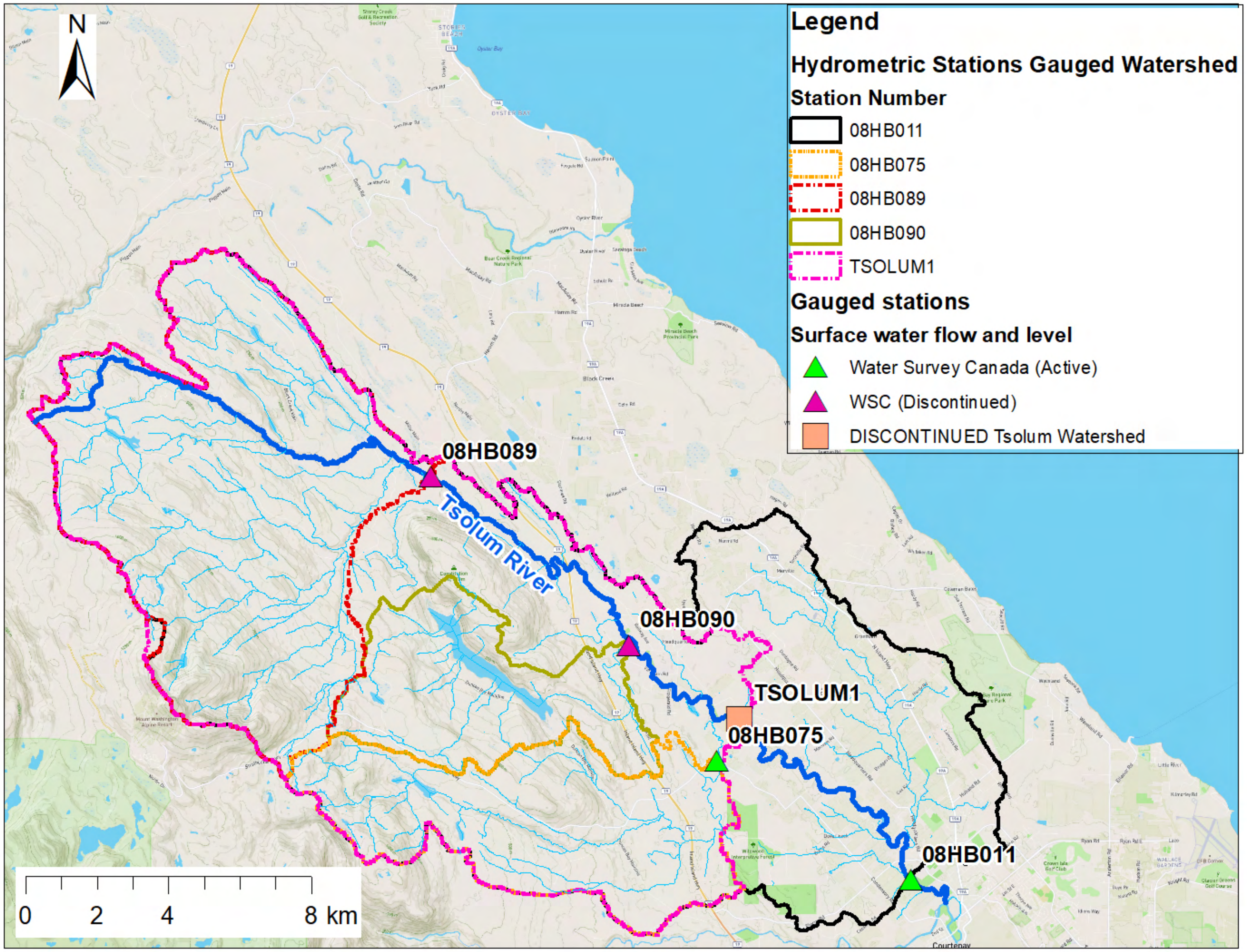
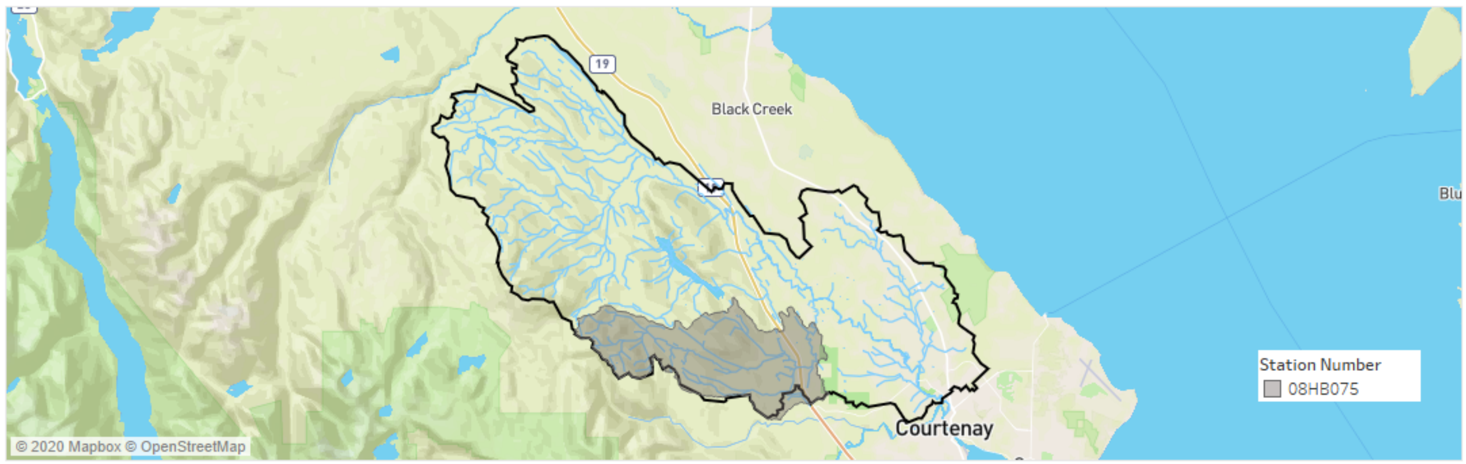


Figure 22. Hydrometric stations and corresponding upstream watersheds included in the model calibration for the Tsolum Watershed

Gauged watershed



Model calibrarion for station DOVE CREEK NEAR THE MOUTH (08HB075)

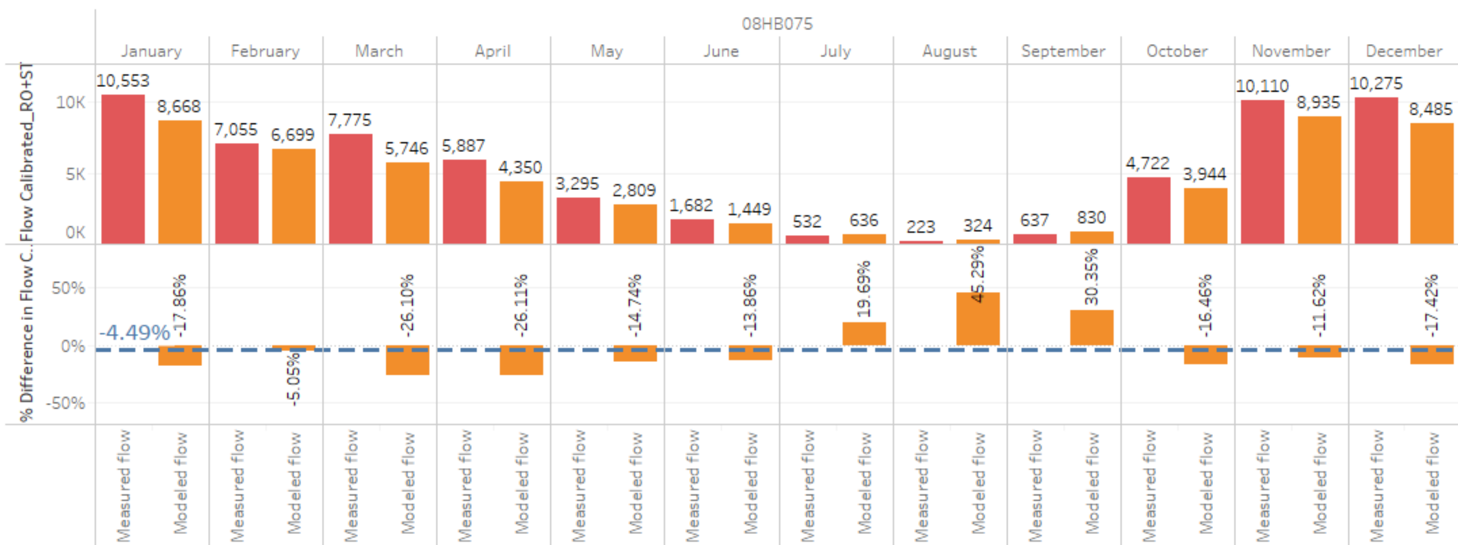


Figure 23. Monthly comparison of modeled and measured flows for Dove Creek Near the Mouth (08HB075)

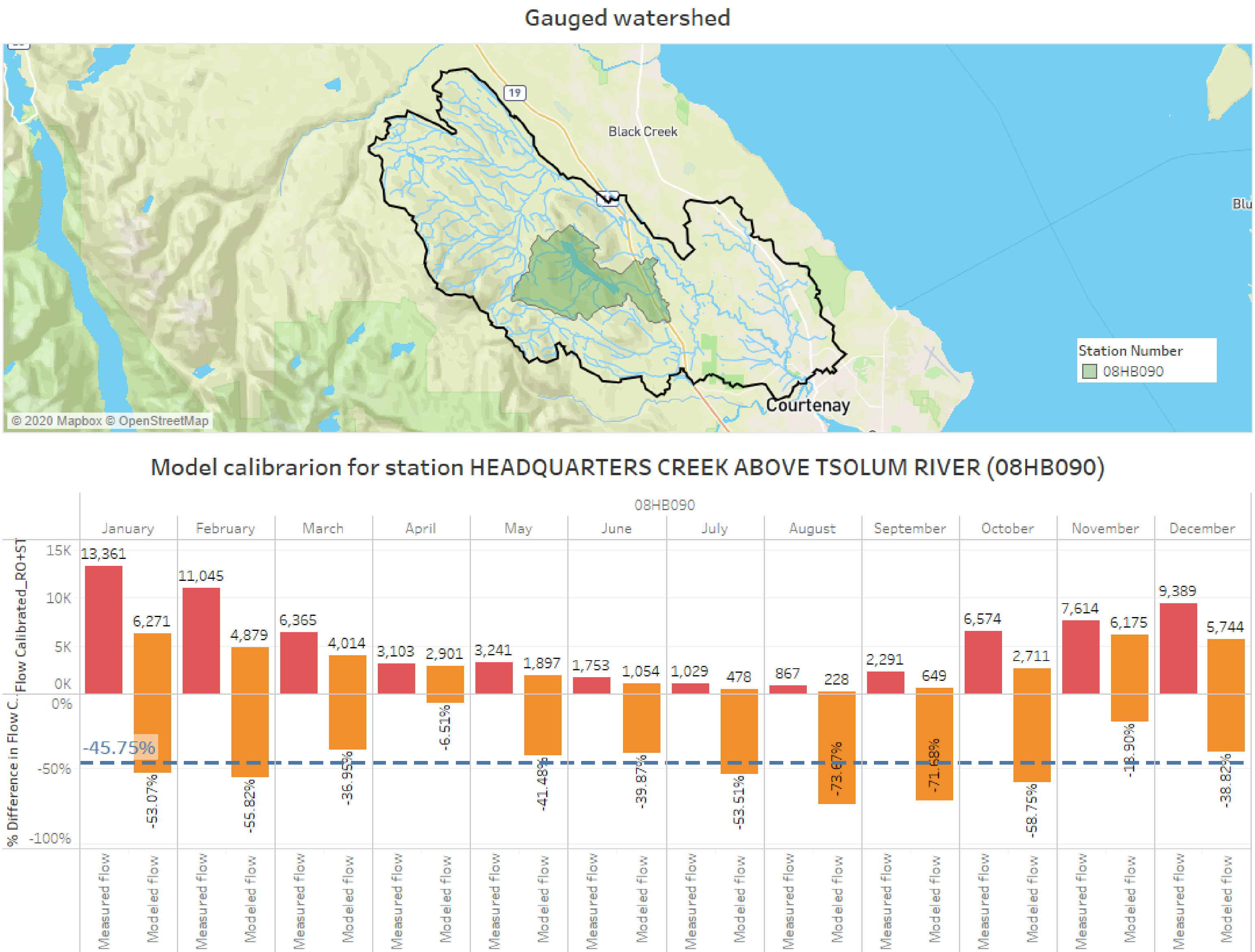


Figure 24. Monthly comparison of modeled and measured flows for Headquarter Creek Above Tsolum River (08HB090)

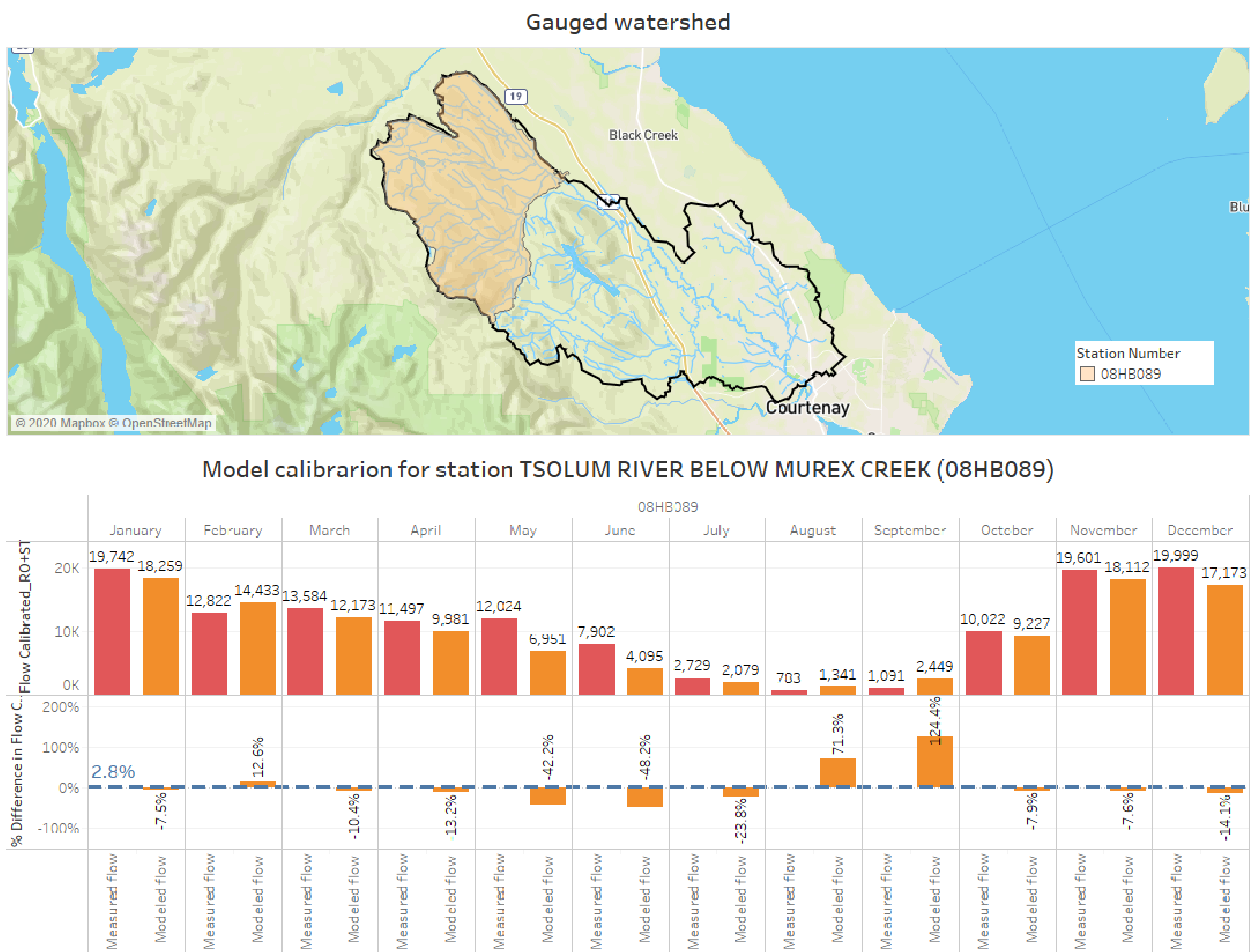
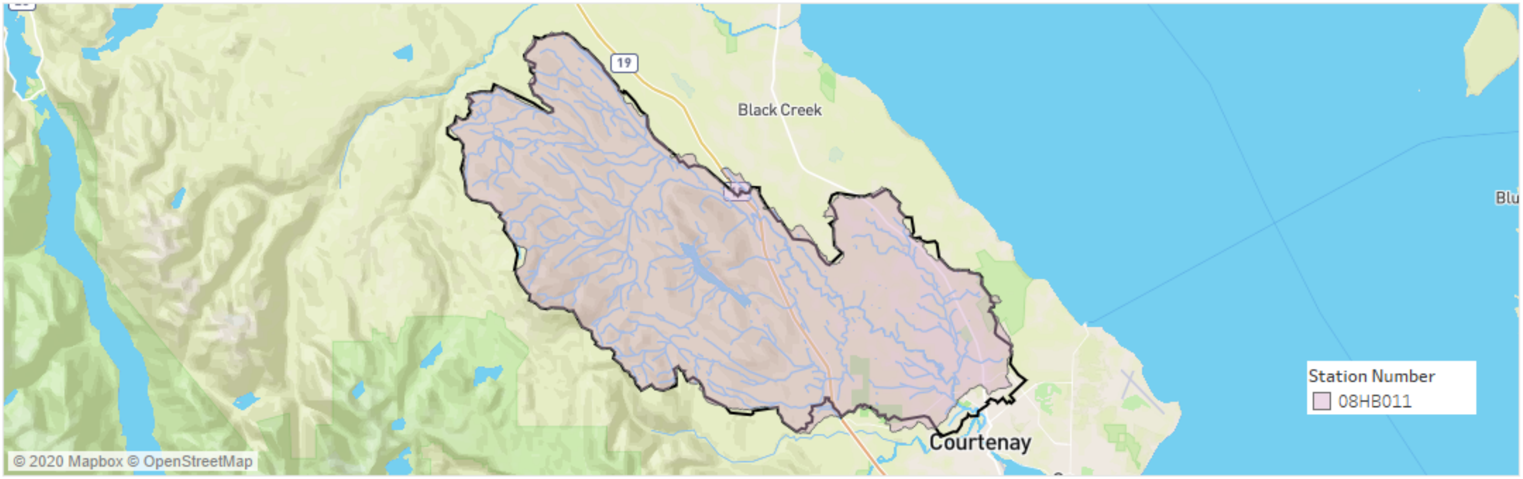


