# *Ecosystem-Based Assessment of the Koksilah River Watershed*

## *Phase 1 Report: Watershed Character and Condition*

*Top image: Looking out into the Koksilah watershed, with Grant Lake in the bottom of photo.*
*Bottom image: Large wetland in upper Koksilah watershed.*

Submitted to:
**Cowichan Station Area Association**

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And finally, we appreciate the following organizations for providing the funding that allowed us to conduct this ecosystem-based assessment of the Koksilah watershed: Real Estate Foundation of BC, Shawnigan Basin Society, Cowichan Valley Regional District Directors for Areas E, B, C, and A, Sidney Anglers Association, the HUB Film Club, and area residents through local fundraising events.

## Introduction

The approximately 30,000-hectare Koksilah River watershed is a place of deep human history and immense ecological richness. Like all watersheds, it is a drainage basin comprised of many smaller drainage basins—where mountains and hillsides are like the edges of a bowl, guiding water to drain downhill into streams, rivers, lakes, and aquifers. From the sub-basins that feed the 44 km-long Koksilah River, to the smallest puddles found in the forest, each is a watershed that is connected to another that is larger or smaller. The highest ground in the watershed also creates a natural boundary, defining distinct (although still interconnected) ecological units. The use of ecological boundaries to define a study area is fundamental to undertaking an ecosystem-based assessment, and is the starting point for this assessment of the Koksilah River watershed.

The Koksilah watershed is located on Vancouver Island, south of the City of Duncan—the nearest urban centre. It is primarily located within the political boundaries of the Cowichan Valley Regional District (CVRD), with a small portion of the upper watershed located in the Capital Regional District. Within the CVRD, the watershed spans five electoral areas: B – Shawnigan Lake, C – Cobble Hill, D – Cowichan Bay, E – Cowichan Station/Sahtlam/Glenora, and F – Cowichan Lake South/Skutz Falls.

The mountains of the upper and middle watershed form part of the Victoria Highlands physiographic region, a transition zone between mountains and lowlands, that is characterized by gently sloping mountains interspersed with deeply incised valleys (Trofymow et al. 1997). Within this region, the Koksilah River and its many tributaries eventually join the Cowichan River, where together they flow into the Cowichan Bay estuary-- the ecosystem where freshwater from the rivers meets tidal saltwater.

It is along Koksilah Ridge where one of the first Quw'utsun' (Cowichan) people fell from the sky, and along the Koksilah River where, for thousands of years, many Quw'utsun' people fished and called home. In addition to the Quw'utsun' people, the watershed has been home to many species of animals, plants, fungi, and microorganisms. Even the water itself has a spirit, as discussed later in this report. In recent history, the watershed has become home to a large settler community, whose livelihoods and well-being also depend on the ecological health and integrity of their environment.

Full of life, the Koksilah watershed can easily be seen as a living entity in and of itself. We attempt to capture this essence in the descriptions of ecological character that follow. We then move on to a discussion of the watershed's current condition, where we find many indications that the future of the watershed is in a delicate position. We hope that this report inspires both conversation and action, needed to ensure the stewardship of this wonderful place.

## Objectives

This report has been commissioned by the Cowichan Station Area Association to describe the ecological character and current condition of the Koksilah River watershed, as a first step towards completing an ecosystem-based watershed assessment. This report represents Phase 1 of the larger project, *Ecosystem-based Assessment of the Koksilah Watershed* (the "Project"), the objectives of which are:

- To prepare an ecosystem-based assessment of the Koksilah watershed applying the principles and methods developed by Silva Forest Foundation and Silva Ecosystem Consultants;
- To ensure that the ecosystem-based assessment addresses questions of interest to the Cowichan Tribes community, and, where permitted, includes local and traditional knowledge shared by Cowichan Tribes community members;
- To maximize community participation in the project, including the inclusion of local knowledge in the ecosystem-based assessment; and
- To provide tools, such as the methodology and maps, for building local capacity in ecosystem-based management in the Koksilah watershed, and encourage wider use throughout the Cowichan region.

In Phase 2 of the Project, maps showing proposed protected landscape networks will be developed that show areas requiring restoration to protect key values in the watershed. Areas suitable for human use will also be identified. These land designations will be developed based on results from Phase 1, which, in its final version will include additional input provided by residents and the Cowichan Tribes.

## Methodology

Information cited in this report stems primarily from a desktop analysis and spatial analysis of existing data. Where possible, field trips and discussions with subject matter and local experts were used to supplement and corroborate those data.

### Desktop Analysis

The desktop analysis relied heavily on a review of existing literature directly and indirectly relevant to the Koksilah watershed. Peer-reviewed sources were given preference when reviewing scientific information. Historical information was taken from published works that draw from oral and written history of the watershed. Subject matter experts were consulted on topics such as hydrology and surficial geology. A full list of information sources is provided in the References section of this report.

Information sources for biological information included:

- BC Breeding Bird Atlas (Bird Studies Canada 2018);
- BC Conservation Data Centre (BC CDC 2018)
- BC Water Tool (2018)
- DataBC (2018)
- Ecocat (BC MOE 2018)
- Fisheries Information Summary System (BC Gov. 2018a)
- Freshwater Fisheries Society of BC (FFSBC 2018)
- Habitat Wizard (BC Gov. 2018b)
- Water Rights Database (BC Gov. 2018c)
- Water Survey of Canada (Gov. of Canada 2018)

## Field Trips

Field trips consisted of driving to locations in the watershed to observe and photograph examples of site-level watershed character and condition. Forest company staff provided guided tours of private managed forests. An aerial tour enabled access to more remote locations, and to review examples of character and condition at a landscape level. Both ground-based and aerial trips assisted with confirming observations made using satellite imagery. Field trips were conducted during July 2018.

## Spatial Analysis

See Appendix 1 for a complete summary of spatial analysis methods.

## Community Review

After the first draft of this report and accompanying maps were prepared, the community was invited to review information gathered about the watershed and to share their own observations during a public meeting. The objectives of the meeting were to display the maps and find out what information was correctly captured, what information was missing, and what information was surprising to residents. Information received from the community was then incorporated into the final version of this report. Cowichan Tribes staff and Cowichan Tribes elder Dr. Arvid Charlie generously reviewed the draft report and maps for inaccuracies and omissions, and amendments were incorporated into this final report.

## Limitations

Certain limitations affected the depth of the analyses in this report and may affect the accuracy of this assessment. As we will discuss in greater detail below, most of the watershed is privately owned through fee-simple ownership. Consequently, detailed data on terrain, wildlife, plants, ecological communities, water, and other values likely exists for privately managed forest, however, is proprietary and therefore not available for our assessment of character and condition of the Koksilah watershed. Fee simple private land ownership also limited access for field study. We relied on publicly available data and information shared by Cowichan Tribes community members, settler community members, and landowners to develop content in this report.

The hydrologic content was led by Martin Carver with assistance from Carol Luttmer and Heather Pritchard. Budget limitations affected the depth of this hydrologic assessment. Martin and Carol were unable to conduct a site visit and relied solely on desk top information. Undoubtedly, more work on this topic is warranted to fully understand the hydrologic condition of the watershed.

Further, the purpose of this report is not to provide an exhaustive inventory of all information available regarding the Koksilah watershed. This report draws from information that serves to indicate the ecological character and current condition of the watershed, current to the time of writing. Other initiatives, studies and reports may be underway to address other questions related to the watershed. Thus, this report should be considered as part of a larger library of information that is ever-changing, and may be updated to reflect new insights as they emerge.

# Part 1: Character of the Koksilah River Watershed

## Introduction

In this report, “ecological character” refers to the pre-industrial, or “natural”, condition of the Koksilah River watershed—which includes modification following natural disturbance and/or Indigenous management systems (Hammond 2009). In contrast, “ecological condition” refers to a modified state following industrial human activities (Hammond 2009).

Ecological character emerges from the interaction between the composition, structure, and function of ecosystems; or rather, ecosystem “parts”, how they are arranged, and how they work. These interactions do not exist in a vacuum but as a dynamic steady state, where a range of natural variability defines the limits for how much and how frequently change can occur before a tipping point is reached (Hammond 2009). Changes that are absorbed by an ecosystem, allowing it to continue to persist, contribute to its resilience (Holling 1973).

The difference between ecological character and condition in the Koksilah watershed will be used to improve understanding of the state of the watershed, and to inform subsequent recommendations for protecting and restoring ecological integrity in the watershed.

We begin our discussion on ecological character by providing an overview of the Quw’utsun’ (Cowichan) people, the original human inhabitants of the Koksilah watershed. This is followed by a brief overview of the climate, hydrology, and terrain features. Natural disturbances are outlined, followed by a description of the forest composition and structures they influenced. And finally, wildlife, fish, plants, and ecological communities that likely occurred in the watershed are provided.

## The First People

Given the importance of Indigenous management systems to the ecological character of the Koksilah watershed, this report begins with a discussion of Quw’utsun’ history and values—as interpreted by the authors. Concerted attempts have been made to represent facts and accounts accurately and respectfully, however, it is likely that inadvertent mistakes have been made. The Quw’utsun’ people are the final authority regarding their own history and values—both past and present.

Thousands of years ago, Syalutsa, the first Quw’utsun’ person fell from the sky and landed near Koksilah ridge (Cowichan Tribes 2018). Not long after, he was followed by his younger brother, Stuts’un, who landed on Swuqus (Mount Prevost). Among the first lessons that Syalutsa and Stutsun were taught by the Creator was to perform kw’aythut (spiritual bathing) “in every little stream, river or lake” (Marshall 1999, p. 16) in order to connect with and learn from spirits, and the land upon which their lives depended. In addition to kw’aythut, Syalutsa taught his brother Stutsun to take only what is needed from the land. Together, these practices allowed the brothers to better understand their place in the world, a teaching that would be passed on to their descendants for generations to come.

Evident from the Quw’utsun’ creation story, water is a powerful source of connection to the land, and spiritual bathing is a fundamental part of culture and identity. The importance of wet places such as rivers, streams, lakes, ponds and pools, to the Quw’utsun’ people is discussed at length by Genevieve Hill in her PhD thesis (2011) following extensive research and consultation with Cowichan Tribes staff and elders. Not only do wet places act as doorways to connect with spirits, some have also been used to tell fortunes and help make life decisions, as well as provide a long list of food and medicine resources (Hill 2011). Hill argues that although Quw'utsun' people have a strong connection to the marine environment, freshwater bodies hold special significance, evident by the many place names and stories associated with streams, rivers, lakes, and ponds, and permanent village sites being located along rivers.

**Figure 1. "Syalutsa opens his eyes when he first comes to our land. He opens his mouth and drinks the water and finds the healing properties within" (Marston 2018). Carving by artist John Marston (Source: Inuit Gallery of Vancouver).**

Like wetlands[1], secluded forest places also hold power. Stz'uminus[2] elder Peter Seymour, in a published interview with Brian Thom (2005), told of how the forest helps to purify dancers before a mask dance, as well as helps the bereaved to work through sadness and grief.

There are also examples that demonstrate an overlap between the spiritual and material importance of both forests and wetlands. Western redcedar is known by non-Indigenous land users to be important for canoe-carving, but "cedar [also] knows what we all feel...it will draw that sadness" (Peter Seymour, as told to Thom, 2005). Cedar is therefore not just a resource; it is regarded as an entity. We presume this to be true for many other "resources".

Having lived here for thousands of years, Quw'utsun' territory including the Koksilah watershed, is full of places that imbue a combined sense of history, culture, identity and land stewardship. For example, in the story of Q'ise'q (Ruby Peter, as told to Thom, 2005), Kisak's mother bathes her son in a creek using balsam branches. Water drops that fall off the branches used by Q'ise'q's mother transform and become the first trout. She later teaches Q'ise'q the proper way to kill a trout by biting its nose and in doing so ensure the perpetual return of trout to what later comes to be known as Trout Creek. When Q'ise'q grows up, he gains the strength to restore his village (Xinupsum) from invaders and his usurping uncle. In recognition of all these good deeds, both Q'ise'q and his mother are immortalized as an island, and a rock, respectively, by Xeels' the transformer. Such physical markers are reminders of the valuable lessons learned by these two ancestors, and serve as tools to teach subsequent generations of how to be a good person and respect the land.

