Koksilah Water Supply & Options Feasibility Project

Prepared for:

Ministry of Forests, Lands, Natural Resource Operations, and Rural Development

Prepared by:

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Executive Summary

The Koksilah watershed is located on the south east side of Vancouver Island, within the traditional territories of the bands of the historic Cowichan Nation (Cowichan Tribes, Halalt First Nation, Lyackson First Nation, Penelakut Tribe and Stz'uminus First Nation) and the Malahat First Nation. Current land use within the watershed is predominantly private managed forest (66% of the watershed). Developed areas in the lower watershed are primarily residential and agricultural. Flows in the Koksilah River and its tributaries frequently fall below the environmental flow needs of the streams. In recent years, summer flows have fallen so low that the survival of one or more fish populations in the streams may have been threatened.

To maintain adequate flows to support the aquatic ecosystem, as well as the economy and wellbeing of the Koksilah watershed community, it is necessary to explore options and, if feasible, implement alternative seasonal water supply solutions. The goal of the Koksilah Water Supply and Feasibility project is to identify and evaluate possible water supply options for meeting summertime water demand and/or maintaining the environmental flow needs of the Koksilah River.

The project began with a review of standard and innovative practices for the development of storage and water supply used in other drought affected watersheds and jurisdictions. Then, seasonal demand data provided by MFLNRORD staff was analyzed to estimate the volume of water desired during the 'dry' season (estimated to be the period from July 1 - September 30). During that period, the demand was found to be approximately 3.4 million m^3 or 0.43 m^3/s to 3.8 million m^3/s (0.48 m^3/s). This is close to one of the preliminary environmental flow needs thresholds identified: 4.9 m^3/s, which is 5% of Mean Annual Discharge (MAD).

The next step of the project involved the preliminary identification of water storage and supply options. To start, subject matter experts, and staff from Cowichan Tribes, Malahat First Nation, and the Province were consulted to identify options, preliminary considerations, and areas to avoid (e.g. areas of spiritual or cultural significance). In this step, previous reports and studies from the watershed were also reviewed. As a result, the following water storage and supply options were identified for consideration: greywater reuse, cisterns, dugouts, water storage tanks, extraction pits, existing lakes, natural features, municipal water supplies, municipal wastewater, Cowichan lake, aquifer storage and recovery, and forest management.

Information was gathered on these options and they were then evaluated according to the following criteria: impact (ability of the option to meet the demand), affordability (estimated relative costs per cubic meter), ease of implementation, ease of use, and reliability. This evaluation was based on the best available knowledge at the time (March 2021) and evaluations may vary based on new information, further assessment, and/or community engagement.

Of these potential solutions, it was found that the options that provided the largest volumes of water were typically most feasible, as they had the greatest impact and were often more affordable per unit of water stored/provided. Options that ranked highly and warrant further investigation include dugouts, water storage tanks, Grant Lake, Cowichan Lake, and aquifer storage and recovery.

Further work is needed to assess the feasibility of these options and next steps to assess feasibility are identified. All the larger (and more effective) storage options require substantial financial investment, so further investigation of these options should include a community engagement component to ensure that the selected option is compatible with community interests. It is anticipated that a Water Sustainability Plan would support and inform the development of future water supply solutions.

Contents

Introduction

Study Area

The Koksilah watershed is located on the south east side of Vancouver Island. The Koksilah River originates in the mountainous areas in southwest portion of the watershed and flows south, then east, and then north toward the watershed outlet at Salish Sea. The Kosilah watershed can be divided into several sub-watersheds, as shown in Figure 1, below. The main tributaries to the Koksilah River from upstream to downstream are: Fellows Creek, Kelvin Creek, Glenora Creek and Patrolas Creek.

The Koksilah watershed is within the traditional territory of the Coast Salish peoples, including Quw'utsun' (Cowichan) Tribes, Malahat Nation, Halalt First Nation, Ts'uubaa-asatz (Lake Cowichan) First Nation, Lyackson First Nation, Stz'uminus First Nation, Penelakut Tribe, and T'sou-ke First Nation. The Koksilah River has cultural and spiritual importance to the local First Nations (Barroso & Wainwright, 2020).

Current land use within the watershed is predominantly private managed forest (encompassing 66% of the watershed). Within the developed areas in the lower watershed, the primary land uses are residential and agricultural (Barroso & Wainwright, 2020).

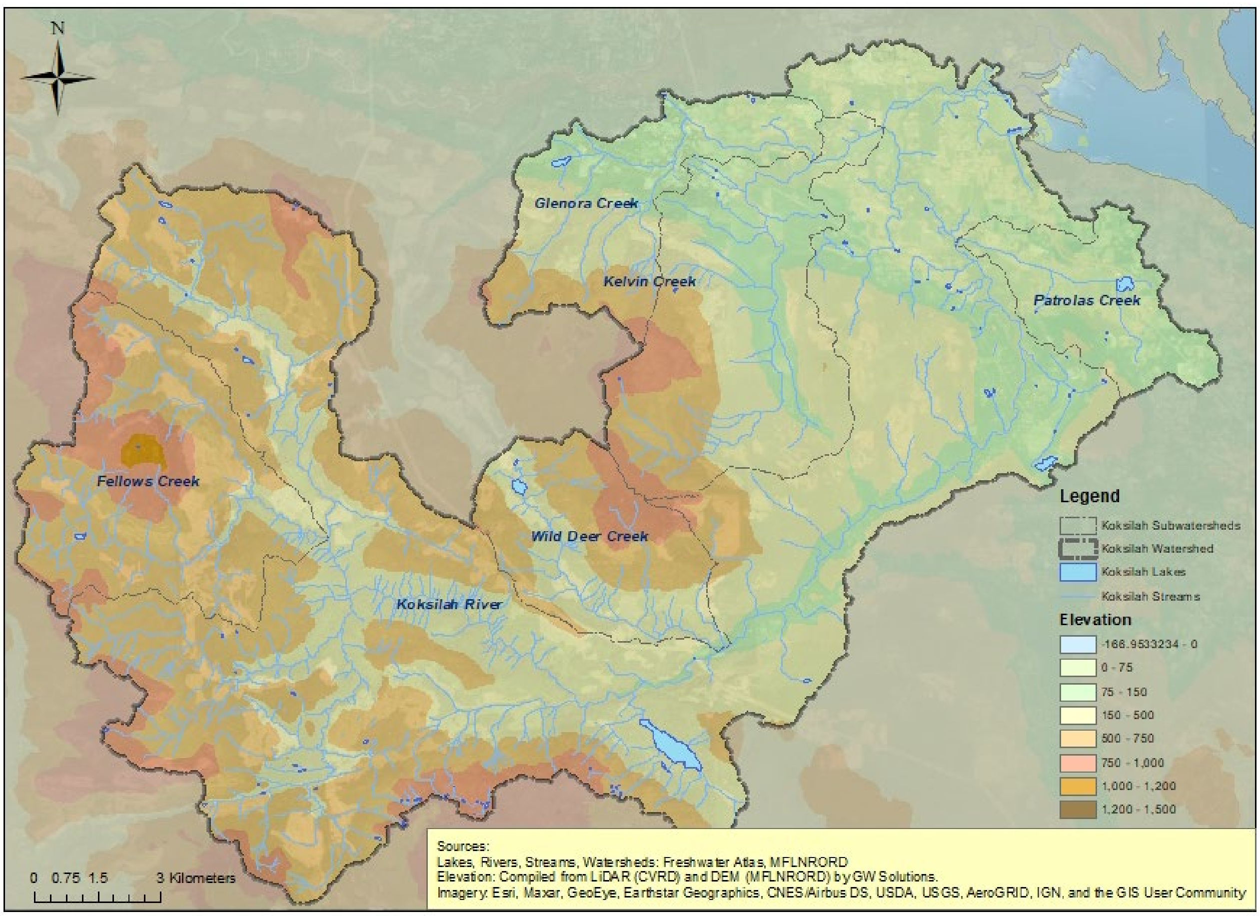

Figure 1: Koksilah watershed boundaries and topographic elevations. Prepared by GW Solutions.

Background

On an annual basis, flows in the Koksilah River and its tributaries frequently fall below the environmental flow needs of the streams. Low flows in the Koksilah watershed have been documented since 1980, when surface water restrictions were imposed and a water management plan was developed to address surface water use (Tutty, 1984; Ministry of Environment and Parks, 1986). While surface water use was restricted in 1980, groundwater use continued to grow (Barroso & Wainwright, 2020). In recent years, summer flows have fallen so low that the survival of one or more fish populations in the streams may have been threatened (Barroso & Wainwright, 2020).

In the summer of 2019, the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD) issued an order under S.88 of the Water Sustainability Act to curtail the diversion of surface and groundwater by specified users in the Koksilah watershed (Barroso & Wainwright, 2020).

In the summer of 2020, eighteen agricultural water users were asked to voluntarily reduce their water use by 50% during the period of lowest flow to prevent the flows from reaching the point where fish populations may be threatened. With status quo water supply and use and a changing climate, it is anticipated that flows will reach critical levels in most years going forward which will continue to put a significant strain on the aquatic ecosystem as well as those that rely on water for their livelihood (Barroso & Wainwright, 2020).

In order to maintain adequate flows to support the aquatic ecosystem, as well as the economy and wellbeing of the Koksilah watershed community, it is necessary to explore options and, if feasible, implement alternative seasonal water supply solution(s).

While this study is focused on water supply/storage options only, it is recognized that long term sustainable solutions will require both demand management and supply/storage options. It is also recognized that more than one supply option may be required, as there may not be one single solution that can address the difference between seasonal supply and demand.

Study Objectives

The objective of the Koksilah Water Supply and Feasibility project is to identify and evaluate possible water supply options for meeting summertime water demand and/or maintaining the environmental flow needs of the Koksilah River. The project includes:

1. Task 1: A review of standard and innovative technologies for the development of storage and water supply used in other drought affected watersheds and jurisdictions.
2. Task 2: An assessment of seasonal water demand: Further analysis of MFLNRORD estimates of water use in the watershed to determine the approximate volume of water that is required to meet summer demand or environmental flow needs of the Koksilah River and its tributaries.
3. Task 3: A preliminary review of Koksilah Watershed for applicable water supply options: An assessment of potential natural water features for storage, consideration of nearby water sources (e.g. Cowichan Lake, municipal water supply, wastewater), land availability and requirements for dugouts, and aquifer storage and recovery suitability. The goal of this task is to identify options that have potential as a solution and warrant further investigation.
4. Task 4: An assessment of the feasibility and estimated relative cost of each potential water supply solution and identification of further work needed to assess potential solutions.

Review of Standard and Innovative Technologies for the Development of Storage and Water Supply

The first step in the Koksilah Water Supply and Feasibility project was to conduct a review of standard and innovative technologies to identify ways in which other communities are addressing water supply challenges in drought affected watershed and jurisdictions.

A scan of approaches in other jurisdictions revealed that many communities around the world are searching for ways to address the water scarcity. The approaches utilized include:

- Water storage tanks/cisterns
- Dugouts
- Dams
- Manufactured Lakes
- Reclaimed water use
- Desalination
- Managed aquifer recharge
- Green infrastructure
- Inter-basin transfers
- Alternative small-scale solutions

While several communities are pursuing ‘newer’ practices such as reclaimed water use, aquifer storage and recovery, managed aquifer recharge, desalination, large inter-basin transfers, and green infrastructure, more traditional approaches such as the use of dugouts, dams, and water storage tanks are still quite common.

In areas facing significant scarcity, many communities are seeking to diversify their supply portfolios to increase resilience to drought by utilising several approaches in combination (Florida Department of Environmental Protection, 2020; Cass, 2018; Gale, 2017). Some communities are combining water storage and management approaches (e.g., injecting treated wastewater into aquifers) to address water supply challenges (Gale, 2017).

A summary of the standard and innovative technologies reviewed is provided below.

Water Storage Tanks/Cisterns

In many areas of the world, water is stored in tanks or cisterns, so it is available for future use. Water that is stored in cisterns/tanks can come from rainwater captured over a catchment area (e.g., a roof), groundwater sources (e.g., wells) or surface water sources (e.g., river, lake).

Water storage tanks typically range in capacity from 350 m^3 (or less) to 22,700 m^3 (Mr. Tank, 2021; CST Industries, 2021). Small tanks and cisterns are commonly used for domestic purposes in several areas of BC and around the world. Large, engineered reservoirs, are commonly used for municipal and industrial purposes. Water storage tanks are less commonly used to store agricultural water, due to their lower capacities and higher storage costs per m^3 than other potential storage options (Russ Batyi, Vortech Plumbing, personal communications; Gordon Ross, CST Industries, personal communications).

While water storage tanks represent a relatively simple and decentralized water storage solution with a long history of use, one of the challenges with this solution is that they hold a limited volume of water. During a drought, there is often insufficient water available to fill tanks and so a water user that relies on water from a storage tank needs to pay to have the water storage tank filled from an alternate supply source. This displaces the water storage need onto a larger storage system or an alternate supply source (Piper, 2020).

Dugouts

For thousands of years, communities have created water storage by digging into the earth to create dugouts or ponds. Dugouts are commonly used to store water for agricultural and industrial purposes in BC and around the world.

Dugouts can be filled by water that flows overland when it rains, or water can be pumped into a dugout from a well or a surface water source (lake, river, stream). In some areas, producers collect water from tile drained fields and use this to fill a dugout (Jill Hatfield, Ministry of Agriculture, Fisheries, and Food [MAFF], personal communications). This approach is costly to develop (it requires field grading, the addition of tile drains, a dugout with pumps and piping, etc.) and is not feasible in all properties. It also requires specific conditions on-site (e.g. a field upgradient of a flat storage area with suitable grades and subsurface conditions).

Dugouts for irrigation purposes utilize a large area of land. They are commonly used in the Interior of BC where cost of land is cheaper, and dugouts can be created on Crown land. However, on Vancouver Island, where land is much more costly and there is little Crown land available, dugouts require that high-value agricultural land is taken out of production. For this reason, dugouts may not be financially feasible in areas with limited public land and high real estate costs (Doug Pepper, MAFF], personal communication).

While dugouts provide local, readily available water, they are susceptible to variations in rainfall volumes (especially if filled with overland flow) and a significant volume of surface water evaporates from a dugout. If a dugout is not large enough to hold sufficient rainwater between precipitation events, the dugout may need to be filled from a source such as a well or stream.

Dams

Around the world, many jurisdictions have created dams to impound water for agriculture, domestic use, and power generation. Dams have also been utilized for flood management and flow augmentation.

While dams are often the cheapest form of water storage per m^3, these large infrastructure projects have typically been built with significant government investment and support and are rarely cost-neutral (Angelakis et. al, 2020).

In recent years, dam construction at a global scale, has decreased significantly. This is due to concerns regarding the environmental impact of dams, increasing costs of dam construction, decreasing government investment in irrigation infrastructure, and the fact that many suitable dam locations have already been developed (Larsen, 2014).

Dams have been constructed for thousands of years and the technology is well-understood. However, climate change reduces our ability to make reliable predictions regarding surface water availability and the reliability of surface water storage. Climate change brings both an increasing need for water storage to address climate variability, and also concerns regarding the reliability of surface water supplies due to climate extremes.

Manufactured Lakes

In some communities, abandoned quarries have been converted into manufactured lakes and utilized to store water. For example, in 2020, the City of Atlanta converted the Belwood Quarry into an emergency reservoir by drilling a 5-mile tunnel from the Chatahoochee River to the quarry (Samuel, 2020). The reservoir is intended to hold 2.4 billion gallons of water and will be used as a backup supply for the city (Gale, 2017).

The Sunshine Coast Regional District also evaluated the potential to use a quarry as a reservoir as part of the Chapman Water system water supply expansion. When evaluating water supply options, they found that the use of the quarry as a reservoir was more cost-effective than modifying the dam on their existing water reservoir. However, the timing of the quarry closing did not meet the timeline of the community's water needs. The quarry business intended to stay in operation for several years and the community was looking for a more immediate water storage solution (Dayton and Knight Ltd., 2007).

Manufactured lakes often require the use of a liner to prevent water losses to the surrounding environment and this significantly increases the cost. For example, in the SCRD study, in 2007, a membrane liner for a potential 1.36 Mm^3 manufactured lake was estimated to be $2.3 million (Dayton and Knight Ltd., 2007).

Reclaimed Water

Over the past century, a growing number of communities around the world have started using treated wastewater, or reclaimed water, for irrigation and industrial purposes, and as a potable drinking water supply source.

Treated wastewater is used for irrigation in the US (e.g. California, Texas, Florida), Australia, Greece, Saudi Arabia, Israel, Morocco, Kuwait, Israel, Qatar, and in several communities in BC (e.g. Kamloops, Spallumcheen Cranbrook, Oliver, communities in the Okanagan, and Dockside Green) (Yuwei & Horvath, 2020; US National Academy of Sciences et al., 1999, Andrew Petersen, MAFF, personal communication).

The use of reclaimed water has been in place informally for thousands of years and more modern use has been underway for approximately 50-100 years. California has been using recycled water since 1910 and Australia has been using recycled water since the 1970s (Yuwei & Horvath, 2020).

The Province of BC has guidelines regarding the use of reclaimed water that can be found in the 'Reclaimed Water Guideline: a 'Companion Document to the Municipal Wastewater Regulation' (MWR). When reclaimed water is used for irrigation, there are limits to the volumes that can be applied daily, as the water is not intended to recharge the aquifer, but rather to support plant growth (Andrew Petersen, MAFF, personal communication).

The US government provides guidelines for reclaimed water use for industrial, irrigation and potable purposes. Potable use is divided into indirect and direct potable use. Indirect potable use is water consumption with an environmental buffer (e.g. aquifer, lake), and direct potable use is water used for human consumption without an environmental buffer.

In several jurisdictions in the US, reclaimed water use is combined with aquifer recharge technologies to replenish groundwater supplies. The Orange County Water District (OCWD) in California is the world's largest indirect potable reuse centre. The system takes highly treated wastewater that would have otherwise been discharged to the Pacific Ocean and treats it using microfiltration, reverse osmosis, and ultraviolet light with hydrogen peroxide. The product water is near-distilled-quality. It then injects it into the ground at the seawater intrusion barrier to reduce saltwater intrusion. It also uses managed aquifer recharge (described below) to allow water to percolate into underground aquifers for indirect potable reuse (Orange County Water District [OCWD], 2020).

On the east coast of the US, in Virgina, the Sustainable Water Initiative for Tomorrow (SWIFT) project is underway. This indirect potable reuse project that involves treating wastewater to drinking water quality standards then injecting it into the Potomac aquifer, which is the size of a Great Lake (United States Environmental Protection Agency, 2021).

Reclaimed water use provides a constant and reliable water supply. When used for irrigation, it reduces the need for fertilizer and nutrient inputs. It can also help prevent the discharge of water with high-nutrient loads to water bodies.

However, there are obstacles associated with public perceptions around use of reclaimed water. Some communities have concerns regarding the treatment and fate of contaminants of emerging concern (CECs) (Clay Reitsma, Joint Utilities Board, personal communication). In cities with heavy industry, when crops are irrigated with incompletely treated recycled water, concentrations of metals can build up in soils and impact crop production and human and animal health.