Figure 25. Monthly comparison of modeled and measured flows for Tsolum River Below Murex Creek (08HB089)

GW SOLUTIONS

Gauged watershed



Model calibrarion for station TSOLUM RIVER NEAR COURTENAY (08HB011)

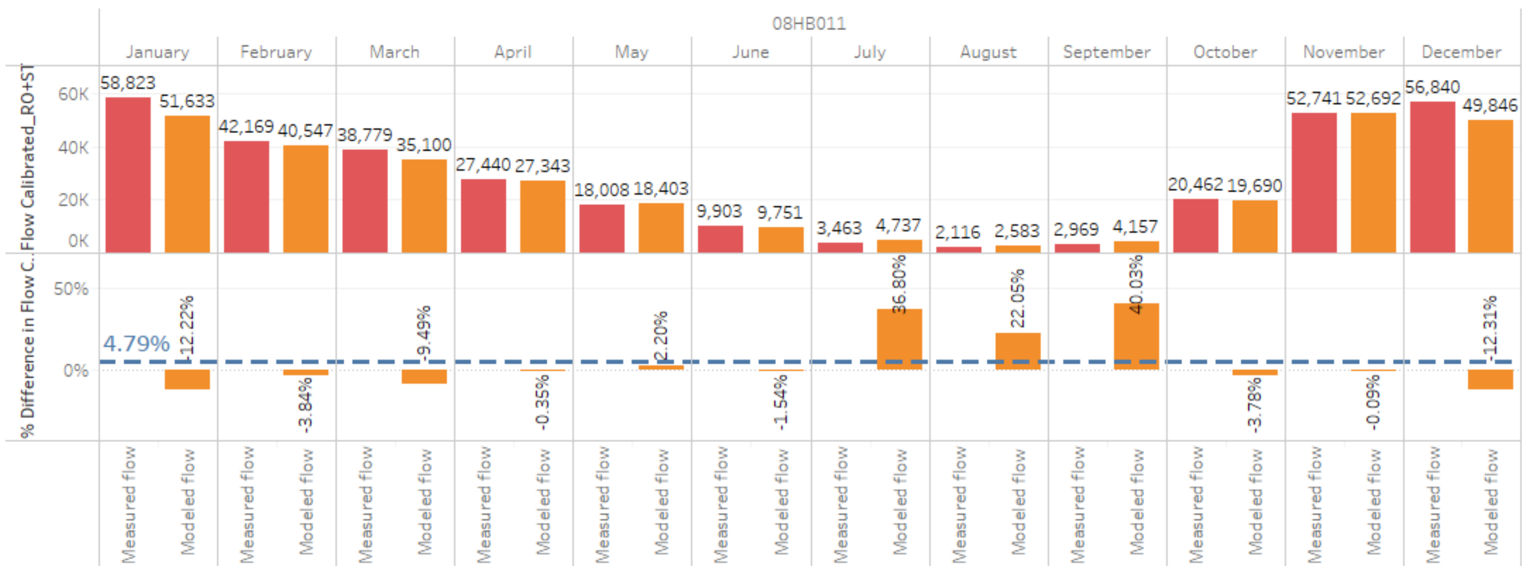


Figure 26. Monthly comparison of modeled and measured flows for the Tsolum River Near Courtenay (08HB011)

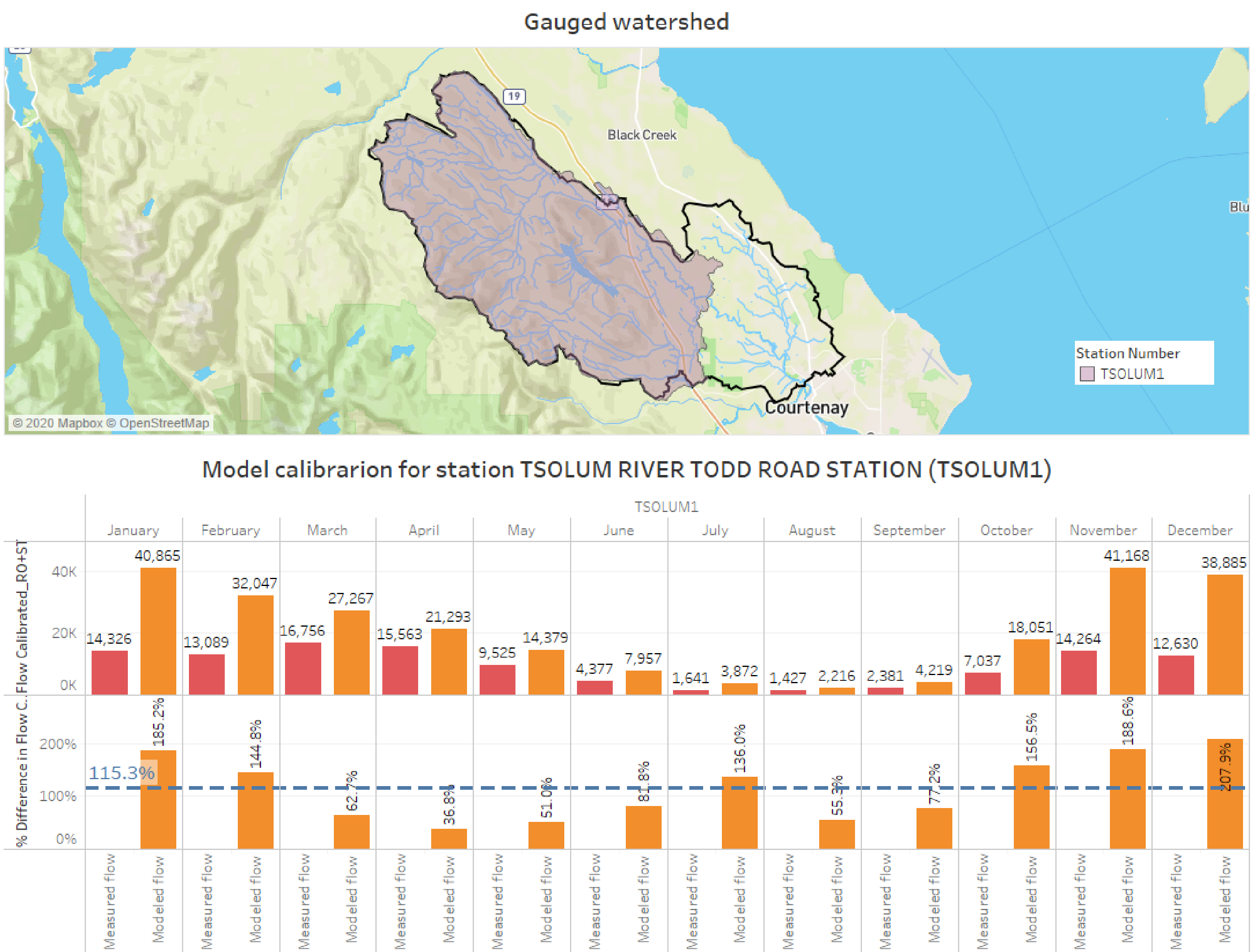


Figure 27: Monthly comparison of modeled and measured flows for Tsolum River Todd Road (Tsolum1)

Estimation of Groundwater Recharge and Runoff

Groundwater recharge was estimated using a GIS-Based Decision Support method based on infiltration factors.

Estimation of infiltration factors

An infiltration coefficient factor is estimated from the sum of individual infiltration coefficients from three factors:

1. Land cover type;
2. Soil type; and
3. Slope.

These factors are determined based on existing information and their individual distributions. A 20 m x 20 m grid cell was used. Groundwater recharge is estimated by multiplying the infiltration factor by the surplus.

Land cover infiltration factor

Land cover has a significant effect on groundwater recharge via the interception and/or dispersion of precipitation by foliage. This prevents or slows precipitation from reaching the ground leading to longer exposure to the atmosphere and increased evaporation. Table 4 summarizes the land cover infiltration factors considered for the study area. Figure 24 shows the resulting gridded model input for the land cover infiltration factor.

Table 7. Land Cover Infiltration Factors

Value	Description	Group	Infiltration Factor
0	No Data	No Data	0
11	Cloud	Cloud	0
12	Shadow	Shadow	0
20	Water	Water	0
31	Snow/Ice	Non-Vegetated Land	0
32	Rock/Rubble	Non-Vegetated Land	0.1
33	Exposed Land	Non-Vegetated Land	0.08
34	Developed	Non-Vegetated Land	0.01
52	Shrub - Low	Shrubland	0.15
81	Wetland Treed	Wetland	0.05
82	Wetland Shrub	Wetland	0.05
83	Wetland Herb	Wetland	0.05
100	Herb	Herb	0.14
110	Grassland	Herb	0.13
121	Annual crops	Herb	0.12
122	Perennial crops and Pasture	Herb	0.12
211	Coniferous - Dense	Forest/Trees	0.2
212	Coniferous - Open	Forest/Trees	0.19
213	Coniferous - Sparse	Forest/Trees	0.18
221	BroadLeaf - Dense	Forest/Trees	0.17
222	BroadLeaf - Open	Forest/Trees	0.16
223	BroadLeaf - Sparse	Forest/Trees	0.15
233	MixedWood - Sparse	Forest/Trees	0.14

Soil infiltration factor

A combination of three soil characteristics and weighting was used: drainage (weighting factor 60%), texture (30%), and geology (10%). These three characteristics were weighted to obtain the soil infiltration factor. Table 5 shows the drainage, texture and geology factors considered for the estimation of the soil infiltration factor. Figure 24 shows the soil infiltration factor gridded model input.

Table 8. Drainage, texture and geology factors

Group	Code	Description	Factor
Drain	I	Imperfectly Drained	0.15
Drain	MW	Moderately Well Drained	0.2
Drain	P	Poorly Drained	0.1
Drain	R	Rapidly Drained	0.4
Drain	W	Well Drained	0.3
Texture	L	Loam	0.3
Texture	LS	Loamy Sand	0.35
Texture	S	Sand	0.4
Texture	SICL	Silty Clay Loam	0.1
Texture	SIL	Silt Loam	0.15
Texture	SL	Sandy Loam	0.2
Geology		Anthropogenic	0.01
Geology		Bedrock	0.2
Geology		Colluvium	0.2
Geology		Fluvial	0.3
Geology		Glacio Fluvial	0.4
Geology		Glacio Marine	0.2
Geology		Ice	0
Geology		Lacustrine	0.1
Geology		Marine	0.1
Geology		Moraine	0.1
Geology		Organic	0.1
Geology		Undefined	0.01
Geology		Undifferentiated	0.2

Slope infiltration factor

Topography influences the infiltration capacity. Relatively flat slopes promote infiltration and steep slopes promote runoff and decreased infiltration. Table 6 summarizes the slope infiltration factors. Figure 24 shows the slope infiltration factor for the Tsolum Watershed.

Table 9. Slope infiltration factors

Groundwater recharge potential	Slope (degree)	Infiltration factor
Lowest	> 24	0.01
Very poor	8.5 - 24	0.02
Poor	4.5 -8.5	0.05
Good	2.7 - 4.5	0.1
Medium	1.8 - 2.7	0.15
Very good	0.2 - 1.8	0.2
High	< 0.2	0.3

Infiltration factor

The sum of slope, soil and land cover factors will determine the percentage of surplus that will recharge the groundwater systems. The following equation was used to estimate the infiltration factor:

$$RP = IF_{soil} + IF_{landcover} + IF_{slope}$$

Where:

RP = Recharge potential;
IF_{soil} = Soil infiltration factor;
$IF_{landcover}$ = Land cover infiltration factor; and
IF_{slope} = Slope infiltration factor.
The resulting infiltration and recharge factors are presented in Figure 24.

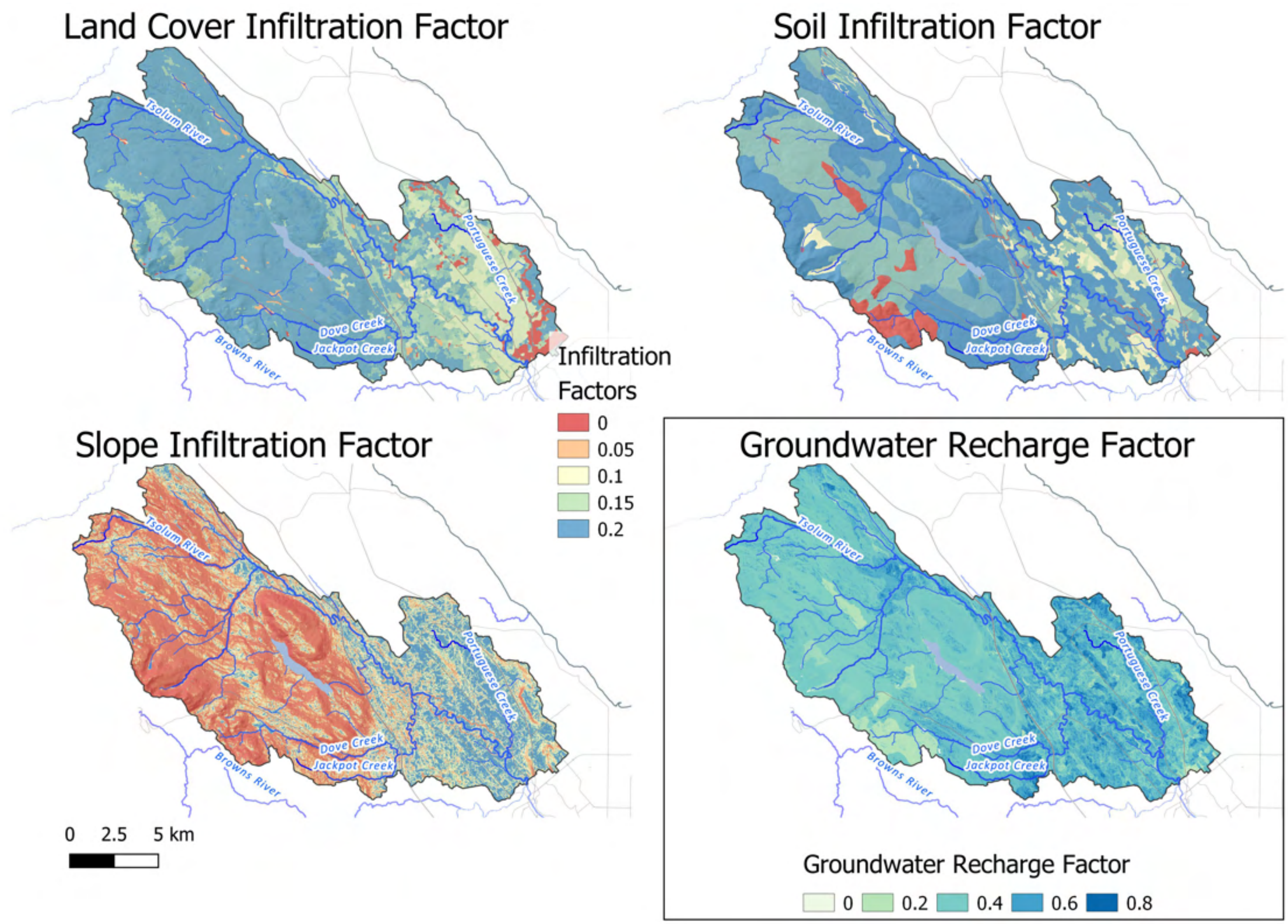


Figure 28. Infiltration and groundwater recharge factors

Estimation of groundwater recharge

The groundwater recharge is estimated by multiplying the modeled surplus and the estimated infiltration factors. The estimated monthly groundwater recharge for the Tsolum Watershed is presented in Figure 25. In general, most of the recharge occurs from November to January and no recharge is observed in July. Results indicate that groundwater recharge varies across the watershed and is greater at higher altitude and less in the lowlands. The groundwater recharge component is critical to the water budget since it is the amount of water replenishing the aquifers within the watersheds.

Estimation of direct runoff

Direct runoff (also called overland flow) is defined as the water that flows over the ground surface directly into streams, rivers, lakes or ocean. Runoff in the Tsolum Watersheds is estimated by subtracting the groundwater recharge to surplus. Figure 26 presents the resulting monthly runoff. Direct runoff of significance typically starts in October and generally ends in April.