Historically significant places that are specific to the Koksilah watershed include the Koksilah village (Xwulqw'selu), a winter village site, which is still located where the current Highway 1 intersects with the Koksilah River (Abel D. Joe, as told to Rozen, 1985). Translations for Xwulqw'selu include the "place having snags [in the river]" (Arthur Joe, as told to Rozen, 1985), and "something that will cause a tangle" (Arvid Charlie, pers. comm.). Several large log jams and standing dead trees were reportedly present in the Koksilah

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[1] Hill (2011) defines all waterbodies including streams, ponds, lakes, and marshes as "wetlands".

[2] The Stz'uminus First Nation, like the Cowichan Tribes, Penelakut Tribe, Halalt First Nation, and Lyackson First Nation are present day communities of the Cowichan Nation. The imposition of the *Indian Act* and reserve system split the Cowichan Nation into these distinct bands.

River near the village site (Rozen 1985), however it is unclear as to how frequently this occurred. The “tangle” could also be a result of an eddy or other morphological feature of the river.

Written records refer to as many as seven longhouses in the Koksilah village during the mid-1800’s (d’Heureuse, in Rozen, 1985), and to at least one longhouse in use during the early 1920’s (Abel D. Joe and Arthur Joe, as told to Rozen, 1985). Two longhouses were located at the soon-to-be built Cowichan Station railway stop, but were deconstructed when the E&N railway was built (Arvid Charlie, pers. comm.). These longhouses were large enough to provide lumber to construct two longhouses at Clemclemaluts (Arvid Charlie, pers. comm.), another traditional village of Cowichan Tribes, located near the Cowichan Estuary at the present day confluence of the Koksilah and Cowichan Rivers. The Koksilah village also featured at least one weir for catching several kinds of fish (Abel D. Joe and Arthur Joe, as told to Rozen, 1985; Arvid Charlie, pers. comm.).

**Figure 2. Canoes on the Koksilah River (Source: BC Archives, Item G-04395).**

Koksilah Ridge (Hwsalu-utsum) is the “place having rush-mat shelters” (Abel D. Joe, as told to Rozen, 1985). The origins of this name date back to the first Quw’utsun’ people when two Sooke women travelling to find Syalutsa made a camp of rush-mat shelters on Deerholme Mountain (Abel D. Joe, as told to Rozen, 1985). It is also in this area that the Thunderbird made one of its homes (Rozen 1985). The area also features caves that were used by wolves (Arvid Charlie, pers. comm.) and black bears during hibernation, and was also a known elk hunting area (Abraham Joe, as told to Rozen, 1985). Other notable places include Marble Falls (xtem’ten) where seasonal salmon fishing camps were located (Arthur Joe, as told to Rozen, 1985). Q’up-q’upasum’, currently known as Cowichan Station near Moss Road, was a gathering place where a fishing weir was located (Arvid Charlie, pers. comm.).

Busy Place Creek (Sh-hwuykwselu) was an important meeting spot and transportation corridor, and prior to industrialization of the area, provided a physical connection between the Cowichan and Koksilah rivers (Tim Kulchyski, pers. comm.). Prior to industrialization, Sh-hwuykwselu was not a distinct creek, but was part of the mainstem of the Cowichan River (Arvid Charlie, pers. comm.). In later years, after the drainage of Sh-hwuykwselu had been drastically altered, the Koksilah River acted as a kind of overflow channel for the Cowichan River during bountiful salmon years (Abraham Joe, as told to Rozen, 1985; Arvid Charlie, pers. comm.).

Taken altogether, we see that stewardship in a Quw'utsun' context requires treating what many non-Indigenous land users regard as resources, as entities and/or ancestral landmarks deserving of respect. Stewardship also requires seeing the connection between all places and all things, as the foundation of culture and identity, and working to maintain those connections.

***Mukw' stem 'i' utunu tumuhw 'o' slhiilhukw'ul*** is an important Quw'utsun' teaching which means "Everything is connected".

## Climate, Surficial Geology and Hydrology

### Climate and Hydrology

The Koksilah watershed, like much of British Columbia, was warmer and drier during the Holocene (approximately 11,700-7000 years before present), owing largely to greater solar insolation and different patterns in atmospheric circulation (Brown 2015). It is during this period that streamflow in the Koksilah River was likely at its lowest and wildfire frequency was high. Forest fires likely affected water quality by increasing water temperatures and causing erosion. As the glaciers began to melt during this period of warming, meltwater volumes led to fluctuating sea levels and rapidly changing river environments (Brown 2015). At approximately 6500 years before present, the climate began to cool and became moister, similar to present-day conditions. Increasing streamflows enabled the expansion of suitable fish habitat into smaller systems. Although cooler and moister, the low elevations of the Koksilah watershed are classified as having a "cool Mediterranean climate" being semi-arid with a mid to late summer water deficit (McKean 1989).

The Koksilah watershed is currently a pluvial, or rain-dominated system (Brown 2015). It is located on the rain shadow side of Vancouver Island and therefore experiences lower annual and monthly rainfall than the west coast (Pike et al. 2010). Average annual precipitation varies across the watershed, with up to 2075 mm in the headwater region to less than half that amount at sea level (Tutty 1984).

The watershed does not have a major lake; instead headwaters include numerous wetlands and four small lakes (examples in Figure 3). Grant Lake is the largest (~28 ha) followed by Wild Deer Lake (~5 ha) (Tutty 1984), both occurring in middle to high elevations. In the lower Koksilah watershed, Dougan Lake in Cobble Hill feeds Patrolas Creek, while Keating Lake feeds Keating Creek which then flows into Glenora Creek. Kelvin Creek watershed, a sub-basin located within the larger Koksilah River watershed, features at least 10 small wetlands (Harris and Usher 2017).

The lakes and wetlands are important features in the landscape providing source water for the Koksilah River. Because they store water, they also have a role in regulating water levels throughout the year. However, the lack of a large lake at the headwaters of the Koksilah River results in very low summer flow levels and winter flow rates that are magnitudes higher. Moreover, the river responds dramatically to significant rains, particularly during large winter storms.

According to long-term river gauge data, peak discharge occurs between November and February, while lowest discharge occurs between June and September (Brown 2015). Tutty (1984) describes the Koksilah River as being “subject to winter flash flooding and low natural summer flows [with] some lower tributary portions of the watershed annually ceas[ing] to flow and go dry”. However, it is important to note that the concept of “flashiness” is relative. When compared to other rivers whose flow is regulated by a large lake, such as the Cowichan River, the Koksilah River may be considered flashy. Though when compared to water flows in steeper, more mountainous watersheds, the Koksilah River may appear relatively less flashy. Also, different portions of the river exhibit different morphological traits affecting flashiness within the river system. For example, stream sections underlain with bedrock will experience more dramatic fluctuations in water levels and velocities, when compared to sections underlain with more pervious substrates like sands and gravels.

**Figure 3. Wetland in the Koksilah River watershed (left) and Wild Deer Lake (right).**

In addition to precipitation, source water for the Koksilah River system also includes flow from groundwater aquifers (Figures 4 and 6). For example, in the lower Koksilah watershed, retreating glaciers left behind permeable deposits interspersed with less permeable clays and silts to form three overlapping sand and gravel aquifers connected to the Cowichan and Koksilah rivers (Figure 4) (Carmichael 2014; Barroso et al. 2013). Towards the middle portion of the watershed, bedrock Aquifer 0200 (Kelvin Creek) is believed to be highly connected to the mainstem and tributaries of the Koksilah River, and sand and gravel Aquifer 0199 (Dougan Lake) is believed to have a moderate to high connection to Patrolas Creek and the Koksilah River (Harris and Usher 2017).

All of the water flowing through the Koksilah watershed ends up in the Cowichan/Koksilah estuary at Cowichan Bay, another important water feature in the landscape. Lambertsen (1987) noted that this estuary is one of the largest in BC and conservatively estimated its size at 300 ha. Historically it was characterized by lush intertidal marshes that were drained by abundant and deeply incised tide channels. These channels served as arteries for nutrient and sediment transport and provided foraging areas and low tide refugia for fish and wildlife. The lower intertidal and the nearshore areas were home to dense stands of eelgrass, important rearing habitat for juvenile salmon and spawning habitat for Pacific Herring. Eelgrass is also an important carbon sink and is a major contributor to nutrient cycling in the estuary. The intertidal beaches and flats produce abundant clams and oysters, a staple in the diet of the Quw’utsun’ people.

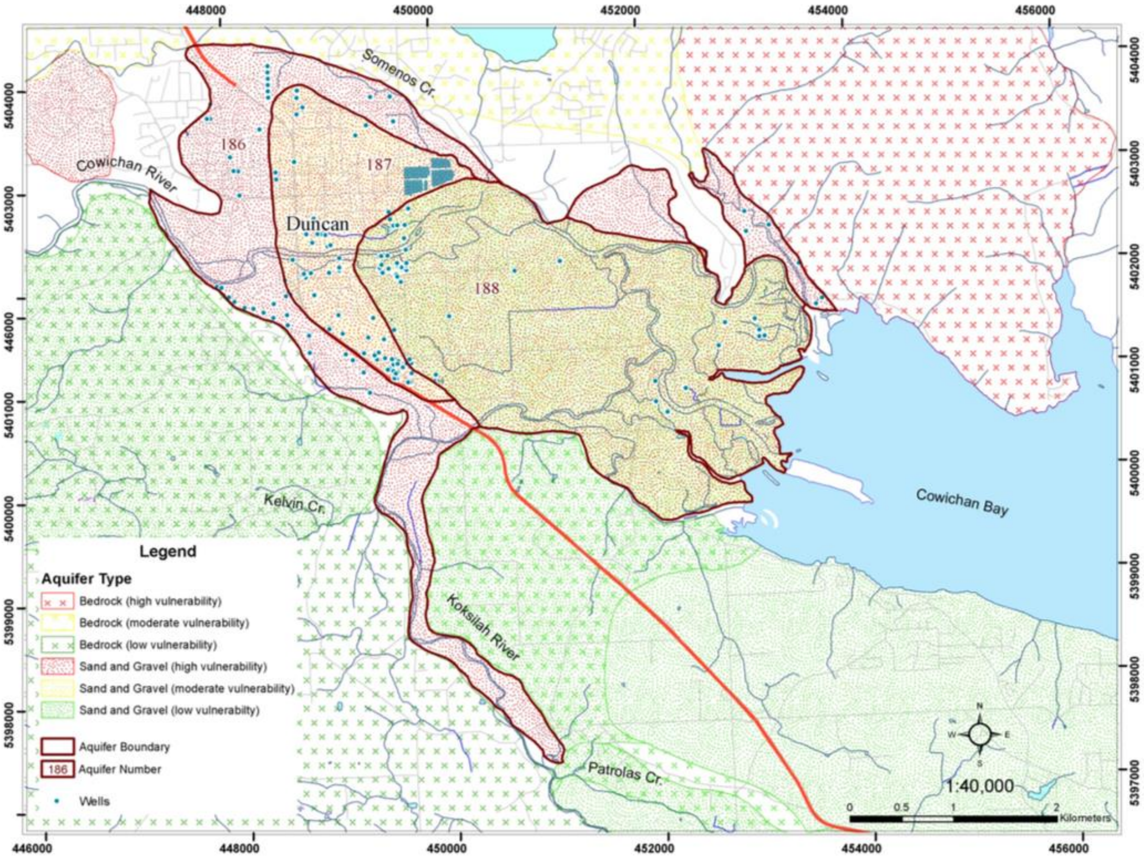

**Figure 4. Aquifers of the lower Koksilah and Cowichan rivers (Source: Barroso et al. 2013).**

The estuary was, and still is, an important staging area for salmon waiting at the mouths of the Koksilah and Cowichan rivers until water flows reach sufficient levels to allow passage upstream to spawning habitats. The estuary also provides habitat for migrating and overwintering waterfowl including Trumpeter Swans, Surf Scoters, Greater Scaups, and Buffleheads, as well as a variety of shorebird species. Great blue heron forage in the estuary year-round and have a large rookery adjacent to the estuary.