Finally, while reclaimed water can provide a substantial, reliable volume of water, it is unlikely to meet 100% of an area's irrigation demand. The volume of water used daily by a domestic household is much smaller than the volume of water required to grow that household's food. So while reclaimed water can help support agricultural water use, it is unlikely to contribute to an entire supply (Food and Agriculture Organization of the United Nations [FAO UN], 2020).

Managed Aquifer Recharge (MAR)

Several communities around the globe are using Manager Aquifer Recharge (MAR) to store water in local aquifers. Managed aquifer recharge is the intentional recharge of water to aquifers, to be used for future human or environmental purposes. It is also called groundwater replenishment, water banking, and artificial recharge (International Association of Hydrogeologists Commission on Managing Aquifer Recharge, 2021).

Aquifers can be beneficial storage areas because they are able to store substantial volumes of water, without the risk of that water evaporating in hot weather. Storing water underground typically costs approximately half as much as cost per m^3 as other water supply and storage options such as reservoirs/dams (David & Pyne, 2014).

Typically, with MAR, when water is abundant (e.g., spring/fall/winter), it is recharged into an aquifer and then taken out later during dry conditions. The source of influent water can be from a river/lake, stormwater, or treated wastewater. There are a variety of approaches to artificially recharge groundwater, including flooding/ water spreading, basins or percolation tanks, injection wells, recharge pits and shafts, etc. The term ASR is typically used to describe approaches that use injection wells.

MAR has been successfully used to augment water supplies in the US (e.g., California, Oregon, Nevada), Australia, India, and many Latin American and Caribbean countries (Bonilla, et al., 2018; United Nations, 2015; GSI Water Solutions, 2021). It is also used to address saltwater intrusion (OCWD, 2020).

Managed aquifer recharge has been used to some degree for thousands of years. In Lima, Peru, in pre-Incan times, the community diverted stormwater to infiltration ditches, to support its water supply needs. The city's water utility is now considering bringing back that ancient technology to support the city's water needs (Tegel, 2019).

The feasibility of MAR depends on a variety of factors including the nature of the aquifer and subsurface geology, and the in situ and recharge water quality.

The interaction and compatibility of the injected water with the groundwater present in the host aquifer is a key aspect of ASR feasibility (Geller & Burt, 2020). Injection of recharge water can cause changes in speciation of metals and affect their mobility and toxicity. Leaching of certain toxic metals such as arsenic, cobalt, iron, manganese, molybdenum, nickel, vanadium and uranium from the aquifer matrix to storage zone has been reported in several ASR systems (Arthur et al., 2005; Meng et al., 2002; Lin & Puls, 2003). Many aquifers have background water quality issues due to local geochemistry or land use activities and so water quality monitoring data are essential in the assessment of the feasibility of ASR.

While one of the benefits of aquifer storage is that there are fewer evaporative losses, it is not realistic to assume that all water that is injected into an aquifer is available at a later date, as some water will be lost to subsurface movement. And while in principle, aquifer storage is more attractive than surface water storage because it is less vulnerable to climatic variations (e.g., reductions in rainfall intensity, duration, and frequency and temperature increases), there can also be challenges with overdraft and poor governance (FAO, 2020).

Desalination

Around the world, several communities are converting seawater to freshwater through a process called desalination. Desalination is used to provide municipal water supplies in the US (e.g., California, Florida, Texas), Saudi Arabia, Japan, Italy, and the United Arab Emirates (Yuwei & Horvath, 2020).

Florida currently leads the US in desalination as a water supply. In Florida, reverse osmosis (RO), is commonly used to desalinate water. RO uses pressure to force salty water through a semi-permeable membrane that leaves salt on one side and forces freshwater through the over. The Tampa Bay Desalination plant uses desalination to produce up to 166,558 m^3 of freshwater per day (Florida Department of Environmental Protection, 2020).

While desalination is heralded as a 'drought-proof' water supply source, it is very costly and energy intensive to desalinate water. For this reason, the majority of the global desalination capacity is used for municipal water supplies (62.3%), industrial water (30.2%), and only a small amount 1.8% of desalinated water is used in irrigation (Yuwei, & Horvath, 2020).

The desalination process also creates 'extra salty' water that must be safely discharged back to the environment. The cost of ocean intakes, outfalls and water distribution all increase the cost of desalination (Robins, 2019).

Inter-Basin Transfers

In some jurisdictions, water is taken from one watershed and utilized in another watershed. Water is commonly piped and pumped from one watershed to another. Inter-basin transfers can mean be carried out at a number of different scales and environmental impacts to both source and receiving basins. A local example of a local surface water inter-basin transfer is the Catalyst Paper diversion from Cowichan for use in the Chemainus watershed. An example of a local groundwater transfer is the use of groundwater from a well in the Koksilah watershed by the Burnum water system - a small water system just outside the watershed boundary.

An example of a large diversion is in China, where the South to North Water Diversion facilitates the inter-basin transfer of 20 billion cubic metres annually from the Yangtze river to the North China Plain (Long, Wang, & Scanlon, 2020).

Inter-basin transfers can be a helpful option in communities with low or depleted supplies. With inter-basin transfers, it is important that the potential impacts are carefully considered as there is the potential for significant adverse ecological impacts and longer-term sustainability issues, if longer term demand and environmental impacts to the source watershed are not carefully considered.

Green Infrastructure

The term ‘green infrastructure’ (GI) refers to nature-based solutions that rely on ecosystems and the services they provide to respond to challenges such as drought, flooding, climate change, food security, etc. Green infrastructure solutions to increase water yield include practices such as wetland restoration and forest management.

Approaches such as riparian area restoration and instream habitat enhancement can also be used to support environmental flow requirements. Riparian area restoration can improve water quality (temperature, dissolved oxygen, sediment, nutrients) and prevent water in streams from becoming too hot for fish to survive during low flows. In-stream habitat improvements can provide fish with refuge and increase the effective depth of water during low flow periods.

With climate change and population growth, there is increasing interest in landscape level interventions to stabilize water supply and improve yields (FAO UN, 2020). As ninety percent of major cities rely on forested watersheds for their water supply, there is a growing interest in using landscape-level approaches like forest management as a nature-based solution to manage water yields (FAO UN, 2019).

Forests consume significant volumes of water through transpiration and are integral components of the water cycle, regulating streamflow, groundwater recharge, and evaporation, and contributing to atmospheric water recycling (e.g., atmospheric aerosols supporting cloud generation) (FAO UN, 2019).

Currently, opportunities to increase water yields and augment low flows through green infrastructure are being explored in many areas of the world including the US (e.g., Arizona, California), Canada (Ontario), Korea, Australia, Peru, China, and India (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2017; Grand River Conservation Authority, 2004; Harper et al., 2020; US Department of Agriculture, US Forest Service, 2021; Saska et al, 2019).

Forest management practices that have been explored focus on retaining water in the landscape (e.g. through reforestation), reducing evapotranspiration (ET) from rapidly regrowing vegetation (e.g., through thinning, longer rotations, reduced density), and maintaining the volume and timing of snowpack and melt (particularly in areas with high radiation exposure).

In California, Arizona, and Colorado, forest managers, working in partnership with water utilities and research institutions have found that forest management practices can increase water yield by up to 55%. However, the results are specific to the local conditions and cannot be generalized to other ecosystems/areas. The forest management practices that produced the greatest increase in yields in these studies involved the use of herbicides, which are highly regulated on US public lands and are not a favorable approach in some communities (Saksa et al, 2019; USDA FS, 1999; Schalau, 2015).

In the US, there is a growing recognition of the role of upper watersheds as water infrastructure, with legal and financial accommodations to support this. California's Water Code recognizes that with climate change, source watersheds are of particular importance to maintaining the reliability, quantity, timing, and quality of California's environmental, drinking, and agricultural water supply, and enables local governments to utilize infrastructure financing for forest restoration and upland vegetation management to restore the watershed's productivity and resiliency (Water Code, §108.5).

In Peru, all water utilities are required to identify opportunities to use green infrastructure to address the timing of flows and increase dry season flows and invest in green infrastructure. A recent review found that green infrastructure was more cost-effective than grey infrastructure ($0.06 USD/$m^3$) even considering uncertainty. Further work was recommended to reduce uncertainty (Gamie, 2015; Fang et al, 2019).

In Australia it was found that while it is possible to increase water yields through forest management, it must be done at a watershed-scale to be effective, and the current decoupling of water supply and forest management provides little financial incentive for forest managers to take such actions (Harper et al, 2020).

The effects of forest management practices on water yields and low flows are complex and vary with watershed characteristics including precipitation, temperature, soil, aspect, latitude, geology elevation, and vegetation characteristics. While clearcutting may increase yields in the short-term, more sustainably approaches taken to manage forests to increase yield can take several years to produce results (Moore, Gronsdahl, & McCleary, 2020; Goeking & Tarboton, 2020; Zhang & Wei, 2021).

Because variations in forest management can have significant positive and negative influences on the hydrologic regime - and these consequences of these effects may not be known with certainty for several years or decades to come (particularly with climate change) - the use of landscape-level interventions at a watershed-scale should be approached systematically and with care.

Alternative Small-Scale Water Storage

Several alternative approaches storing water were also identified, including the storage of excess rainwater from roads, under roads in cities, proposed by a company in Europe (Better World Solutions, 2021) and also the creation of sub-surface dams storing water from roads in Africa (Nissen-Petersen, 2006). It is unclear if these approaches have been piloted in North America. However, the volumes of water that could be stored using these approaches would be relatively small and the cost involved in reconstructing roadways is significant. These approaches would be limited by the subsurface geology and their compatibility with local engineering standards.

Seasonal Water Demand

Surface water and groundwater demand estimates for the Koksilah watershed were provided by FLNRORD. These estimates were further processed to estimate how much water may be required to meet summer demand or environmental flow needs of the Koksilah River and its tributaries.

In the project kick-off meeting, it was advised to consider demand in the period between July 1 and September 30. For that 92-day period, an analysis of the available data found that the estimated demand is approximately 3.4 m^3/s (0.43 m^3/s) and could be as high as 3.8 million m^3 (or 0.48 m^3/s).[1]

While assessment is presently underway to identify an appropriate critical environmental flow threshold for the Koksilah River, two critical environmental flow thresholds have been proposed: a higher threshold of 0.49 m^3/s equivalent to ~5% MAD, and an interim lower threshold of 0.18 m^3/s based on preliminary assessment of instream habitat suitability for Coho and Steelhead species and other factors (Barroso & Wainwright, 2020).[2]

The estimated seasonal demand is close to the higher environmental flow threshold of 5% MAD, or 4.9 million m^3 (0.49 m^3/s).

Approach

MFLNRORD staff provided estimates of daily consumptive water demand from surface water and groundwater sources, categorized by water use purpose (e.g., agricultural, commercial/industrial, domestic) for the period between May 1 - Sep 30. These estimates were developed during an assessment of demand completed as part of the curtailment process in 2018 and 2019 and included both estimates of licensed surface water and groundwater use as well as inferred groundwater demand. The estimates assumed consistent water use through the summer months.

Given that the period between July 1 and September 30 includes the highest use of the summer, the daily demand estimates provided by MFLNRORD were adjusted to consider monthly variations in use. It is commonly assumed that domestic and waterworks users consume more water in the summer, due to outdoor irrigation of lawns and gardens and increased indoor cleaning use (e.g. greater shower, bath and laundry use). It is also generally assumed in southern BC that irrigation use peaks mid-July.

The estimated daily demand for each month was determined by applying a coefficient of use based on the water licence purpose. The monthly use coefficients are shown in Table 1.

Monthly coefficients for non-agricultural demands were assigned based on prior work (Sentlinger & Metherall, 2020). Monthly coefficients for agricultural use were developed using the BC Agriculture Water Calculator.[3] The BC Agriculture Water Calculator was used to estimate the average, monthly demand values

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[1] The 3.4 m^3/s assumes that only areas that were identified as irrigated in the 2013 Agricultural Land Use Inventory (MoA, 2013) are included. The 3.8 m^3/s includes areas that have 'Irrigation Potential' and where irrigation systems may have been installed since 2013.

[2] There are also other species that are threatened by low flows including trout, Chinook, chum, etc. (Tracy Fleming, personal communication).

[3] https://bcwatercalculator.ca/agriculture/welcome

on ten parcels of agricultural land, assuming a distribution of crops and irrigation system types that matched the Koksilah watershed (van der Gulik, Neilsen, Fretwell, & Tam, 2013).

Table 1: Coefficients of Water Use by Month for Consumptive Uses

Month	Water Licence Purpose Classification						
	Waterworks	Domestic	Recreational	Stock watering	Irrigation	Commercial	Industrial
January	0.85	0.85	0.85	0.95	0	1	1
February	0.85	0.85	0.85	0.95	0	1	1
March	0.85	0.85	0.85	0.95	0	1	1
April	0.85	0.85	0.85	0.95	0	1	1
May	0.95	0.95	0.95	1.05	0.52	1	1
June	1	1	1	1.07	1.18	1	1
July	1.5	1.5	1.5	1.08	1.55	1	1
August	1.5	1.5	1.5	1.08	1.17	1	1
September	1.1	1.1	1.1	1.07	0.59	1	1
October	0.85	0.85	0.85	0.95	0	1	1
November	0.85	0.85	0.85	0.95	0	1	1
December	0.85	0.85	0.85	0.95	0	1	1

Coefficients obtained from prior work (Sentlinger & Metherall, 2020). Coefficients for Irrigation were applied to the Recreation category because most use in this category is for golf course irrigation (Megan Wainwright, personal communication). Livestock watering coefficients were developed using the BC MAFF Livestock Watering Factsheets (Ministry of Agriculture, 2006), Commercial use assigned as Enterprise.

The water use coefficients were applied to the daily demand estimates from FLNRORD, considering the number of days in each month, to develop an estimate of daily water use for the months of May - September. The results for both unlicensed (inferred) and licensed use are shown in Tables 2 and 3.

Table 2: Estimated Daily Unlicensed Consumptive Groundwater Demand by Month

	Estimated Daily Water Demand by Month (m^3/day)				
Type of Water Use	**May**	**June**	**July**	**August**	**Sept**
Commercial	1,391	1,391	1,391	1,391	1,391
Domestic	990	1,042	1,563	1,563	1,146
Industrial	1,282	1,282	1,282	1,282	1,282
Irrigation	3,973	9,022	11,833	8,947	4,489
Recreational	0	0	0	0	0
Stock watering	224	228	230	230	228
Waterworks	2,039	2,147	3,220	3,220	2,361
Total	**9,900**	**15,112**	**19,519**	**16,634**	**10,899**

Table 3: Estimated Daily Licensed Consumptive Groundwater and Surface Water Demand by Month

	Estimated Daily Water Demand by Month (m^3/day)				
Type of Water Use	**May**	**June**	**July**	**August**	**Sept**
Commercial	2	2	2	2	2
Domestic	232	244	366	366	268
Industrial	5,576	5,576	5,576	5,576	5,576
Irrigation	7,164	16,266	21,335	16,132	8,094
Recreational	1	2	3	2	1
Stock watering	75	76	77	77	76
Waterworks	11	11	17	17	13
Grand Total	**13,061**	**22,179**	**27,377**	**22,173**	**14,031**

*Includes both surface water and groundwater licences.

It is important to note that licenced and inferred quantities are not metered, and actual water demand may be lower or higher than indicated.

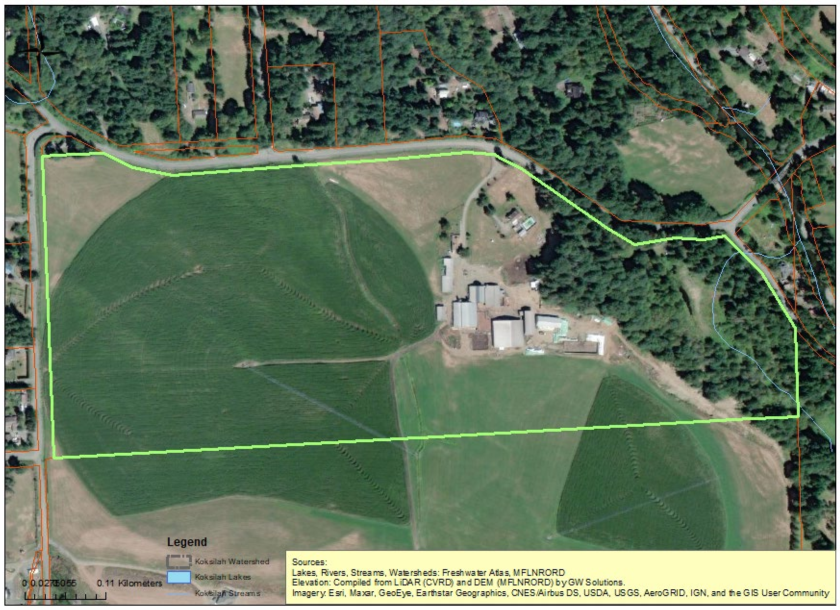
To assess the reliability of the results, they were compared to the data from the demand analysis completed as part of the curtailment process (Barroso & Wainwright, 2020). There is generally close alignment with the licence values. Average daily licensed surface water use over the period from May - September is estimated to be 18,549 m^3/day in the curtailment study and 18,626 m^3/day in this work. Average daily groundwater use over the period from May – September is estimated to be 13,728 m^3/day in the curtailment study and 13,196 m^3/day in this work. Some variation in results is acceptable, given the variation in approach and updates to the raw demand data since 2018, 2019 (Megan Wainwright, personal communications).

Overall, it was found that the most significant volume of consumptive water use in the July 1 - Sep 30 period is for irrigation. Much of the irrigation water in the Koksilah watershed is used to irrigate forage (ALUI, 2013). Water used for irrigation of forage should comply with the Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses but does not need to be potable water quality (MoA, 2018).

Potential for Greater Demand

As noted above, any approach to estimating demand has the potential to both under-estimate and over-estimate demand. The following identifies one way in which the above approach may under-estimate demand and identifies a potential higher demand estimate if a more conservative approach is desired.

In the curtailment work, properties identified as having 'Irrigation Potential' were not included in the estimates of inferred groundwater use. In this work, it was recommended that the team take the same approach, as including them has the potential to lead to over-estimating demand (Megan Wainwright, personal communication).



A review of randomly selected properties that had been classified as having 'Irrigation Potential', found that several had evidence of an irrigation system in use. Figure 2 shows an example of the largest property in this category (outlined in green) with evidence of irrigation. Several of the other properties in this category also appeared to have irrigation systems.

Provincial staff noted that while there were wells on these properties and there may be irrigation use, several of these properties were excluded from the count of inferred groundwater use because the property owner held a water licence for irrigation on an adjacent property. It was assumed that the groundwater well was primarily for domestic use and that including these properties in the count of inferred groundwater demand for irrigation may result in double counting of demand (Megan Wainwright, personal communication). This is a reasonable assumption, given an understanding of common approaches to water use on agricultural properties throughout the Province. However, it has the potential to under-estimate demand.

As a detailed review of irrigation use is beyond the scope of this work, these properties were excluded from the estimate of demand. If areas with 'Irrigation potential' are included, it would increase the estimated demand from irrigation by 46%. If a more conservative approach is desired, then these properties could be included. If properties with 'Irrigation Potential are included, then the total estimated demand would be 3.8 million m^3, rather than 3.4 million m^3 over the period between July 1 – Sep 30.