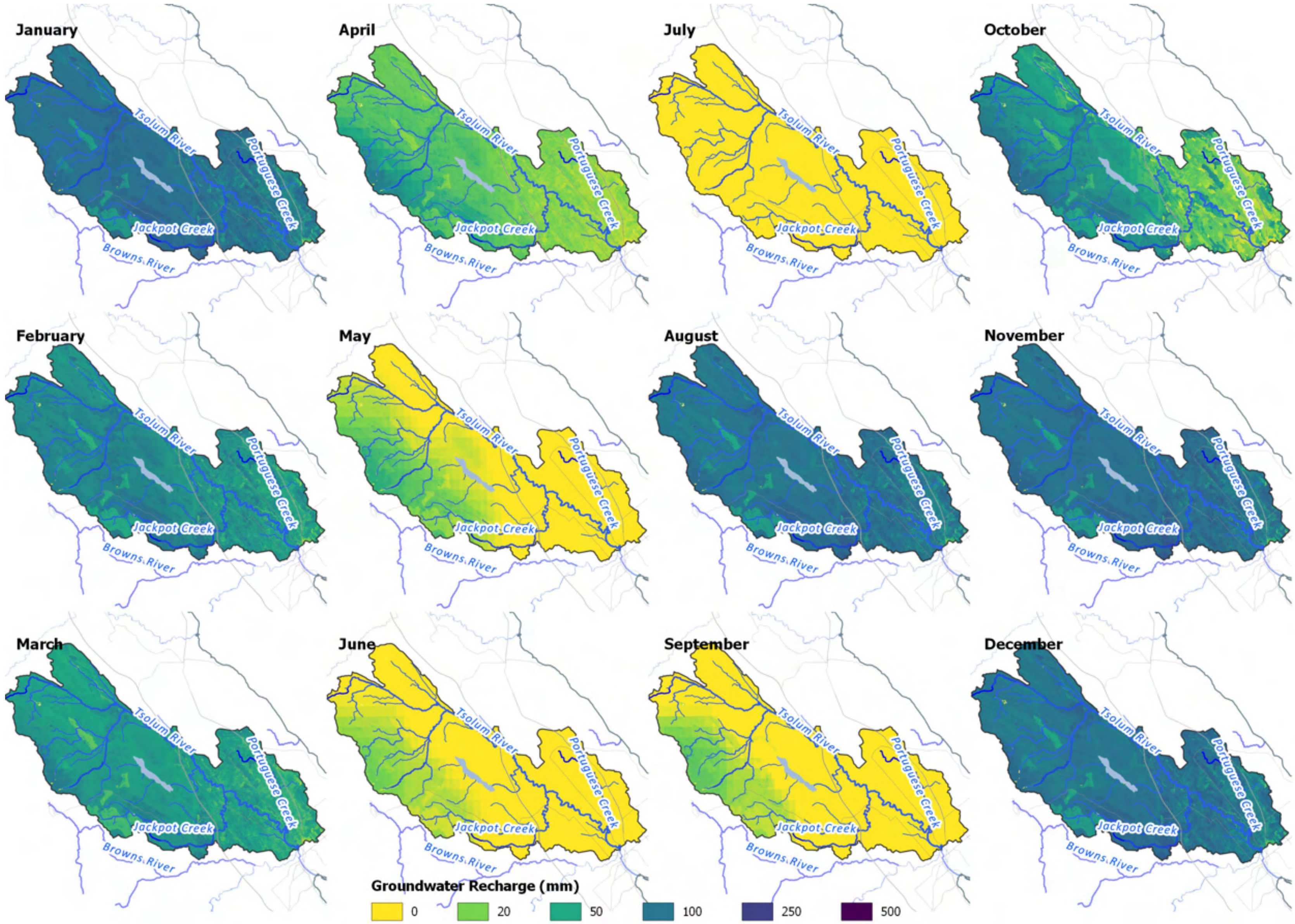


Figure 29. Monthly estimated groundwater recharge

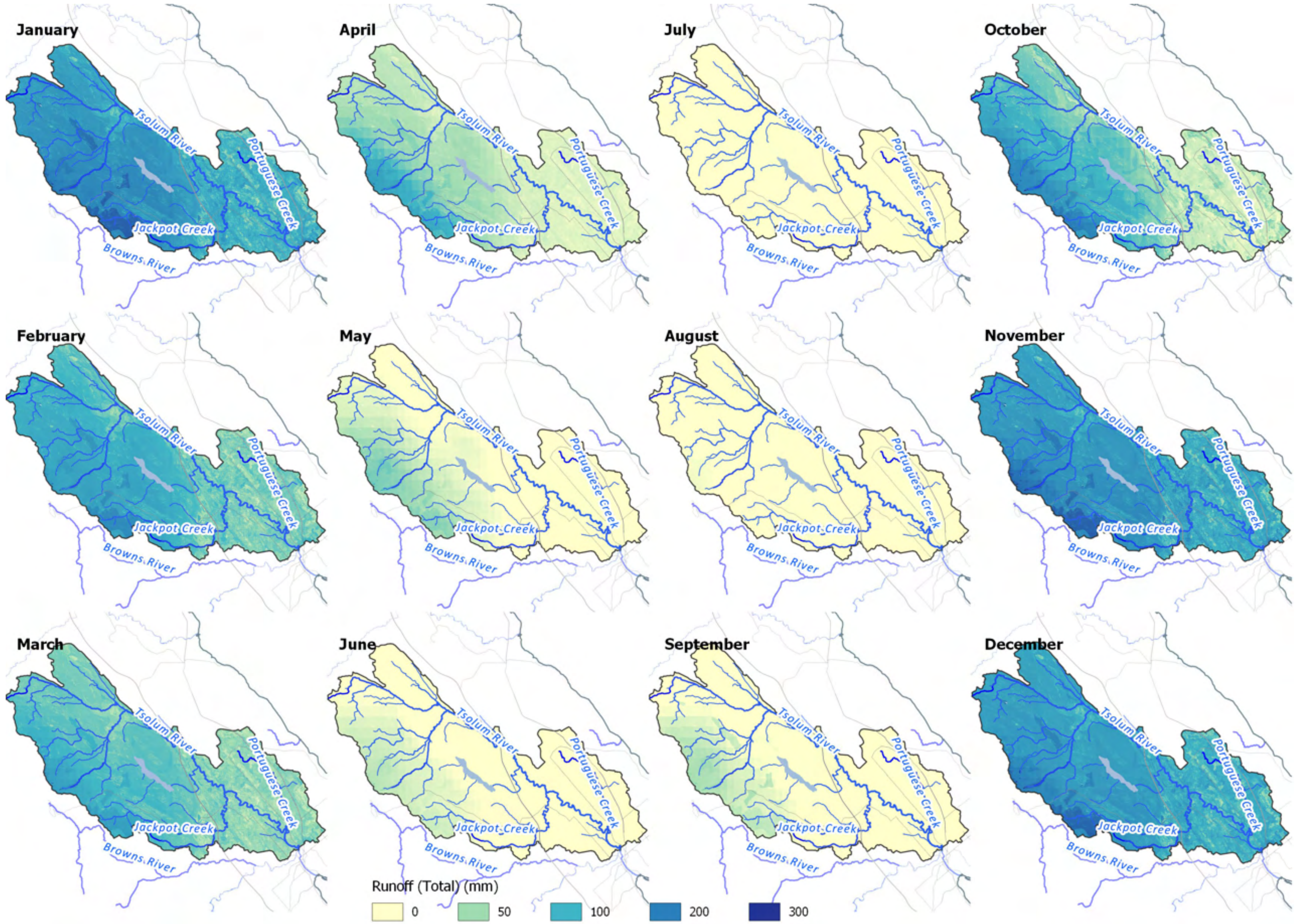


Figure 30. Monthly estimated direct runoff

Estimation of Baseflow and Runoff in the Stream Channel for the Tsolum Watershed

As mentioned in Section 5.5.2, to separate runoff and baseflow within the stream channel, the dataset for station 08HB011 was used to compute Boxplots and Baseflow Index (BFI: the ratio of baseflow to total flow). The BFI has been computed using the 14 hydrograph separation methods (McGill,R. Tukey,J.W (1978)).

Figure 27 shows the separated baseflow and runoff for the Tsolum River's channel at the location of the Tsolum River Near Courtnay. The computed index was applied to the stream channels flowing into the Tsolum River mainstem.

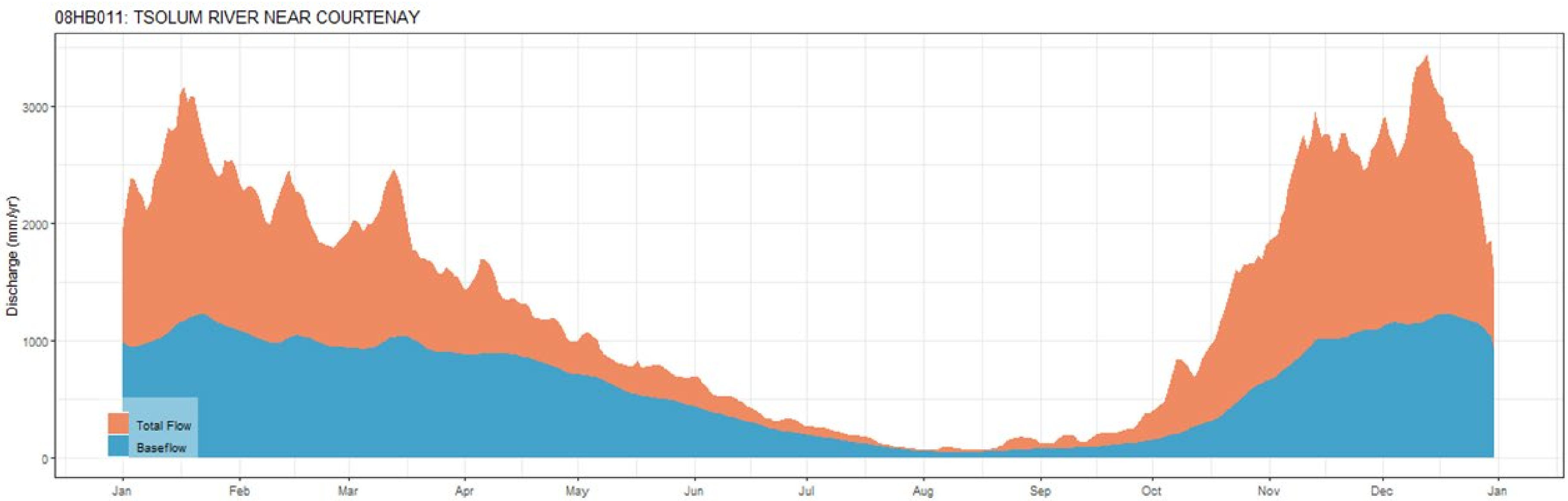


Figure 31: The separated baseflow and runoff within the Tsolum River Channels at the location of hydrometric station 08HB011

To finalize the water budget, all water withdrawals from the groundwater resources and surface water bodies have been considered in the groundwater recharge and surface water flows.

The water budget reports for each sub-watershed of the Tsolum Watershed are presented in Appendix 2. The water budget report for Dove Creek watershed as an example is presented in Figure 28.

The water budget report is composed of three elements:

- A map showing the location of the corresponding watershed (shaded boundary);

- A Water Budget Summary, showing the monthly volumes in cubic decameters of precipitation, actual evapotranspiration, stream flow (runoff and baseflow), water usage, and estimated groundwater recharge. Water usage is not reported when there is no usage; and

- The baseflow and runoff components.

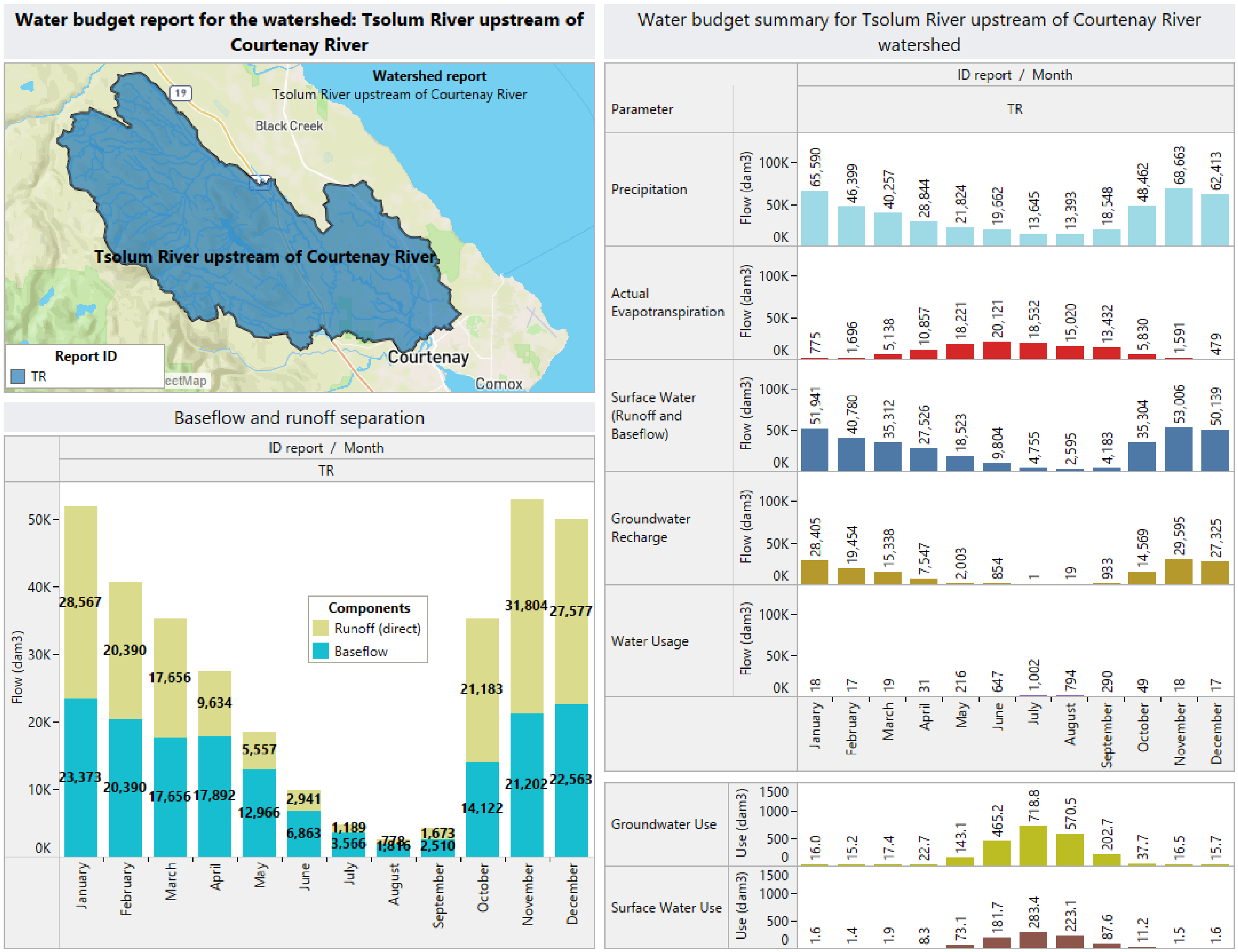


Figure 32: Water budget report for Tsolum River upstream of Courtenay River

Conclusions

Based on the completed study, we draw the following conclusions:

1. The charts illustrating the comparison between modeled flows and measured flows generally indicate better matching of the modeled flows for stations that have more complete data. It is challenging to model flows in systems showing such high seasonal contrast (i.e. large flows during the wet period of the year and low flows at the end of summer). Generally, the difference between modeled and measured flow increases when the flows are very low. Overall, the gridded model provides an adequate estimation of the groundwater recharge and the calibration results confirm the model to be a reliable tool to estimate a water budget for the Tsolum Watershed.

2. Model results indicate actual evapotranspiration ranges between 18% and 30% of the precipitation and groundwater recharge between 30% and 39% of the yearly precipitation.

3. Aquifers play a very important role in water supply as approximately 76% of the total water demand is provided by groundwater, the remaining 24% relying on surface water.

4. There is a very strong contrast between the wet period and the dry period of the year. July through October are months with low flows and for which groundwater is a key contributor to the stream/surface water flow. During these months, any additional extraction of groundwater for irrigation is not recommended or should be done with extreme caution not to jeopardize the environmental flow needs.

5. Maps have been generated to illustrate areas and estimated rates of groundwater recharge. These maps can be used in planning for an approach to optimize access to and use of water for irrigation and agricultural purposes.

Recommendations

Based on the completed work, GW Solutions makes the following recommendations:

1. We recommend only relying on a certain percentage of the recharge rate as a safe extraction rate and adjusting the extraction rates over time as surface water and groundwater is monitored and reviewed. An approach similar to that presented in the Draft BC Water Science Series No. 2018-05 *Estimating Groundwater Availability for Allocation in BC* should be considered. The net extraction of groundwater from the Tsolum Watershed is a small fraction of groundwater recharge, however, this does not ensure sustainability, and monitoring efforts should be prioritized. The concept of sustainability applied to aquifers is presented in *Canada's Groundwater Resources*[31].

2. This study was conducted at the watershed scale and water use in aggregate and does not include the level of detail required to address the potential impacts of individual groundwater users. Groundwater extraction from a given source may adversely impact surface water, environmental flow needs or other users. Current or future groundwater extraction for agriculture will have to be designed considering these potential impacts.

3. Water consumption should be better monitored to ensure sustainability. Indeed, water demand can be differentiated into two categories:

    a. Use that results in net water consumption (e.g., irrigation with a component lost to evaporation); and,

    b. Use where water is returned to the watershed (e.g., discharge of grey water back to the subsurface).

    Measures should be taken to promote and implement the metering of water use.

4. Groundwater levels in aquifers should be actively monitored and the monitoring data should be regularly updated and analyzed to determine the cumulative impacts of extraction and use. The network of monitoring wells should be enhanced, and the location of monitoring wells take into account present and potential future needs as well as the proximity of streams to monitor the impact on environmental flow needs.