## Surficial Geology and Terrain

The Koksilah watershed is dotted with high points throughout the upper and middle portions of watershed, with elevations up to 1070 m on Waterloo Mountain to the west, 844 m on Mount Lazar to the south, and 892 m on the Koksilah Ridge to the east. Northeast of Koksilah Ridge, the terrain becomes flatter as it approaches Cowichan Bay.

A terrain inventory map at 1:50,000 scale shows that the upper and middle portions of the watershed are dominated by thin, colluvial veneers < 1 m thick to bedrock, and thick, till blankets > 1 m thick overtop bedrock (Figures 5 and 6). Colluvium is formed by pieces of bedrock and other surficial materials that weather away and are moved by gravity down steeper slopes. A colluvial veneer indicates areas where there are shallower soils. Till is surficial material left behind by melting glaciers which can be compacted or uncompacted depending on how it was deposited. Deep, uncompacted till has greater capacity to absorb or "buffer" precipitation, while compacted till and thin, colluvial veneers would have reduced capacity to quickly absorb and store precipitation (Brian Roberts, pers. comm.).

Loss of vegetation and forest cover in areas with thin, colluvial veneers can result in more surficial run-off and less groundwater recharge, altering natural hydrologic patterns and increasing sediment flow into streams.

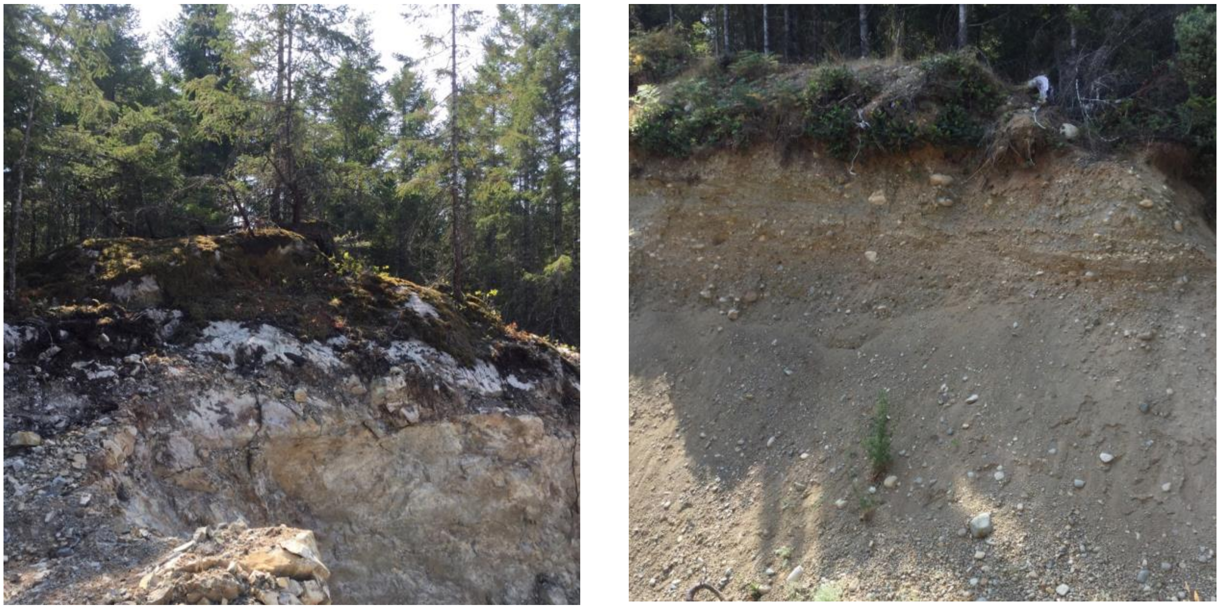

Figure 5. Soil depths and types in the Koksilah River watershed: colluvial veneer less <1m thick to bedrock (left), and till blanket >1m thick over bedrock (right).

## Terrain Sensitivity

Sensitive terrain includes areas that are naturally predisposed to mass movement (e.g., landslides) and disturbance (e.g., erosion, compaction). Within the Koksilah watershed, areas that may be sensitive to disturbance include those near the confluence of Glenora and Kelvin Creeks, and along the Koksilah River between Riverside Road and Kingburne Road. Both areas feature steeper slopes and mapped gullies (Guthrie 2005a), where there is greater potential for erosion (Figure 6). In the lower watershed, where Highway 1 bisects flatter terrain, glacial moraine and fluvial materials dominate. A pocket veneer of organic material underlies the area surrounding Dougan Lake. Areas featuring glacial moraine sediments are generally of a finer texture and may contain silt and clay, which are prone to erosion and instability, particularly in areas with steep slopes exposed to runoff (Brian Roberts, pers. comm.).

Potential for karst formations has also been identified in the Koksilah watershed (Figure 6). These sensitive limestone formations are found throughout Vancouver Island and can form caves, sunken streams and springs, and can provide habitats for uncommon plant and wildlife species (Pike et al. 2010). In that it is known that caves exist in the watershed, it is possible that karst formations do occur at some of these potential sites.

In general, the Koksilah watershed is considered to be at low risk for landslide due to relatively flat terrain and relatively low rainfall (Guthrie 2005b). Areas which may be more prone to landslide include steep stream banks and shorelines (Guthrie 2005b), as well as areas with potential for gullies and movement, as shown in Figure 6.

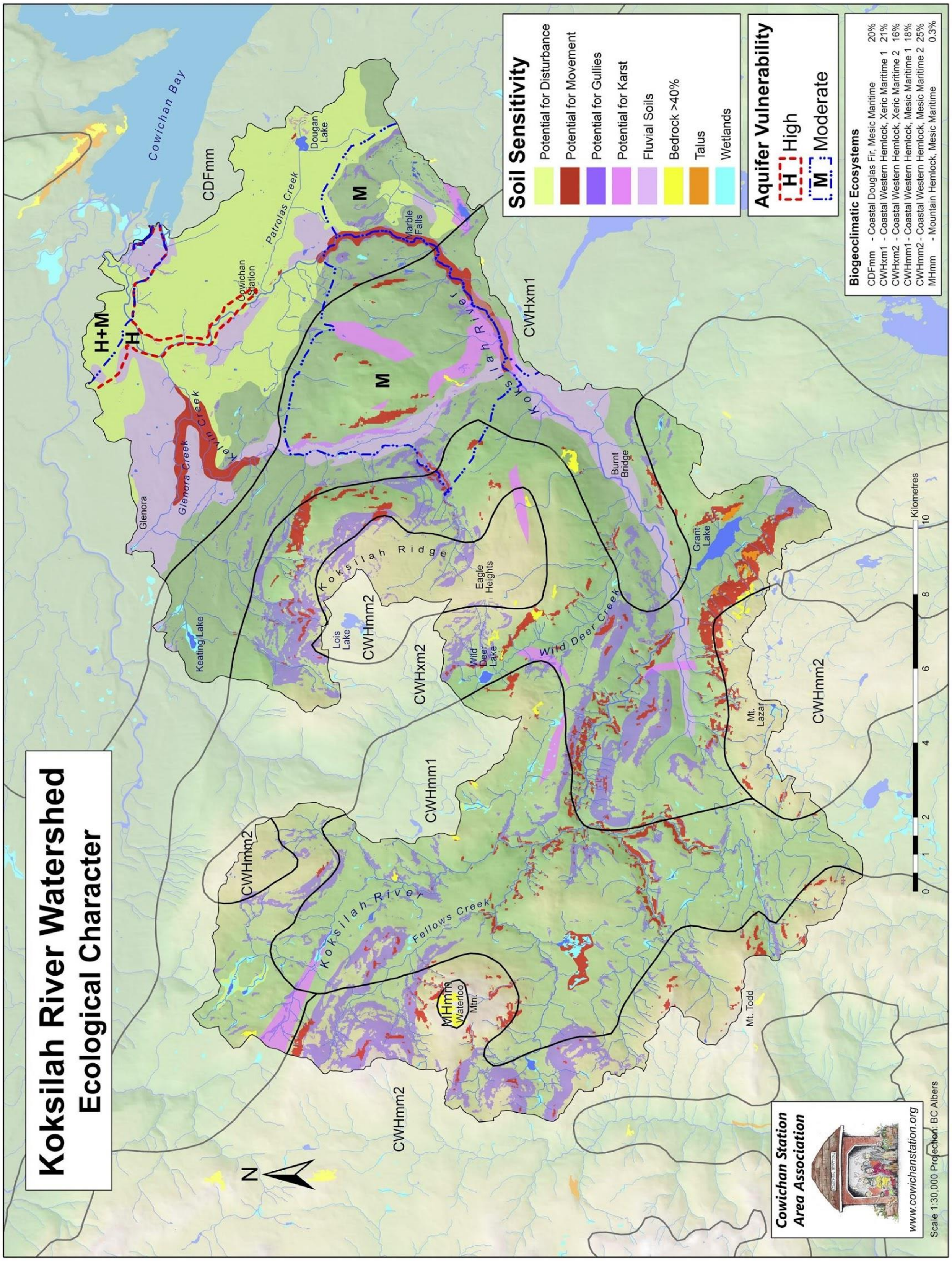

Figure 6. Ecological character of the Koksilah River watershed.

## Natural disturbance patterns

Figure 7. Fire-scarred standing dead tree in Koksilah Provincial Park.

Historically, the Koksilah landscape was constantly changing, shaped by natural disturbances that influenced plant and tree species composition, tree ages and sizes, and arrangement of dead standing and fallen trees, among other things.

Wildfire was a prominent natural disturbance shaping the landscape. Wildfire frequency in the Koksilah watershed has changed dramatically since the glaciers retreated. A warmer and drier climate developed across Vancouver Island, bringing with it regularly occurring wildfires that strongly influenced forest composition and structure (Brown 2015). These conditions remained until approximately 6,500 years ago, when the climate shifted to cooler, moister conditions. At that time, wildfires became displaced by wind as the dominant form of disturbance on the wetter western slopes of Vancouver Island (BC MOF and BC MOE 1995). Meanwhile on the drier eastern slopes of Vancouver Island, fire, although becoming infrequent, remained the dominant form of disturbance shaping forest ecosystems (BC MOF and BC MOE 1995).

In the more recent past, wildfire in similar forest types in the Pacific Northwest often followed prolonged periods of drought, occurring on average every 434 years (Hemstrom and Franklin 1982). Cooler, north-facing slopes and riparian areas would remain unburned for periods between 700-1000 years, while drier slopes burned every 350 years or so. As a result, forests over 100 years were common across the landscape. At lower elevations, frequent low-intensity fires occurred in the Cowichan Valley every four years on average, maintaining open forest and plains conditions (Bjorkman and Velland 2010). These fires were likely initiated by Indigenous people to manage food plants for themselves and forage for wildlife (Pellatt and Gedalof 2014).

Figure 8. Historic forests consisted of large trees that originated after wildfire.

Wildfires would burn moderate-sized areas and skip over others, such as riparian and sparsely vegetated areas. This fire behaviour created diversity in the landscape, leaving patches of mature and old forest, interspersed with young developing stands. The long delay between fires also resulted in a high degree of connectivity across the landscape (BC MOF and BC MOE 1995).

While wildfire has been the dominant disturbance type in the watershed, insects and other forest pathogens have also played a role in shaping ecosystems, creating a mosaic of age classes each with their unique structure. Root diseases such as laminated root rot (*Phellinus weiri*), would weaken and kill individual or small pockets of trees, usually Douglas-fir or grand fir (Allen et al. 1996). Biologically diverse pockets would develop consisting of standing dead trees, fallen trees, and dense shrub layers. Also common in the landscape, Douglas-fir beetle (*Dendroctonus pseudotsugae*) would be present at very low levels attacking individual or small pockets of stressed trees (Furniss 2014). On occasion, usually associated with drought or following windstorms that damage or kill large areas of trees, Douglas-fir beetle outbreaks lasting around three years would occur, killing large tracts of mature Douglas-fir forest.