Preliminary Identification of Water Supply Options

A preliminary scan of water supply options in the Koksilah watershed was conducted, using the following approach:

1) Initial kick-off meeting
2) Review of background materials
3) Engagement with Cowichan and Malahat First Nations, provincial government staff, and local community members and subject matter experts.

The first step began at the project kick-off meeting, where provincial staff provided high level guidance on options. The meeting was attended by the consulting team as well as the MFLNRORD Director of Resource Management, MFLNRORD Water Authorizations Section Head/contract monitor, and MAFF Water Management Specialist.

Participants noted that, at this point, it is best to keep all options 'on the table' and suggested that the goal of this study should not be to eliminate options, but rather to take a 'blue sky' look at potential solutions and understand which options are likely to be most effective, and the pros and cons of each approach.

Review of Background Materials

A review of background materials provided additional insight into the issues and opportunities in the Koksilah. Materials reviewed included:

- Water Use and Management in the Koksilah River Watershed (Barroso & Wainwright, 2020)
- The Koksilah River: Streamflows and Salmon Production (Tutty, 1984)
- Koksilah Watershed Hydrological Analysis (Hatfield, 2021)
- Cowichan-Koksilah Water Management Plan (Ministry of Environment and Parks, 1986)
- Koksilah Regulatory Response to Low Flows Effectiveness Analysis (Northwest Hydraulic Consultants, 2020)
- Koksilah Watershed Engagement: External Engagement Summary (MODUS, 2021)
- Website: koksilahwater.ca

Preliminary Consultation

Next, Cowichan and Malahat First Nations and provincial staff were contacted to identify, at a high-level, potential options, initial considerations, and areas that should be avoided (e.g., culturally sensitive areas).

First, representatives from the Cowichan Tribes and Malahat Nation were contacted, including:

- Tracy Fleming, Cowichan Tribes
- Heather Adams and Tristan Gale, Malahat Nation

Then, the following provincial staff, community members, and local subject matter experts were contacted to obtain a better understanding of local context and potential solutions:

- Andrew Peterson, Water Management Specialist, MAFF
- Jessica Doyle, Water Protection Section Head
- Doug Pepper, Regional Agrologist, MAFF

- David Tattam, Water Use Manager, retired Dairy farmer, retired Environmental Farm Plan (EFP) representative
- Wayne Haddow, retired Regional Agrologist, organizer of the Koksilah Group EFP
- Darren Brown, Director of Environmental Programs, BC ArdCorp

Main points and options emerging from the engagement are identified below.

Comments from Cowichan Tribes Staff

In general, Cowichan Tribes has a strong preference for water storage and supply options that result in minimal environmental disturbance. If environmental alteration is 'required', it would be best to do it in areas that have previously been disturbed.

Staff also noted a strong preference for actions that help restore the natural hydrologic regime and support groundwater recharge and reduction of winter flooding.

Comments on specific water supply/storage options included:

- *Rainwater cisterns:* Cistern use likely to be supported.
- *Water tanks:* On-site or shared water storage options likely to be supported.
- *Dugouts:* Dugouts likely to be supported, provided they are created without destroying wetland habitat, because the vegetation in wetlands are medicines. There was also an interest in understanding if dugouts would cause reductions in groundwater recharge and affect the water cycle and aquifers over the long term.
- *Extraction pits:* Extraction pits were suggested as a solution by Cowichan Tribes staff. Staff provided an inventory of extraction pits in the watershed and background information on the pits.
- *Existing lakes:* Cowichan Tribes would prefer to avoid dams and wetland disturbance. Wild Deer Lake and Lois Lake are culturally sensitive areas and should be removed from consideration. Grant Lake may be a culturally important area. Elders to be consulted on this.
  There may be an interest in surface water storage if it can play a role in flood modulation. Several communities in the watershed are affected by winter flooding and most of the Cowichan membership are subjected to the downstream effects of upstream watershed management. Reserve lands experience significant flooding in the winter, so water storage solutions that help deal with excess winter water are worth exploring.
- *ASR, reclaimed water use*: While Cowichan Tribes staff expressed no initial opposition to more technologically involved approaches like reclaimed water use and ASR, they noted that it would be essential to understand potential impacts and areas of application before deciding on them. Reclaimed water use would not be appropriate in areas of cultural or spiritual significance, because purity is very important for cultural or spiritual purposes. Staff expressed an interest in ASR if it helps to reduce winter flooding.
- *Cowichan Lake*: Cowichan Tribes would not be supportive of transferring water from the Cowichan to the Koksilah watershed because the Cowichan also has significant summer flow challenges and large withdrawals (e.g., large use by Crofton Mill). Cowichan Tribes would also not be supportive of using water from the Cowichan River for irrigation in the Koksilah in times of drought.
  Staff also noted that it was unlikely that this option would be supported by the broader community because the Cowichan watershed has its own set of flow and storage concerns.

- *Municipal water supply:* Staff noted that there are already problems with low flows in the Cowichan River, so taking more water from aquifers that are connected to this river did not seem like a good option.

Comments from Staff at Malahat Nation

Staff at Malahat Nation also expressed a strong preference for options that help restore the natural hydrologic regime, support groundwater recharge, and reduce winter flooding. Staff also noted a preference for options that result in minimal environmental disturbance. Comments on specific solutions included:

- *Dugouts:* Any large excavations warrant careful attention in terms of archeology. For the Malahat Nation, this concern increases closer to the coast. There were also questions regarding the impact of evaporation from open dugouts on the water cycle. The use of dugout/reservoir covers was proposed.
- *Existing Lakes*: Dams are not desirable due to potential impacts on anadromous species, habitat (e.g., shifts in the hydrologic regime may cause changes in sediment transport, spawning gravels, and water quality), species composition, and overall environmental alteration. Staff noted that the Malahat Nation needs to be involved in any potential discussion around alteration to Kingzett Lake.
- *Cowichan Lake:* Taking water from Cowichan Lake makes a lot more sense than trying to increase storage upstream in the Koksilah watershed and it is something that could be implemented quickly.
- *ASR:* Open to the idea. It is important to understand water quality impacts and ensure water quality is sufficient.
- *Reclaimed water use:* Staff were open to the idea but said that further information is needed on water quality impacts (e.g., whether CECs are taken up by grass, or remain in the soil to infiltrate into the aquifers) and effectiveness of treatment.
- *Forest management:* Any forest management interventions would have to offset the expected increase in evapotranspiration due to natural forest recovery. It is important to ensure that any forest practices intended to support hydrologic function also consider ecosystem impacts. For example, thinning may have a high ecological cost.
- *Additional suggestion:* Malahat Nation included a direct request for the Province to investigate the option of purchasing the lands and businesses of the largest water licence holders and 'retiring' those licences.
- *External sources:* Olliphant Lake was noted as a potential water supply option. The Malahat Nation recently acquired the lake which has an aging 80-year-old dam. There has been some work done in 2006 to estimate the volumes of water available in the lake. However, in conversation it was determined that the volumes are quite minimal compared to the Koksilah seasonal demand and the distance from the Koksilah demands too great.

Comments from Provincial Staff, Community Members, and Subject Matter Experts

The following preliminary comments were made on potential water supply options:

- *Existing Lakes*: Many producers have an interest in seeing Grant Lake explored as an option, due to the high cost of farm dugouts, including the cost of removing land from production (Wayne Haddow, personal communication, Doug Pepper, personal communication; David Tattam, personal communication).

- *Reclaimed water:* Many producers would use reclaimed water to irrigate forage if it were an option (Wayne Haddow, personal communication, Doug Pepper, personal communication; David Tattam, personal communication).
- *Dugouts:* Many producers would use dugouts if there was funding assistance. While it is not feasible on all properties, several producers are interested in creating dugouts. However, it can be very costly. For example, a 1-acre dugout would be needed to store sufficient water to irrigate a 14-acre forage field. This would cost from $150,000 - $550,000, plus the loss of 7.5% of production/revenue. Current funding for dugouts is very limited (50% of costs up to $10,000).
- It is also not physically possible to create dugout storage on all properties and the land costs and soil conditions in the Koksilah make it more difficult than in some other areas of the Province (Wayne Haddow, personal communication, Doug Pepper, personal communication; David Tattam, personal communication).
- *Green infrastructure*: Many producers and community members are interested in further research to understand impact of forest practices on the hydrologic regime and proposed the exploration of forest management practices to support the hydrologic regime (Haddow, 2021; MODUS, 2021; Darren Brown, BC ArdCorp, personal communications; Wayne Haddow, personal communication).
- Producers shared that uncertainty around water supply not only causes disruptions and losses to their business and family incomes, it also takes a significant emotional toll. They noted that community-wide irrigation scheduling is not a solution, as it significantly impacts income and has a high business cost (Haddow, 2021; Darren Brown, BC ArdCorp, personal communications; Wayne Haddow, personal communication).

Following this initial research and the review of best practices in other jurisdictions, the following options were identified for further investigation:

On-site small-medium scale
- Greywater reuse
- Cisterns
- Dugouts
- Water storage tanks

Off-site medium-large-scale
- Extraction pits
- Existing lakes
- Natural features

Existing Systems
- Municipal water supplies
- Municipal wastewater
- Cowichan Lake

Aquifer/watershed-scale
- Aquifer storage and recovery
- Green infrastructure

Evaluation of Water Supply Options

Once the preliminary identification of water supply options was completed, further research was conducted to evaluate the water supply options. Options were assessed according to the criteria shown in Table 4.

Table 4: Criteria Used to Evaluate Water Supply Options

Criteria	Description
Key Criteria	
Impact	Identifies the effectiveness of the option, in terms of its ability to provide the desired volume of water at the right time. Considers estimated storage/supply volume as a percent of total seasonal demand (July-Sep).
Affordability	Identifies at a high-level, relative cost for materials and construction and assigns a rating of low, medium, or high based on the cost per m^3 to construct.
Adoptability/Ease of Implementation	Considers compatibility with community (e.g., community interests and capacity), stakeholders, administrative/regulatory requirements (e.g., Dam Safety Regulation), barriers to implementation, compatibility with First Nations interests, etc.
Ease of Use	Identifies the effort/cost to maintain, considering maintenance requirements, administration, water quality considerations, etc.
Reliability	Identifies the likelihood of source remaining available under changing future conditions (e.g. climate change).
Additional Considerations (addressed where appropriate/relevant)	
Independent benefits & trade-offs	Example of a tradeoff: environmental impacts, loss of land base for production. Example of a benefit: flood modulation.
Additional comments	

Each option was ranked according to the above criteria, using the assessment criteria shown in Table 5, below.

Table 5: Approach to Ranking Water Supply Options

Criteria	Low	Medium	High
Volume of water	0-33% of demand	34-67% of demand	68-100%+ of demand
Affordability ($/m3)	$100-$1,000/m^3	$10-$100/m^3	<$10/$m^3$
Ease of implementation (time, effort, likelihood of success)	• 5+ years • High effort ($, time) • Low likelihood of success • Most key players not interested	• 1-4 years • Moderate effort • Moderate likelihood of success • Some key players may be uninterested	• <1 year • Low effort • High likelihood of success • Most key players interested
Ease of use (access, maintenance)	• Low ease of use High effort/cost of maintenance	• Moderate effort/cost of maintenance • Moderate ease of use	• Easy to use • Low effort/cost of maintenance
Reliability	• High	• Medium	• Low

To assess the feasibility of each option, the following research methods were used:

- Engagement with local subject matter experts.
- Review of relevant reports, research studies, and websites.
- Data collection and analysis.

A list of individuals and organizations contacted can be found in Appendix A. Relevant reports, studies, websites, and personal communications are cited throughout. Further details on the data analysis can be found in Appendices B-D. GW Solutions was engaged in the assessment of ASR and a full report of the ASR feasibility assessment can be found in Appendix D.

The following provides an overview of each option and then ranks each option as low, medium, or high according to the feasibility criteria. The rankings are based on information gathered during the project period (February - March 2021). For several options, further feasibility assessment is required. Future community engagement and dialogue may also bring new insights to inform the rankings.

This section concludes with a table which provides the rankings for each option and assesses relative feasibility. It is followed by information on next steps to assess the feasibility of each option.

On-site small-medium scale water supply/storage options

Greywater reuse

Introduction

Greywater reuse typically refers to the reuse of water from baths, showers, bathroom basins and laundries. Generally, water from toilets, the kitchen sink, and dishwasher is not included as greywater because it can have levels of oils and greases that are too complex to treat in a typical greywater treatment system. Greywater can be reused for low-risk purposes either inside the home for toilet flushing or it can be used outdoors for sub-surface irrigation and ornamental gardens (BC Ministry of Health, 2017).

Potential Volumes of Water that Could be Made Available.

In the Koksilah watershed, there are approximately 1,222 households (MoA, 2013). If each of these households used approximately 1 m^3/day indoors and 60% of the indoor water use was reused as greywater, over 92 days (from July 1 – Sep 30) this would save (or provide) 67,454 m^3 of water. This accounts for approximately 1.98% of the seasonal demand over that period.

Distance from Demand and Works Required

A greywater system provides water on the same site as a water demand. The works required depend on how the greywater will be used. Greywater systems vary in complexity from a bucket/switch in/under sink that goes to infiltration lines to a dual plumbing set-up for indoor toilet use (BC Ministry of Health, 2017). If greywater is to be used indoors for toilet flushing, then a higher level of treatment would be required than for outdoor use.

Cost

The cost of a greywater system depends on how the greywater will be used. For example, it could cost $1,500 for a greywater system and $500 a reservoir to use greywater outdoors for irrigation or garden use. Alternately, it could cost $15,000 for a greywater system for indoor use (NovaTec Consultants Inc., 2004). Overall, greywater systems typically cost \$30-\$230/m^3 of water saved/provided.

Administrative/Regulatory Considerations

Indoor use of greywater must meet the Health Canada Guidelines for Domestic Reclaimed Water for Use in Toilet and Urinal Flushing. Greywater is considered sewage according to the Sewerage System Regulation. When it leaves the building, it must go into a sewer/sewerage system, unless authorized under the 2012 Building Code. The 2012 Building Code allows for the construction of non-potable water systems and sub-surface irrigation with non-potable water. The Health Canada Guidelines for Domestic Reclaimed Water for use in Toilet and Urinal Flushing provide further guidance for grey water systems and is referenced in the BC Building Code. Local governments may also create bylaws to allow discharge of greywater, provided it meets the provisions in the 2012 Building Code (BC Ministry of Health, 2017).

There are several water and wastewater systems in the Koksilah watershed and there may be local bylaws with requirements around connecting additional sewerage or dual plumbing systems to those systems.[4]

[4] Cowichan Station is on septic. Wastewater from South Duncan, Cowichan Bay, and Eagle Heights goes to the JUB (Keith Lawrence, Senior Environmental Analyst, CVRD, personal communication). Lambourn Estates has its own wastewater system, producing a small volume of high-quality effluent, and has a sewage outfall.

Maintenance

Maintenance requirements are medium to high. Grey water must be treated and disinfected before storage and use to reduce pathogens and smell. The treatment system must be maintained, and the user of a greywater system must pay attention to chemicals utilized (e.g., cleaners, personal care products, laundry detergents). Further considerations are provided in the document, '*Health Information for Grey Water Re-Use*' (Ministry of Health, 2017).

Additional Considerations

Trade-offs

Environmental impacts: There is the potential for environmental impacts with greywater systems if they are used for outdoor use. If a user that discharges greywater to the outdoors is not careful with the chemicals that they are using or treatment system maintenance, they may release contaminants into the environment.

Additional benefits

Greywater use may cause users to be more conservative with water use.

Comments

Community interest: Some community members may find greywater systems undesirable.

Ranking According to the Feasibility Criteria

Impact	Very Low
Affordability	Low
Ease of implementation	Low
Ease of use	Low
Reliability	High

Cisterns

Introduction

Cisterns are currently used in many areas of Vancouver Island and the Gulf Islands to capture and store rainwater and/or modulate flows from low-producing wells. They are typically used to provide water for indoor use or for hobby gardening. They are not commonly used for agriculture, as most agricultural users require larger volumes of water that can be stored more cost-effectively using ponds/dugouts (Russ Batyi, Vortech Plumbing, personal communication).

Most households that rely on water from rainwater harvesting typically use 1250 - 1500-gallon tanks (5.5 - 6.8 m^3). The volume required in each household depends on household size and can be calculated by multiplying the number of people in a household by 50 - 80 gallons per person per day.

While there is a significant supply of rainwater in the winter months, and it would be ideal to be able to capture a large volume of winter water to supply the summer shortfall, it is typically recommended that a rainwater cistern is a small/moderate size, because if too much water is stored, it can stagnant and grow bacteria.

For indoor use, it is recommended to use a filter and disinfect water using UV or chlorine injection (Russ Batyi, Vortech Plumbing, personal communication).

Potential Volumes of Water that Could be Made Available

If one 1,500-gallon (6.81 m^3) cistern was utilized by each of the 1,222 households in the Koksilah watershed, then this would create 8,322 m^3 of storage. If the tank was full on July 1, and each household collected any rain that fell (assuming a 100 m^2 roof) from Jul 1 - Sep 30, then a total of 43,528 m^3 could be made available (Regional District of Nanaimo, 2012).

If the tank was filled with groundwater before July 1 and supplemented with rainwater over the summer season, then the volume would be the same.

This would provide approximately 1.3% of the seasonal demand.

Distance from Demand and Works Required

Rainwater cisterns are typically placed at the site of demand. Cisterns need to be installed on level, hard ground (or another graded surface) and secured. If a rainwater source is used, a rainwater harvesting system is needed to capture rainwater, and a delivery system is needed to bring the rainwater into the house (e.g., submersible pump, reservoir, pressure system, treatment system). An overflow is also needed, and the tank should be vented. There are two ways in which the system can be set up: either a constant pressure system or a standard pressure tank. Constant pressure systems are more expensive but much more popular, as they allow a user to turn on multiple fixtures at the same time (Russ Batyi, personal communication).

Cost

Cost varies with size, treatment, and type of pressure system used (constant vs standard). It costs approximately $1,350 for a 1,500-gallon tank, $1,800 - $3,500 for the submersible pump and pressure tanks, and $1,800 for UV treatment (Vortech Plumbing, 2021; Russ Batyi, personal communication).

Per cubic meter, without UV treatment, a rainwater collection and use system costs approximately \$435 - \$700/m^3. With UV treatment it would cost \$700 - \$960/m^3. The range of prices reflect constant pressure vs standard pressure systems.

Administrative/Regulatory Considerations

There are limited regulatory considerations when using rainwater harvesting use in a single residential household. If water is used indoors for potable use, it should meet Health Canada's Guidelines for Canadian Drinking Water Quality. Installations should meet BC Plumbing Code requirements for potable water distribution pipes and backflow prevention devices, BC Building Code requirements for building and roof structures, maximum flow loads and drainpipes, and drainage away from structures, and BC Electrical Code requirements for wiring and pumps (RDN, 2012).