5. Discontinued river guages should be reactivated. New guages should be installed immediately upstream of the confluence of the major tributaries and at the discharge point of any areas of interest. Data on flow should be continuously monitored. This will prove essential in 5, 10, 15 years and later in the future for the calibration and reliance of numerical models that will be used and required to manage and protect water and ecosystems.

[31] *Canada's Groundwater Resources*, Rivera (ed.) ISBN 978-1-55455-292-4, published by Fitzhenry and Whiteside Limited, 2013

6. A quantitative analysis of the potential impact of climate change to the water budgets should be completed.

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Yours truly,
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APPENDIX 2

Water Budget Reports for Sub watersheds (Agricultural Water Demand Model)

APPENDIX 3

Water Budget Reports for Sub watersheds (Assessment Boundaries)

APPENDIX 1

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Appendix C: Tsolum River Agricultural Watershed Management Plan – Environmental Flow needs Screening Assessment

Tsolum River Agricultural Watershed Management Plan

Environmental Flow Needs Screening Assessment

Prepared for:

Elucidate Consulting

February 25, 2021

Prepared by:

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EXECUTIVE SUMMARY

This report provides an environmental flow needs (EFN) screening-level assessment for the Tsolum River Watershed as part of Phase 2 of the Tsolum River Agricultural Watershed Plan. The objective of this report is to evaluate how increased agricultural water demand in the Tsolum River watershed will affect EFN Risk Management Levels in the Tsolum River and its tributaries according to the Environmental Risk Management Framework outlined in the Provincial EFN Policy. Measures to support more detailed EFN assessment for the Tsolum River watershed are identified based on the outcome of this screening level assessment.

Assessment of EFN requires consideration of the environmental setting. To support the EFN screening-level assessment, key background information relevant to environmental flows in the Tsolum River watershed was reviewed and synthesized. In addition, a detailed review of the 2014 Tsolum River Watershed Fish Habitat Assessment Procedure was completed to evaluate the utility of this existing dataset for designing future field studies to assess EFN in the Tsolum River watershed.

The EFN screening-level assessment was completed for nine Points of Assessment (POAs) in the Tsolum River watershed; these POAs were developed considering the locations of current and potential future water demand. Assessment locations include tributaries where additional agricultural demand is anticipated (Portuguese Creek, Dove Creek and its tributaries Jackpot and Piercy Creek, and Headquarters Creek), and points on the Tsolum River just upstream of these major tributaries. Eleven water demand scenarios were assessed, including current water demand (licensed and modelled) and three future agricultural production scenarios (each with and without climate change). Risk Management Levels were calculated based on hydrological and water demand estimates provided by GW Solutions.

August was identified as the month of highest flow sensitivity for all POAs. Under current conditions during August, surface water demand for all POAs was assessed at Risk Level 2 under current conditions. Under six future scenarios of increased agricultural production, Risk Level 3 was assessed for all scenarios with one exception (one scenario at Tsolum River upstream of Headquarters Creek). When total water demand (surface water and groundwater) is considered, current demand in August was assessed at Risk Level 3 in Tsolum River from the Dove Creek confluence to the Courtenay River confluence, and within Portuguese Creek; at all POAs, all scenarios with increased agricultural production were assessed at Risk Level 3. The Provincial EFN Policy requires consideration of water withdrawals from both surface water sources and hydraulically connected aquifers because extraction of groundwater directly and indirectly influences streamflow. Given the unknown extent to which groundwater extraction influences surface flows in the Tsolum River watershed, the EFN screening results for total water demand (surface and groundwater) can be considered the 'worst-case' potential effect of water withdrawal on surface flows.

The Provincial EFN Policy recommends detailed habitat assessment for water withdrawals assessed at Risk Level 3, requiring detailed characterization of Tsolum River watershed hydrology, identification of critical fish habitats and flow-related environmental issues, and field and modelling

studies to quantitatively assess the effects of water withdrawal. We provide some discussion around these requirements, including estimates of effort required to complete specific tasks for detailed assessment.

The Water Sustainability Act provides a mechanism for regulators to implement temporary protection orders for fish when flow rates drop below a Critical Environmental Flow Threshold, which is sometimes defined by regulators at 5% of mean annual discharge in the absence of more detailed information. For each POA, the flow rate corresponding to 5% of mean annual discharge has been estimated to support regulatory determination of the Critical Environmental Flow Threshold, should a temporary protection order become necessary.

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1. INTRODUCTION

1.1. Background

The Comox Valley Regional District (CVRD) is developing the Tsolum River Agricultural Watershed Plan to address ongoing and future concerns about water availability in the Tsolum River watershed. Ecofish Research Ltd. (Ecofish) was retained by Elucidate Consulting on behalf of the Comox Valley Regional District (CVRD) to complete an environmental flow needs (EFN) screening level assessment for the Tsolum River Watershed. The *Water Sustainability Act* (WSA) defines EFN as the volume and timing of water flow required for proper functioning of the aquatic ecosystem.

1.2. Objectives

The objective of this report is to evaluate how agricultural water demand in the Tsolum River watershed affects EFN Risk Management Levels in the Tsolum River and its tributaries based on the Provincial EFN Policy (Province of BC 2016). The Provincial EFN Policy provides a coarse screen for assessing risk to EFNs from water use approval applications where the origin of water is a river or creek, or an aquifer reasonably likely to be hydraulically connected to a river or creek. Herein we apply the Environmental Risk Management Framework described within the Provincial EFN Policy to calculate the Risk Management Level associated with current and prospective future water demand.

1.3. Scope of Work

The Risk Management Levels associated with current and prospective water demand are calculated at nine Points of Assessment in the Tsolum River watershed (POAs) (Map 1). These POAs were developed considering the locations of current and potential future water withdrawal and include tributaries where additional agricultural demand is anticipated, and points on the Tsolum River immediately upstream of these major tributaries:

1. Tsolum River upstream of Courtenay River confluence;
2. Tsolum River upstream of Portuguese Creek;
3. Tsolum River upstream of Dove Creek;
4. Tsolum River upstream of Headquarters Creek;
5. Dove Creek upstream of Tsolum River;
6. Jackpot Creek upstream of Dove Creek;
7. Piercy Creek upstream of Dove Creek;
8. Portuguese Creek upstream of Tsolum River; and
9. Headquarters Creek upstream of Tsolum River.

For each POA, the EFN screening level assessment was completed in five steps following the Provincial EFN Policy Environmental Risk Management Framework (Province of BC 2016):

1. Identify special considerations (Section 2);
2. Review environmental background and assess fish presence (Section3);
3. Summarize current and prospective water demand (Section 4);
4. Estimate mean monthly discharge (MMD) and mean annual discharge (Section 5); and
5. Determine Risk Management Levels based on flow sensitivity, stream size, withdrawal rate, and biological resources present (fish-bearing vs. non-fish bearing) (Section 6).

Risk management measures (i.e., measures to further assess or mitigate potential effects of water withdrawal) are discussed in relation to the calculated Risk Management Levels (Section 7). In addition, we provide flow rates corresponding to 5% of mean annual discharge for each POA, which has been identified by regulators (Szczot, pers. comm. 2018) as the generic provincial critical environmental flow threshold (CEFT) (Section 8).

2. SPECIAL CONSIDERATIONS

Under the Provincial EFN Policy (Province of BC 2016), areas of cultural sensitivity qualify for special consideration in the assessment of EFN. The Tsolum River watershed lies in the heart of the unceded traditional territory of the K'òmoks First Nation (KFN) and has been a vital part of the KFN community since time immemorial. KFN are active participants in Tsolum River watershed stewardship and KFN knowledge, values, and concerns have been discussed as part of this EFN assessment (Hardy and Frank, pers comm, 2020, see Appendix D). Key values identified that relate to surface water quantity include:

- Treaty right to hunt, fish and gather;
- Spiritual cleansing and other cultural uses;
- Economic value – fishery (and other--e.g., water...);
- Navigability; and
- Important to the cultural identity and cultural practices of KFN.

Many of the environmental issues identified by KFN are incorporated into Section 7. Additional flow-related issues identified include water chemistry, riparian health, aggradation from upstream activities, downstream effects to K'òmoks Estuary, and hydrological and stream morphology changes due to land use changes.

KFN have identified the area around Pentledge IR#2 (at Tsolum River/Courtenay River confluence) as a specific area of cultural sensitivity. This location is a historic site that is culturally important and is also a modern day cultural and economic site. There is also a parcel of future treaty settlement lands (currently confidential) that could be considered an area of cultural of spiritual interest. KFN have also noted that areas of special interest and spiritual and cultural value are not necessarily things that can be quantified and mapped, and some areas of significance are confidential.

3. BACKGROUND REVIEW

3.1. Baseline Synthesis

Key background information relevant to environmental flows in the Tsolum River watershed is summarized in tabular format in Appendix A. For each assessment location, this table contains:

- Numbering for the associated FHAP reaches (Clough 2014);
- Stream length (total and surveyed);
- Length accessible by anadromous fish;
- Description of reach morphology;

- Key hydrological information, including availability of monitoring data;
- Description of the land use and alteration;
- Description of habitat (spawning and rearing);
- Information on fish observations;
- Description of access, barriers, and fish distribution;
- Description of environmental concerns;
- Comments from K'òmoks First Nation; and
- Watershed area.

Information on fish presence is required to apply the Environmental Risk Management Framework described within the Provincial EFN Policy (Province of BC 2016). Fish presence is summarized for each POA in the following section.

3.1.1. Fish Presence

The Tsolum River and major tributaries are low gradient streams readily accessible to anadromous salmonids; as a result, all POAs are fish-bearing. The specific salmonid species present at each POA are summarized in Table 1 (Heim, pers. comm 2020-'21) and further detail is provided in the Fisheries Background Review Table (Appendix A). In addition to these salmonid species, Pacific Lamprey (*Entosphenus tridentatus*), Coast Range Sculpin (*Cottus aleuticus*), Prickly Sculpin (*Cottus asper*), and Threespine Stickleback (*Gasterosteus aculeatus*) are present for all POAs.

Table 1. Salmonid species present at each Point of Assessment.

Location	Salmonid Species Present
Tsolum River upstream of Headquarters Creek	PK, CO, RB, CT, CH
Tsolum River upstream of Dove Creek (to Headquarters Creek)	PK, CO, RB, CT, CH
Tsolum River upstream of Portuguese Creek (to Dove Creek)	PK, CO, RB, CT, CH, CM
Tsolum River upstream of Courtenay River (to Portuguese Creek)	PK, CO, RB, CT, CH, CM
Portuguese Creek upstream of Tsolum River	CO, RB, CT, CH, CM
Piercy Creek upstream of Dove Creek	CO, CT
Jackpot Creek upstream of Dove Creek	CO, CT
Dove Creek upstream of Tsolum River	PK, CO, RB, CT
Headquarters Creek upstream of Tsolum River	PK, CO, RB, CT

PK: Pink Salmon (*Oncorhynchus gorbuscha*)
CO: Coho Salmon (*Oncorhynchus kisutch*)
RB: Rainbow Trout / Steelhead (*Oncorhynchus mykiss*)
CT: Cutthroat Trout (*Oncorhynchus clarkii*)
CH: Chinook Salmon (*Onchorhynchus tshawytscha*)
CM: Chum Salmon (*Oncorhynchus keta*)

3.2. FHAP Review

BC's Fish Habitat Assessment Procedure (FHAP) was developed in the late 1990's to assesses habitat through the lens of historical impacts from forest harvesting, and focuses on restoration and rehabilitation of habitat that has been previously impacted (Johnston and Slaney 1996). Reconnaissance-level and detailed assessment of EFN (i.e., Risk Level 2 and Risk Level 3 Risk Management Measures) requires specific information typically collected as part of FHAP (Level 1), described in Provincial guidance for environmental flows assessment (Lewis *et al.* 2004).

In 2014, a FHAP (Clough 2014) was conducted for the Tsolum River and significant salmon-bearing tributaries using methodology from Vancouver Island Urban Salmonid Habitat Program (USHP) Assessment and Mapping Procedures Manual. A subset of habitat units within each waterbody were surveyed. Each habitat unit was mapped with photographs and data are available publicly online. We have reviewed the existing FHAP data for the Tsolum River watershed and compared these data to the requirements specified in Lewis *et al.* (2004). In the following sections, we provide discussion on the information collected, the completeness of the dataset, and the flow conditions that were surveyed.

3.2.1. Information Collected

The FHAP approach described in Lewis *et al.* (2004) focuses on describing and quantifying fish habitat based on methodology provided in Johnston and Slaney (1996) with some modifications. Required data include:

a. Mesohabitat type;

b. Channel type;

c. Particle diameter – D95;

d. Gradient/slope;

e. Roughness; and

f. Cover.

3.2.1.1. Mesohabitat type

Mesohabitat type designations obtained in habitat assessments (e.g., cascade, glide, pool, riffle) are used to identify groups of habitat units that respond similarly to changes in streamflow and to characterize the sensitivity of habitat to changes in flow. There are several methods for defining habitat unit categories, ranging from coarse (slow waster or fast water, i.e., pool or riffle) to more complex, hierarchical classification schemes. Johnston and Slaney (1996) recommend an intermediate-level classification scheme that includes delineation of fast water habitat units into turbulent (riffles) and non-turbulent habitats (glides), and separation of riffles into high gradient (cascades) and lower gradient (riffles) categories.

Mesohabitat type designations for the Tsolum River FHAP are limited to two categories: riffle and pool (i.e., the coarsest classification scheme). Some glides in the Tsolum River watershed may be mis-characterized as pools (the mesohabitat type that is least sensitive to reduced streamflow) and hence the amount of flow-sensitive habitat may be underestimated in the existing data. If further habitat mapping is completed for the Tsolum River, we recommend assigning more detailed mesohabitat unit designations as described above, and further delineating glides into deep (run) and shallow glide habitats, i.e., classification of habitat units as riffle, cascade, glide, pool, or run. In addition, re-mapping an existing reach using the more detailed classifications could provide some insight into the quantity of run and glide habitats that are currently assigned as riffles or pools.

3.2.1.2. Channel Type

Channel type is a record of the general morphology of the stream channel and can be used to establish relative value of the channel as salmonid habitat. Though not recorded in the Tsolum River Watershed FHAP data, channel descriptions for each reach are provided in Gooding (2015).

3.2.1.3. Particle Diameter – D95

D95 is a measure of the diameter (along the b-axis) of the bed material particle that is larger than 95% of materials in the stream channel; this measurement is an important indicator of fish habitat quality. Measures of D95 were not collected in the Tsolum River Watershed FHAP.

3.2.1.4. Gradient/slope

Measures of gradient were recorded in every surveyed unit for the Tsolum River Watershed FHAP, however, the accuracy of recorded values is unknown. All pools were denoted to have a gradient of 0% despite photos suggesting some units may be better characterized as glides or runs (with gradients closer to 0.5%). Additionally, riffle mesohabitat units were identified with gradients greater than 5% which would classify them as cascades mesohabitat units according to Johnston and Slaney (1996). Gradient/slope should be measured as accurately as possible (i.e. survey level and rod are preferred to clinometer). Gradient information is provided at the reach level in Gooding (2015).

3.2.1.5. Roughness

Roughness is a measure of the irregularity of the substrate surface and is measured as the height of the average particle protruding from the streambed. Measures of roughness were not collected as part of the Tsolum River Watershed FHAP.

3.2.1.6. Cover

Tsolum River Watershed FHAP recorded the percent of cover provided by boulders, large woody debris (LWD), cut-banks, vegetation, and other sources. Johnston and Slaney (1996) recommend separation of vegetation cover into two categories (instream vegetation cover and overhanging vegetation cover), and inclusion of deep pool habitat as a cover type.

3.2.2. Completeness of data

The stream lengths surveyed in the Tsolum River Watershed FHAP are summarized in Table 2. The Tsolum River watershed FHAP survey included data collection for at least 10 habitat units in each reach (as defined in Clough 2014), overall providing data for ~ 25% of the Tsolum River mainstem, 12% of Headquarters Creek, 5% of Dove Creek, and 8% of Portuguese Creek.

3.2.3. Survey flows

The assignment of mesohabitat types depends on the flow conditions surveyed, e.g., a riffle at low flow may become a run when more flow is present. Ideally, FHAP data are collected under low flow conditions (Lewis *et al.* 2004). Clough (2014) reports that the Tsolum River Watershed FHAP survey data were collected between September 30 and October 24, 2014, and during this period flow increased from base low flow (the majority of surveys) to flood conditions. A description of the flow conditions during surveys, as described by Clough (2014), is provided in Table 2.

3.2.4. Summary

The FHAP data collected for the Tsolum River watershed provide some of the information required in Provincial guidance for environmental flows assessment (Lewis *et al.* 2004) that is referenced under Risk Management Measures for Risk Level 2 and Risk Level 3. However, the FHAP data collected to date do not include detailed mesohabitat mapping, and so additional data collection may be required to ensure confidence in assessment of EFN for the Tsolum River watershed.