## Ecosystem Composition, Structure and Function

Composition, structure and function are the three key elements of ecological character. Where "composition" is the variety of species present, "structure" refers to the type, size, condition, and spatial arrangement (e.g., uniform or clumped) of structures present (e.g., snags, fallen trees). The interaction between composition and structure results in "function", the work or processes carried out by an ecosystem. Examples of ecosystem functions include regulation of hydrologic cycles, maintenance of biological diversity, and purification of air and water (Franklin et al. 2002). "Function", in turn, influences composition and structure. All three elements are important to maintaining whole ecosystems and ecological integrity.

### Composition

Forest composition in the Koksilah watershed varied over time and space. At the broad spatial scale, elevation, topography and proximity to the coast strongly influenced the character of ecological communities—from the low elevation (i.e., <150 m) Coastal Douglas-fir zone to the mid elevation Coastal Western Hemlock zone and finally to the high elevation (i.e., >1000 m) Mountain Hemlock zone.

Lower elevation ecosystems (generally below 150 m) were likely a mosaic of prairie, plains, open forest, and dense forest (Bjorkman and Velland 2010). Large Douglas-fir trees with thick fire-resistant bark were dispersed throughout the fire-maintained plains and open forests.

The more densely forested areas at elevations above 150 m were typically comprised of Douglas-fir interspersed with western redcedar, grand fir, and small amounts of western hemlock. Douglas-fir tended to dominate the drier eastern slope ecosystems of middle and upper elevation forests due to the influence of wildfires (Brown 2015). Although these higher elevation forests received more moisture than lower elevation ecosystems, water deficits could still occur in the summer (Meidinger and Pojar 1991).

Higher elevation (i.e., >1000 m) ecosystems, rare in the watershed, were dominated by mountain hemlock and amabilis fir, along with some western hemlock and yellow cedar in the tree layer, and *vaccinium* species (e.g. blueberry, huckleberry) in the shrub layer (Green and Klinka 1994).

**Figure 9. Diversity in vegetation in the Koksilah River watershed.**

At a finer scale, composition also varied according to specific site conditions within broader ecological zones. Different soil types, moisture conditions, aspects, and finer scale differences in elevation across the Koksilah landscape influenced the types of developing ecosystems. For example, red alder, black cottonwood, and bigleaf maple could be found in moist and riparian sites, while arbutus and Garry oak occupied dry, rocky areas (Meidinger and Pojar 1991). A middle elevation dry south-facing slope, known as Eagle Heights, has a rare grassland meadow of Garry oak and arbutus trees, with extensive wildflowers and small caves (BC MWLAP 2001). Within and near this grassland meadow occur rare ecological communities such as Douglas-fir - Arbutus, Garry Oak - Ocean spray, and Arbutus - Manzanita (BC MWLAP 2001).

Natural disturbance further influenced ecosystem composition and structure in varied ways depending on the intensity and frequency of disturbance. Following wildfire, many forest ecosystems would start as even-aged Douglas-fir forests, sometimes taking over 100 years to establish, growing quickly at first and then more slowly until the canopy closed (Brown 2015; Winter et al. 2000). Western white pine was also common in the main canopy of some Koksilah forests (Collis and Alexander 1966), as another post-fire species that persisted into later stages of secondary succession (BC MOFR 2015). Gradually these forests would develop into more complex, uneven-aged forests, following unique developmental pathways depending on site-specific conditions and the nature of disturbance. For example, Douglas-fir trees would die and provide canopy gaps for more light to reach western redcedar and western hemlock seedlings growing in the understory. These shade-tolerant species would then “release”, or grow more quickly,

**Figure 10. Rock outcrop adjacent to the Trans Canada Trail in the Koksilah River watershed.**

and mature to become part of the main canopy. If the gaps were big enough and allowed sufficient light to reach the forest floor, shade-intolerant Douglas-fir seedlings would recolonize the openings and become the dominant species (Getzin et al. 2006).

## Structure

As a new forest establishes following a wildfire, different processes occur influencing the development of different structures over time (Franklin et al. 2002). Competition between trees, as well as disturbances such as low intensity fire, landslides, wind, insects, and disease are just some of the processes constantly at work influencing forest structure. Animals, decay fungi, and wood decomposing insects are also at work subtly changing the way the forest looks. Even though change is always occurring, large living trees, standing dead trees, and fallen trees are almost always prominent features in all forests, from the very young to the very old. Even following the initial wildfire, these legacy structures persist to some degree (Franklin et al. 2002).

**Figure 11. Structural diversity within the Koksilah River.**

Other structures that would have been encountered in forests in the Koksilah watershed include horizontal layers of understory trees and shrubs, mature trees with dead tops or large limbs, and soil pits and root wads resulting from fallen trees. Structural diversity at the landscape scale included deciduous patches, areas missed by the fire (e.g., riparian areas or cool aspects) or large pockets of windfall.

The presence of some structures changes over time making certain forest phases more structurally diverse (Franklin et al. 2002). For example, large fallen logs are often abundant in the newly regenerating forest, but as the forest matures, they decompose blending into organic soil layers. As time continues, some of the old trees die and large fallen logs once again appear on the forest floor. As another example, when a young forest matures and the canopy closes, light levels and wind reduce, temperatures moderate, and humidity increases, changing the abundance and species of shrubs, herbs, lichens, and insects, with some increasing and some decreasing (Franklin et al. 2002).

As Douglas-fir forests approach 200 years, structural diversity begins to maximize (Franklin et al. 2002). Large old trees die producing large standing dead trees and dead fallen trees. New patches of trees begin to grow in the newly formed gaps. Crowns of shade-tolerant young trees, such as western hemlock and western redcedar, reach the overstory canopy of the Douglas-fir, creating a continuous canopy from near ground level upwards. Forests consist of irregularly spaced large, old Douglas-fir trees with deep crowns, along with layers of various sizes and ages of shade tolerant species in the understory (Winter et al. 2000). At around 800 years, if another wildfire has not occurred, the Douglas-fir begins to die out in greater numbers, and a hemlock-cedar forest develops.

**Figure 12. Large trees are important structures in the forested landscape.**

## Function

How ecosystems function is both a product of the interactions between ecosystem composition and structure. Since composition and structure change over time, so do the range of functions. Marcot (2017 and references therein) describes the many important functions of standing dead trees and dead downed wood in mature and older coastal forests. Standing dead trees are used by cavity nesting birds, bats, and other species for breeding, foraging, and roosting. Over a quarter of all vertebrate species in Coastal Douglas-fir and Coastal Western Hemlock forests (as found in the middle and upper elevations of the Koksilah watershed) require cavities for breeding (Bunnell et al. 1999 and references therein). The sloughed bark that accumulates at the base of trees provide habitat for snakes, lizards, and amphibians. Hollow logs, standing and fallen, provide denning and cover for many fur bearers including black bears, fisher, and marten (Marcot 2017). Trees with hollow butts often contain ants, the main diet of Pileated Woodpeckers, which hammer their way into the hollow core of trees to reach the ants. Dead and dying trees also provide habitat for lichens, invertebrates, and fungi.

Downed wood provides travel routes and breeding habitat for many wildlife species from small invertebrates to large Black Bears. Large logs tend to hold moisture better than small logs and, when shaded, hold five times more moisture than exposed logs providing preferred habitat for amphibians (Bunnell et al. 1999). Downed trees also act as nurse logs, elevating new seedlings above competing vegetation and providing a concentrated source of water and nutrients (Marcot 2017).

Figure 13. Riparian forests are especially diverse and valuable ecosystems.

Large downed wood can hold large volumes of water and, in one study, held 25 times more water than that held in the surrounding soil (Marcot 2017). Dead wood contributes to healthy soil ecosystems by adding non-compacted soil structure, and by supporting the biological activities of mycorrhizal fungi, insects, and fungi that promote the release of nutrients. Dead wood also helps to stabilize soils and reduce surface erosion by slowing moving surface water and by acting like a sponge absorbing extra surface moisture (Marcot 2017). Also, the organic soils that support the downed wood allows heavy rainfall to rapidly infiltrate below such that surface run-off is unlikely (Moore and Wondzell 2005).

Very large fallen Douglas-fir logs decompose slowly, possibly over centuries, providing long-lasting reservoirs for water, mycorrhizal fungi, microbes, and nutrients. These reservoirs make water available to vegetation and important ectomycorrhizal fungi (i.e., fungi that act as root extensions for plants with whom they have symbiotic relationships) during periods of drought (Marcot 2017). The standing dead trees and fallen logs combined made up as much as 30% of the biomass in coastal old growth forests, reaching up to 1000 tonnes per ha (Church 1994).

Fallen trees in riparian forests can add complexity to stream channels. In-stream, the fallen logs provide cover for fish and amphibians, while riffles produce spawning habitat. The mixing of water travelling over the logs help aerate the water improving oxygen levels in the river (Bunnell et al. 1999). Dead trees that fall into the river can create log jams that alter water flow, changing the character of lower stream sections by creating complex and diverse riparian ecosystems.

Old trees with their deep canopies regulate many conditions in the forest. They intercept somewhere between 21% and 35% of annual rainfall, according to results from three studies on Vancouver Island (Hetherington 1994; Hudson

Figure 14. Understory plants are one of the multiple forest layers that intercept and slow precipitation.

2003 and references therein). This reduces the rainfall reaching the ground especially in spring and summer months, which can moderate streamflow and potential for surface erosion during big storms, though other variables are also involved. Deep canopied trees also moderate air temperatures and reduce light intensity affecting the microclimate in the forest (Bunnell et al. 1999). Together with the large volume of fallen dead wood and deep organic soils, the old growth trees contribute to regulating water on and in the soil, keeping moisture available for periods of summer drought. In addition, in the winter, the large canopies intercept snow making it easier for wildlife to travel and find winter forage.

## Ecological Character - Understory Plants

The diverse ecosystem types in the Koksilah watershed provided a wide range of habitats able to support many plant species and ecological communities. In the previous section, the discussion focused primarily on the function of trees in these ecosystems. This section focuses on the functions provided by some of the understory plant species that occurred in the Koksilah watershed, primarily for wildlife, water, and the Quw'utsun' people.

The many shrub species provided breeding habitat for songbirds and grouse (Huggart et al. 2009). Berries like salmonberry, salal, and huckleberry were important food sources for many bird and mammal species. Bears require large volumes of berries for adequate weight gain prior to hibernation (Bunnell et al. 1999). Deer and elk would forage on shrubs as well as ferns, grasses, and other plants. Larger shrubs would provide safety cover for large animals like deer, while ferns and other low plants would serve as good cover for ground-nesting birds, small mammals, amphibians, and ground-dwelling insects. Fallen leaves from the shrubs and other plants produced moisture-holding organic matter and habitat for insects and fungi (Huggart et al. 2009), all of which are important for building healthy soils.


**Figure 15. Vanilla leaf in a riparian forest.**

In riparian areas, in addition to wildlife habitat, the herb and shrub layer also had an important role in maintaining water quality and fish habitat. Overhanging shrubs, such as willow and dogwood, shaded streams, helping to moderate water temperatures. The vegetation would intercept heavy rainfall, reducing the potential for surface water to carry sediment to streams. Roots stabilized stream banks, keeping sediment out of streams and holding large logs embedded in stream banks. Streamside vegetation was also an important source of organic matter, dropping leaves and insects into the water for fish to eat and adding nutrients to the aquatic ecosystem.

### *Indigenous use of plants*

*(An important note to the reader: Although the information cited within in this section is attributed to published works by individuals who are not of Quw'utsun' or any other Coast Salish ancestry, it is the Indigenous knowledge holders regarding indigenous plant use and any other subsequently mentioned traditional practice, to whom credit is due.)*

All ecosystems and the plants they host have their place in indigenous culture. Examples of plant use by and importance to Quw'utsun' people, described by Turner (1998) and Hill (2001), provide a glimpse into the role of plants in traditional life. The following examples highlight the full range of ecosystems and species that were, and still are, relied upon as part of a way of life, both material and spiritual. The following paragraphs describe some of the indigenous uses, past and present, of plants found in the Koksilah watershed.