Maintenance

Maintenance is typically low. A sediment filter should be changed every 6 months and the UV bulb changed annually, at a cost of approximately \$300/year (Vortech Plumbing, 2021). A full description of maintenance and operation requirements can be found in the RDN Rainwater Harvesting Guidebook (Regional District of Nanaimo, 2012).

Reliability

Cisterns are a relatively unreliable water source. While they provide the owner with a fair degree of control over their water supply, rainwater-supplied cisterns are very vulnerable to variations in precipitation. While all rainwater-supplied sources are vulnerable to precipitation, due to the relatively small volumes of water stored in cisterns, they are particularly vulnerable.

Additional Considerations

Additional benefits

A rainwater cistern can support emergency preparedness. In the event of an emergency that impacts well water access/quality, a resident can order water from an outside source to be delivered to a cistern.

Ranking According to the Feasibility Criteria

Impact	Very Low
Affordability	Low
Ease of implementation	Medium-High
Ease of use	Medium-High
Reliability	Low

Dugouts

Introduction

A dugout is a reservoir or impoundment constructed by excavating into the ground to collect and store water. Dugouts, or manufactured ponds, can be filled with groundwater, surface water, snow melt, rainwater, runoff, or a combination of these. Dugouts are typically used to store water for livestock watering and/or irrigation. They can also be used to store water for industrial purposes.

Several producers in the Koksilah River watershed already use dugouts to store water. Ponds in the area are typically dug to a depth of 16 - 18 feet deep, and vary in width, based on the producer's space and water needs. Side slopes are typically 3:1 and sometimes 2:1, if subsurface conditions permit (Ken Motherwell, Motherwell Excavating & Logging, personal communication).

Deeper dugouts are more desirable than shallow dugouts because less water is lost to evaporation and water is better retained lower in the ground where soil is heavily compacted. However, not all the depth of a pond is usable water. Some water is lost to evaporation (approx. 16" over the growing season on the Island) 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.

In the Koksilah watershed, in-situ soils are somewhat less conducive to dugouts than in other areas of the Province. There are typically more porous soils in the Koksilah, which make it hard to seal dugouts. The most common soil in the area is Fairbridge soil (Wayne Haddow, personal communication). Fairbridge soil *may* have enough clay that if it were properly prepared, at depth, leakage would be minimal. However, there are also significant volumes of peat, sand, and gravel which are more porous (Wayne Haddow, personal communication; David Tattam, personal communication).

Additional clay is often required to prevent water loss from the dugout. However, due to the local subsurface conditions, clay can be quite difficult to acquire in the area (Ken Motherwell, personal communication; Wayne Haddow, personal communication)

To fully prevent connection with aquifer in the area, liners may be required. Liners can be very costly (e.g., ~$200,000 for a 1-acre dugout). They are also quite susceptible to damage by wildlife, so the dugout would need to be fenced and wildlife kept out of the dugout (Ken Motherwell, personal communication).

Dugouts typically require a large area of space to provide sufficient water for irrigation. In the Koksilah watershed, a 100-acre field would likely require a 7.5-acre dugout, assuming 6 m of depth and 3:1 sides. There is very little/no available land on farm properties that is not in production or has an existing use (e.g., dwelling), so to construct a dugout to cover the seasonal demand would require that approximately 7.5% of the land on the property is taken out of production.

Potential Volumes of Water that Could be Made Available

To determine the potential volumes of water that could be made available using dugouts, data on watershed attributes and land use was compiled and analyzed. A description of the process is provided in Appendix C.

Overall, it was found that up to 8 million m^3 of storage could be created using dugouts. This assumes that 7.5% of **all** land in production is converted to dugouts, that there is a depth to bedrock greater than 6 m, a slope of less than 5%, and the area is not a mapped wetland or environmentally sensitive area.[5] It does not consider the suitability of soils as that information was not available at a sufficient resolution.

If it was possible to create this much storage using dugouts, then it would support 100% of the seasonal water demand. However, it is unlikely that soils are suitable for dugouts in many areas of the watershed.

Without considering soil types, approximately 49% (268 out of 552) of all properties with crops (irrigated and unirrigated) had restrictions related to depth to bedrock, slope, ESAs, or lot size that would have prevented landowners from meeting seasonal water needs through dugout storage. When considering the 119 lots with irrigation, then approximately 37% (44/119) of properties had physical constraints (e.g., insufficient depth to bedrock, slopes, ESAs, lot size) that would have prevented them from storing seasonal water needs in dugouts. The distinction between irrigated and non-irrigated properties is made, because the 119 lots that have irrigation are the ones that were considered in the demand analysis.

A review of the properties where dugouts were identified as not feasible found that approximately 60% of the restrictions were limited by constraints related to depth to bedrock, slope, ESAs, and approximately 40% were limited by lot size (which didn't allow a dugout of sufficient depth to compensate for evaporative losses to be created). Lots in the latter category are more likely to be lower volume water users.

It is important to note that it is very unlikely that 7.5% of all available farmland would be converted to dugouts. Cropped land is the primary source of revenue for farm businesses, and for many businesses it is not financially feasible to lose 7.5% of revenue by taking land out of production.

Distance from Demand and Works Required

A farm dugout is typically located close to crops where water is needed. Where a producer has multiple fields separated by a road or another property, a dugout may not be able to supply water to the farther field.

Works required include dugout, pump, pipes, filter, fencing, and potentially liner and/or cover. The cost of a pump and pipe to transport water from a dugout varies with application (e.g., how far the water needs to be pumped and the type of irrigation system). Many producers also need to filter water to prevent sediment or algae from affecting pumps and irrigation equipment. Dugout water used for drip irrigation must be filtered (e.g., a disk filter with a 120-mesh costing approximately: $250 - $600) (Southern Irrigation, personal communication). Dugouts should be enclosed by a tall (e.g., 8') fence for safety and liability purposes.

Cost

The costs to dig a dugout vary significantly with site conditions. A 1-acre (9,000 m^3) dugout in the Koksilah would typically cost $150,000 - $350,000, depending on site conditions. If a liner is needed it would cost approximately $200,000 for a 1-acre pond (Ken Motherwell, personal communication). On average, dugout storage costs approximately $17 - $62/m^3. This does not include the lost revenue (approximately 7.5%).

Administrative/Regulatory Considerations

There are three main legal/regulatory considerations when building a dugout: Dam Safety Regulation, Water Sustainability Act (water licenses), and liability.

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[5] Depth to bedrock mapping developed by GW Solutions Inc. as part of the ASR feasibility assessment. Slope derived from DEM, prepared from 1/1.5m LiDAR data, provided by GW Solutions Inc., using data from GeoBC (GeoBC, 2021). ESA and wetland mapping obtained from MFLNRORD and CVRD (MFLNRORD, 2021; CVRD, 2018).

Dam Safety Regulation

If water is stored above grade, it is considered a dam. It is generally recommended that producers avoid building a dam, to avoid costly requirements for engineering, construction, inspections, and maintenance under the Dam Safety Regulation.

If a dam is the best, or only, option on a property, it is recommended that the property owner 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 10,000 m^3 of water, with a side less than 7.5 m, and limited/no downstream consequences if it fails) (Province of BC, 2021).

Water Sustainability Act

Dugouts do not require a licence if the water in the dugout 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 licence is needed for the volume removed from the source. A water licence is also needed for storage.

For example, if building a dugout and 'topping it up' with groundwater, a producer would need to have a water licence for irrigation on the well and a water storage licence for the dugout.

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 and a rope so that anyone who falls can (ideally) climb out.

Maintenance

For a full list of operational and maintenance concerns, the BC Farm Dugout Manual can be consulted (Ministry of Agriculture, 2013). Key issues and concerns include:

- Pump and Filter: A dugout generally requires the use of a filter and pump system with ongoing maintenance needs.
- Pond maintenance: Dugout should be maintained to support water quality and reduce algae growth. Supplemental flows (e.g., from a well) can help improve aeration.
- Liner: If dugout is lined, the liner will need maintenance and eventual replacement.

Reliability

Any water source that obtains water from rainfall is vulnerable to variations in precipitation. A dugout is a moderate-sized storage structure and is less vulnerable to precipitation variations than a cistern, but more vulnerable than a dam. If size the dugout so it is filled with water collected from a stream or well during the wet season, the water source is much more reliable.

Additional Considerations

Trade-offs

Loss of land for production: While dugouts make sense in the Interior (where there is Crown land available and lower real estate costs), on the Island, they are much less financially feasible on the Island, where the cost of land is high and there is limited/no unused or Crown land available to create water storage (Doug Pepper, Feb 24). Unless there is a section of land that is unproductive, building a dugout is often not feasible from a financial perspective. A review of the ALUI data found that there is little to no land available on farmed properties, where dugouts are feasible, that is not in production.

Recently, 19 producers collaborated in a Group Environmental Farm Plan (GEFP) in the Koksilah Watershed (Haddow, 2021). The GEFP report recommends actions to improve water availability as a high priority and suggests incentives for the development of water supply and storage.

While participation in the GEFP may allow additional funding for farm dugouts, it is not close to the costs required to cover dugout construction and the loss of production capacity. For example, a 1-acre dugout may cost $150,000 - $550,000 plus lost revenue, but the 2020/2021 EFP Beneficial Management Practices only covers 50% of dugout costs up to $10,000.

Environmental impacts: Dugouts are commonly developed in low-lying areas where water naturally drains. These are commonly wetlands. Digging into a wetland and then sealing the bottom to prevent connection to the aquifer would reduce recharge and negatively effect the hydrologic regime.

Additional comments

One community member recommended that producers capture and store storm runoff from farms in dugouts for later use. This requires both financial feasibility and certain site conditions that are not present on all properties. First, the property would have a large catchment area with low angle slopes (e.g., 2 - 5%). (Low catchment area slopes would support drainage while reducing sediment transport/erosion). The catchment area would be sloped downhill towards a large potential storage location. As the Cowichan area is known for its 'egg carton', undulating topography, this layout is less common. Also, the downstream portion of the property would need to be free of existing uses (e.g., houses, barns) or wetlands, etc. In addition, there would need to be sufficient depth to bedrock and suitable soil types in the storage location to construct an impoundment. Finally, if the property were on a suitable slope with suitable sub-surface conditions, and water naturally flowed downhill to an available area, unless the topography naturally held back water (in which case, there would be a pond or wetland at that location already), the property owner would need to build a dam to impound the water. If the property owner had the space and funds available to build an impoundment sufficient to irrigate a 100-acre field (which could be approximately 200 m x 150 m), with a 4% slope in the property, they could potentially be building a dam that was over 8 m high. A dam of such height in a developed area would likely be classified as a high consequence dam and subject to Part 3 of the Dam Safety Regulation, with significant engineering, inspection, and maintenance requirements. While the idea of utilizing stormwater from the property makes good sense, it can be more challenging to apply in practice, due to physical and human-created constraints (e.g., Dam Safety Regulation).

Ranking According to the Feasibility Criteria

Impact	Medium-High
Affordability	Medium
Ease of implementation	Medium
Ease of use	Medium
Reliability	Medium

Water storage tanks

Introduction

Large, steel reservoirs, or water storage tanks are commonly used by municipal, industrial users, and agricultural users to store water, feed, and other products. These tanks are more similar to buildings and have been constructed to hold as much as 22,700 m^3 of liquid (CST Industries, 2021) and typically have a 50-year lifespan.

Potential Volumes of Water that Could be Made Available

If 50, 22,700m^3 tanks were installed on farm properties, then 1,135,00 m^3 of water could be provided. This would provide approximately 33% of the seasonal demand.

Distance from Demand and Works Required

It would be ideal to install the tank close to an irrigated area and water supply source so that it was a short distance from demand.

Works required include site preparation, tank (comes with local engineering costs, geotechnical report, construction materials, installation), and connections to the water supply source (Gordon Ross, CST Industries, personal communication).

Cost

A 22,700 m^3 tanks costs approximately $1,689,000, or $75/m^3. Smaller tanks may cost slightly less per cubic meter due to reduced engineering requirements with smaller tanks (Gordon Ross, CST Industries, personal communication).

Administrative/Regulatory Considerations

A building permit is generally required.

Maintenance

Typically, minimal maintenance is required.

Reliability

As a moderate-sized storage structure, a water storage tank is more reliable than a cistern, and less reliable than a dam. If users are filling the tank with water from a groundwater or surface water source, collected during the wet season, that increases the reliability of the storage/source.

Ranking According to the Feasibility Criteria

Impact	Medium
Affordability	Medium
Ease of implementation	High
Ease of use	High
Reliability	High

Off-site medium-large-scale water supply/storage options

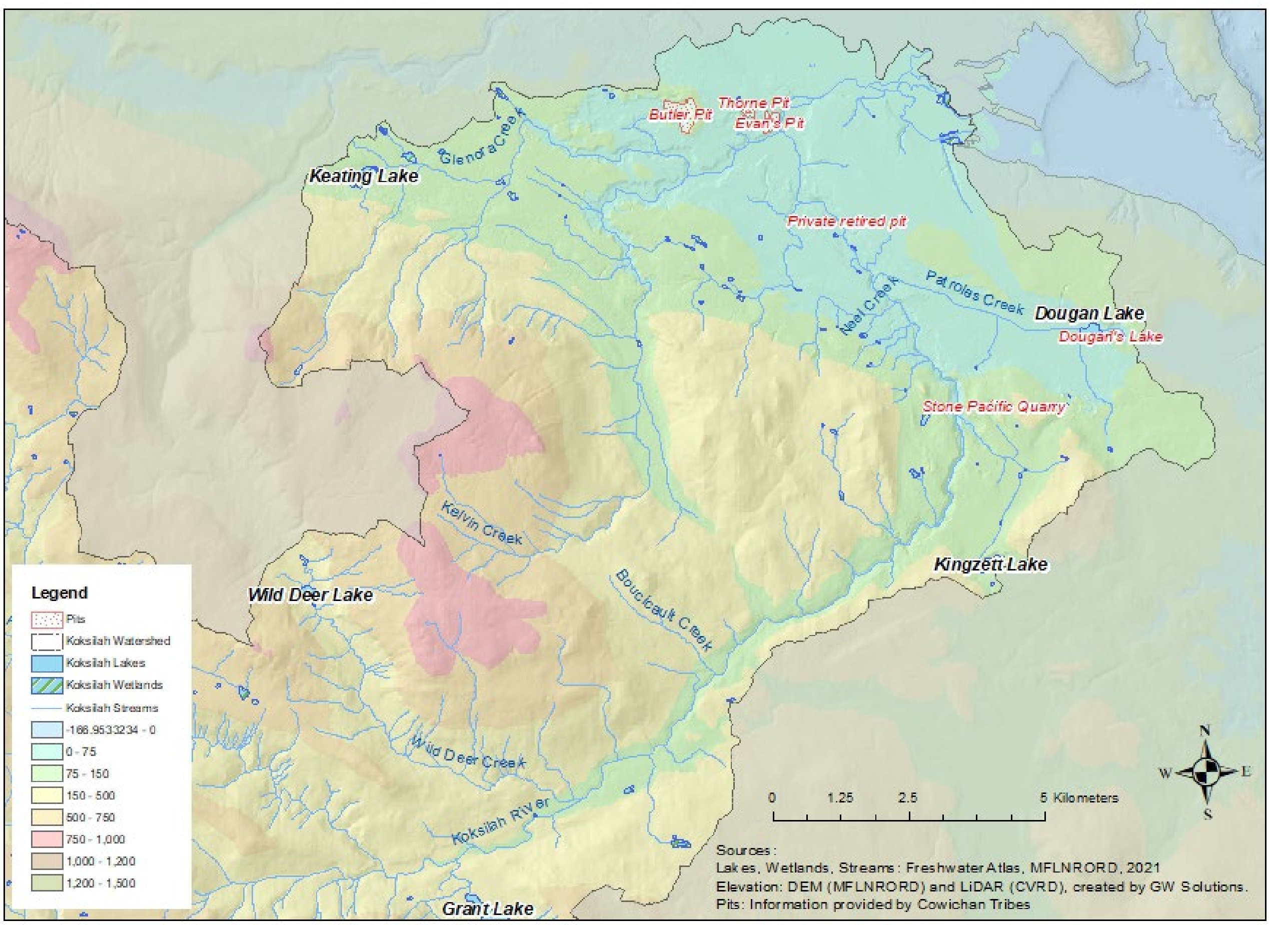
Extraction pits

Introduction

The potential for extraction pits to be used as manufactured lakes was also explored. The following pits were identified in the Koksilah area:

- Evan's Pit
- Butler Pit
- Dougan's Lake Pit
- Stone Pacific Quarry
- Koksilah Pit
- Thorne Pit

These are shown in Figure 3 below. Three smaller pits were also identified on private properties, but were excluded from the analysis, due to their limited storage capacity. Kingzett Lake was also identified as a quarry and is included in the analysis of existing lakes. In later discussion, the Cobble Hill quarry was noted as an option for future consideration (Tracy Fleming, personal communication).



In total, these pits cover approximately 400,000 m^2 in the Koksilah watershed. Many of them are in varying levels of excavation. As part of the commitment to reclaim land, most pit owners/operates are re-filling the pits as they excavate. Several have already added a substantial volume of fill to the pits. None of the larger pits intends to close in the near future (Leah Godau, Evan's Pit, personal communication; Aggregates Manager, Butler Pit, personal communication). Further information on the extractions pits is included in Table 6 on the following page.

Potential Volumes of Water that Could be Made Available

Due to the fact that the pits are currently being filled, further excavation would be required to convert these pits to manufactured lakes. However, if all the available area on the properties was excavated and the pits lined to create a manufactured lake, then approximately 4 million m^3 of storage space could be created. If 2 m is removed for evaporation, dead storage, and freeboard, that would make 3.59 million m^3 or 100% of demand available.[6]

Further work would need to be done to ascertain the feasibility of lake construction at these sites. For example, the Butler pit is elevated above the surrounding area and the current user is excavating the hillside (Aggregates Manager, Butler Pit, personal communication). If the owner was interested in the creation of a manufactured lake at this site (they are not), then a site investigation would need to be completed to understand the feasibility of creating a lake at this location. It is likely that a dam would be needed to store water, which may reduce the feasibility of this location.

Distance from Demand and Works Required

Table 6 provides details on the distance to demand for each pit.

To create a manufactured lake at any of the pits, then the pits would need to be excavated and a liner and pump plus ancillary piping installed. As noted above, it is likely that a dam would be needed to contain water at the site of the Butler Pit.

A water distribution system would likely also be needed to transport water to users. If all pits were used, this would be a more complex distribution system, due to the high number of sources and users.

Figure 4 provides an example of a potential water distribution network to currently irrigated properties in the Koksilah.

Cost

At a very high level, it can be estimated that the cost to create manufactured lakes using pits could be between \$6 - 25/m^3. This assumes that excavation costs are approximately \$4/m^3 and a membrane liner used which costs anywhere from \$2.50 - \$20/m^3 (liners would need to be custom developed for the varying sized lakes) (Ken Motherwell, personal communication).

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[6] Potential volumes that can be stored were calculated by using the equation for a prismoid: $V = (d/6) \times (At + Ab + 4 Am)$
Where: $At = L \times W$, $Ab = (L - 2 \times ES \times d)(W - 2 \times SS \times d)$, $Am = (L - ES \times d)(W - SS \times d)$
It was assumed that the lake uses all available property area (with a 2 m buffer on the property edges), has a depth of 15m or the depth to bedrock (whichever is less), and is square with 3:1 side slopes. It is assumed that water is taken from either groundwater or surface water sources during the wet season.