Table 2. Length of habitat surveyed in Tsolum River Watershed FHAP and description of flow condition during habitat survey (Clough 2014)

Waterbody	Reach	Length (m)	Survey Length (m)	Survey Length (%)	Survey Flow Condition[1]
Tsolum River	T1	2,080	956	46%	low
	T2	1,306	660	51%	low
	T3	889	588	66%	low-moderate
	T4	1,639	672	41%	low-moderate
	T5	6,964	797	11%	low
	T6	4,375	387	9%	low-moderate
	T7	1,747	449	26%	low-moderate
	T8	1,903	700	37%	low-moderate
	T9	3,853	765	20%	low-moderate
	T10	1,775	706	40%	low-moderate
	T11	1,113	649	58%	low-moderate
	T12	1,240	310	25%	low-moderate
	T13	2,048	182	9%	low-moderate
	Total	**30,932**	**7,821**	**9% to 66%**	
Portuguese Creek	P1	611	329	54%	moderate
	P2	1,929	124	6%	moderate
	P3	1,822	159	9%	moderate
	P4	2,221	0	0%	
	P5	1,214	296	24%	moderate
	P6	4,087	0	0%	
	Total	**11,884**	**908**	**0% to 54%**	
Dove Creek	D1	1,723	370	21%	low
	D2	1,571	0	0%	
	D3	3,294	303	9%	low
	D4	1,319	0	0%	
	D5	921	0	0%	
	D6	2,067	435	21%	low
	D7	3,691	0	0%	
	D8	6,367	0	0%	
	Total	**20,953**	**1,108**	**0% to 21%**	
Headquarters Creek	HQ1	3,303	440	13%	moderate
	HQ2	721	335	46%	moderate
	HQ3	2,228	0	0%	
	Total	**6,252**	**775**	**13% to 46%**	

[1]Surveys completed between September 30 and October 24, 2014, under conditions ranging from base low flows to flood flows

4. CURRENT AND PROSPECTIVE DEMAND

Water demand estimates for each POA were provided by G.W. Solutions (Barroso Pers. Comm 2020). Separate estimates are provided for demand from surface water and from groundwater sources, although some future agricultural demand sources are unknown. Separate estimates are provided for surface water demand and groundwater demand because surface water withdrawals have a direct effect on streamflow, while the influence of groundwater withdrawals on streamflow is indirect and influenced by the location of withdrawal, aquifer characteristics, and the subsurface hydrology of the watershed. The total water demand estimated here as the sum of surface water demand and groundwater demand represents the 'worst-case' potential effect of water withdrawal on streamflow in Tsolum River and its tributaries. Consideration of the total water demand is consistent with the Provincial EFN Policy (Province of BC 2016), which requires consideration of water extraction from both surface water sources and hydraulically connected aquifers.

4.1. Current Demand

The Environmental Risk Management Framework is evaluated for two estimates of current demand for each POA.

The first estimate of current water demand (Scenario 1) reflects water withdrawals currently licensed within the Tsolum River watershed, which may differ from actual withdrawal, either lesser (due to licensed allocation not currently in use), or greater (due to unlicensed withdrawal of water).

The second estimate of current water demand (Scenario 2) considers agricultural water use separately from other sources, according to estimates from the Agricultural Water Demand Model (AWDM) rather than from water licence data. Non-agricultural licensed use, domestic usage estimated based on lot size, and small water supply systems licensed by Vancouver Island Health Authority are also included in this estimate (as they are in Scenario 1). The estimates of demand from Scenario 2 are generated in the same way as the prospective water demand scenarios modelled by the AWDM (Scenarios 3-11) where agricultural demand is varied.

4.2. Prospective Demand Scenarios

The Environmental Risk Management Framework is evaluated for nine prospective agricultural water demand and management scenarios:

1. Improved irrigation management: good management, current climate, current land use, current irrigation systems;
2. More people begin irrigating (efficiently): current irrigation systems plus efficient systems installed on un-irrigated land, good management, current land use, current climate;
3. Increased production A (48% forage & pasture);
4. Increased production B (60% forage & pasture);
5. Increased production C (85% forage & pasture);

6. Current conditions plus increased demand due to climate change;
7. Increased production A plus climate change[1];
8. Increased production B plus climate change[1]; and
9. Increased production C plus climate change[1].

These scenarios are analogous to the current demand estimates under Scenario 2, with adjustments to agricultural demand as described above. No adjustments are made to account for increased demand from non-agricultural uses. A full description of the agricultural water demand scenarios is provided in the appendices of the Phase 2 Report (Metherall 2021).

5. HYDROLOGY

Mean monthly discharge was estimated based on water budget modelling completed by GW Solutions (2020). Monthly discharge was provided in units of cubic decameters per month; these values were used to calculate mean monthly discharge and mean annual discharge for completion of the Environmental Risk Assessment Framework (Province of BC 2016). We note that the hydrological estimates for Tsolum River during the summer may reflect flow augmentation from storage at Wolf Lake (and hence overestimate natural streamflow downstream of Headquarters Creek).

For several POAs, the discharge estimates are based on modelled rather than measured flows because hydrometric data were not available for all locations. The model was calibrated by comparing modelled data to gauged data from all available hydrometric stations in the watershed considering data from the years 1981-2010 (the most recent climate normal data). We note that in more recent years, measured flows in the summer months are lower than modelled results, and flows may further decrease with climate change. The Water Budget Study (G.W. Solutions 2020) provides further information on the water balance model and an analysis of flows, including a statistical comparison between modelled and measured flows and some analysis of the differences.

[1] The scenarios that include climate change effects on water demand (Scenarios 7-9) were modelled using climate data available from the Pacific Climate Impacts Consortium. The climate models used were access1 rcp85, canESM2 rcp85, and cnrm-cm5 rcp85, run for three years: 2053, 2056, 2059.

6. RISK MANAGEMENT LEVELS

Risk Management Levels for each POA for each month were calculated under the two estimates of current demand and nine prospective water demand scenarios. These calculations were completed using the information from Sections 2 to 5 above according to the Environmental Risk Management Framework (Figure 1):

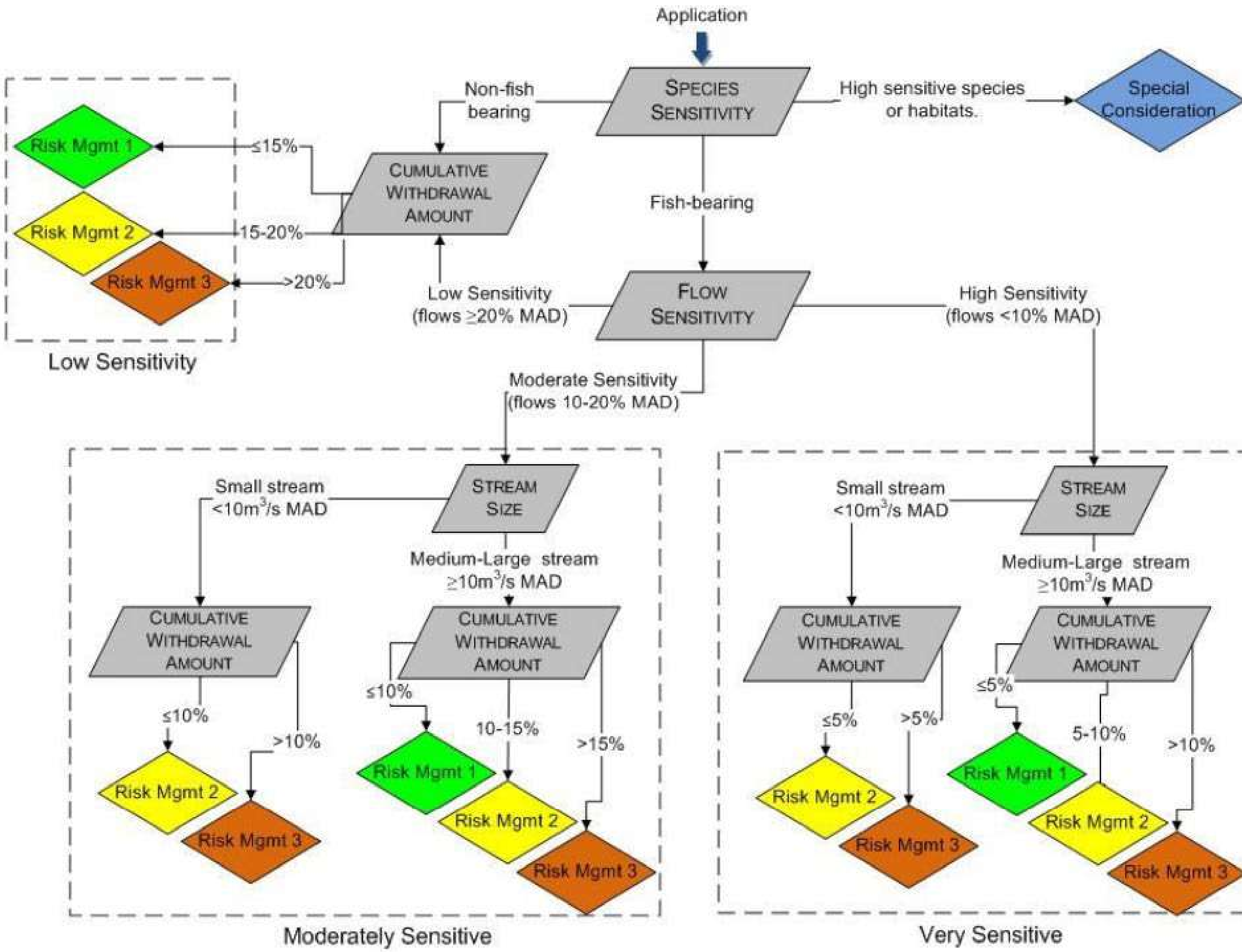
1. All POAs are fish-bearing;
2. Flow sensitivity for each month was determined by calculating mean monthly discharge (MMD) as a percentage of mean annual discharge (MAD);
3. The stream size for each POA was assessed as either small or medium-large based on MAD; and
4. The Risk Management Levels were calculated for each month based on items 1-3 above and the current and prospective demand rates.

Risk Management Levels were evaluated for total demand (surface water plus groundwater) and surface water demand only. Information underlying these calculations is provided in spreadsheet format in Appendix B (by POA for each month), and an alternative presentation (by month for each POA) is presented in spreadsheet format in Appendix C.

Risk Management Levels are provided for each POA and water demand scenario in the following subsections in tabular format. Brief discussion of these Risk Management Levels is provided, comparing current water demand to demand under increased agricultural production.

We note that this screening-level assessment relies on historical streamflow data; consideration of streamflow under future climate conditions is recommended as an area of future work (see Section 7.1.1.2 below).

Figure 1. Environmental Risk Management Framework (Province of BC 2016).



6.1. Tsolum River Upstream of Courtenay River

Considering surface water sources only, current water demand for Tsolum River upstream of Courtenay River (Table 3a) is assessed at Risk Level 1 for all months except August (Risk Level 2). Prospective demand scenarios with additional irrigation (Scenarios 4-11) increase August demand to Risk Level 3. The six scenarios with increased agricultural production (Scenarios 5-7 and 9-11) increase the Risk Level from June to September from Risk Level 1 to Risk Level 2 or Risk Level 3, indicating that increased agricultural production will extend the duration of elevated risk to EFN in Tsolum River. Considering both surface water and groundwater sources (Table 3b), current demand is assessed at Risk Level 3 for July and August. Increased agricultural production increases the Risk Level for June and September from Risk Level 1 to Risk Level 3.

We note that Tsolum River Restoration Society (Heim, pers. comm 2020-'21) has highlighted Tsolum River upstream of Courtenay River as the only POA assigned as a medium-large stream under the Risk Management Framework because estimated mean annual discharge exceeds 10 m^3/s. If this POA is considered a small stream (i.e., MAD is reduced to 9.99 m^3/s), then the current surface water demand risk increases to Risk Level 3 in August and total water demand is assessed as Risk Level 3 for and both July and August (Table 4).

Table 3. Results of the EFN Environmental Risk Management Framework for Tsolum River between Portuguese Creek and Courtenay River considering demand from a) surface water sources and b) surface and groundwater sources.

a) Surface water sources

Month	Mean Monthly Discharge (m³/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed allocation	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	19.393	183%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	16.708	158%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	13.184	125%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	10.620	100%	low	1	1	1	1	1	1	1	1	1	1	1
May	6.916	65%	low	1	1	1	1	1	1	1	1	1	1	1
Jun	3.782	36%	low	1	1	1	1	2	2	3	1	2	3	3
Jul	1.775	17%	moderate	1	1	1	1	3	3	3	1	3	3	3
Aug	0.969	9%	high	2	2	2	3	3	3	3	3	3	3	3
Sep	1.614	15%	moderate	1	1	1	1	2	3	3	1	3	3	3
Oct	13.181	125%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	20.450	193%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	18.720	177%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	10.580													

b) Surface and groundwater sources

Month	Mean Monthly Discharge (m³/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	19.393	183%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	16.708	158%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	13.184	125%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	10.620	100%	low	1	1	1	1	1	1	1	1	1	1	1
May	6.916	65%	low	1	1	1	1	1	1	1	1	1	1	1
Jun	3.782	36%	low	1	1	1	3	3	3	3	1	3	3	3
Jul	1.775	17%	moderate	1	3	3	3	3	3	3	3	3	3	3
Aug	0.969	9%	high	2	3	3	3	3	3	3	3	3	3	3
Sep	1.614	15%	moderate	1	1	1	3	3	3	3	1	3	3	3
Oct	13.181	125%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	20.450	193%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	18.720	177%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	10.580													

Table 4. Results of the EFN Environmental Risk Management Framework for Tsolum River using the 'small stream' framework for a) surface water sources and b) surface and groundwater sources.

a) Surface water sources

Month	Mean Monthly Discharge (m^3/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate (efficiently)	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
1	19.393	194%	low	1	1	1	1	1	1	1	1	1	1	1
2	16.708	167%	low	1	1	1	1	1	1	1	1	1	1	1
3	13.184	132%	low	1	1	1	1	1	1	1	1	1	1	1
4	10.620	106%	low	1	1	1	1	1	1	1	1	1	1	1
5	6.916	69%	low	1	1	1	1	1	1	1	1	1	1	1
6	3.782	38%	low	1	1	1	1	2	2	3	1	2	3	3
7	1.775	18%	moderate	2	2	2	2	3	3	3	2	3	3	3
8	0.969	10%	high	3	3	3	3	3	3	3	3	3	3	3
9	1.614	16%	moderate	2	2	2	2	3	3	3	2	3	3	3
10	13.181	132%	low	1	1	1	1	1	1	1	1	1	1	1
11	20.450	205%	low	1	1	1	1	1	1	1	1	1	1	1
12	18.720	187%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	9.990													

b) Surface and groundwater sources

Month	Mean Monthly Discharge (m^3/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate (efficiently)	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
1	19.393	194%	low	1	1	1	1	1	1	1	1	1	1	1
2	16.708	167%	low	1	1	1	1	1	1	1	1	1	1	1
3	13.184	132%	low	1	1	1	1	1	1	1	1	1	1	1
4	10.620	106%	low	1	1	1	1	1	1	1	1	1	1	1
5	6.916	69%	low	1	1	1	1	1	1	1	1	1	1	1
6	3.782	38%	low	1	1	1	3	3	3	3	1	3	3	3
7	1.775	18%	moderate	2	3	3	3	3	3	3	3	3	3	3
8	0.969	10%	high	3	3	3	3	3	3	3	3	3	3	3
9	1.614	16%	moderate	2	2	2	3	3	3	3	2	3	3	3
10	13.181	132%	low	1	1	1	1	1	1	1	1	1	1	1
11	20.450	205%	low	1	1	1	1	1	1	1	1	1	1	1
12	18.720	187%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	9.990													

6.2. Tsolum River Upstream of Portuguese Creek

Considering surface water sources, Tsolum River from Dove Creek to Portuguese Creek is currently assessed at Risk Level 2 from July to September (Table 5a). The six scenarios with increased agricultural production (Scenarios 5-7 and 9-11) are assessed at Risk Level 3 for both July and August. Considering both surface and groundwater sources, demand for this section of Tsolum River is currently assessed at Risk Level 3 in August, and Risk Level 2 for July and September. Water demand from increased agricultural production is assessed at Risk Level 3 from July through September, and for June, demand increases from Risk Level 1 to Risk Level 2 or Risk Level 3, depending on production scenario.

Table 5. Results of the EFN Environmental Risk Management Framework for Tsolum River between Dove Creek and Portuguese Creek considering demand from a) surface water sources and b) surface and groundwater sources.

a) Surface water sources

Month	Mean Monthly Discharge (m³/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	16.103	183%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	13.857	158%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	10.791	123%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	8.703	99%	low	1	1	1	1	1	1	1	1	1	1	1
May	5.682	65%	low	1	1	1	1	1	1	1	1	1	1	1
Jun	3.213	37%	low	1	1	1	1	1	1	1	1	1	1	1
Jul	1.510	17%	moderate	2	2	2	2	3	3	3	2	3	3	3
Aug	0.854	10%	high	2	2	2	2	3	3	3	2	3	3	3
Sep	1.628	19%	moderate	2	2	2	2	2	2	2	2	2	2	3
Oct	11.260	128%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	16.812	191%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	15.371	175%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	8.791													

b) Surface and groundwater sources

Month	Mean Monthly Discharge (m³/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	16.103	183%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	13.857	158%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	10.791	123%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	8.703	99%	low	1	1	1	1	1	1	1	1	1	1	1
May	5.682	65%	low	1	1	1	1	1	1	1	1	1	1	1
Jun	3.213	37%	low	1	1	1	1	1	2	2	1	2	3	3
Jul	1.510	17%	moderate	2	2	2	3	3	3	3	2	3	3	3
Aug	0.854	10%	high	2	3	3	3	3	3	3	3	3	3	3
Sep	1.628	19%	moderate	2	2	2	2	3	3	3	2	3	3	3
Oct	11.260	128%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	16.812	191%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	15.371	175%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	8.791													

6.3. Tsolum River Upstream of Dove Creek

Tsolum River between Headquarters Creek and Dove Creek is currently assessed at Risk Level 2 in July and August (Table 6). For the six scenarios with increased agricultural production (Scenarios 5-7 and 9-11), water demand is assessed at Risk Level 3 for July and August.