Cedar, a very important traditional species, has many uses. Along with Douglas-fir, cedar is used to make stakes for fishing weirs that are tied together with wild cherry bark twine (Hill 2011). The roots and fine branches of cedar are very strong and flexible therefore useful for making fishing nets. The inner bark is used for weaving baskets, mats, clothing, and rope, while the inner cambium beneath the bark is collected in spring and eaten. Whole cedar trees are used for making planks for longhouses as well as carving canoes, and totem and mortuary poles (Hill 2011).

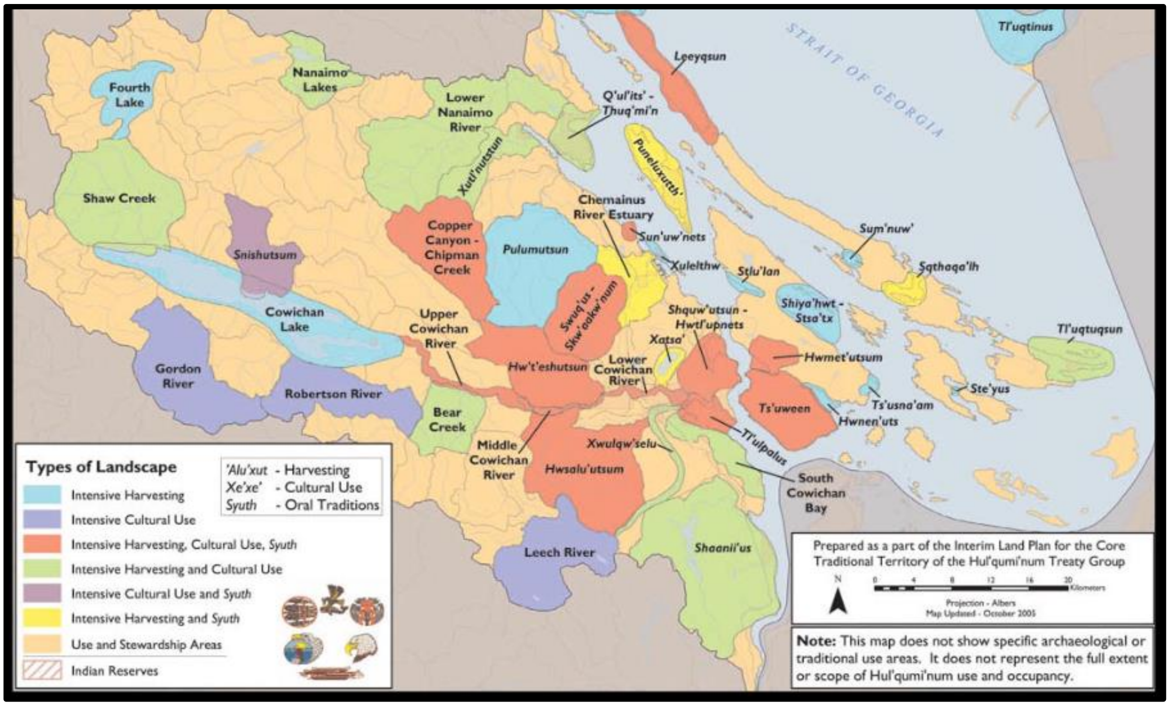

**Figure 16. Traditional use areas of the Cowichan Nation (Source: Shxunutun's Tu Suleluxwtst, Interim Strategic Land Use Plan for the Hul'qumi'num Core Traditional Territory).**

Several tree and plant species have strong wood and fibres, making them especially valuable. Yew wood is very strong therefore useful for making fish hooks, harpoon shafts, and paddles (Hill 2011). Dogwood is used for making bows and arrows while ocean spray wood is preferred for making sticks for barbequing salmon, cambium scrappers, and halibut hooks (Turner 1998). Bitter cherry bark is also very strong and is used for making twine, nets, and fishing line. Wood collected from red alder and maple was, and still is, used for smoking fish while their cambium is collected and dried for eating (Hill 2011).

Rushes, cattails, and grasses are dried and woven into mats using long needles made from ocean spray and yew wood. Mats are used at home, to cover food and supplies, placed on cedar frames as temporary shelters when traveling, and are also been given away at ceremonies.

Baskets were, and still are, made from reeds and bark of cedar, willow, and bitter cherry. They have many uses including collecting food plants such as camas bulbs. Other food plants collected in the Cowichan Valley include blue elderberry, strawberry, trailing black berry, salmonberry, cranberry, cow parsnip, black cap, salal, Labrador tea, Indian plum, and mint.

## Ecological Character - Wildlife

The natural disturbances in the Koksilah landscape created diversity in habitat elements, supporting different life stages of many wildlife species. The large canopies of the old trees provided abundant insects for foraging birds, large branches for nesting platforms, large cone crops for red squirrels and other seed foragers, and snow interception that provided winter habitat for deer and various mammals (Huggart et al. 2009). Some of these large trees would eventually die and become large standing dead trees, providing dens for bears and other carnivores, breeding sites for cavity-nesting birds such as woodpeckers and small mammals, and roosting sites for bats (Bunnell et al. 1999). After dead trees fell, they would become cover for small mammals, breeding habitat for some amphibian species, and growing sites for fungi and invertebrate species (Huggart et al. 2009). Deciduous patches also provided nest trees for numerous species, while small mammals, amphibians, and invertebrates thrived in the deep litter layer of the forest floor (Huggart et al. 2009). Over time, the structures in these forests would change, and along with this, species using them would change (Bunnell et al. 1999).

**Figure 17. Species of special concern, Western Toad (*Anaxyrus boreas*).**

Riparian forests, in particular, are very important for wildlife. These forests surrounded Koksilah River, the numerous smaller creeks and ephemeral streams, wetlands, and small seeps. The greater diversity of habitat elements (e.g., large trees, dead trees, downed wood, shrubs, deciduous trees, abundant forage, and insects) in riparian forests supports greater wildlife abundance and more successful reproduction (Bunnell and Dupuis 1995; Bunnell et al. 1999). This diversity also supports greater richness of wildlife species with over half of all forest-dwelling vertebrate species occurring in riparian areas (Bunnell and Dupuis 1995; Bunnell et al. 1999).

In the Koksilah watershed, some species like American Beaver, River Otter, Mink, American Water Shrew, Western Toad, Northern Red-legged Frog, Western Red-backed Salamander, Rough-skinned Newt, and Painted Turtle would spend most of their life in the riparian forests[3]. Large cavity nesters, such as Western Screech Owl, would live in riparian forests

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[3] The species listed in this section may have occurred in the Koksilah watershed based on current information in the BC CDC database: B.C. Conservation Data Centre. 2018. BC Species and Ecosystems

using the large standing dead trees for nesting and feeding on the small mammals living in the dead and downed wood (BC MOE 2013).

Other species would use many habitat types and only spend part of the time in riparian forests. Pileated Woodpecker would likely nest in upland areas but regularly return to riparian forests to forage (Bunnell and Dupuis 1995). Bats would roost outside riparian areas but often forage over open water (Bunnell et al. 1999). Marbled Murrelet and Northern Goshawk would nest on platforms provided by strong limbs of large trees in riparian areas but use other ecosystem types as well. Wandering Salamanders require moist soils and well-decayed dead wood and would therefore often be found in riparian forests (BC MOE 2017). Wide ranging carnivores such as Black Bear, Cougar, Wolf, and Wolverine, and wide ranging herbivores such as Roosevelt Elk and Black-tailed Deer, would also spend part of their time in riparian forests. Riparian corridors were important travel corridors for these species.

The riparian forests and waterbodies they surrounded provided, and still provide, the Quw'utsun' people with important resources (Hill 2011). Waterfowl provided eggs and were harvested for meat and feathers. The duck down was used to add softness to blankets while the feathers were used to decorate garments. Beaver was harvested and their incisors were used as woodworking tools. Mink were known to have a powerful spirit and were used by shamans in healing rituals (Hill 2011).

Although very different from riparian forests, the dry grassland meadows and Garry Oak ecosystems in the Koksilah watershed provide habitat for a unique and diverse group of wildlife species. In the Pre-Contact era, Western Bluebird, Lewis's Woodpecker, and Long-billed Curlew, and Common Nighthawk were likely present. Raptors would have included Peregrine Falcon, Prairie Falcon, Rough-legged Hawk, Short-eared Owl, and Barn Owl. Sharp-tailed Snake would have been found in rocky dry areas interspersed in the grasslands.

## Ecological Character - Fish

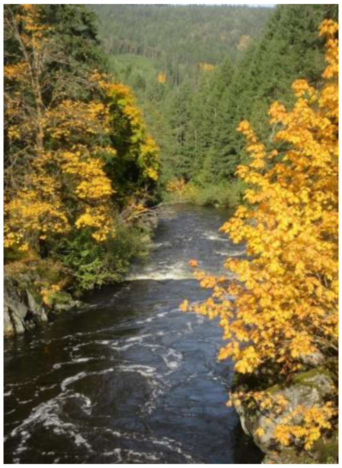

**Figure 18. Koksilah River in Koksilah Provincial Park.**

According to Brown (2015), salmon likely appeared in the Koksilah watershed around 6000 years ago. Prior to this time, conditions were likely too warm and dry to support adequate spawning habitat. As the climate cooled and precipitation increased, larger streams began to provide required habitat (Brown 2015). The glacial deposits ensured a constant supply of spawning gravel, while moderate turbidity provided hiding cover from predators (Church 1994 and references therein).

Based on Tutty (1984), fish species likely included Coho Salmon, Chinook Salmon, Chum Salmon, Steelhead, Cutthroat Trout, and Dolly Varden. Marble Falls, located 21km up Koksilah River, would have provided a migration barrier, limiting movement of most salmon to potential spawning habitat further up in the watershed while the strong swimming Steelhead would not have been stopped by the falls.

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Explorer. B.C. Minist. of Environ. Victoria, B.C. Available: http://a100.gov.bc.ca/pub/eswp/ (accessed Jun 10, 2018) or were confirmed in Koksilah Provincial Park (BC MWLAP 2001).

While the diversity and abundance of fish species in the Koksilah River system was not as rich as in the neighbouring Cowichan River (Abraham Joe, as told to Rozen, 1985), the Koksilah River was, and still is, an important source of food fish for the Quw'utsun' people. Coho and Steelhead are both noted to have been "abundant" (Rozen, 1985). Trout were also present in the early days of Quw'utsun' history.

Chief William Seymour has been quoted as saying, "Every year the Quw'utsun' people were assured great riches as the spawning salmon returned to the Cowichan, Koksilah, and other rivers and streams. Our Elders carefully managed the harvest and sharing of fish through the use of fish weirs, a gift from the First Ancestor Syalutsa. The weirs ensured abundant food for our people to eat, while allowing enough fish to reach the spawning beds to ensure future returns. Other resources were equally managed with an eye to future abundance. The watershed was healthy and sustained us" (reported by CWHCI 2017).

## Part 2: Condition of the Koksilah River Watershed

The above narrative describes what the Koksilah River watershed may have been like during historic times. Now we switch to a look at how the watershed has changed since the onset of European settlement. This begins with an overview of settlement patterns and is followed by several subsections detailing how settlement affected various values in the watershed.

### Influences of Settlement on Original Character

### Colonization

**Figure 19. View of Cowichan Bay and the mouth of the Koksilah River between 1900-1920. (Source: Cowichan Valley Museum and Archives, CVM 1990.7.21.1)**

In this section we attempt to convey some of the key historic events that resulted in the alteration of original character in the Koksilah watershed to its present day condition. It is important to note that ours is not an exhaustive account of events. In particular, we acknowledge that we do not even begin to understand the impact of European settlement on the Quw'utsun' people and land management in the watershed.