Table 6: Extraction Pits Reviewed in the Koksilah Watershed[7]

Pit Name	Approx. Cleared Area (m^2)	Approx. Lot Size (m^2)	Estimated Current Depth (m)	Depth to Bedrock (m)	Potential Volume[8] (m^3)	Distance to Demands	Proximity to Water source	Environmental Considerations	Land Owner-ship Type	Intend to Close in the Near Future?
Evan's Pit	10,500	75,000	Variable	50.00	782,116	100m (across river to large licensed user), 500m-1.5km from unlicensed groundwater	40m. At intersection of Kelvin Cr and Koksilah River	Next to riparian area, Moss' Elfin habitat	Private	Maybe 2035
Butler Pit	100,000	235,000	Variable. 5-10m.	55.00	2,884,737. May not be available. Excavating into a hill.	1-2km from smaller irrigators (across roads)	Groundwater source required. 450m over road, properties to seasonally dry creek.[9] 850m over road, properties to Kelvin Cr.	None areas nearby	Private.	Closing in approx. 40 years. Rehabilitation plan TBD based on market. Pit is higher than any of the surrounding area. Once complete, will be level with the street and higher than the farm nearby.
Dougan's Lake Pit	3000	26,750	6	80.00	40,500	Approx. 300m uphill from Valleyview Centre. Approx. 600m-2km from a few smaller irrigators.	Groundwater source would be required, as closest surface water source is Dougan Lake across the highway.	No ESAs noted	Cowichan Tribes	Not recommended for use

[7] All values are obtained from a desktop review. Further work is needed to determine sizes, potential volumes, and assess feasibility.

[8] Assuming either15 m or depth to bedrock, if less than 15m.

[9] Noted in curtailment study (Barroso & Wainwright, 2020).

Pit Name	Approx. Cleared Area (m^2)	Approx. Lot Size (m^2)	Estimated Current Depth (m)	Depth to Bedrock (m)	Potential Volume [8] (m^3)	Distance to Demands	Proximity to Water source	Environmental Considerations	Land Owner-ship Type	Intend to Close in the Near Future?
Stone Pacific Quarry	7300	17,000	12	10.00	99,794	Approx. 800m-2km down hill through forested land and across rivers to smaller irrigators	No streams nearby. Groundwater source required.	Surrounded by Douglas Fir Ecosystem ESA	Private.	Did not evaluate further due to limited size.
Koksilah Pit	10000	11,315	9	50.00	63,000	750m from large irrigator (across road and river). Up to 2km to other small irrigators	300m (through Evan's Pit) to the Koksilah River	Next to riparian area, Moss' Elfin habitat	Cowichan Tribes	Did not evaluate further due to limited size
Thorne Pit	5500	23,000	12	50.00	174,423	750m from large irrigator (across road and river). Up to 2km to other small irrigators	Groundwater source required. 500m across highway, properties to Koksilah R.	None nearby	Cowichan Tribes	Did not evaluate further due to limited size

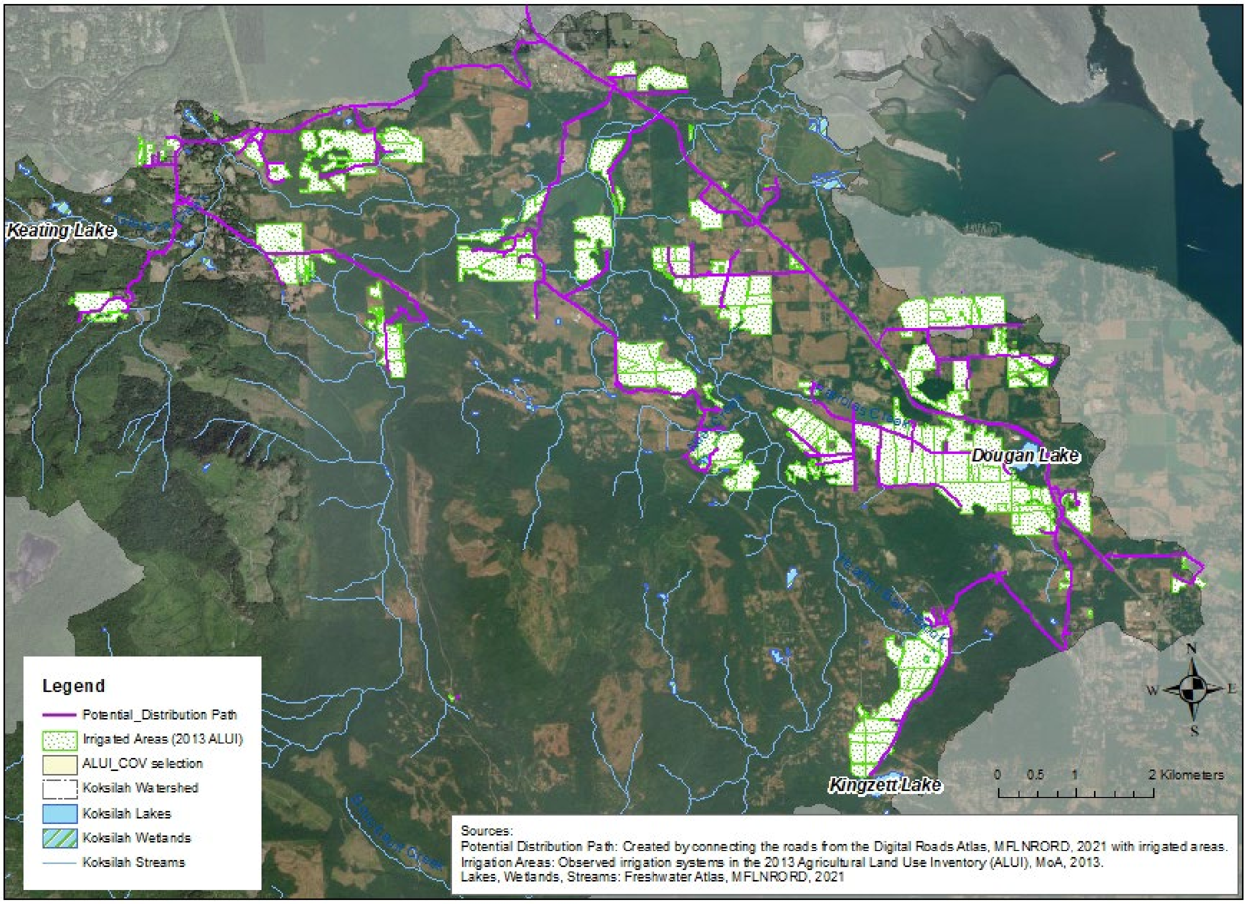


Figure 4: Potential distribution network to transport water to irrigated areas. Layout initially constructed as part of a request to estimate demands for a system that connected to the Cowichan River, which is why the pipe is shown leaving the watershed to the north.

If a distribution system were added to the cost, at an estimated cost of $15 million, the cost could increase to $10 - $30/m^3. This assumes approximately $8 million for a pump and $7 million for distribution (assuming 12km of 36" pipe at $125/foot and 65km of 8" pipe at $8/foot).

Administrative/Regulatory Considerations

Currently, none of the larger pits are intending to close in the next 15 years (Evan's/CP: 2035-2040, Butler: 2045-2050). The aggregate managers noted that at this time they were not wanting to commit to creation of a manufactured lake as a rehabilitation plan (Leah Godau, Evan's Pit, personal communication; Aggregates Manager, Butler Pit, personal communication).

Dam Safety Regulation: Further work is needed to be done to determine if manufactured lakes can be created on each site without creating a dam. It is likely that if a lake was created on the site of the Butler Pit (shown in Figure 5), a high consequence dam would be created, as the site is on a hill above the surrounding properties, and there are homes and businesses very nearby.

If this option was pursued, then there would need to be a water licence holder on each site and an organization responsible for building and operating a distribution system.

Maintenance/Ease of Use

An organization would need to take on the responsibility for developing and operating a distribution system. The distribution and supply system for this option scores lower on ease of use, because the storage areas would be distributed throughout the watershed, which would add extra complexity to the water source and distribution system.

Reliability

If water was pumped into the manufactured lake during the winter and then extracted during the summer, then the source would be relatively reliable.

Additional Considerations

Benefits

This approach makes use of existing land disturbance.

Ranking According to the Feasibility Criteria

Impact	High
Affordability	Medium
Ease of implementation	Very Low
Ease of use	Low-Medium
Reliability	High

Existing lakes

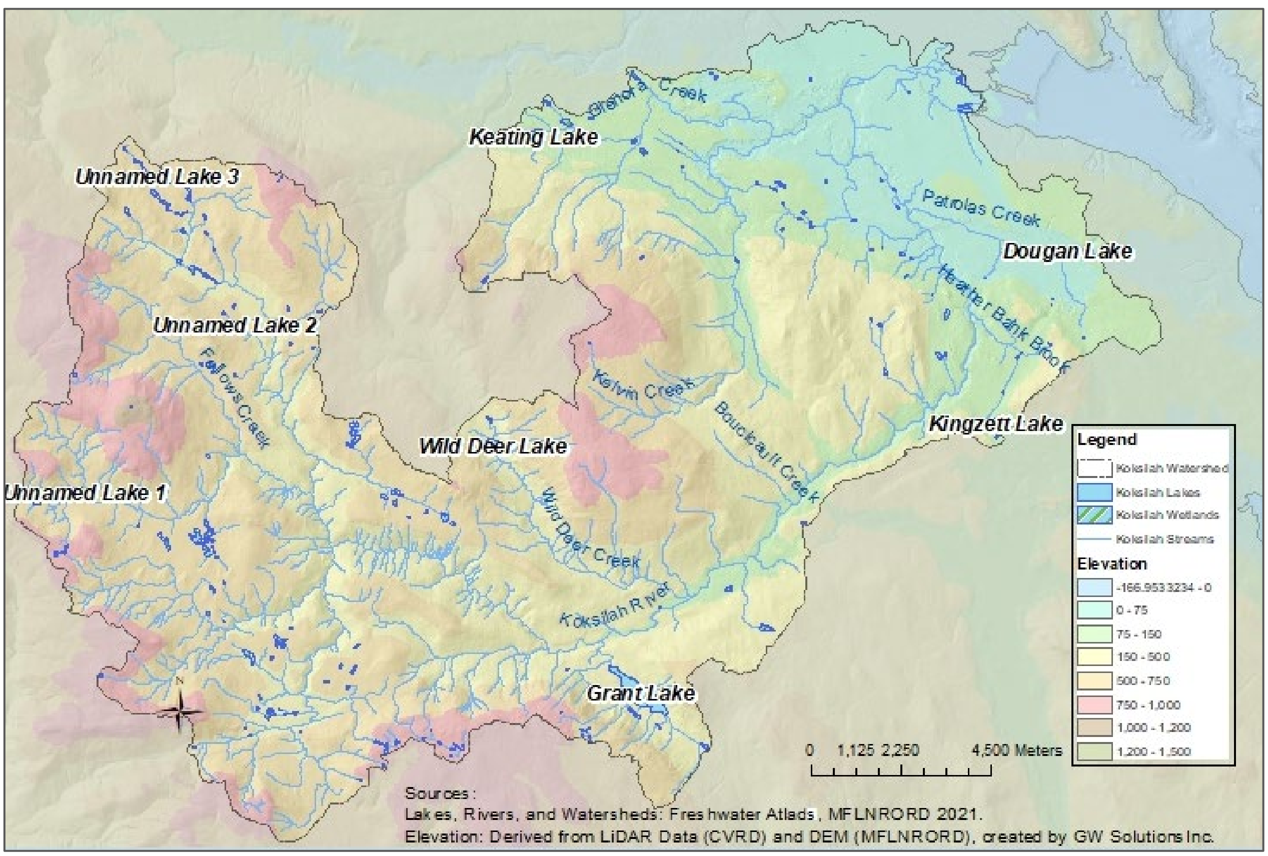
Introduction

The Koksilah River currently does not have a large lake or reservoir in its headwaters that could provide storage to augment streamflow during periods of low precipitation. Several prior studies and assessments have suggested the consideration of headwater storage to support irrigation demands and fish flow releases (Tutty, 1984; Ministry of Environment and Parks, 1986). These assessments have identified Grant Lake as the most suitable potential location for storage.

To assess the potential for water storage in the upper watershed, lakes with an area > 2 ha were reviewed, including:

- Grant Lake
- Dougan's Lake
- Kingzett Lake
- Keating Lake
- Unnamed upper ws lake 1
- Unnamed upper ws lake 2
- Unnamed upper ws lake 3

Wild Deer Lake was not investigated, as it was identified by Cowichan Tribes as an area of cultural significance. These lakes are shown in Figure 6.



The ideal lake for creating water storage would have a sufficiently broad basin with sides that could contain the desired volume of stored water. The lake would also have a narrow outlet that could be easily dammed.

In addition, the drainage area upstream of a reservoir location would be large enough that the reservoir can be filled over the wet season, even in dry years, without significantly adversely affecting flows in the downstream reach.

Table 7 provides an overview of the lakes in the Koksilah watershed, including a high-level assessment of their topography and suitability for storage. Appendix B provides detailed information on each lake, including estimates of monthly, yearly, and wet season inflows to each lake.

Table 7: Lakes in the Koksilah watershed

Storage Option	Area (ha)	Description of Topography	Suitability for Storage
Grant Lake	54.11	Lake has a broad basin with low angle sides closer to the lake and steeper sides higher up. The lake has a long-angle outlet and head. A review of topography at the head of the lake suggests that there is *likely* sufficient elevation at the head of the lake that a dam at the upstream end would not be required. The outlet to lake is quite wide (approx. 300m) and low-gradient, with low angled sides. Further investigation required to assess feasibility and cost of a dam at the outlet.	Moderate
Dougan's Lake	9.75	Not investigated due to constraints. Its next to highway and raising lake 1m would flood highway ROW. Also, it is likely that the majority of the lake volume is already allocated.	Low
Wild Deer Lake	7.88	Not investigated as it is a culturally sensitive area (Cowichan Tribes).	None
Kingzett Lake	7.88	Very small drainage area and basin. Very low angle sides that offer little containment. Close to watershed boundary. Outlet is very wide and low gradient.	Low
Keating Lake	5.35	Very small drainage area and basin. Very low angle sides that offer little containment. Outlet is very wide and low gradient.	Low
Unnamed Lake 1	2.31	Very small drainage area and basin. Very low angle sides that offer little containment. Outlet is very wide and low gradient.	Low
Unnamed Lake 2	2.25	Very small drainage area and basin. Very low angle sides that offer little containment. Outlet is fairly wide and low gradient.	Low
Unnamed Lake 3	2.08	Very small drainage area and basin. Very low angle sides that offer little containment. Outlet is very wide and low gradient.	Low

According to this assessment, Grant Lake, shown in Figure 7, is the most suitable lake for storage.

Potential Volumes of Water that Could be Made Available

Table 8 identifies estimated volumes of water that could be stored in each lake, considering the upstream drainage area (approximate inflows to lakes) and the lake sizes. Further work would be needed to assess volumes more accurately, considering terrain, local precipitation, evaporative losses, environmental flow needs, etc.

At a high-level, it is estimated that approximately 1.6 million m^3 of water could be stored at Grant Lake, which could provide up to 47% of the estimated seasonal demand. Further work is needed to assess feasibility of a dam on the lake and the likelihood of the water being available during a dry year, without impacting environmental flow needs.

Distance from Demand and Works Required

Grant Lake is 0 km from existing demands if water demand is taken from the river, and 20-30 km from larger irrigators. Due to the curved shape of the watershed, there is no direct route available to larger demands. Appendix B includes estimates of distance from demands for all lakes.

To create storage on any of the lakes would require the construction of a dam. Further work would be required to assess feasibility and design a dam. The outlet of Grant Lake does not have steep sides, as shown in Figure 8. Based on a desktop review of topography, it was assumed that an additional 3 m of storage is the greatest possible height of storage. Further work is needed to assess the feasibility of storage at this location and provide a more accurate estimate of the potential volume of water that could be contained.

Figure 7: Grant Lake

Cost

Generally, creation of large-scale storage costs approximately \$1 - \$3/m^3. Using this estimate, the creation of 1.6 million m3 of storage at Grant Lake could cost approximately \$5 million. This does not include work done to assess environmental impacts, assess feasibility of a dam, engineering and design, cost to purchase land, administrative effort, etc.

Administrative/Regulatory Considerations

A dam at Grant Lake that was capable of impounding 1.6 million m^3 of water would be subject to Part 3 of the Dam Safety Regulation and is likely to have high maintenance, inspection, and reporting requirements.

Currently, the dam is on private property and cannot be viewed from the road. Further work is needed to assess the interest of the property owner and the feasibility of a dam on the site.

If there is an interest in developing storage at this site, an organization would need to take responsibility for obtaining a water licence, leading assessment, design and construction efforts, and owning and maintaining the dam.

Table 8: Estimated Inflows and Potential Storage Volumes in Koksilah Lakes

Storage Option	Drainage Area (m2)	Potential Inflow: Average Year (m3)	Potential Inflow: Drought Year (m3)	Potential volume w 3m dam*	Percent of Dry Season Demand	Can 3m dam be filled in a dry year?	Physical Suitability	Rationale
Grant Lake	7,888,000	7,306,781	3,653,390	1,623,300	47%	YES	Moderate	Lake at approximately 240m. Wide outlet. Has a moderately large upstream drainage area. On private property, and can't even view lake from road, so would need owner's permission for future work/feasibility assessment.
Dougan's Lake	NA	-	-	-	9%	NO	Low	Not possible to dam, as its right next to the highway in low angle terrain. Likely fully licensed (123,348 m^3/year)
Wild Deer Lake	3,438,000	3,184,674	1,592,337	236,400	7%	YES	NA	Lake at approximately 380 m. Identified as an area of cultural significance by Cowichan Tribes. No further exploration.
Kingzett Lake	950,000	880,000	440,000	236,400	7%	NO	Low	Licensed for Land Improvement. Small catchment area so would need to collect water from an alternate source (e.g., groundwater in winter). Also, small basin, so unlikely to hold a significant volume of water.
Keating Lake	2,389,000	2,212,969	1,106,484	160,500	5%	YES	Low	Licensed for Irrigation 34,537 m^3/year. Surrounded by wetlands. Small basin that would not contain a large volume of water.
Unnamed Lake 1	3,042,000	2,817,853	1,408,927	69,300	2%	YES	Low	Small, far from demands, surrounded by wetlands
Unnamed Lake 2	676,000.00	626,190	313,095	67,500	2%	YES	Low	Too small and far from water demands.
Unnamed Lake 3	700,000	648,421	324,211	62,400	2%	YES	Low	Connected to several wetlands, and several wetlands at the outlet. Not recommended due to the amount of wetland alteration that would occur for the relatively small volume of water that could potentially be impounded (and small amount that could be collected due to small catchment size).