Table 6. Results of the EFN Environmental Risk Management Framework for Tsolum River between Headquarters Creek and Dove Creek considering demand from a) surface water sources and b) surface and groundwater sources.

a) Surface water sources

Month	Mean Monthly Discharge (m³/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	11.770	182%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	10.167	158%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	7.850	122%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	6.392	99%	low	1	1	1	1	1	1	1	1	1	1	1
May	4.224	65%	low	1	1	1	1	1	1	1	1	1	1	1
Jun	2.465	38%	low	1	1	1	1	1	1	1	1	1	1	1
Jul	1.183	18%	moderate	2	2	2	2	3	3	3	2	3	3	3
Aug	0.694	11%	moderate	2	2	2	2	3	3	3	2	3	3	3
Sep	1.314	20%	low	1	1	1	1	1	1	1	1	1	1	1
Oct	8.357	129%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	12.154	188%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	11.090	172%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	6.454													

b) Surface and groundwater sources

Month	Mean Monthly Discharge (m³/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	11.770	182%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	10.167	158%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	7.850	122%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	6.392	99%	low	1	1	1	1	1	1	1	1	1	1	1
May	4.224	65%	low	1	1	1	1	1	1	1	1	1	1	1
Jun	2.465	38%	low	1	1	1	1	1	1	1	1	1	1	1
Jul	1.183	18%	moderate	2	2	2	2	3	3	3	2	3	3	3
Aug	0.694	11%	moderate	2	2	2	2	3	3	3	2	3	3	3
Sep	1.314	20%	low	1	1	1	1	1	1	1	1	1	1	1
Oct	8.357	129%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	12.154	188%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	11.090	172%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	6.454													

6.4. Tsolum River Upstream of Headquarters Creek

Current water demand for Tsolum River upstream of Headquarters Creek is assessed at Risk Level 2 in July and August (Table 7). Water demand associated with increased agricultural production during August is assessed at Risk Level 3 for five of the six increased production scenarios (Scenarios 5-7 and 9-11) when surface water sources are considered, and for all six increased production scenarios when both surface and groundwater sources are considered. July surface water demand is assessed at Risk Level 3 for two of the increased agricultural production scenarios, and total demand is assessed at Risk Level 3 for all six increased production scenarios.

Table 7. Results of the EFN Environmental Risk Management Framework for Tsolum River upstream of Headquarters Creek considering demand from a) surface water sources and b) surface and groundwater sources.

a) Surface water sources

Month	Mean Monthly Discharge (m³/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	8.747	180%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	7.576	156%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	5.849	120%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	4.872	100%	low	1	1	1	1	1	1	1	1	1	1	1
May	3.249	67%	low	1	1	1	1	1	1	1	1	1	1	1
Jun	1.931	40%	low	1	1	1	1	1	1	1	1	1	1	1
Jul	0.943	19%	moderate	2	2	2	2	2	2	2	2	2	3	3
Aug	0.583	12%	moderate	2	2	2	2	2	3	3	2	3	3	3
Sep	1.071	22%	low	1	1	1	1	1	1	1	1	1	1	1
Oct	6.407	132%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	9.014	185%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	8.246	170%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	4.861													

b) Surface and groundwater sources

Month	Mean Monthly Discharge (m³/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	8.747	180%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	7.576	156%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	5.849	120%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	4.872	100%	low	1	1	1	1	1	1	1	1	1	1	1
May	3.249	67%	low	1	1	1	1	1	1	1	1	1	1	1
Jun	1.931	40%	low	1	1	1	1	1	1	1	1	1	1	1
Jul	0.943	19%	moderate	2	2	2	2	3	3	3	2	3	3	3
Aug	0.583	12%	moderate	2	2	2	2	3	3	3	2	3	3	3
Sep	1.071	22%	low	1	1	1	1	1	1	1	1	1	1	1
Oct	6.407	132%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	9.014	185%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	8.246	170%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	4.861													

6.5. Portuguese Creek Upstream of Tsolum River

Considering surface water demand only (Table 8a), Portuguese Creek is currently assessed at Risk Level 2 from July to September. Surface water demand for all six increased agricultural production scenarios (Scenarios 5-7 and 9-11) is assessed at Risk Level 3 from June to September.

Considering surface and groundwater sources (Table 8b), current demand for Portuguese Creek is assessed at Risk Level 3 from June to September. Increased demand during May for all six agricultural production results in an increase in assessed risk, from Risk Level 1 to Risk Level 3.

Table 8. Results of the EFN Environmental Risk Management Framework for Portuguese Creek considering demand from a) surface water sources and b) surface and groundwater sources.

a) Surface water sources

Month	Mean Monthly Discharge (m³/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	2.504	183%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	2.173	158%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	1.823	133%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	1.458	106%	low	1	1	1	1	1	1	1	1	1	1	1
May	0.937	68%	low	1	1	1	1	1	1	1	1	1	1	2
Jun	0.432	32%	low	1	1	1	1	3	3	3	1	3	3	3
Jul	0.201	15%	moderate	2	2	2	2	3	3	3	2	3	3	3
Aug	0.087	6%	high	2	2	2	3	3	3	3	2	3	3	3
Sep	0.084	6%	high	2	2	2	2	3	3	3	2	3	3	3
Oct	1.472	107%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	2.774	202%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	2.554	186%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	1.371													

b) Surface and groundwater sources

Month	Mean Monthly Discharge (m³/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	2.504	183%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	2.173	158%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	1.823	133%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	1.458	106%	low	1	1	1	1	1	1	1	1	1	1	1
May	0.937	68%	low	1	1	1	2	3	3	3	1	3	3	3
Jun	0.432	32%	low	1	3	3	3	3	3	3	3	3	3	3
Jul	0.201	15%	moderate	2	3	3	3	3	3	3	3	3	3	3
Aug	0.087	6%	high	2	3	3	3	3	3	3	3	3	3	3
Sep	0.084	6%	high	2	3	3	3	3	3	3	3	3	3	3
Oct	1.472	107%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	2.774	202%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	2.554	186%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	1.371													

6.6. Dove Creek Upstream of Tsolum River

Dove Creek is currently assessed at Risk Level 1 between October and June, and Risk Level 2 between July and September (Table 9). All scenarios with increased agricultural production (Scenarios 5-7 and 9-11) are assessed at Risk Level 3 in July and August, regardless of water source, and demand for the shoulder months of June and September is also assessed at Risk Level 3 for some increased agricultural production scenarios.

Table 9. Results of the EFN Environmental Risk Management Framework for Dove Creek upstream of Tsolum River considering demand from a) surface water sources and b) surface and groundwater sources.

a) Surface water sources

Month	Mean Monthly Discharge (m³/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	3.314	186%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	2.811	158%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	2.201	123%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	1.720	97%	low	1	1	1	1	1	1	1	1	1	1	1
May	1.076	60%	low	1	1	1	1	1	1	1	1	1	1	1
Jun	0.569	32%	low	1	1	1	1	1	1	1	1	1	2	2
Jul	0.241	14%	moderate	2	2	2	2	3	3	3	2	3	3	3
Aug	0.121	7%	high	2	2	2	2	3	3	3	2	3	3	3
Sep	0.318	18%	moderate	2	2	2	2	2	2	3	2	2	2	3
Oct	2.296	129%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	3.533	198%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	3.246	182%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	1.782													

b) Surface and groundwater sources

Month	Mean Monthly Discharge (m³/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	3.314	186%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	2.811	158%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	2.201	123%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	1.720	97%	low	1	1	1	1	1	1	1	1	1	1	1
May	1.076	60%	low	1	1	1	1	1	1	1	1	1	1	1
Jun	0.569	32%	low	1	1	1	1	1	2	2	1	2	3	3
Jul	0.241	14%	moderate	2	2	2	2	3	3	3	2	3	3	3
Aug	0.121	7%	high	2	2	2	3	3	3	3	2	3	3	3
Sep	0.318	18%	moderate	2	2	2	2	2	2	3	2	2	3	3
Oct	2.296	129%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	3.533	198%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	3.246	182%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	1.782													

6.7. Jackpot Creek Upstream of Dove Creek

Jackpot Creek is currently assessed at Risk Level 1 between October and June, and Risk Level 2 between July and September (Table 10). All scenarios with increased production (Scenarios 5-7 and 9-11) are assessed at Risk Level 3 in July and August, regardless of water source, and demand for the shoulder months of June and September is also assessed at Risk Level 3 for some increased production scenarios.

Table 10. Results of the EFN Environmental Risk Management Framework for Jackpot Creek upstream of Dove Creek considering demand from a) surface water sources and b) surface and groundwater sources.

a) Surface water sources

Month	Mean Monthly Discharge (m^3/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	0.521	192%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	0.431	159%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	0.341	126%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	0.240	88%	low	1	1	1	1	1	1	1	1	1	1	1
May	0.136	50%	low	1	1	1	1	1	1	1	1	1	1	1
Jun	0.071	26%	low	1	1	1	1	1	3	3	1	1	3	3
Jul	0.037	14%	moderate	2	2	2	2	3	3	3	2	3	3	3
Aug	0.018	7%	high	2	2	2	2	3	3	3	2	3	3	3
Sep	0.034	13%	moderate	2	2	2	2	2	2	3	2	2	2	3
Oct	0.343	127%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	0.569	210%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	0.519	191%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	0.271													

b) Surface and groundwater sources

Month	Mean Monthly Discharge (m^3/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	0.521	192%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	0.431	159%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	0.341	126%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	0.240	88%	low	1	1	1	1	1	1	1	1	1	1	1
May	0.136	50%	low	1	1	1	1	1	1	1	1	1	1	1
Jun	0.071	26%	low	1	1	1	1	1	3	3	1	1	3	3
Jul	0.037	14%	moderate	2	2	2	2	3	3	3	2	3	3	3
Aug	0.018	7%	high	2	2	2	2	3	3	3	2	3	3	3
Sep	0.034	13%	moderate	2	2	2	2	2	2	3	2	2	2	3
Oct	0.343	127%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	0.569	210%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	0.519	191%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	0.271													

6.8. Piercy Creek Upstream of Dove Creek

Piercy Creek is currently assessed at Risk Level 1 between October and June, and Risk Level 2 between July and September (Table 11). All scenarios with increased agricultural production (Scenarios 5-7 and 9-11) are assessed at Risk Level 3 in July and August, regardless of water source, and under future climate conditions demand for September is assessed at Risk Level 3 for all increased agricultural production scenarios.

Table 11. Results of the EFN Environmental Risk Management Framework for Piercy Creek upstream of Dove Creek considering demand from a) surface water sources and b) surface and groundwater sources.

a) Surface water sources

Month	Mean Monthly Discharge (m^3/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	0.490	196%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	0.406	162%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	0.315	126%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	0.221	88%	low	1	1	1	1	1	1	1	1	1	1	1
May	0.128	51%	low	1	1	1	1	1	1	1	1	1	1	1
Jun	0.064	26%	low	1	1	1	1	1	1	1	1	2	2	2
Jul	0.026	10%	moderate	2	2	2	2	3	3	3	2	3	3	3
Aug	0.010	4%	high	2	2	2	2	3	3	3	2	3	3	3
Sep	0.034	13%	moderate	2	2	2	2	2	2	2	2	3	3	3
Oct	0.314	126%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	0.527	211%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	0.478	191%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	0.250													

b) Surface and groundwater sources

Month	Mean Monthly Discharge (m^3/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	0.490	196%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	0.406	162%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	0.315	126%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	0.221	88%	low	1	1	1	1	1	1	1	1	1	1	1
May	0.128	51%	low	1	1	1	1	1	1	1	1	1	1	1
Jun	0.064	26%	low	1	1	1	1	1	1	1	1	2	2	2
Jul	0.026	10%	moderate	2	2	2	2	3	3	3	2	3	3	3
Aug	0.010	4%	high	2	2	2	2	3	3	3	2	3	3	3
Sep	0.034	13%	moderate	2	2	2	2	2	2	2	2	3	3	3
Oct	0.314	126%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	0.527	211%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	0.478	191%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	0.250													

6.9. Headquarters Creek Upstream of Tsolum River

Headquarters Creek is currently assessed at Risk Level 1 from October to June, and Risk Level 2 from July to September (Table 12). All increased agricultural production scenarios (Scenarios 5-7 and 9-11) are assessed at Risk Level 3. The assignments of Risk Level 2 and Risk Level 3 are based on the small stream size and moderate to high sensitivity (from July to September), which may be overstated given augmentation from Wolf Lake during low flow months.

Table 12. Results of the EFN Environmental Risk Management Framework for Headquarter Creek upstream of Tsolum River considering demand from a) surface water sources and b) surface and groundwater sources.

a) Surface water sources

Month	Mean Monthly Discharge (m³/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed allocation	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	2.379	192%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	2.031	164%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	1.527	123%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	1.139	92%	low	1	1	1	1	1	1	1	1	1	1	1
May	0.718	58%	low	1	1	1	1	1	1	1	1	1	1	1
Jun	0.411	33%	low	1	1	1	1	1	1	1	1	1	1	1
Jul	0.181	15%	moderate	2	2	2	2	2	2	2	2	2	2	2
Aug	0.086	7%	high	2	2	2	2	3	3	3	2	3	3	3
Sep	0.245	20%	moderate	2	2	2	2	2	2	2	2	2	2	2
Oct	1.567	127%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	2.427	196%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	2.186	177%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	1.238													

b) Surface and groundwater sources

Month	Mean Monthly Discharge (m³/s)	% of Mean Annual Discharge	Flow Sensitivity	Risk Management Level										
				Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Jan	2.379	192%	low	1	1	1	1	1	1	1	1	1	1	1
Feb	2.031	164%	low	1	1	1	1	1	1	1	1	1	1	1
Mar	1.527	123%	low	1	1	1	1	1	1	1	1	1	1	1
Apr	1.139	92%	low	1	1	1	1	1	1	1	1	1	1	1
May	0.718	58%	low	1	1	1	1	1	1	1	1	1	1	1
Jun	0.411	33%	low	1	1	1	1	1	1	1	1	1	1	1
Jul	0.181	15%	moderate	2	2	2	2	2	2	2	2	2	2	2
Aug	0.086	7%	high	2	2	2	2	3	3	3	2	3	3	3
Sep	0.245	20%	moderate	2	2	2	2	2	2	2	2	2	2	2
Oct	1.567	127%	low	1	1	1	1	1	1	1	1	1	1	1
Nov	2.427	196%	low	1	1	1	1	1	1	1	1	1	1	1
Dec	2.186	177%	low	1	1	1	1	1	1	1	1	1	1	1
Annual	1.238													

6.10. Summary

During the lowest flow month of August, surface water demand for all POAs is assessed at Risk Level 2 under current conditions (Table 13a). Surface water demand from increased agricultural production (Scenarios 5-7 and 9-11) is assessed at Risk Level 3 for all scenarios, except for Increased Production A in Tsolum River upstream of Headquarters Creek.

During August, current total water demand (surface and groundwater) is assessed at Risk Level 3 in Tsolum River from the Dove Creek confluence to Courtenay River confluence, and within Portuguese Creek (Table 13b). Water demand associated with increased agricultural production is assessed at Risk Level 3 for all locations and scenarios.

Table 13. Results of the Environmental Risk Management Framework for August considering demand from a) surface water sources and b) surface and groundwater sources

a) Surface water sources

Location	Mean Monthly Discharge (m³/s)	Mean Annual Discharge (m³/s)	% of Mean Annual Discharge	Stream Size	Flow Sensitivity	Risk Management Level										
						Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate (efficiently)	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Tsolum River upstream of Courtenay River	0.969	10.580	9%	med-large	high	2	2	2	3	3	3	3	3	3	3	3
Tsolum River upstream of Portuguese Creek	0.854	8.791	10%	small	high	2	2	2	2	3	3	3	2	3	3	3
Tsolum River upstream of Dove Creek	0.694	6.454	11%	small	moderate	2	2	2	2	3	3	3	2	3	3	3
Tsolum River upstream of Headquarters Creek	0.583	4.861	12%	small	moderate	2	2	2	2	2	3	3	2	3	3	3
Portuguese Creek upstream of Tsolum River	0.087	1.371	6%	small	high	2	2	2	3	3	3	3	2	3	3	3
Dove Creek upstream of Tsolum River	0.121	1.782	7%	small	high	2	2	2	2	3	3	3	2	3	3	3
Jackpot Creek upstream of Dove Creek	0.018	0.271	7%	small	high	2	2	2	2	3	3	3	2	3	3	3
Piercy Creek upstream of Dove Creek	0.010	0.250	4%	small	high	2	2	2	2	3	3	3	2	3	3	3
Headquarters Creek upstream of Tsolum River	0.086	1.238	7%	small	high	2	2	2	2	3	3	3	2	3	3	3

b) Surface and groundwater sources

Location	Mean Monthly Discharge (m³/s)	Mean Annual Discharge (m³/s)	% of Mean Annual Discharge	Stream Size	Flow Sensitivity	Risk Management Level										
						Licensed demand	Current conditions (est. using AWDM)	Current with improved irrigation mgmt.	Current crops, more people irrigate (efficiently)	Increased production A (48% forage & pasture)	Increased production B (60% forage & pasture)	Increased production C (85% forage & pasture)	Current conditions plus climate change	Increased production A plus climate change	Increased production B plus climate change	Increased production C plus climate change
Tsolum River upstream of Courtenay River	0.969	10.580	9%	med-large	high	2	3	3	3	3	3	3	3	3	3	3
Tsolum River upstream of Portuguese Creek	0.854	8.791	10%	small	high	2	3	3	3	3	3	3	3	3	3	3
Tsolum River upstream of Dove Creek	0.694	6.454	11%	small	moderate	2	2	2	2	3	3	3	2	3	3	3
Tsolum River upstream of Headquarters Creek	0.583	4.861	12%	small	moderate	2	2	2	2	3	3	3	2	3	3	3
Portuguese Creek upstream of Tsolum River	0.087	1.371	6%	small	high	2	3	3	3	3	3	3	3	3	3	3
Dove Creek upstream of Tsolum River	0.121	1.782	7%	small	high	2	2	2	3	3	3	3	2	3	3	3
Jackpot Creek upstream of Dove Creek	0.018	0.271	7%	small	high	2	2	2	2	3	3	3	2	3	3	3
Piercy Creek upstream of Dove Creek	0.010	0.250	4%	small	high	2	2	2	2	3	3	3	2	3	3	3
Headquarters Creek upstream of Tsolum River	0.086	1.238	7%	small	high	2	2	2	2	3	3	3	2	3	3	3

7. RISK MANAGEMENT MEASURES

The Provincial EFN Policy includes recommended considerations for Risk Management Measures, such as further assessment or mitigation of potential effects of water withdrawal. Many of these measures are regulatory tools (italicized in list below) or have been previously recommended or discussed in the context of the Tsolum River Agricultural Watershed Plan, e.g., by GW Solutions (2020) and Metherall (2019) (underlined in list below). These measures include:

Level 1:

1. Assess veracity of information and ensure appropriate methods are used; and
2. Consider downstream users and species/habitats.