Land privatization on Vancouver Island began with colonization, as fee simple ownership did not exist prior to European settlement. While the roots of British colonization extend as far back as the mid-1700s, it is arguable that the following series of key events in the mid-1800s form the origins of Indigenous land appropriation and privatization in the Koksilah watershed, along with most of southern Vancouver Island:

1) The granting of Vancouver Island to the Hudson's Bay Company (HBC) for safeguarding British interests in 1849 (Encyclopaedia Britannica 2018);

2) The start of the commercial fishery in the 1860s (Hill 2011);

3) The barring of Indigenous people from preempting land, which would last until the mid-1950s (Hill 2011);

4) The establishment of the federal *Indian Act* and creation of Indian Reserves;

5) The conveyance of Vancouver Island from the HBC to the British Crown in 1867 (Hill 2011); and

6) The E&N railway grant in 1883, resulting in most of the area not already preempted for farming or settlement, being granted to Robert Dunsmuir as private land (Figure 20). Large parcels were subsequently sold by Dunsmuir to forestry companies in order to fund building the railway (University of Victoria undated).

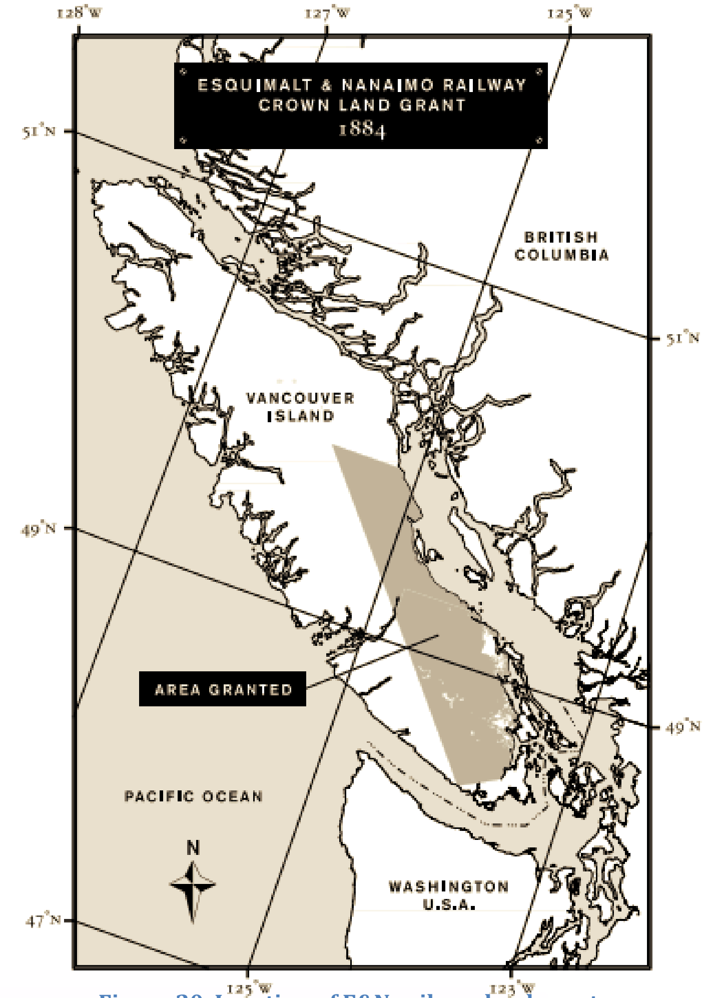

**Figure 20. Location of E&N railway land grant (Source: HTG 2007).**

Several sources refer to the impact of privatization and loss of access to lands on the Quw'utsun' people such as, for example, the desecration and permanent alteration of spiritual sites following land development (Thom 2005) and the loss of traditional food hunting, gathering, and cultivation sites (Hill 2011 and references therein). It is equally important to note how the exclusion of Indigenous people from their traditional territory has affected the ecological composition, structure, and function of the landscape.

The maintenance of Garry oak ecosystems is perhaps one of the best known examples of Indigenous land management in British Columbia. While Garry oak ecosystems originated in response to warmer and drier conditions in geologic history, evidence shows that they persisted, even as the climate cooled, as a result of cultural burning by Indigenous people (Pellatt and Gedalof 2014). For thousands of years, fires were ignited in late summer and fall to create conditions favourable for food resources such as camas, berries, and seeds. These resources were encouraged by suppressing the growth of Garry oak and other tree species, maintaining a savannah type of environment. Colonial policies such as the *Bush Fire Act* of 1874, implemented by European settlers to restrict cultural burning, resulted in less burning by Indigenous populations. Colonization in general transformed Garry oak ecosystems from grassland savannah to forest (Pellatt and Gedalof 2014 and references therein).

Another example is the alteration and loss of wetlands. This topic has received less attention, perhaps owing to the fact that wetlands were primarily managed by Indigenous women whose work may have received less recognition by patriarchal colonists (Hill 2011). Families' exclusive harvest rights to plots of moisture-loving plants were maintained by clearing adjacent land (Hill 2011), presumably to reduce competition from other plants. Historic and contemporary wetland drainage and watercourse diversions for agricultural, residential, commercial and resource development reduced the extent of conditions needed for such wetland species to exist.

Both examples highlight ways in which European settlement and, in particular, the privatization of land have disrupted long established ecological relationships where Indigenous land management play an integral role. Unlike "hard" archaeological evidence such as fire pits and longhouse sites, wetlands are not as easily recognized as historically significant eco-cultural features. Consequently, the protection of wetlands is limited by the relatively marginal recognition they are given in contemporary land use policies, many of which are rooted in 19th century colonial values (Hill 2011).

## Land Development

### *Agriculture, Mining, and Forestry*

The onset of agriculture, mining, and forestry in the Koksilah watershed are closely tied. Farming was strongly encouraged by the British government as part of colonization, leading to the development of "a series of little settlements along the one highway from Chemainus in the north to the South Cowichan" (Watt 2000). Correspondence dating back to the 1890s also refers to farming by Quw'utsun' people. For example, a letter sent in 1891 to the B.C. Indian Superintendent describes the loss of barns and crops that belonged to Quw'utsun' people living on reserve, as well as the loss of reserve land, due to a log jam thought to be caused by logs being transported down the Cowichan River (O'Donnell, 1988).

Early dairy farms (i.e., circa 1860) supplied larger communities up island where mining and forestry were already quite active, as well as to Victoria (Watt 2000). The establishment of the Cowichan Creamery is thought to have been the catalyst for "real farming and cattle raising in the Cowichan Valley" (Watt 2000), and likely set the stage for the expanse of dairy farmland present in the Koksilah watershed today. Currently, agriculture covers nearly 15% of the Koksilah watershed occupying low elevation areas (Figure 21).

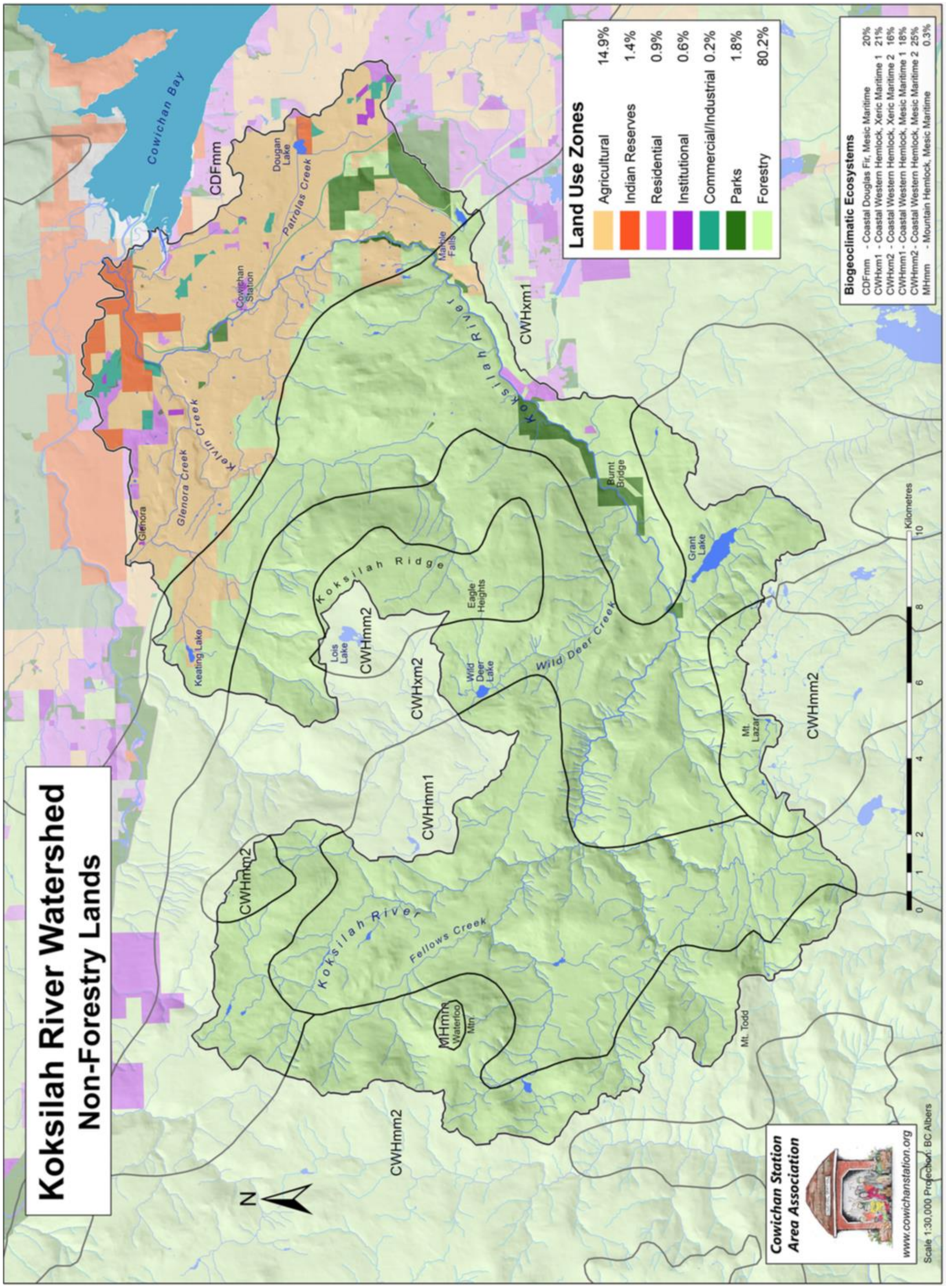

Figure 21. Types and distribution of non-forestry lands in the Koksilah River watershed.

Figure 22. Farm near Cowichan estuary c. 1900 (Source: Watt 2000, BCARS G06896).

Mining began in the Koksilah watershed by the early 1900's, including the King Solomon (nicknamed "Kinsol") Mine (copper and silver) located near Humes Creek. The Directory of Vancouver Island and Adjacent Islands also lists a stone quarry, sawmill, and ranch on Kelvin Creek (along with other businesses) located in the Koksilah and Cowichan Station settlements in the year 1909 (Provincial Publishing Company 1909).

Figure 23. Kinsol trestle and logging train above Koksilah River, c. 1954 (Source: Cowichan Valley Museum and Archives, CVMA 2006.8.5.1).

In 1920 the Kinsol Trestle railway bridge was completed, opening up the middle and upper parts of the watershed to logging. As noted above, much of the Koksilah watershed was granted, without the consent of Quw'utsun' people, to the E&N Railway Company in exchange for construction of the railway. E&N later subdivided and sold this land to other private interests, advertising "tracts of valuable timber" adjacent to the railway (Hul'qumi'num Treaty Group 2007).

While some lands were purchased by smaller companies, most of the Koksilah watershed is now held by fewer than a handful of large forestry companies (Hul'qumi'num Treaty Group 2007). At one time, one of these companies was MacMillan Bloedel. In 1998 MacMillan Bloedel announced their intent to phase

Figure 24. Douglas-fir near Koksilah, c. 1929, photographed by BC Forest Service (Source: BC Archives, NA-05895).

out clearcutting and move toward a variable retention silvicultural system (Bunnell and Dunsworth 2009). Despite being designated "Timber Zone" (emphasizing commercial timber production) by MacMillan Bloedel, the Koksilah watershed was intended to be managed using a variable retention approach with a target of 28% of the productive forest to be retained in reserves (Bunnell and Dunsworth 2009). In 1999, MacMillan Bloedel was purchased by Weyerhaeuser. Then in 2005, Weyerhaeuser sold its BC coastal private timberlands, including most of the private forest land in the Koksilah watershed, to Island Timberlands (Island Timberlands 2009). Island Timberlands private land holdings occupy nearly 50% of the Koksilah watershed (Figure 26). The second largest private forest landowner in the watershed is TimberWest, who manage 15% of the watershed. Google Earth images indicate that the practice of variable retention forestry has been abandoned and clearcut logging has continued as the primary silvicultural system in the Koksilah watershed (Figure 25). Since 2018, the management of both Island Timberlands and TimberWest land holdings has been carried out by a single entity, Mosaic Forest Management.