*Further information on mean monthly inflow estimates for each lake are given in Appendix B. Note: the assessment of inflows is based on historical unit runoff across the watershed. It does not consider variations in precipitation by elevation or potential climate change impacts. The estimates for lake storage do not include evaporation losses (assumed to be approximately 12" over the 92 day period) or gains from precipitation (approximately 6" over the 92 day period) (Hatfield, 2020), as further work is needed to estimate storage volumes to a level of accuracy greater than 1m.

There are currently two water licences for power generation purposes on the creek which comes out of the lake. There is also a domestic licence on the creek.

The lake and surrounding area are currently for sale (Cali Melenchenko, personal communication). A group of community members is currently investigating the purchase of the lake property to protect the environmentally sensitive area around the lake. The group is known to be aware of the drought issues and supportive of efforts to mitigate them, but it is unclear at this time if a dam on the property is compatible with their intended use (Tracy Fleming, personal communication).

Ease of Use/Maintenance

Maintenance costs for storage on Grant lake would be high as the dam would be subject to Part 3 of the Dam Safety Regulation, because it would hold over 1,000,000 m^3. There would need to be an organization responsible for holding the water licence on the lake. Unless a distribution system was created, water would only be available to fish and producers along the Koksilah mainstem. A distribution system would allow water to be used in the other subwatersheds and increase ease of use/access but would also increase maintenance costs.

Reliability

A dam at Grant Lake would be vulnerable to variations in precipitation and further work is needed to assess reliability of water supply in the relatively small catchment, with changing climate.

As shown in Table 8, according to an initial assessment, a reservoir to increase storage by 3 m at Grant Lake is likely to fill during a dry year. However, further work would need to be done to confirm this, considering changing climate, precipitation trends across the watershed, and environmental flow needs.

Additional Considerations

Potential benefits

Flood modulation potential: All of the lakes evaluated had relatively low catchment areas compared to the watershed area and dams on them would provide minimal flood modulation benefits. The Grant Lake catchment is approximately 2.5% of the total Koksilah watershed area.

Trade-offs

Economic/environmental: Investing in large scale storage in the mainstem watershed may not help other sub watersheds.

Environmental impacts: Table 9 identifies wetlands, ESAs (CVRD, 2018), and fish and wildlife occurrences at each of the lakes (BC Conservation Data Centre, 2021).

Additional comments

Cowichan Tribes and Malahat Nation have expressed a preference for avoiding the creation of dams.

Community Interest: In a recent community engagement report, several respondents discussed having a water storage system as a potential solution to low summer flows, and winter floods. They were supportive of surface water storage and cited the weir system that exists in the Cowichan watershed as an example of what could be possible for the Koksilah (MODUS, 2021). There are also likely individuals and groups that would be opposed to the creation of a dam, due to the environmental impacts.

Table 9: Environmental Considerations at Lakes in the Koksilah Watershed

Lake	Wetland Area Impacted (ha)[10]	Potential ESA Impacts	Fish and Wildlife Prescence
Grant Lake	3.14	Raising lake level likely to affect 63,282m^2 of mature forest ESA at head of lake.	In lake: Cutthroat Trout and Rainbow Trout in Lake, Cutthroat Trout at Confluence of Koksilah
Dougan's Lake	NA	12,194m^2 swamp ESA	Coho, Steelhead, Cutthrout Trout, Rainbow Trout, Pumpkinseet, Threespine Stickleback
Wild Deer Lake	NA	Culturally sensitive	Rainbow Trout
Kingzett Lake		Raising water level would affect approx. 5200m^2 of woodland ESA. Currently a pond ESA	Fish: none; Wildlife: Northern Red Legged Frog
Keating Lake	7.60	Raising water level would affect large wetland ESAs surrounding lake.	Fish: Coho, Cuthroat Trout, Rainbow Trout; SAR: Warty Jumping-Slug
Unnamed Lake 1	2.25		
Unnamed Lake 2	No mapped wetlands at lake		
Unnamed Lake 3	4.5 plus 2.7 just downstream		

Ranking According to the Feasibility Criteria

Impact	Medium
Affordability	High
Ease of implementation	Medium
Ease of use	Medium
Reliability	Medium

[10] Area of wetlands potentially impacted (ha) (within same 10m contour line)

Natural features

Introduction

A desktop study of the Koksilah watershed topography was conducted to assess natural features in watershed and determine if there were areas that were suitable for storage.

The ideal natural feature would be a broad, low gradient, adequately sized basin, with a narrow outlet to dam, and slopes around the reservoir high enough to contain the raise in water level needed to develop the desired storage. These conditions are typically found at existing lakes, but the Koksilah topography was reviewed to determine if there were other areas where the terrain favored holding back water with minimal construction efforts.

To identify opportunities to store water using natural features, a desktop review of terrain was conducted using the following: the 1 to 20,000 scale contour mapping provided by the TRIM program, an updated digital elevation model (DEM) (developed using 1 m LiDAR in the lower watershed and 30 m DEM in the upper watershed), BC Freshwater Atlas (FWA) lakes, streams, and wetland mapping, and CVRD ESA mapping.

The following was considered when assessing natural features:

- Storage potential: considering basin area, potential depth, & slopes.
- Water source: catchment size (upstream drainage area).
- Environmental impacts: potential wetland area impacted, fish and wildlife presence, ESAs.

Five areas were reviewed in detail. These are listed in Table 10.

It was found that natural features 1, 3-5 are unlikely to be suitable for containing water so they were not investigated further. Natural feature 2, shown in Figure 8, was identified as the most feasible option. This area was also identified in the in Cowichan-Koksilah watershed plan (noted by Tutty) as a potential storage area for waterfowl and fisheries purposes.

Potential Volumes of Water that Could be Made Available

Potentially 1.5 million m^3, or up to 44% of seasonal demand could be stored in natural feature 2. Further work is required to assess feasibility of storage at this location and obtain more accurate estimates.

Distance from Demand and Works Required

The distance from demand is 0 km, if stored water is left in the Koksilah river. The area is 19-26km via road through private managed forest land to the larger demands, so it is likely not feasible to pipe to users.

The land currently appears to be mostly treed. Land would need to be cleared and a dam created. The potential dam location is approximately 200 m down a steep hill from the road. It is likely that a road would need to be created to the site.

Cost

The costs to construct a dam at this location are difficult to assess, without visiting the site. However, if it is estimated that storage costs \$3/m^3, then storage at this location would cost approximately \$4.5 million. This does not include cost of land clearing, road construction, acquisition of land, etc.

Table 10: Natural areas assessed for water storage potential

Storage Option	Location	Area (m2)	Elevation (river, top of basin)	Estimated potential storage depth (m)	UDA	Wetland Area (m2)	Stream gradient (%)	Potential storage volume (area*dam height)	Percent of Seasonal Demand (%)	Comments re feasibility
Natural Feature 1	48.721868, -123.912220	188,787	485m, 495m	8	6,813,585	8,401	1%	1,510,294	44%	Would submerge two roads
Natural Feature 2	48.694044,-123.885422	181,909	438m, 461m	10	21,939,473	0	1%	1,500,000	44%	Would not cover roads, heavily treed, access via A Rd, would cover the convergence of two streams. Suggested in 1986 water management plan and Tutty for waterfowl and fisheries.
Natural Feature 3	48.663217, -123.930724	240,216	538m, 542m	5	9,636,596	0	2%	1,201,081	35%	Over a road. Limited containment. Very low-angled sides,
Natural Feature 4	48.666842, -123.847723	646,452	494m, 500m	4	2,948,243	51,039	3%	2,585,808	76%	Over roads/OHV area in head, not very useful due to low containment potential (only 4m from river bottom to top of 'sides' of basin at head, and wetlands
Natural Feature 5	48.646465, -123.924208	193,332	536, 539	1.5	246,000	0	5%	NA	NA	Has a road through it, removed from consideration due to road, limited containment potential, etc.

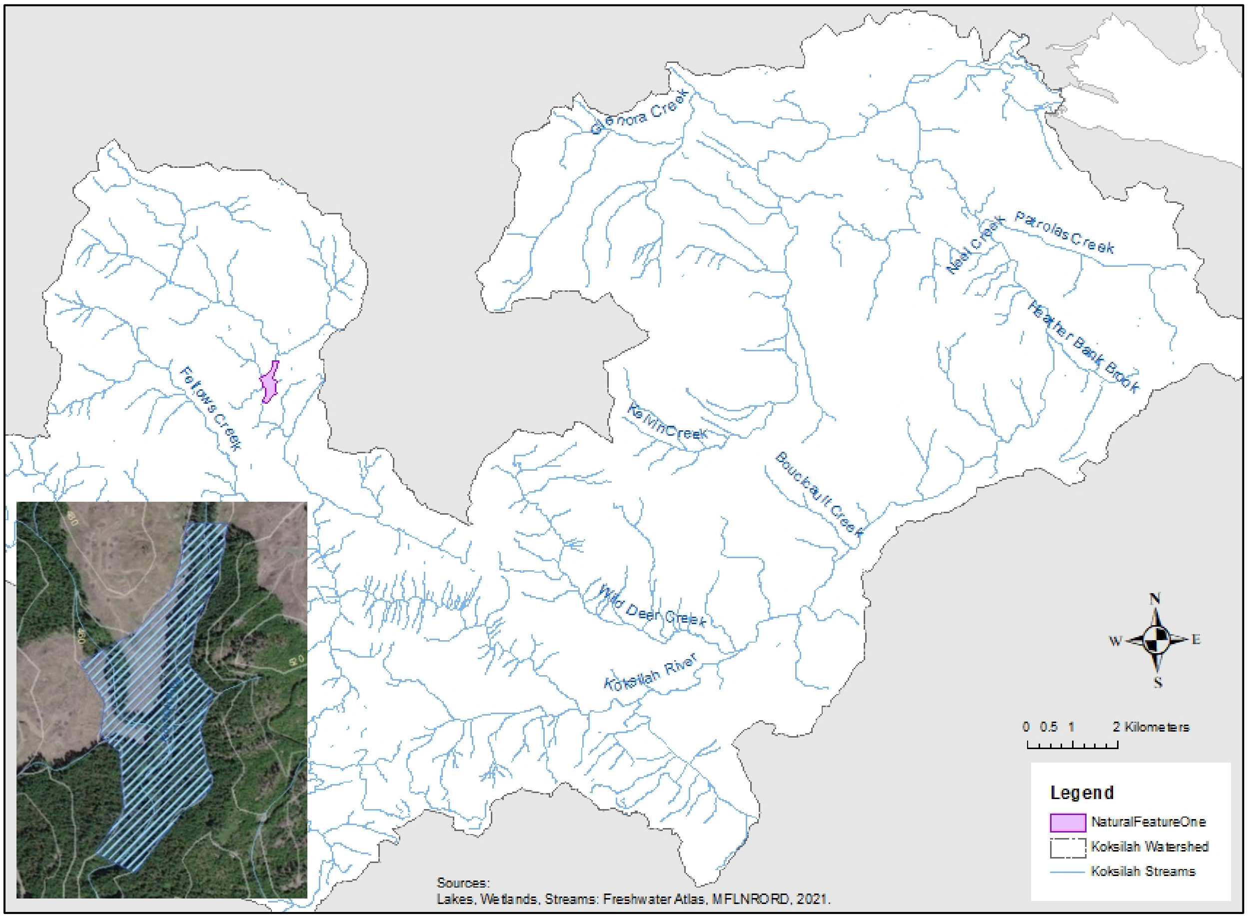


Figure 8: Natural area with water storage potential

Administrative/Regulatory Considerations

The land at the site is privately owned and managed by Mosaic. Mosaic is not interested in having dams on their property due to concerns regarding liability (David Beleznay, Manager of Hydrology & Terrain, Mosaic, personal communication). However, Mosaic is open to working with governments if a water storage structure is deemed the best solution for the community. If this option were pursued, an agreement would need to be developed with Mosaic for land use or ownership, and access.

A dam that is greater than 1,000,000m^3 would be subject to Part 3 of the Dam Safety Regulation. An organization would need to hold the water licence and be responsible for dam operation, maintenance, and inspections.

Maintenance/Ease of Use

Maintenance costs would be high as the dam would be subject to Part 3 of the Dam Safety Regulation. The water would only be available to fish and producers along the Koksilah mainstem. If the water was to be used in the other subwatersheds, then a water distribution system would need to be created.

Additional Considerations

Potential benefits

Flood modulation: Flood modulation: Catchment size is approximately 7% of watershed area, so while it is unlikely to have a significant flood modulation effect, there may have some.

Potential trade-offs

Economic: Removal of land from forest harvesting/production.

Environmental: The feature covers a small area (approximately 2,000 m^2) of Mature Forest ESA. Steelhead presence was observed in the stream segment where storage could be created; Rainbow Trout and Steelhead were observed upstream (Pritchard et al, 2019).

Ranking According to the Feasibility Criteria

Impact	Medium
Affordability	High
Ease of implementation	Low
Ease of use	Low-Medium
Reliability	Medium

Existing systems as water supply/storage options

Municipal water supplies

Municipal water supplies were investigated to determine if there was additional capacity in the area. The following was found:

- City of Duncan: has no capacity for additional servicing in the Koksilah watershed, unless it is allowed to develop a supply well in the Koksilah watershed (John Pite, Manager of Engineering, City of Duncan, personal communication).
- CVRD: has no additional capacity in the in area. All nearby water systems are very small. In the future, Shawnigan Lake North (south of the watershed) might have some capacity for residential use. It is currently out of compliance for surface water treatment. The CVRD is pursuing additional sources for this system now and will know soon if there is additional capacity. The CVRD is unlikely to provide water from this system for irrigation use (Brian Dennison, Manager of Water Management, CVRD, personal communication).

Due to the limitations of existing municipal water supply systems, this option was not pursued further.

Ranking According to the Feasibility Criteria

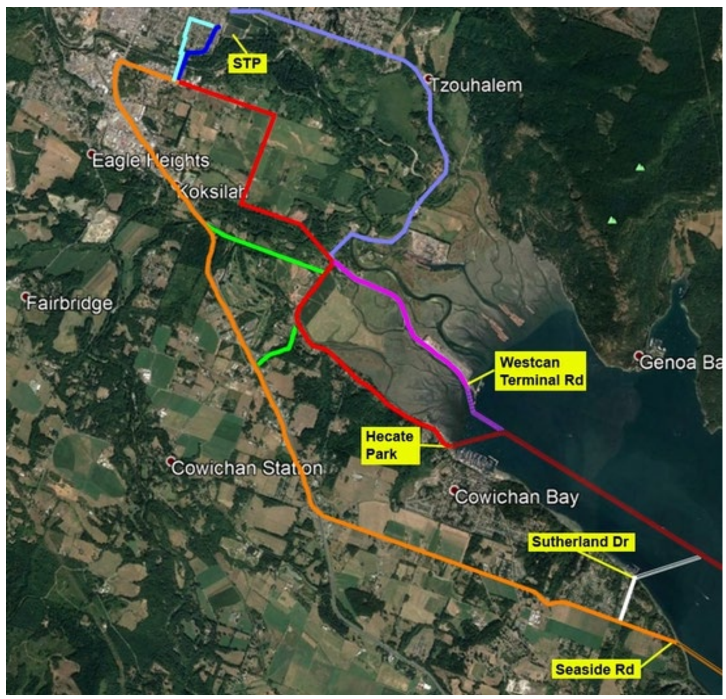
Impact	None
Affordability	NA
Ease of implementation	None
Ease of use	NA
Reliability	NA

Municipal wastewater

Introduction

The Joint Utility Board Sewage Treatment Plant is a hybrid secondary/tertiary treatment plant that treats wastewater from North Cowichan, Duncan, Cowichan Bay, Eagle Heights and Cowichan Tribes (the CVRD Central Sector Area). The Plant is operated by the District of North Cowichan (DNC) and discharges highly treated effluent into the Cowichan River (Clay Reitsma, Senior Manager, Engineering, District of North Cowichan, personal communication).

The JUB is in the process of moving the sewage treatment plant outfall to a new location at the edge of Cowichan Bay (Municipality of North Cowichan, 2021). The JUB is three years into the outfall relocation project and is currently in the design phase, considering several different routes, including one that goes by Cowichan Station and is close to water irrigation demands in the Koksilah (see orange line in Figure 9). The JUB intends to begin construction in 2022.



The route through Cowichan Station is currently the least attractive option to the JUB, from both an engineering and financial standpoint. It has been difficult to obtain permission for construction along the highway (or frontage roads). Also, it costs more to build on a major highway and the highway route is longer, requiring higher pressure in pipes, potentially an additional booster station, and a more costly pipe material to withstand higher pressures (Clay Reitsma, personal communication).

Currently, treated effluent from the JUB usually meets the standards for reclaimed water use for forage irrigation and aggregate washing. However, it occassionally fails to meet standards due to algael blooms which elevate Total Suspended Solids (TSS) levels above 45 mg/L. For effluent to be re-used, the water treatment system would need to be upgraded. Currently, the treatment system is not scheduled to be updated until 2061 (Clay Reitsma, personal communication).

If effluent was to be reused for non-potable use, an organization would need to take responsibility for obtaining a permit for reuse, developing community support, financing the booster pump station and distribution, and obtaining support for the highway route.[11]

[11] While a route along Koksilah Rd was as a potential option by Cowichan Tribes staff, it is not an option that is currently under consideration (Tracy Fleming, personal communications).

Potential Volumes of Water that Could be Made Available

The potential volume of water that could be provided by the wastewater treatment plant between July 1 - September 30 (if treatment was upgraded to meet quality standards) is 828,000 m^3. This is based on the expected production of 9,000 m^3/day in the summer, over a 92-day period. The outputs from the plant are anticipated to grow by 1% per year (Clay Reitsma, personal communication). This volume would provide approximately 24% of seasonal demand.

Distance from Demand and Works Required

If the outfall was planned along the highway route, then the source would be close to water demands. A distribution system would need to be developed and maintained to transport water to properties.

Works required would include: the selection and construction of the longer outfall route, an upgrade to the wastewater treatment plant (secondary or tertiary treatment), a booster pump station, and ancillary piping to distribute to producers. If water was to be used for irrigation, then it is anticipated that tertiary treatment would be requested by the community (Clay Reitsma, personal communication).

Cost

The estimated cost would be approximately \$90/m^3. This includes the cost of a treatment upgrade (secondary treatment upgrade at an estimated cost of \$60 million), a booster pump station (\$7/8 million), and ancillary piping (assuming \$7 million). A very high-level estimate for the cost of a distribution system is approximately \$4/m^3 (Clay Reitsma, personal communication).

Administrative/Regulatory Considerations

In BC, guidelines for the use of reclaimed water are provided in the 'Reclaimed Water Guideline: a Companion Document to the Municipal Wastewater Regulation'. The MWR includes four categories for reclaimed water use, based on the level of treatment/water quality (Ministry of Environment, 2013):

1) Indirect potable reuse (use to replenish a potable water source or potential potable water source, or an application, such as food crops and urban reuse, where a very high level of quality is warranted)
2) Greater exposure potential (use on agricultural crops, golf courses, cemeteries, residential lawns, greenhouses, silviculture operations, urban reuse and landscaping around parks, playgrounds, schools)
3) Moderate exposure potential (use on some agricultural crops such as forage and commercial and industrial applications)
4) Lower exposure potential (use on pasture, fodder, aggregate washing).