Level 2 (in addition to Level 1 measures):

1. Establish adequate baseline hydrological data before withdrawals;
2. Prepare reconnaissance-level fish and fish habitat impact assessment;
3. *Issue seasonal licence or restrictions during low flow periods;*
4. Development of off-stream storage;
5. *Inclusion of a daily maximum or instantaneous withdrawal rate;*
6. *Limit pump intake size;*
7. *Monitor and report water use during higher risk flow periods;*
8. *Monitor low flows and limit withdrawals when flows drop below a certain level;*
9. *Ministry staff to conduct audit of basin use/beneficial use review; and*
10. *Refuse application to withdraw water.*

Level 3 (in addition to Level 2 measures):

1. *Issue limited licence term, allowing for review and potential adjustment; and*
2. Prepare detailed habitat assessment (e.g., Lewis *et al.* 2004, Hatfield *et al.* 2007).

Special considerations (e.g., sensitive species, cultural sensitivities):

1. Apply regional fish periodicity chart.

In the following sections we provide further details around those Level 2 and Level 3 measures that are not regulatory tools and have not been discussed in previous Tsolum Agricultural Watershed Planning reports. These measures involve detailed characterization of Tsolum River watershed hydrology, identification of critical fish habitats, additional scoping of flow-related environmental issues, and conducting a detailed assessment of the response of the aquatic environment to changes in flow. Some or all of these measures may be required before further allocation from Tsolum River watershed is permitted, depending on the location, timing, and volume of additional water withdrawal (i.e., considering the Risk Levels in Section 6). Prior to proceeding with these measures, we recommend consultation with regulators to confirm the scope of further EFN assessment.

7.1. Level 2 Measures

The Risk Management Measures described in this section are applicable to evaluate additional water withdrawals assessed at Risk Level 2. Some of these measures may be considered to improve understanding of EFN in the Tsolum River watershed, regardless of future water demand.

7.1.1. Baseline Hydrological Data

Baseline hydrological data provide the information on the five critical components of the flow regime that regulate ecological processes in river ecosystems: flow magnitude, frequency, duration, timing, and rate of change (Poff *et al.* 1997). Hence, understanding baseline hydrology is critical to assessing the effects of water withdrawal on the aquatic ecosystem (as well as understanding how much water may be available for allocation).

7.1.1.1. Long-term Hydrological Records

The Environmental Risk Management Framework applied in this report requires coarse information on the annual hydrological trends in flow; this information (timing and magnitude of streamflow) is provided for the Tsolum River watershed in the water budget modelling completed by GW Solutions (2020). Additional consideration of baseline hydrology is recommended as a Risk Level 2 measure, and a long-term baseline hydrological record is required for detailed assessments of flow withdrawal (a Risk Level 3 measure). Lewis *et al.* (2004) recommend a minimum 20-year continuous record to define baseline conditions against which to measure water withdrawal effects, to capture the full natural variation in annual, daily, and seasonal flow. Such long-term records allow for more detailed analysis of the flow regime – e.g., characterizing magnitude and frequency of low flows that may limit productivity of the aquatic ecosystem. Where long-term data are not available, a regional analysis may be completed to develop synthetic hydrological data time series.

Long-term records are available from Water Survey of Canada for Tsolum River near Courtenay (Station 08HB011) and Dove Creek (Station 08HB075). For locations where shorter records are available, synthetic hydrology can be generated by developing a predictive relationship between the POAs and one of the longer-term stations above (e.g., via regression analysis and consideration of unit run-off estimates from GW Solutions 2020). Locations with flow records less than 20 years include Tsolum River below Murex Creek (upstream of Headquarters Creek), Tsolum River near Todd Road (between Dove Creek and Portuguese Creek), and Headquarters Creek upstream of Tsolum River.

In locations where there are no historical hydrological data, it may be reasonable to assume the same unit run-off as a nearby gauging station (e.g., Dove Creek unit runoff could be assumed for Piercy Creek and Jackpot Creek) or unit run-off proportional to a nearby gauging station considering the unit runoff estimates from GW Solutions 2020; these estimates could be validated by spot discharge measurements. For some POAs, this type of extrapolation may not be reasonable;

specifically, it is likely that trends in unit run-off in Portuguese Creek are different than Tsolum River or Dove Creek given that it is a seasonal stream and it is uniquely located on the east side of the Tsolum River. To characterize baseline hydrology in Portuguese Creek, hydrometric data could be collected and then correlated to the Tsolum River data to construct a synthetic long-term hydrological data time series. Additional study of Portuguese Creek hydrology would improve the understanding of the factors that cause drying and disconnection from the mainstem of Tsolum River. We note that any of the predictive methods described above would incorporate historical water use in the Tsolum River watershed.

7.1.1.2. Consideration of Climate Change

The Environmental Risk Management Framework is evaluated based on historical hydrological information, however historical average and variance statistics may not be representative of future climate conditions. In the future, this region of Vancouver Island is expected to see drier summers, more winter precipitation as rainfall rather than snowfall, and reduced snowpack (PCIC 2020), potentially resulting in higher winter flows, an earlier and lower-magnitude freshet, and a longer period of summer low flow.

Further assessment of prospective water use from the Tsolum River watershed should consider future climate conditions. Options for consideration of future climate conditions vary in complexity from simply assuming a past year as a proxy for future climate conditions (e.g., 2015 had an early and brief freshet, dry summer) to using downscaled climate projections of precipitation and temperature to develop a future water budget or hydrological time series.

7.1.2. Fish and Fish Habitat

Effective environmental flows are protective of ecological values that are sensitive to flow, hence understanding EFN requires that aquatic species that are present and critical habitats be identified and characterized. Extensive work has been completed and is ongoing to characterize the fish community and habitat in the Tsolum River watershed (Heim, pers. comm 2020-'21). In this section we provide some discussion of prior work and considerations for future work to improve understanding of fish and fish habitat in the Tsolum River watershed.

7.1.2.1. Synthesize Existing Data

There are numerous data sources for fish and fish habitat in the Tsolum River watershed covering decades of assessment (e.g., Bainbridge and Chamberlain 1998, Campbell 1999, Clough 2014, Gooding 2015, O'Neill 2020, ongoing baseline studies described by Heim, pers. comm 2020-'21). To identify critical habitats and inform a detailed EFN assessment, these data should be integrated into a single spatially-referenced dataset including fish and redd observations, locations of potential and confirmed barriers, key habitats, locations of potential thermal refugia (O'Neill 2020), and key restoration sections (as recommended by Remillard and Clough, 2015). These data would allow the development of a map of fish and habitat distribution in the Tsolum River watershed as well as a fish periodicity table (based on the Puntledge River fish periodicity, Healey *et al.* 2020).

7.1.2.2. Habitat Surveys

The Tsolum River Watershed FHAP (Clough 2014) was completed for a subset of habitats within the Tsolum River watershed. Remillard and Clough (2015) identify the areas of the Tsolum River watershed that were not surveyed as a key information gap, particularly the measurement of critical rearing habitat. Locations of further surveys should be identified and prioritized in consideration of the current and potential future Risk Management Levels and any prospective critical habitats that emerge from the synthesis dataset described in Section 7.1.2.1. Future surveys should be completed considering the methodological recommendations in Section 3.2, i.e., using a detailed mesohabitat classification scheme.

7.1.2.3. Confirm Flow-Related Issues

Flow-related constraints to fish passage within the Tsolum River mainstem and from its tributaries to the Tsolum River have been identified by stakeholders (Hardy and Frank pers. comm. 2020, Heim, pers. comm 2020-'21). The extent of these issues and their potential affect to fish productivity in the Tsolum River watershed is currently unknown. Additional consideration should be given to these issues to determine their potential effect on the fish habitat productivity and hence priority for more detailed assessment.

Fish Isolation

There are seasonal tributaries that have been identified as important overwintering habitat that provide refuge from high flows (Heim, pers. comm 2020-'21). During the late spring, these tributaries become disconnected from the Tsolum River mainstem, potentially isolating newly emerged fry or out-migrating smolts and resulting in mortality (due to predation, depletion of oxygen, or eventual dewatering of the stream). Earlier or reduced freshet, in combination with increased water demand early in the season, has the potential to exacerbate isolation of fish in these tributaries. Portuguese Creek has become disconnected annually since at least the 1970's (Heim, pers. comm 2020-'21), however, the number of fish trapped in Portuguese Creek (and hence potential effect on the overall fish population) is unknown. The number of fish trapped in Portuguese Creek could be estimated by monitoring spring flow in Portuguese Creek (e.g., during annual monitoring of the fish fence, Heim, pers. comm 2020-'21) and conducting fish sampling when the disconnection occurs (e.g., using mark-recapture sampling as was completed in Towhee Creek, Tripp *et al.* 2020) or by salvaging specific isolated pools and extrapolating along the length of the watercourse. Quantification of isolation in Portuguese Creek would provide context on the effect of isolation on the population and determine if potential mitigation or restoration actions (such as those completed on Towhee Creek) are warranted.

There are anecdotal reports of fish isolated in pockets of water within side channels and along the margins of the mainstem Tsolum River, particularly in sections with wide channels with elevated gravel bars, and within a flood channel (Heim, pers. comm 2020-'21). Natural isolation of fish during periods of declining streamflow could be exacerbated by water use, e.g., during dry weather when the natural rate of flow decline may be exacerbated by water use, particularly as agricultural water needs increase. The magnitude of mainstem isolation is unknown; additional data on mainstem isolation could be gathered by standardized documentation of isolation observations when other fisheries work is being completed. Over time, these records of key information on fish isolation (location, number and species of fish present, photographs) could inform a biological opinion on the importance of fish isolation within the Tsolum River mainstem and hence whether further study of this issue is warranted.

Mainstem Fish Migration

In-migration of spawning Pink salmon begins in the third week of August (Heim, pers. Comm 2020-'21); during low flow years they may be unable to migrate beyond the old Reese Bridge location (~ 2 km upstream of Courtenay River) due to insufficient water levels at critical riffles. Fish that do not return to the Courtenay River or move to the Puntledge River may experience stress due to high water temperatures in the Tsolum River. Given that there are known locations where fish passage may be constrained (Heim, pers. comm 2020-'21), we recommend mapping these locations and comparing to the location of the potential thermal refugia identified by O'Neill (2020). This would identify if low water levels are preventing pink salmon from accessing cooler waters upstream that may be more suitable for holding in the late summer prior to spawning.

7.2. Level 3 Measures

For situations where water demand is assessed at Risk Level 3, Provincial EFN Policy (Province of BC 2016) recommends a detailed habitat assessment.

7.2.1. Detailed Habitat Assessment

A detailed habitat assessment for the Tsolum River watershed would be used to quantify the effects of current and potential future water use on aquatic habitat, to inform critical environmental flow thresholds (CEFTs) specific to this watershed, and could also be used to identify minimum instream flow requirements for incorporation into future water licensing decisions. Any detailed habitat assessment should be designed considering available information on fish and fish habitat and flow-related issues, and include consideration of the items described in Section 7.1.2 and 7.1.2.3 above. Detailed habitat assessments consist of field studies measuring aquatic habitat under a range of flow conditions, analysis of the field data to quantify habitat as a function of flow, and application of these relationships to hydrological data (described in Section 7.1.1) to quantify habitat under alternative water use scenarios.

Provincial guidance for instream flow studies (Lewis *et al.* 2004) provides a standardized methodology for designing, collecting, and analyzing data to develop habitat-flow relationships for use in detailed habitat assessments (the BC Instream Flow Methodology), recognizing that alternative methods may be suitable if recommended by experienced registered professionals and agreed to by regulatory agencies. The sampling design in the BC Instream Flow Methodology is intended to develop habitat-flow relationships for a specific section of river. However, given the length of the Tsolum River, following the exact methodology would require the completion of laborious habitat surveys (Section 7.1.2.2). An alternative sampling design is the 'representative reach' approach, where the most important flow-sensitive habitats are intensively sampled and assumed to represent flow-sensitive habitat for the entire stream. This approach provides high confidence in the habitat-flow relationships in the intensely sampled representative reach and is efficient because field sampling is concentrated around a single point of access. There is a trade-off; high confidence for a specific reach is obtained at the cost of uncertainty in unsampled locations. To reduce the risk of intensely sampling the wrong locations, the guidance of professionals with experience in the river is sought, and sites are selected with collaboration with regulators, First Nations groups, and other stakeholders.

In addition to the development of habitat-flow relationships, studies to support assessment of specific flow-related issues may be required (e.g., isolation in tributaries, longitudinal migration within the Tsolum River mainstem as described under Section 7.1.2.3).

7.3. <u>Other Measures</u>

7.3.1. Hydrological Assessment

Provincial guidance (Province of BC 2016) provides methodology for coarse screening-level EFN assessments to determine if a more detailed habitat assessment (Lewis *et al.* 2004) is required. In the absence of detailed habitat data, in some contexts it is useful to complete an intermediate-level assessment of the effects of water use via a hydrological method, e.g., the Indicators of Hydrologic Alteration method (Richter *et al.* 1996). These methods include calculation of ecologically-relevant flow statistics (e.g., low flow statistics) that describe how water use affects streamflow and hence may affect the aquatic ecosystem. This type of analysis could be completed for the Tsolum River stations with existing hydrometric data. If additional modelling is completed to characterize baseline hydrology (Section 7.1.1.1) or hydrology under climate change (Section 7.1.1.2), then these data could be included in the hydrological assessment. A hydrological assessment does not rely on detailed field data (and hence can be completed without depending on the items described in Section 7.1.2 and 7.2), however it does not explicitly quantify the response of the aquatic environment to water use. Hence, this type of assessment could be used to characterize the effects of water use on EFN (using flow as a proxy for environmental response), recognizing that hydrological methods produce greater uncertainty than a detailed assessment. Consultation with regulators, First Nations groups, and other stakeholders could determine if this type of method is suitable for portions of Tsolum River or its tributaries.

7.4. <u>Summary</u>

Additional tasks that would facilitate EFN assessment, as described above, are summarized in Table 14. For each task, this table provides the associated Risk Level, reference to the report section containing the detailed task description, estimated effort (in person-days), whether a Qualified Professional (QP) would be required to complete the work (based on our understanding of community resources, e.g., Tsolum River Restoration Society), and linkages to other items within the table. It is anticipated that community resources (e.g., Tsolum River Restoration Society) could synthesize the existing data on fish and fish habitat in the Tsolum River and investigate the issues of fish isolation and longitudinal migration.

We recommend consultation with regulators and other stakeholders to discuss these measures and develop an approved scope of work prior to initiation of these tasks.

Table 14. Additional tasks to facilitate EFN assessment in Tsolum River watershed

Risk Level	Section	Task Description	Estimated Effort* Office	Field	Requires QP?	Dependencies
2	7.1.1.1	Long-term hydrological records	Moderate	Moderate	Y	
	7.1.1.2	Consideration of climate change	Low-Moderate		Y	
	7.1.2.1	Syntheize existing data	Low			
	7.1.2.2	Habitat surveys	Low	Moderate	Y	7.1.2.1
	7.1.2.3a	Fish isolation - tributary	Low	Moderate		
	7.1.2.3a	Fish isolation - mainstem	Low	Low		
	7.1.2.3b	Mainstem fish migration	Low			
3	7.2.1	Detailed habitat assessment	High	High	Y	7.1.1 (all), 7.1.2 (all)
n/a	7.3.1	Hydrological assessment	Moderate		Y	

*Low = less than 2 days, Moderate = 2 days to 2 weeks, High = greater than 2 weeks

8. CRITICAL ENVIRONMENTAL FLOW THRESHOLDS

The *Water Sustainability Act* defines the Critical Environmental Flow Threshold (CEFT) as the volume of water flow below which significant or irreversible harm to the aquatic ecosystem of the stream is likely to occur. The CEFT can be used by regulators to manage withdrawals during periods of critically low flow. In the absence of detailed assessments, in some cases regulators consider 5% of mean annual discharge as the CEFT (Szczot, pers. Comm. 2018). For each POA, the flow rate corresponding to 5% mean annual discharge is provided in Table 15. It is important to note that these flow rates should not be considered target flow rates sufficient to sustain aquatic life; rather, they provide a point where regulators may consider a temporary protection orders under Sections 86-88 of the *Water Sustainability Act*.