Current land use designation is illustrated in Figures 21 and 26. Forestry is the main land use, occupying 80% of the watershed. Most forest management is on private land with only 6% of the watershed in the provincial Crown forest, managed by BC Timber Sales (BCTS) and within two Woodlot Licences.

Figure 25. Recent clearcut logging in the Koksilah River watershed.

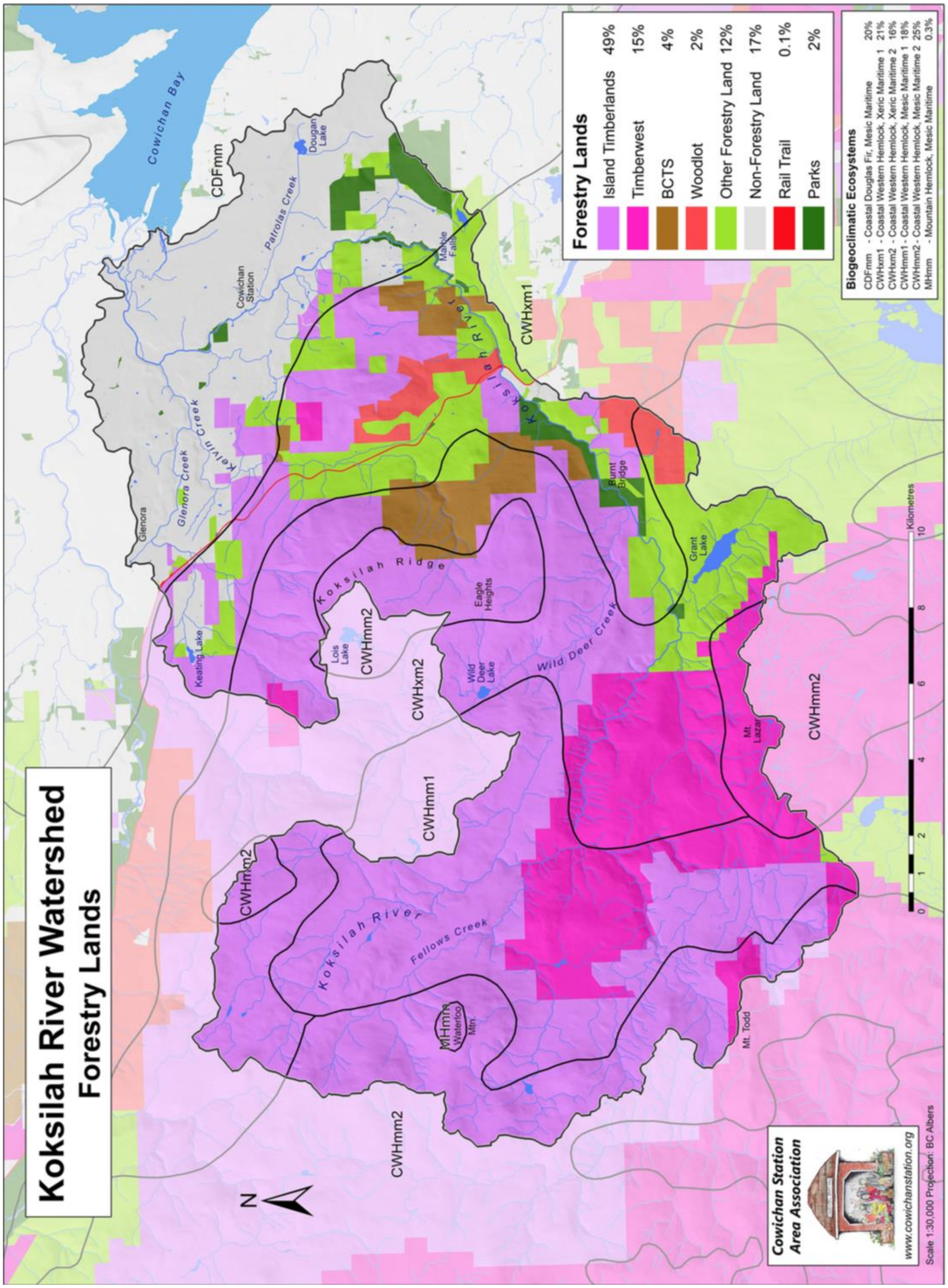

**Figure 26. Forestry lands in the Koksilah River watershed.**

## *Cowichan Estuary*

The Koksilah/Cowichan estuary is a both a contributor to, and indicator of, overall watershed health (Figure 27). As earlier mentioned, the eelgrass beds of the estuary provide important rearing habitat for juvenile salmon, as a source of forage and as protection from predators, so that they may return as adults to spawn in natal streams of the Koksilah watershed. The capacity for the estuary to support salmon, however, has declined with the onset and expansion of industrial, agricultural and residential activities near, or within, the estuary. The capacity of the estuary to provide shellfish that are safe for human consumption has also declined, an outcome that has had significant impacts on the Quw'utsun' people, who have long relied on shellfish as a traditional food source.

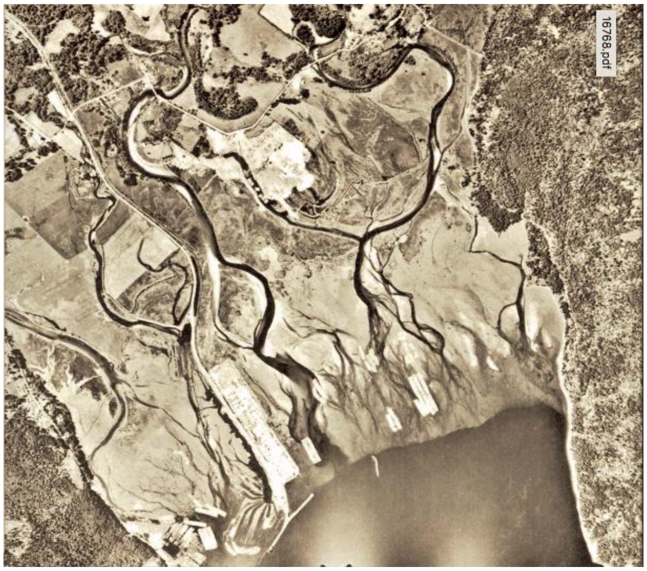

**Figure 27. Aerial view of the Cowichan estuary in 1972 (Source: Bell and Kallman 1976).**

Around the middle of the last century when development in the Cowichan Valley accelerated, pressures emerged in the Cowichan estuary causing damage to this sensitive ecosystem (Lambertsen 1987) (Figure 28). Habitat and habitat function was lost as intertidal areas were drained, diked, and filled for agriculture and various commercial and industrial uses. Log handling and storage created negative impacts such as: shading and disturbing estuary sediments, leaching of toxins, and a build-up of bark and wood material (Bell and Kallman 1976). The purchase and expansion of the sawmill by then-owner, Doman Industries led to infilling a portion of the estuary with sawmill waste, known as "hogfuel", whose leachates are among other sources of legacy pollution (Bell and Kallman 1976).

The population living adjacent to the estuary also grew at an astounding annual rate of 8.8% between 1966 and 1971 (Bell and Kallman 1976). High levels of fecal coliform counts led to the implementation of a permanent sanitary shellfish harvesting closure by the Department of Fisheries and Oceans, attributed to sewage discharge into the Cowichan River (still active), and Cowichan Bay (no longer active), as well as from land surface run-off (Bell and Kallman 1976).

In an attempt to stop further damage and restore lost habitat, in 1986 the BC provincial government issued an Order in Council giving the Cowichan Estuary Environmental Management Plan the force of law and requiring its implementation (Lambertsen 1987). The authority of this plan prevented issuance of any additional licences, permits, or powers for activities that could cause damage to the estuary. Land designations established areas for continued industrial and agriculture use as well as areas for habitat management and conservation. Agreements were put in place with key industrial users of the estuary to change land and water use activities in support of estuary recovery. An agreement was also established with Canadian National Railway, the primary fee simple owner of most of the land within the intertidal zone, ensuring that most of the estuary would be managed for

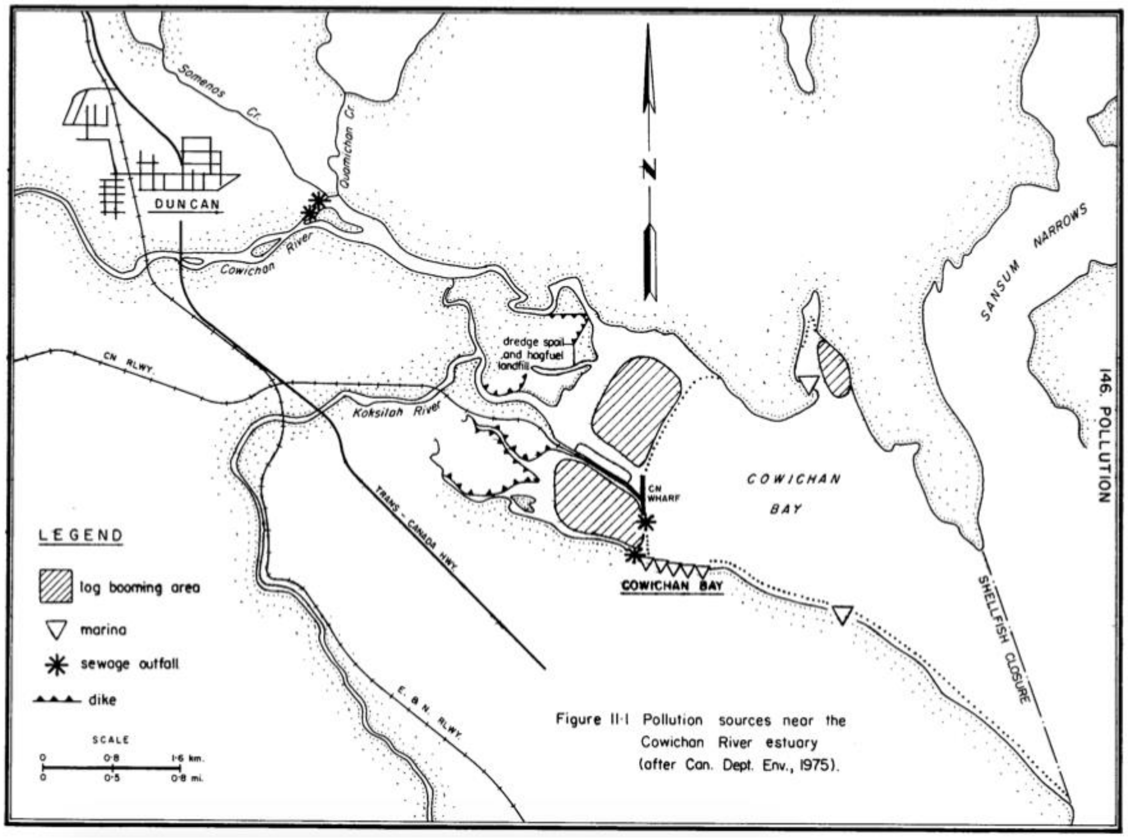

**Figure 28. Sources of pollution and disturbance in the Cowichan estuary, as of 1975 (Source: Bell and Kallman 1976).**

habitat, though it also allows for some current and future industrial needs, including a possible port expansion.