To meet the water quality standards for lower exposure potential, the treatment system at the JUB would need to be upgraded. The Liquid Waste Management Plan would also need to be updated and this would require public engagement. Staff are concerned that the public would not be supportive of water reuse due to the proximity to domestic wells (Clay Reitsma, personal communication).

If the water were to be reused, an organization (proponent) would need to apply for a hold the permit for water reuse. That organization would also need to take on the task of obtaining community support for water reuse and provide funding for additional costs such as the booster pump station and distribution. Support would also need to be obtained for construction along highway (Clay Reitsma, personal communication). It was noted that Koksilah Road may be an option to consider, as well (Tracy Fleming, personal communication).

Maintenance

The proponent holding the permit for water reuse would be responsible for operation, maintenance, and administration of the distribution system.

Reliability

Wastewater is a reliable supply of water and availability is likely to increase in the future.

Additional Considerations

While it is anticipated that several producers would be interested in obtaining water for irrigation use, it is also anticipated that there would be substantial resistance from the broader community due to concerns regarding the impact on groundwater and shared drinking water sources.

While reclaimed water use for irrigation is only intended to be used by plants for transpiration and is not intended to infiltrate into the aquifer, JUB staff believe that the use of treated effluent for irrigation would draw concerns regarding impacts on groundwater and surface water quality (particularly the impacts of CECs). (Clay Reitsma, personal communication). JUB staff noted that a recent proposal for biosolids application was met with signficant community resistance. A signficant community outreach and engagement effort (e.g. specialists were brought in to explain the technology) was made but this was not effective in reducing community concerns. Because of this, JUB staff have noted that DNC staff and politicians may not be interested in acting as a proponent for the use of reclaimed water for irrigation purposes (Clay Reitsma, personal communication). The other partners in the JUB (Cowichan Tribes, City of Duncan, CVRD) were not interviewed and may be more (or potentially less) supportive.

Ranking According to the Feasibility Criteria

Impact	Low-Medium
Affordability	Medium
Ease of implementation	Low
Ease of use	Medium
Reliability	High

Cowichan Lake

Introduction

There is currently a design process underway to raise the weir on Cowichan lake by 0.7 m to support environmental flows in the Cowichan River. The goal of the project is not to provide additional water supplies, but to maintain fish and salmon populations in the dry drought summer months. Currently, the weir design is four months away from completion (Leroy Van Wieren, Project Manager, Weir, Cowichan Valley Regional District, personal communications).

The project is the result of an extensive water use planning process. In 2018, a water use plan was developed. The planning process involved a significant public engagement component. The water use plan specifies how much water is to be stored to address minimum flows in the summer and explains that the goal is to maintain minimum flows throughout the summer of 7.5 m^3/s in order to support environmental flows and licensed uses such as the pulp and paper mill (Leroy Van Wieren, personal communications).

At this time, it is unknown who will ultimately own the weir. Cowichan Tribes recently received funds to build the weir, but it is not known who will operate it and hold the licence (Leroy Van Wieren, personal communications).

Accessing water from Cowichan Lake could theoretically be approached in two ways:

1) An organization could apply for a water licence on the Cowichan River to provide water to the Koksilah watershed.
2) An organization could request to halt the existing design process and request that additional water storage be added in Cowichan Lake to provide water for the Koksilah River.

While there would be challenges associated with either approach, it is likely that the first option would be simpler. Community support for further raising the weir is anticipated to be low. There has already been significant community debate around raising the weir by 0.7 m, due to concerns about the impact to shoreline environments and restrictions to access and reduction of property area around the lake (Leroy Van Wieren, personal communications).

The first option would likely result in a less reliable water source (see 'Reliability'). Cowichan Tribes staff noted that would likely be little to no support from Cowichan Tribes and local and provincial governments for a water licence on the Cowichan River to use water for irrigation in the Koksilah during drought conditions (Darryl Tunnicliffe, personal communication).

Cowichan Tribes staff also noted that there is likely to be little support from Cowichan Tribes and local government for the second option (halting the weir design process), given the many years of coordinated and supportive efforts that have been made to get to the current point in the weir upgrade process. The weir design is nearly finished, and federal funding has been secured for a significant portion of its construction (Darryl Tunnicliffe, personal communication).

Potential Volumes of Water that Could be Made Available

It is unknown how much water could be made available from the Cowichan River. To understand potential availability would require revisiting prior environmental flow needs work and the water use plan. Potentially up to 100% of the Koksilah seasonal demand could be provided, as the lake area is large with significant storage potential.

Distance from Demand and Works Required

The river (at its closest points) is approximately 2.5-3.5 km from the larger demands in the Koksilah watershed.

The works required would be dependent on whether the weir was to be raised even further. Regardless, an intake location would need to be selected and water transported to the Koksilah watershed. It may be most efficient to work with an existing intake owner (e.g. Catalyst). If water was delivered to farms, there would need to be a new distribution system.

Cost

The cost of construction for the currently planned Cowichan weir upgrade is $0.37/m^3 (Leroy Van Wieren, personal communications). If water were to be used in the Koksilah watershed, the cost for additional study plus pumping and distribution would need to be considered.

To distribute water throughout the Koksilah irrigated area, could cost (at a very high level) approximately $17 million, assuming $8 million for a pump and $7 million for distribution (assuming 12 km of 36″ pipe at $125/foot and 65 km of 8″ pipe at $8/foot).

Administrative/Regulatory Considerations

The support of Cowichan Tribes would need to be obtained to move forward with this work. A request to draw additional water would likely require re-visiting the water use plan (which may take 6-12 months), additional environmental and engineering assessments, community engagement, acquisition of a water licence, identification of an organization to take responsibility for water licence and coordinated effort to lead this work.

If water from the Cowichan River was to be utilized, a route and associated access would need to be identified to transport water via pipe into the Koksilah watershed. Potential pathways may include the BC Hydro Right of Way (RoW), Highway, or private properties. A statutory RoW would likely be required. Also, an organization would need to be responsible for operating and maintaining the distribution system.

Ease of Use/Maintenance

A distribution system would need to be developed, operated, and maintained.

Reliability

Storage at Cowichan Lake is vulnerable to variations in precipitation. In a drought year, water use in the Koksilah would likely be viewed as a lower priority than water use in the Cowichan, so there would be concerns that water may not be available when it is needed most (Leroy Van Wieren, personal communications).

Additional Considerations

Trade-offs

Revisiting the weir upgrade project would delay environmental flow benefits to the Cowichan River (Leroy Van Wieren, personal communications). However, it could benefit environmental flows in the Koksilah. Also, taking water from one river and using it to augment flows in another may impair fish migration (Cali Melnechenko, personal communications). If water is only piped to lower Koksilah, it would not benefit the upper Koksilah and subwatersheds.

Ranking According to the Feasibility Criteria

Impact	TBD/High
Affordability	High
Ease of implementation	Medium-High
Ease of use	Medium
Reliability	Low-Medium

Aquifer/watershed-scale water supply/storage options

Aquifer storage and recovery (ASR)

Introduction

Aquifers in the Koksilah watershed were investigated to assess their suitability for aquifer storage and recovery (ASR), also known as managed aquifer recharge (MAR). As noted earlier, MAR refers to the intentional recharge of water to aquifers for subsequent use or environmental benefit. In this case, the term ASR is used to refer to the injection of water into the aquifer for future use and environmental benefit.

An ASR feasibility report, completed by GW Solutions Inc., fully describes the ASR feasibility assessment, and can be found in Appendix D.

To investigate the feasibility of ASR, the aquifers in the Koksilah watershed, identified in Table 11, and shown in Figure 10, were assessed, considering three broad components:

- Water quantity
- Water quality
- Ease of implementation and operation

The following provides a high-level overview of these components. Full details are in Appendix D.

Table 11: Overview of Mapped Aquifers in the Koksilah Watershed

Aquifer ID	#186	#188	#197	#198	#199	#201	#202
Aquifer name	Lower Cowichan River A	Lower Cowichan River C	Cherry Point	Cowichan Bay	Fairbridge	Heather Bank	Koksilah River Valley
Descriptive location			Includes Cowichan Bay, Cowichan Station, Hillbank, Cherry point, and Dougan Lake	Includes Cowichan Bay, Cowichan Station, Hillbank, and Fairbridge	West of Koksilah River, include Fairbridge	West slope of Cobble Hill, along the east banks on the Koksilah River	Upgradient Koksilah River Valley
Material	Sand and Gravel	Sand and Gravel	Sand and Gravel	Bedrock	Sand and Gravel	Sand and Gravel	Bedrock
Confinement	Unconfined	Confined	Confined	Fractured sedimentary rock	Confined	Unconfined	Fractured crystalline bedrock
Strata unit	Salish Sediments	Vashon Drift	Quadra Sand/Dashwood Drift	Nanaimo Group, sedimentary rocks	Quadra Sand/Dashwood Drift	Quadra Sand/ Dashwood Drift	Bonanza Group and Sicker Volcanic rocks

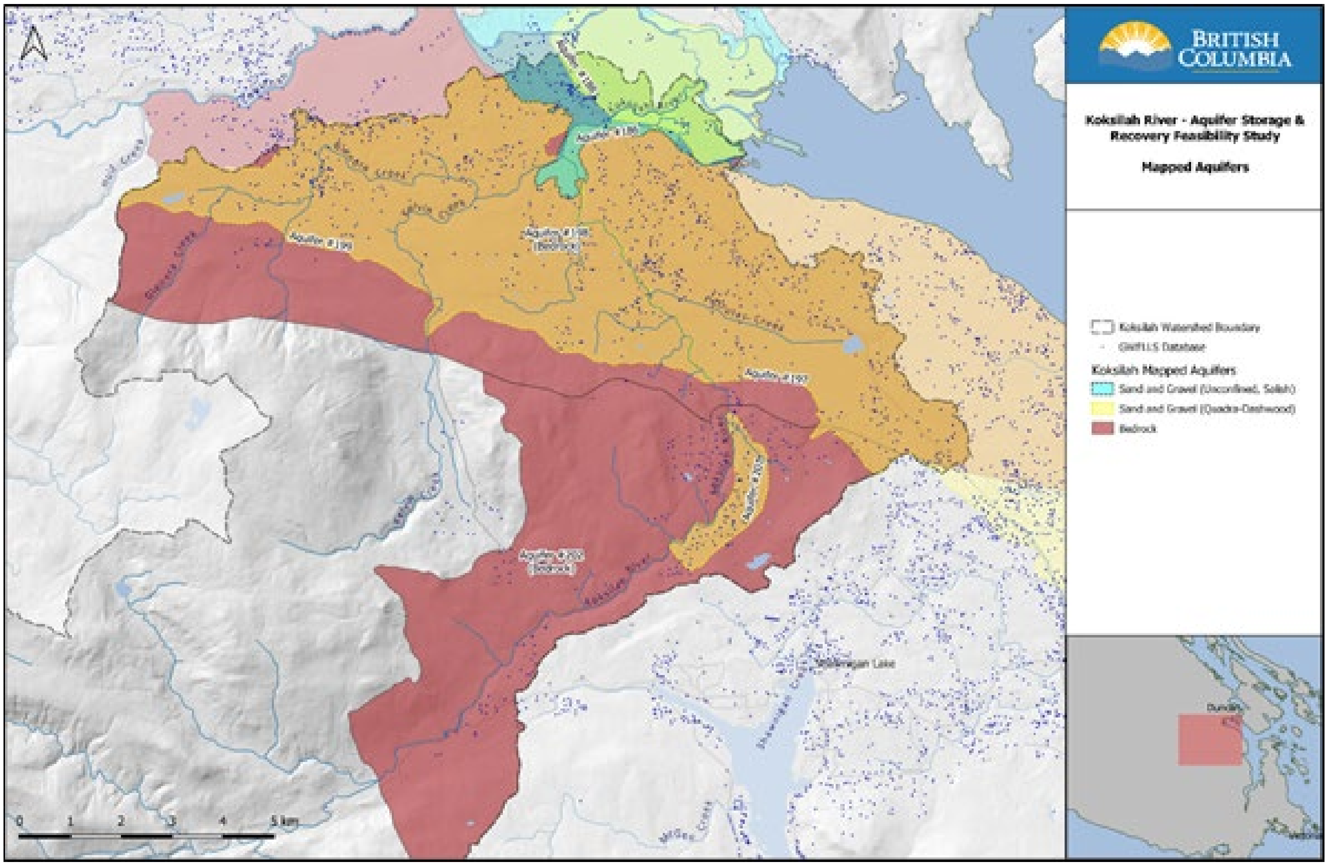


Figure 10: Provincial mapped aquifers within/intercepting Koksilah watershed

Water Quantity

The feasibility assessment of aquifers for ASR, according to the water quantity component, included consideration of:

- **Potential storage capacity:** This considered aquifer area, aquifer thickness, overburden thickness (as shown in Figure 11), unsaturated thickness above the aquifer, and total available volume (aquifer volume times the storage coefficient in confined aquifers or specific yield in unconfined aquifers).
- **Potential holding capacity:** This considered the potential for the aquifer to retain the recharged water versus transmit water downgradient. It is a function of the hydraulic gradient, transmissivity and the extent of the recharge zone, or the compliance zone (an estimation of the distance travelled by groundwater in one month). The holding capacity of the aquifer is higher when the length of compliance zone is shorter.
- **Level of local aquifer stress:** This considered whether the aquifer is gaining/losing water from stream, stream depletion factors, average groundwater level and river flow trends in dry and wet months, and annual water demands and demands per unit area.

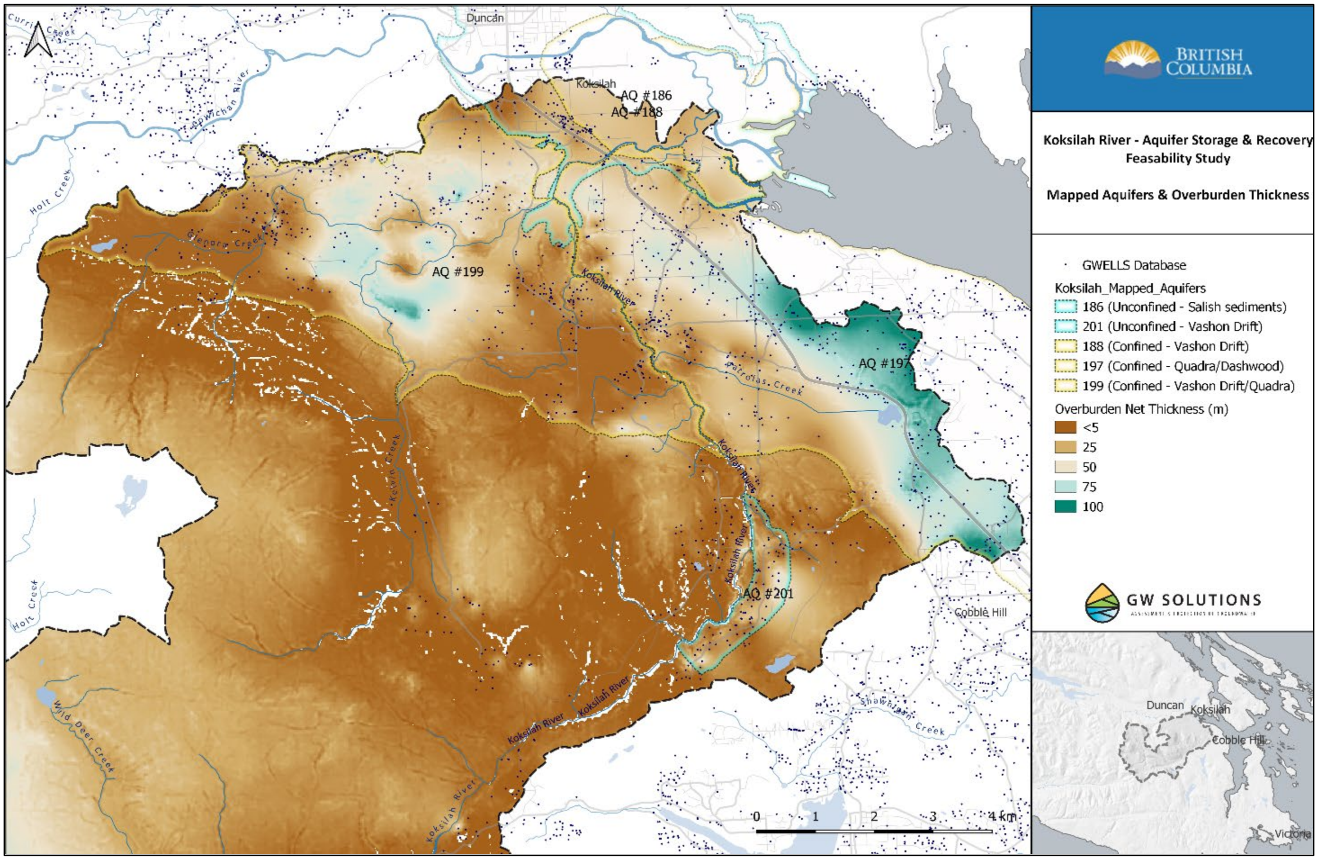


Figure 11 The overburden net thickness in northern parts of the Koksilah watershed.

Water Quality

The feasibility assessment of aquifers for ASR, according to the water quality component, included consideration of:

- Chemistry of available recharge water
- Chemistry of in situ groundwater

Geochemical interactions between the injected water and the native/ambient groundwater are critical in assessing the feasibility of ASR. For instance, the Parksville, Vancouver Island ASR Project was halted after injection resulted in arsenic mobilization within the aquifer. In this case, arsenic originating from the sediment resulted in the drinking water guidelines being exceeded during early cycle tests. Remediation of the resulting water to remove arsenic would have been cost prohibitive.

Since many aquifers in BC have background water quality issues due to local geochemistry or land uses (Geller and Burt, 2020), water quality monitoring to understand the compatibility of recharge water and in situ water, is essential in the assessment of the feasibility of ASR. Another important consideration in coastal aquifers is their potential risk of saline water intrusion (Geller and Burt, 2020). Proximity to the coast increases this risk, however, the depth and type of strata are also important criteria.

In this assessment, existing water quality data was reviewed, and each aquifer and potential source combination was assessed and ranked to identify aquifers and water sources with the lowest number of exceedances and greatest likelihood of compatibility.

Ease of Implementation and Operation

The feasibility assessment of aquifers for ASR, according to the ease of implementation and operation component, included consideration of:

- **Accessibility:**
    - Distance to river/square root of aquifer area (m)
    - Depth to confining bed or water level (m)
- **Available volume of recharge water:**
    - Annual average recharge water volume (m^3)
    - Annual average recharge water volume per unit area of the aquifer (m^3/m^2)
- **Required treatment** for recharge water (surface water)
- **Revised Metric**: a volumetric assessment of the aquifer feasibility (details in Appendix D).

Results

Aquifer #197 was selected as the most suitable aquifer for ASR based on the water quantity, water quality and operation criteria.

Aquifer #197 could potentially be used to store approximately 27 million m^3, should its saturated thickness increase from 25 m to 60 m. It has the second largest area (22 million m^2) and the shortest length of compliance zone in one month (30 m) when compared to the other unconsolidated aquifers. It has one of the smallest stream depletion factors relative to the distance to the nearest stream of 500 m and 1000 m.