Table 15. Streamflow rates corresponding to 5% of mean annual discharge, which may be considered a critical environmental flow threshold by regulators (Szczot, pers. comm. 2018).

Location	Mean Annual Discharge (m^3/s)	5% of Mean Annual Discharge (m^3/s)
Tsolum River upstream of Courtenay River	10.580	0.529
Tsolum River upstream of Portuguese Creek	8.791	0.440
Tsolum River upstream of Dove Creek	6.454	0.323
Tsolum River upstream of Headquarters Creek	4.861	0.243
Portuguese Creek upstream of Tsolum River	1.371	0.069
Dove Creek upstream of Tsolum River	1.782	0.089
Jackpot Creek upstream of Dove Creek	0.271	0.014
Piercy Creek upstream of Dove Creek	0.250	0.013
Headquarters Creek upstream of Tsolum River	1.238	0.062

9. CLOSURE

This report provides a screening-level assessment of environmental risk associated with increased agricultural water demand in the Tsolum River watershed according to the Provincial EFN Policy (Province of BC 2016). Based on the risk management levels identified, detailed assessment of EFN may be required before further water from the Tsolum River watershed is licensed for withdrawal. Considerations for further assessment are described in detail to support prioritization and scoping of future work to assess EFN. Additionally, this document provides flow rates that may be considered in the determination of Critical Environmental Flow Thresholds for the Tsolum River watershed.

RREFERENCES

Bainbridge, G. and D. Chamberlain. 1998. Tsolum River Tributaries Mapping & Inventory Project. Sensitive Habitat Inventory and Mapping (SHIM) Surveys. Available online at https://docs.google.com/file/d/0BxixYjvpOF3neFNPZVE0ajllMTA/edit. Accessed on January 12, 2021.

Campbell, 1999. State of the Tsolum River. A comprehensive report on work completed by the Tsolum River Task Force. April 1997-March 1999. Available online at http://www.tsolumriver.org/uploads/4/0/5/7/4057952/state_of_the_tsolum_river.pdf. Accessed on January 8, 2021.

Clough, D. 2014. Tsolum River Watershed – Fish Habitat Assessment Report (FHAP). Consultant's report prepared for Tsolum River Restoration Society. December 2014. Available online at: http://www.tsolumriver.org/uploads/4/0/5/7/4057952/tsolumriver_watershed_fish_habitat_assessment_report_cloughdec2104.pdf. Data available at https://www.google.com/maps/d/u/0/viewer?mid=1nBRWm3HhhQNRQyhAusi6EAjebMo&ll=49.75914568190351%2C-125.09365740228156&z=14. Accessed on November 16, 2020.

Gooding, D. Tsolum River Channel Morphology and Bedload Assessment. Consultant's report prepared for Tsolum River Restoration Society. April 2015. Available online at https://drive.google.com/file/d/0B-PzbbChak1-ZnhmeGNtYm5EZk0/view. Accessed on May 14, 2020.

G.W. Solutions 2020. Water Budget Study for Tsolum River Watershed. Consultant's Report prepared by G.W. Solutions for Elucidate Consulting. December 2020.

Hatfield, T., A. Lewis, and S. Babakaiff. 2007. Guidelines for the collection and analysis of fish and fish habitat data for the purpose of assessing impacts from small hydropower projects in British Columbia.

Healey, K., M. Hocking, K. Akaoka, and A. Lewis. 2018. Comox Valley Water Treatment Project. Puntledge River Fisheries Habitat Effects Assessment. Consultant's report prepared for the Comox Valley Regional District by Ecofish Research Ltd, December 11, 2018.

Johnston, N.T. and P.A. Slaney. 1996. Fish habitat assessment procedures. British Columbia Ministry of Environment, Lands, and Parks and British Columbia Ministry of Forests, Victoria B.C. WRP Technical Circular No.8. 97 p.

Lewis, A., T. Hatfield, B. Chilibeck, and C. Roberts. 2004. Assessment Methods for Aquatic Habitat and Instream Flow Characteristics in Support of Applications to Dam, Divert, or Extract Water from Streams in British Columbia. Report prepared for MWLAP and MSRM. misc., Report prepared for the Ministry of Water, Land and Air Protection and the Ministry of Sustainable Resource Management.

Metherall, C. 2019. Tsolum River Agricultural Watershed Plan: Phase 1. Consultant's report prepared by Elucidate Consulting for Comox Valley Regional District. Available online at: https://www.comoxvalleyrd.ca/sites/default/files/docs/Projects-Initiatives/tsolum_river_agricultural_watershed_plan_-_phase_one_report.pdf. Accessed on November 16, 2020.

Metherall, C. 2021. Tsolum River Agricultural Watershed Plan: Phase 2. Consultant's report prepared by Elucidate Consulting for Comox Valley Regional District.

O'Neill, K. 2020. A Climate Adaptation Plan: Identifying Thermal Refugia for Salmonids in the Tsolum River. Master of Science Thesis, Simon Fraser University and British Columbia Institute of Technology.

PCIC (Pacific Climate Impacts Consortium). 2020. Plan2Adapt Tool for Comox Valley in 2050's. Available online at https://services.pacificclimate.org/plan2adapt/app/. Accessed on November 16, 2020.

Poff, N., J. Allan, M. Bain, J. Karr, K. Prestegaard, B. Richter, R. Sparks, and J. Stromberg. 1997. The Natural Flow Regime. BioScience, 47(11), 769-784. doi:10.2307/1313099

Province of BC (Province of British Columbia). 2016. Environmental Flow Needs Policy. dated 29 February 2016. Available online at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/water-rights/efn_policy_mar-2016_signed.pdf. Accessed on November 16, 2020.

Remillard, B. and D. Clough. 2015. Tsolum River Habitat Status Report. Consultant's report prepared for Tsolum River Restoration Society. October 2015. Available online at: https://drive.google.com/file/d/0B-PzbbChak1-azQzWWtWSkNSU2M/view. Accessed November 16, 2020

Richter, B. D., J.V. Baumgartner, J. Powell, and D.P. Braun. 1996. A method for assessing hydrologic alteration within ecosystems. Conservation Biology, 10(4), 1163–1174.

Tripp, D. A. Chamberlain and C. Heim. 2020. Juvenile Coho Salmon Population Size and Rescue in Pond 1 on Towhee Creek, a Small Tributary of the Tsolum River, BC. Report prepared for Tsolum River Restoration Society, June 2020. Available online at http://www.tsolumriver.org/uploads/4/0/5/7/4057952/2020_pond_1_final_report.pdf Accessed on January 7, 2020.

WSC (Water Survey of Canada) 2020. Water Survey of Canada historical hydrometric data. https://wateroffice.ec.gc.ca/mainmenu/historical_data_index_e.html. Accessed on November 16, 2020.

Personal Communications

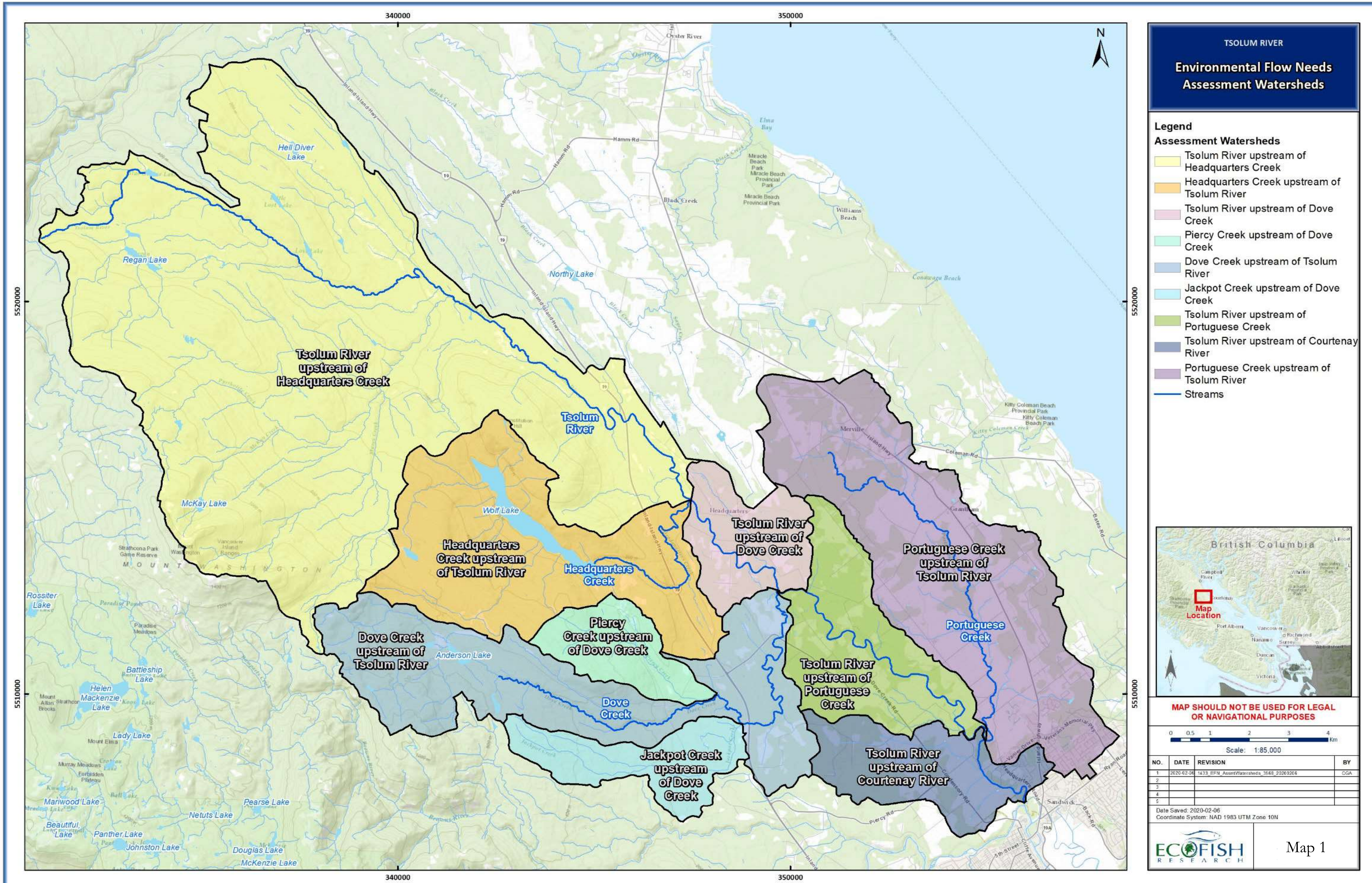
Barroso, A. 2020. Hydrogeologist, GW Solutions, Inc. Emails to Katie Healey on November 15, November 17, November 20, 2020, and December 17, 2020.

Hardy, R. (Councillor) and R. Frank. (Assistant Negotiator), K'òmoks First Nation. 2020. Phone conversation with Katie Healey, Ecofish Research Ltd. on July 7, 2020.

Heim, C. 2020-2021. Program Coordinator, Tsolum River Restoration Society. Phone conversations and emails with Katie Healey, Ecofish Research Ltd. between November 12, 2020 and January 7, 2021.

Szczot, J. 2018. Senior Aquatic Ecologist, FLNRORD. Email re: PUN Fish Habitat Assessment TOR, May 15, 2018.

PROJECT MAPS



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APPENDICES

Appendix A. Fisheries Background Review Table

**See Excel File Appendix*

Appendix B. Spreadsheet Evaluation of the Environmental Risk Management Framework, Summarized by Month

**See Excel File Appendix*

Appendix C. Spreadsheet Evaluation of the Environmental Risk Management Framework, Summarized by Point of Assessment

**See Excel File Appendix*

Appendix D. Summary of EFN Conversation with Richard Hardy and Ron Frank, K'òmoks First Nation – July 7, 2020

1. SUMMARY

The Tsolum River watershed lies in the heart of the unceded traditional territory of the K'òmoks First Nation (KFN) and has been a vital part of the KFN community since time immemorial. Water is the basis of all life and key to the KFN culture, expression of rights, and economy. Prior to colonial settlement, the Tsolum valley was used by KFN for hunting and fishing, medicine procurement, agriculture, and recreation. KFN has always seen rivers, lakes and oceans of the KFN Territory as 'highways'--where streams/lakes were highways, linked by trails for such things as the all-important trade routes and familial links with West Coast First Nations --including Hupacasath who have direct family connections with KFN. Today, many in the KFN community hunt and fish in the Tsolum watershed, and gather berries and medicinal plants. Many community members recreate and spend time in the watershed with their children and families, especially in the summer. KFN is also an active participant in watershed stewardship. Through the KFN Guardian Watchmen Program, the community participates in monitoring and restoration activities. KFN holds property adjacent to Tsolum River at IR2 as well as anticipated future parcels of land as part of treaty negotiations.

The following values related to surface water quantity in the Tsolum River were identified:

- Treaty right to hunt, fish and gather;
- Spiritual cleansing and other cultural uses;
- Economic value – fishery (and other--e.g. water...);
- Navigability; and
- Important to the cultural identity and cultural practices of KFN.

The following flow-related environmental issues/concerns directly influenced by surface water quantity in the Tsolum River were identified:

- Fish habitat:
    - Physical habitat (depth/velocity);
    - Water temperature (also affects cultural use experience, e.g., spiritual cleansing);
    - Water chemistry; and
    - Riparian;
- Aggradation from upstream activities, particularly near IR#2--and erosion;
- Fish passage and isolation, including tributary areas;
- Downstream effects to K'omoks estuary; and

- Hydrologic and stream morphology changes due to past land/resource management activities (including forest harvesting, agricultural land clearing and draining, large historic fires).

KFN also identified specific concerns related to agricultural water use that are related to flow in Tsolum River;

- Deterrence of wildlife from historic water access by fencing (and draining of wetlands);
- Agricultural runoff, removal of riparian zones as an environmental filter (and wildlife corridor);
- Draining of wetlands--groundwater impacts and wildlife/migratory birds impacts; and
- Land use impacts, zoning impacts on protection of water quality.

KFN is in the late stages of Treaty negotiations in a time of recognition and reconciliation. The treaty negotiations include rights for groundwater; KFN has been studying and monitoring groundwater in Royston and Williams Beach and has generously agreed to share groundwater information with the Tsolum River Agricultural Watershed Plan process. KFN has expressed concern that there are many wells within Tsolum watershed but insufficient monitoring, and that there are perpetual water licences issued with no significant monitoring or assessment of effect—particularly for commercial and industrial uses. KFN also raised questions about consideration of KFN future water needs in the estimates for future water demand.

Appendix D: Engagement Events

Over the course of the development of the Agricultural Watershed Plan (Phases One and Two from 2018 to 2021), the CVRD used several approaches to engage with stakeholders and other levels of government to better understand issues and priorities and get input on solutions. This included:

- Nine meetings with the Agricultural Watershed Planning Advisory Committee
- Direct engagement with farmer's institutes and stewardship community through:
  - Emails to membership
  - Presentations at Annual General Meetings
  - Phone calls
  - Social media
  - Meetings with membership
- Engagement with the broader community
  - News release
  - Survey

The CVRD also engaged with the KFN to better understand their perspective and obtain input so that the project does not infringe on the exercise of traditional rights.

The following engagement activities were part of Phase Two of the project:

Kick-off meeting to discuss technical aspects of project:

- January 13: included representatives from the KFN, CVRD, TRRS, and consulting teams.

Advisory Committee engagement:

- March 3, 2020
- October 29, 2020
- December 14, 2020
- May 6 (TBD), 2021

Direct engagement with producers:

- Emails to membership of CVFI and MIFI in October 2020.
- Social media posts for CVFI and MIFI in October 2020.
- Oct 23: Zoom meeting with members of MIFI.
- Emails to membership of CVFI and MIFI in February 2021.
- Social media posts for CVFI and MIFI in February 2021.
- Feb 10, 2021: Zoom meeting with CVFI membership to present results of water budget and EFN assessment and discuss recommendations.
- Feb 9, 2021: Zoom meeting with MIFI directors and members that farm in the watershed to present results of water budget and EFN assessment and discuss recommendations.
- Many phone calls with members of farmer's institutes and local producers.

Direct engagement with stewardship community:

- January 7, 2021: Meeting with TRRS to obtain input on background fisheries information
- February 10, 2021: meeting with representatives from CVCP and TRRS to obtain feedback on recommendations.
- Phone calls and emails

KFN engagement:

- July 7, 2020: Meeting to better understand fisheries background and KFN interests
- Nov 2, 2020: Meeting to understand KFN concerns and interests related to water in the Tsolum watershed.
- December 7, 2020: Meeting with KFN and CVRD to and share results of work-to-date including water supply and demand assessment, EFN risk assessment, and water management options research.
- Feb 11: Meeting to discuss recommendations 1-3.
- Feb 25: Meeting to discuss recommendations 3-5.
- April 21: Meeting to discuss draft report.
- Emails in development of pre-amble

Overall, there was considerable alignment on the key issues and recommended solutions. There was also a clear need for further cross-sectoral engagement to increase understanding about each group's investment in the watershed and areas of potential concern and collaboration.

Key themes emerging from the engagement included:

- Use a holistic approach.
- Restore hydrologic function and health of the watershed.
- Agricultural water use should be a priority on ALR land.
- Local understanding of the watershed of the watershed should be incorporated.
- Indigenous knowledge of the watershed should be incorporated.
- The impacts of forestry must be understood and addressed.
- Take a thoughtful approach to watershed governance.
- Consider climate change impacts.
- Support producers in stewardship.
- Land use planning tools should be utilized to protect watershed health.
- Recognize that supply and demand and risk assessment considers historical averages and not low flow risk – particularly with changing climate.