With regards to levels of aquifer stress, Aquifer#197 is the most vulnerable aquifer based on the negative trend of flow in the nearest river (the Koksilah River with trend of -0.029 m3/s/yr), and because it has the largest water demand (equivalent to 56.5% of the whole watershed demand), and the highest demand per square meter per year (0.106 $m^3/m^2/yr$).

The water quality assessment identified the recharge water (surface) for aquifer #197 would likely require three types of water treatment (disinfection, treatment for metals, and treatment for physical properties).

The depth to water in Aquifer #197 is the largest of all the unconsolidated aquifers, thus offering the largest amplitude for potential storage. In addition, the proximity of the Koksilah River would be supportive of its artificial recharge.

Further investigation is required. The following next steps have been identified to further assess the feasibility of ASR and implement (if possible):

- **Phase 1:** ASR Pilot Design and Baseline
- **Phase 2:** ASR Pilot Implementation
- **Phase 3:** ASR Full Expansion

Potential Volumes of Water that Could Be Stored

It was estimated that up to 27,000,000 m^3 could be stored in Aquifer #197, providing well over 100% of the demand. Further work is needed to assess whether this is all available storage space.

A local subject matter expert (retired well driller) noted that that there is significant variability within the aquifer (e.g. knobs of bedrock) that may influence storage capacity. In addition, some areas of the aquifer have artesian conditions which may affect containment and holding capacity (David Slade, personal communications).

Distance from Demand and Works Required

ASR could potentially provide water at the point of use for users who draw water from the aquifer in the Petrolas Creek subwatershed and in portions of the Koksilah watershed mainstem. It may also support flow augmentation in Petrolas Creek and the Koksilah River. This would need to be confirmed through further investigation.

Works required would include an intake on Koksilah River, water treatment (disinfection, treatment for metals, physical properties), pipe, pumping, and injection wells.

Cost

It is estimated that the cost to recover and store water using ASR, would be approximately $0.5/$m^3$. This considers ASR design, implementation and operation.

A cost estimate for implementation is presented in Table 12. It assumes 12 injection/recovery wells (two during pilot and 10 during full expansion) at a cost per well of approximately $1 million.

Table 12 Cost estimate for ASR implementation

PHASE	SCOPE	TASK	DESCRIPTION	SUB-TOTAL	TOTAL PHASE COST
Phase 1: ASR Pilot Design and baseline	Developing understand of the defined area for Recharge, Storage and Recovery	Desktop studies to highlight the data gaps and where more data needed to be collected	Conducting desktop studies for the location of Monitoring points	$7,500	**$421,000**
		Implementation of additional observation points to develop the monitoring program and baseline data	Surface water gauge installation (three gauges)	$59,900	
			Developing observation well network at multiple levels by drilling and testing boreholes (minimum 6 test wells)	$218,000	
			Surface water sampling (water quality purpose) for one year (monthly sampling)	$41,400	
			Groundwater sampling (water quality assessment purpose) (twice a year in 6 test wells and 4 private neighbouring wells)	$35,800	
	Baseline development	Updating our desktop studies	Analyzing and interpretating the data collected	$9,000	

PHASE	SCOPE	TASK	DESCRIPTION	SUB-TOTAL	TOTAL PHASE COST
		based on the new findings	Structure a database and develop the baseline for water quality and water pressure for the project	$12,000	
	Coordination	Definition of the framework	Determination of monitoring locations/ time stages/ facilities and equipment for pilot	$7,500	
		Coordination	Planning/ordering/ permit(s) applications/safety	$30,000	
Phase 2: ASR Pilot Implementation	ASR Pilot design study/ Pilot Implementation	Construction	Drilling 4 boreholes (100m) and pump testing	$141,547	**$1,885,000**
			Drilling and completion of 2 production wells (70m)	$100,640	
			Pumping test in production wells (minimum 72 hour for 2 of wells)	$52,000	
			Lefranc and Lugeon permeability tests	$30,000	
			Data interpretation to select the location of Pilot ASR	$15,000	
			Fencing to exclude water source areas	$20,000	
			Pipeline design and installation	$765,000	
			Electrical pump and controller or solar pump	$80,000	
			Pressure system (if it is needed)	$0	
			Treatment system (Design, material and installation)	$156,000	
			Pump and utility house construction	$150,000	
			Water storage tank (material and installation)	$0	
		Operation	Start up the ASR Cycle	$36,000	
	ASR Pilot Evaluation and Risk Assessment	Evaluation	Monthly water quality monitoring (10 tests wells, 2 production wells and 4 neighbouring private wells)	$220,800	
			Monitoring groundwater pressure	$18,000	
			Monitoring surface water level/flow	$18,000	
			Aquifer modelling	$45,000	
			Data Interpretation to estimate Aquifer storage and recovery rate	$12,000	
			Determination the technical issues and other concerns / uncertainties	$12,000	

PHASE	SCOPE	TASK	DESCRIPTION	SUB-TOTAL	TOTAL PHASE COST
		Risk Assessment	Data interpretation to conduct risk assessment for the Pilot study and risk prediction for ASR full implementation	$7,500	
			Contingency Plan to reduce the risk and modification	$6,000	
Phase 3: ASR Full Expansion	Optimization analysis	Feasibility analysis to optimize/ enhance the initial ASR Plan		$30,000	**$9,762,000**
	Expansion	Expand the ASR Implementation with additional 10 injection wells		$9,731,600	
Subtotal					$12,068,000
Communication with the multidisciplinary teams and contractors (12% of engineering cost)					$121,860
TOTAL					$12,190,000

Main assumptions for the cost estimate include:

- Test boreholes would be drilled to depths of 100 m and production wells would be drilled to depths of 80 m.
- ASR system includes surface water intake, pipes (inflow and outflow), treatment system (stage 2), pumping wells, pump house.
- Water quality will be monitored at surface water intake/before treatment, after treatment, at the location of pumping wells. Lab cost at $650 per sample for full potability analysis.
- Consulting field work supervision rate ($1,500/day).
- Monitoring equipment includes Level logger at $1,500 per logger (Pressure, temperature and conductivity) and baro logger at $350 per logger.
- Pipelines lengths in Aquifer #197 from 0.5 km to 3 km. Design and construction of 8" pipe $250,000/Km
- Treatment plant for pilot $150,000 (stage 2).
- Pump for 1,000US GPM exploration estimated at $20,000 per pump.
- No storage tank was included.

Administrative/Regulatory Considerations

Any work would need to be in line with the Water Sustainability Act and Groundwater Protection Regulation. The Province does not currently have a regulatory framework for ASR. This may impede implementation.

Maintenance/Ease of Operation

Further work is required to assess maintenance efforts. A distribution system could be used but may not be required. With the information available at this time, the ease of operation is rated as medium/TBD.

Reliability

The water source for an ASR project would be an intake in the mid-lower portion of the Koksilah watershed. At this point in the river, there is likely sufficient winter flows (due to the large upstream catchment area) that winter water supplies are reliable.

Further work is needed to assess the reliability of the aquifer in containing water. This would be determined through future feasibility assessment.

Additional Considerations

Potential benefits

ASR would help augment an over-utilized aquifer. It is currently estimated that 57% of the groundwater used in the watershed comes from Aquifer #197. ASR also has the potential to support baseflow to Petrolas Creek and the Koksilah River.

Ranking According to the Feasibility Criteria

Impact	High
Affordability	High
Ease of implementation	Low-Medium
Ease of use	TBD/Medium
Reliability	High

Green infrastructure

Introduction

The area upstream of demand in the Koksilah watershed was investigated to identify opportunities to utilize green infrastructure to restore the hydrologic regime and increase yields. Common green infrastructure approaches to increase yields and augment low flows at a landscape scale include wetland restoration and forest management. Riparian area improvements and instream habitat enhancement can also be used to support aquatic life during low flows.

The predominant land cover in the Koksilah watershed is managed forest (65%). The dominant land cover in the lower Koksilah watershed is residential and agricultural land and the dominant land cover in the upper Koksilah watershed (upstream of most of the demand), is forest, with some roads and wetlands. A review of satellite imagery found that in the lower watershed, while most riparian areas are forested, some reaches of Petrolas Creek have minimal riparian cover. Most wetlands in the watershed appear to be in a natural state, but it is likely that some wetlands were removed in the lower watershed during land development (Tracy Fleming, personal communications).[12]

In the upper watersheds, forests are actively managed, with most forests in second growth (Pam Jorgenson, personal communications). Most of the forest land is privately owned and managed by Mosaic and the remaining is in other forms of ownership/management (Crown, woodlot, other private owners) (personal communications, David Beleznay). Currently, Mosaic Forest Management considers impacts on the hydrologic regime throughout its planning and operations (David Beleznay, personal communications).

In the past, forest managers in the Pacific Northwest (PNW) have focused water management efforts on maintaining the hydrologic regime, with a particular emphasis on reducing peak flows to prevent flooding, erosion, sediment transport and water quality impacts. However, with climate change and increasing awareness of environmental flow needs, there is a growing interest in understanding the effects of forest management on seasonal low flows.

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).

There are several watershed characteristics which are correlated with an increase in the effect of forest disturbance on low flows, including low elevation terrain, south facing aspects, mid-elevation snowpack, proximity to the ocean, and a rain dominated hydrologic regime (Segura et. al, 2020; Moore, Gronsdahl, & McCleary, 2020; Goeking & Tarboton, 2020). These are all at play in the Koksilah watershed, which is a

[12] The health of forests, wetlands, riparian areas, and instream habitat cannot be properly assessed through satellite imagery.

relatively low elevation watershed, with a rain-dominated hydrologic regime, more south-facing aspects (particularly in the upper watershed), snowpack primarily in the 800-1100 band, and a costal influence. While the forests in the Koksilah watershed include a broad mosaic of stand ages, most are in a phase of hydrologic recovery (Hatfield, 2020).

The physical characteristics of the Koksilah make it a good candidate for exploring the relationship between forest management and seasonal flows, and the potential for the use of forest management in low flow augmentation. However, further work is needed to understand how much - if any - water could be made available, the cost of the potential increase (financially, environmentally, etc.), and the interest of forest managers and rights holders in this work. Much of the current research in the area was not done at a similar scale and the research watersheds did not have the same variation in stand age or the physical characteristics of the Koksilah (David Beleznay, personal communications).

In 2020, Cowichan Tribes commissioned a study to better understand the causes of low flows. This work provided an insightful analysis of factors in the watershed which may influence low flows, and firmly demonstrated the influence of climate change on watershed conditions. The study included an assessment of the influence of forest cover changes on low flows, by considering the relationship between forest age and ET, using local forest data and ET estimates from prior research (in Europe) (Hatfield, 2020). While the study found a limited relationship between forest cover and low flows, there is room for further exploration, considering the physical characteristics of the Koksilah watershed, local ET estimates (using PNW species and climate), forest conditions (e.g., soils, species, gap dynamics, canopy density, etc.) and the inter-relationship between these factors and hydrologic processes (e.g., timing and volumes of recharge, snowmelt, etc.). The study recommended the development of a watershed-scale Forest Management Plan, which, if identified with low flow considerations in mind, may further elucidate the relationship between forest cover changes and water availability and identify opportunities for enhancement of low flows.

A research proposal is currently in development which proposes collaboration between Mosaic, Cowichan Tribes, and UVIC to better understand the relationship between forestry and the Koksilah watershed (David Beleznay, personal communications). While the potential for yield augmentation is not identified as part of this work, the project could play an important role in growing the knowledge on this complicated topic.

It is important to note that sustainably increasing yields through green infrastructure is not a quick or easy solution. Any actions would involve working closely with land managers and rights holders. Under existing legislation, forest managers consider a variety of values (fish, wildlife, terrain, water quality, visuals, economic, etc.), and it may be difficult to obtain flow augmentation results while supporting all values.

Any actions taken to augment flows using land cover should have a firm scientific basis, and consider Indigenous knowledge, because land cover alteration taken at a large scale (as is typically needed to support yield enhancement) has the potential to have negative consequences for the hydrologic regime (and other values), if not done carefully.

Further work is needed to determine the potential volumes of water that could potentially be made available through green infrastructure, and the costs and benefits of such actions in the Koksilah watershed. Given the characteristics of the Koksilah, this work is likely to be of value in supporting water management and mitigating the impacts of climate change over the long-term.

Ranking According to the Feasibility Criteria

Impact	TBD
Affordability	TBD
Ease of implementation	TBD
Ease of use	TBD
Reliability	TBD

Additional Suggestions

The following suggested were proposed as water supply options, but not investigated further:

- Cowichan River aquifers: The aquifers are highly connected to the river and the system is already stressed. Further withdrawal from these aquifers is likely to cause environmental impacts. Without creating storage, it would simply be moving the challenge from one watershed to another.
- Desalination: The costs to desalinate water are very high and the water would also need to be pumped uphill. As the largest users in the watershed are for irrigation and industrial use, it is not realistic to expend the energy and cost to desalinate water (e.g., using reverse osmosis) for these purposes. It would be much more cost-effective to pursue other local solutions (e.g., rainwater harvesting) to support residential water demands.

Summary Table

Table 13 on the following page provides a summary of the rankings for the feasibility of each option. Each option is giving a score of 1, 2, or 3 based on whether the option rated as low, medium, or high. A final feasibility score, calculated by averaging each ranking for an option, is provided to assist in identifying, at a high level, relative feasibility.

It is important to note that this summary table weights all criteria equally. A weighted assessment, which provides a higher value on criteria such as impact and/or affordability would provide another perspective on the feasibility.

Finally, many of these ratings are subjective and the rankings will likely change as further information becomes available. This assessment is intended to provide a starting point for a conversation around the relative feasibility of options in the watershed.

Table 13: Summary of Water Storage and Management Options. Ranked Low/Medium/High (1-3) and Average Score (out of 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-Site Small-Medium Scale	**Greywater Reuse**	Very Low (0.5/3)	Very Low (0.5/3)	Low (1/3)	Low (1/3)	High (3/3)	**Low (1.2/3)**
	Cisterns	Very Low (0.5/3)	Low (1/3)	Medium-High (2.5/3)	Medium-High (2.5/3)	Low (1/3)	**Medium (1.5/3)**
	Dugouts	Medium-High (2.5/3)	Medium (2/3)	Medium (2/3)	Medium (2/3)	Medium (2/3)	**High (2.1/3)**
	Water Storage Tanks	TBD/Medium (2/3)	Medium (2/3)	High (3/3)	High (3/3)	High (3/3)	**High (2.6/3)**
Off-Site Medium-Large-Scale	**Extraction Pits**	High (3/3)	Medium (2/3)	Very Low (0.5/3)	Low-Medium (1.5/3)	High (3/3)	**Medium (2/3)**
	Existing Lakes	Medium (2/3)	High (3/3)	Medium (2/3)	Medium (2/3)	Medium (2/3)	**High (2.2/3)**
	Natural Features	Medium (2/3)	High (3/3)	Low (1/3)	Low-Medium (1.5/3)	Medium (2/3)	**Medium (1.9/3)**
Existing Systems	**Municipal Water Supplies**	None	NA	NA	NA	NA	**NA**
	Municipal Wastewater	Low-Medium (1.5/3)	Medium (2/3)	Low (1/3)	Medium (2/3)	High (3/3)	**Medium (1.9/3)**
	Cowichan Lake	TBD/High (3/3)	High (3/3)	Medium (2/3)	Medium (2/3)	Low (1/3)	**High (2.2/3)**
Aquifer/Watershed-	**Aquifer Storage and Recovery**	TBD/High (3/3)	High (3/3)	Low (1/3)	TBD/Medium (2/3)	Medium-High (2.5/3)	**High (2.3/3)**
	Green Infrastructure	TBD	TBD	TBD	TBD	TBD	**TBD**

Next Steps

Table 14 identifies work needed to assess the feasibility of options that received a ranking of High.

Table 14: Next steps to assess the feasibility of potential solutions

Option	Preliminary Constraints Identified	Next Steps to Assess Feasibility	Notes on Timing
Dugouts	• Cost	• Identify funding source. • Engage with producers and industry groups to develop funding plan.	• No time restrictions identified.
Water Storage Tanks	• Cost	• Determine the water quality impacts of collecting water in the wet season and storing it in a large tank for several months. • Engage with producers to assess interest/space availability. • Identify funding source.	• No time restrictions identified.
Existing Lakes (Grant Lake)	• Land ownership • Dam feasibility (suitability of site, inflows in drought year) • Environmental flow needs	• Engage with Cowichan Tribes and Malahat Nation to assess interest. • Engage with landowner to assess interest. • Engage with community group that is organizing to buy the lake. • Conduct engineering feasibility assessment. • Assess impact on environmental flows.	• Land is apparently for sale (as of March 21, 2021) and there is a community group that is interested in purchasing to protect the area. It is unclear if a dam is compatible with their conservation interests.
Cowichan Lake	• Project currently underway • Cowichan Tribes not interested • Water Use Plan and EFN study complete	• Engage with Cowichan Tribes and Malahat Nation to assess interest. • Assess interest among community and local governments in revisiting water use plan and EFN study. • Determine approach (e.g., water license with existing weir height vs. raising weir height) • Conduct feasibility study for intake, distribution system, EFNs, etc.	• Weir design is currently four months from completion, Cowichan Tribes has already received funding for construction.
ASR	• Further feasibility assessment required • Lack of regulatory framework	• Engage with Cowichan Tribes and Malahat Nation to assess interest. • Engage with community to assess interest (especially well owners that draw from selected aquifer). • Phase 1: ASR Pilot Design and baseline (see Appendix D). • Phase 2: ASR Pilot Implementation (see Appendix D) • Development of regulatory framework (by Province)	• No time restrictions identified

Option	Preliminary Constraints Identified	Next Steps to Assess Feasibility	Notes on Timing
Green Infrastructure	• Lack of local information • Potentially, landowner interest	• Engage with landowners, Cowichan Tribes, and Malahat Nation to assess interest. • Conduct further work to identify, assess and select green infrastructure approaches that are likely to support the hydrologic regime and reduce the severity of low flows. • Research to understand the relationship between land cover and low flows in the Koksilah, especially with climate change.	• Research proposal being developed related to land cover and watershed health. • Forest Sustainability Plan noted as a potential recommendation of a WSP.
Purchase Licences	• Cost, licence holder interest	• Determine interest of the Province and licence holders in having the Province purchase the lands and businesses of the largest water licence holders and 'retiring' those licences.	• No time restrictions identified, but the sooner it was completed, the sooner environmental benefit.

The solutions that ranked as most feasible are mostly large-scale solutions which are costly and have a range of costs and benefits. A community engagement process is recommended so that information on these options can be shared with the community and the community can be engaged in decision-making. A Water Sustainability Planning process may provide suitable opportunities for community engagement and is supported.

Conclusion

The research analyses conducted in this study have found that there are several water supply options that may be feasible in the Koksilah watershed. The options that have been found to be most feasible are larger-scale solutions that require significant investment and community interest. Recommendations for next steps to assess feasibility have been provided. Community engagement is identified as a critical next step in evaluating water supply and storage options. The review also found that there is not one clear or easy water storage or supply solution. It is likely that a number of options could be used in the short and long term – in conjunction with demand management – to increase the available water for aquatic habitat.

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