Several restoration initiatives have been completed to-date, including a reduction in log storage from 49% to 19% of the estuary (Lambertsen 1987), eelgrass re-planting and increased access to juvenile salmon habitat through breaching the causeway that divides the Cowichan estuary. A shellfish harvesting closure has continued to be in place for Cowichan Bay since 1973. Some progress has been made by the Cowichan Watershed Board working in conjunction with farmers to reduce coliforms through improved manure management and by the CVRD who have implemented regulations requiring sewer connections for float homes in Cowichan Bay.

### *Urban Development*

As mentioned above, the Koksilah watershed is located primarily within the Cowichan Valley Regional District (CVRD), which was established in 1967 in response to the rapid population growth that accompanied greater resource extraction and the consequent need for more land use planning and services (British Columbia, undated). In 1994 the first Official Community Plan (Area E) concerning the Koksilah watershed was developed and included constraints limiting the extent and intensity of urban development across the watershed. This included 12 ha and 80 ha minimum parcel sizes for areas allocated as part of the Agricultural Land Reserve and forestry, respectively (CVRD 1994).

In an effort to contain and concentrate growth, development in some areas intensified. One such area is the Koksilah Business Park, which is located within the natural floodplain of the Cowichan and Koksilah rivers and forms part of the Sh-hwuykwselu (Busy Place Creek) sub-watershed. Prior to industrial development the area was used for agriculture and in the 1950s Sh-hwuykwselu was re-routed to accommodate agricultural drainage (O'Donnell

2018). Demand for light industrial land to support agriculture, forestry, and service sectors increased significantly between 1984 and 1994 (CVRD 1994), leading to the dense industrial development present today. While concentrating growth in this area has offered benefits, such as more convenient servicing and reducing conflicts between neighbouring land users, concerns have been raised over the water quality and ecosystem integrity of Sh-hwuykwselu. Flooding is a primary concern along with salmon habitat quality and water quality. Large algal blooms are visible in the creek, invasive American bullfrogs have recently appeared in the area, and volunteers have recorded very low salmon counts (O'Donnell 1994). A stormwater management and mitigation plan is under development for Sh-hwuykwselu, but is not yet available.

Future population growth is projected to be slow, at a conservative rate of 1% over 25 years, across the Cowichan-Koksilah Official Community Plan area. The high proportion of land zoned as agriculture and forestry will likely continue to limit urban development across most of the watershed. Areas surrounding the lowest parts of the Koksilah River however are currently zoned for residential, light industrial and commercial uses.

Along with this agricultural, industrial, and residential development, follows the demand for water use. Surface water licences occur throughout the lower watershed on the Koksilah River, Grant Lake, several smaller creeks and brooks, and numerous springs. The greatest volume of water is allocated for irrigation (57%) and industrial use (40%) (BC Gov. 2018c). Domestic use accounts for less than 2% of the total allocated volume. Other minor surface water licences secured are for livestock use and aquaculture.

## Invasive Plants

As noted in the CVRD invasive species strategy, invasive plants pose a threat to biodiversity and sensitive ecosystems across the Cowichan region. While scotch broom is considered a medium risk species, it covers more than 400 ha of the Cowichan region (CVRD, 2014), including dense distribution along the power line right-of-way that runs through the Koksilah watershed. Scotch broom is considered extremely flammable and could increase the risk of urban-rural interface forest fire (CVRD 2014).

High-risk species such as Japanese Knotweed occupy only 38 ha across the region; however, this species grows aggressively, produces chemicals that are toxic to other plants, and presents significant risks to native plant riparian areas (CVRD 2014). While more common along the Cowichan River, incidence of knotweed are also mapped within the Koksilah watershed.

**Figure 29. Occurrence of Japanese knotweed on southern Vancouver Island (Source: Invasive Plant Committee 2009).**

## Climate Change

The climate of the Koksilah watershed is undergoing a long-term change toward hotter and likely wetter conditions. Projected changes based on Global Climate Models (also called General Circulation Models)(GCM) are summarized for the coastal region of British Columbia by the Pacific Climate Impacts Consortium (PCIC undated). The changes in precipitation are projected to continue for decades, and even centuries, if society is unsuccessful in rapidly limiting its production of greenhouse gases. In addition, there is now extensive peer-reviewed scientific literature indicating that due to a range in responses and feedback mechanisms that are not incorporated into the GCM projections, the GCM projections themselves are underestimating the climate changes that are most likely to occur. There is a significant body of authoritative scientific evidence in this regard - see, for example, Brown and Caldeira (2018) and Steffen *et al.* (2018). Further, emissions of global greenhouse gases are tracking the worst-case scenario and there is no sign of them abating.

Based on the Plan2Adapt Tool available on PCIC's website, the projections for the Cowichan Valley Regional District (CVRD) (including the Koksilah watershed) can be summarized as follows:

| **Climate Parameter** | **Season** | **Projected Change[1] from 1961-1990** | | |
|---|---|---|---|---|
| | | **2020s** | **2050s** | **2080s** |
| Mean temperature change (deg. C) | Annual | +0.9 | +1.6 | +2.5 |
| Precipitation (% change) | Annual | +3% | +6% | +8% |
| | Summer (JJA) | -8% | -18% | -19% |
| | Winter (DJF) | +2% | +5% | +10% |

[1] Projected change is based on the median of a PCIC standard set of Global Climate Model (GCM) projections.

# Current Condition

## Condition - Landscape

### *Changes to Forest Cover*

The rapid settlement of the Cowichan Valley, including the Koksilah watershed, changed many of the ecosystems over a short period of time. Using data from historical land survey records for the Cowichan Valley from 1859 then re-surveyed in 2007, it was determined that low elevation Coastal Douglas-fir forests changed significantly in terms of species composition, density, and size classes of trees (Bjorkman and Velland 2010). Approximately 40% of the landscape quickly changed from open growing forests, plains, and prairies to agriculture and urban settlement. Where historically 33% of the Coastal Douglas-fir ecosystem was plains and prairie with fewer than 100 trees per hectare, by 2007 this amount declined to less than 3% of the landscape because of settlement and development activities. Nearly the entire Coastal Douglas-fir ecosystem in the Koksilah watershed is now managed for agriculture (Figure 21).

Remaining forests were altered either through fire suppression or harvesting. Fire suppression allowed dense thickets to develop under the old growth canopy, changing light and moisture conditions and therefore understory vegetation. The clearcut logging that occurred also allowed dense forests of smaller trees and different plant communities to develop. The harvesting of the old growth Douglas-fir has likely increased the amount of maple in some areas (Bjorkman and Velland 2010). Western redcedar may only be present now in low elevation Coastal Douglas-fir forests because elimination of fire has allowed this thin barked species to establish.

In recent history, wildfire and logging have been the main sources of disturbance in upper and middle portions of the watershed and have significantly altered large areas of the landscape (Figure 30). A lightning strike on Waterloo Mountain in 1920 burned 774 ha of high elevation forest (DataBC 2018a). All other recorded fires in the watershed have been human-caused.

While the earliest logging occurred primarily in low elevation forests accessible to the railroad, by the 1950's road building into upper elevation forests expanded harvesting operations throughout the watershed. Harvesting by MacMillan Bloedel reduced the area of older forest[4] (>140 years) from nearly 30,000 ha to approximately 3,000 ha by the time the land was sold to Weyerhauser in 1999 (Figures 30 and 31). Early harvesting of second growth forests was primarily in low elevation areas, presumably to increase agricultural lands and to develop residential areas. In middle and upper elevations, industrial logging of second growth forests began in the early 1980's, and since about 2001 most of the harvesting has been in these younger forests. By the time TimberWest and Island Timberlands acquired the properties in 2005, little old forest was left in the Koksilah watershed (approximately 1,650 ha, or 5.5% of the original area containing old forest) and harvesting has since concentrated on second growth forests, though it appears that some old forest continues to be logged. As of summer 2018, approximately 1,200 ha of old forest remained. Of this, 300 ha is known to be 'old growth' forest, that is, at least 250 years old.

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[4] Old growth forest is defined as forest >250 years old. Due to data limitations and to better illustrate harvest history it was decided to combine old growth forest with older mature forests (140 to 250 years) for this analysis.

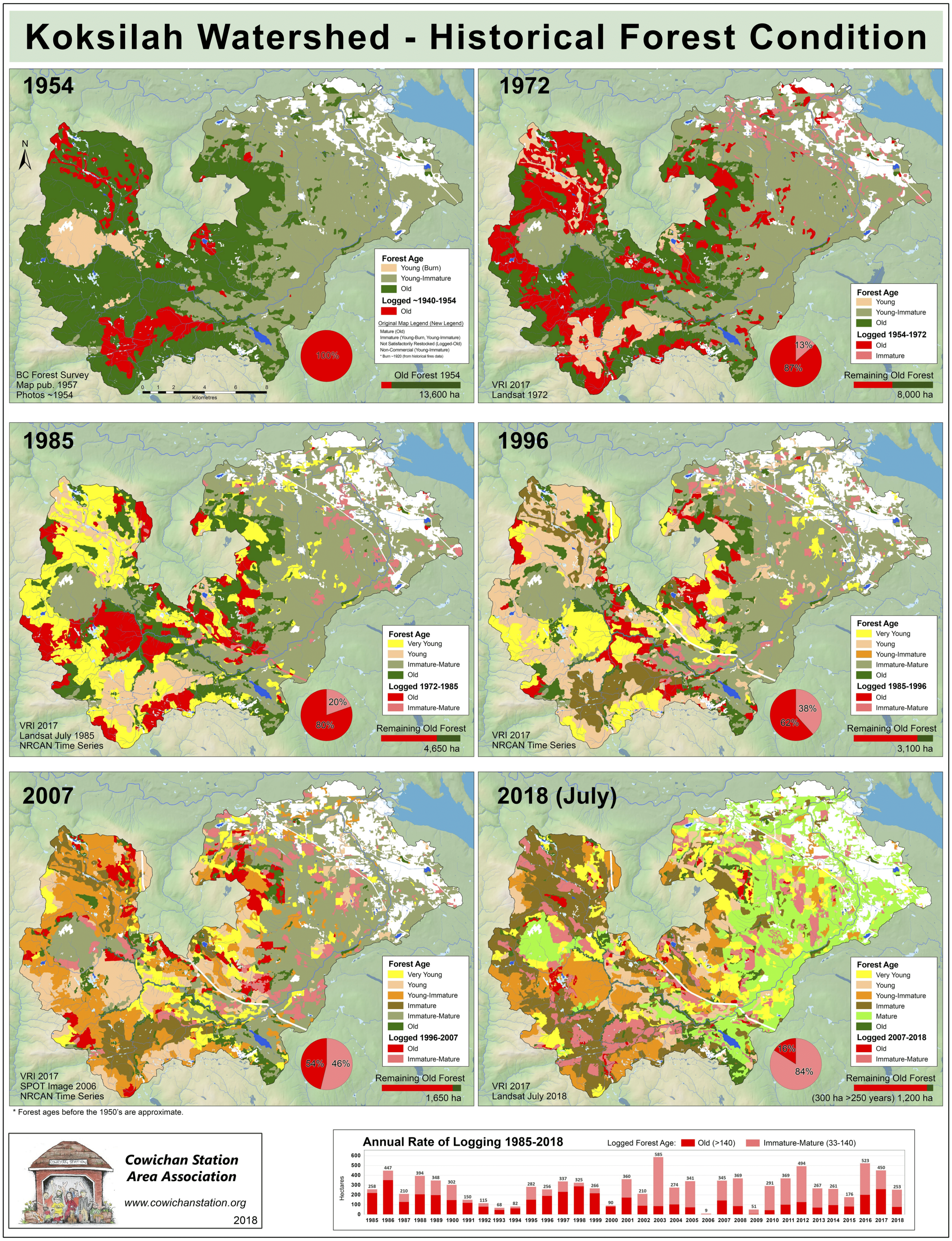

**Figure 30. Historical Forest Condition, Koksilah River Watershed**

Historical and recent logging, in combination with land clearing associated with agriculture and rural/urban development, has resulted in most of the forest in the watershed as currently being less than 60 years old; over 80% of the forested landbase is below this age (Figure 30). Whereas historic forests were dominated by old growth, currently only about 1% of the forest in the watershed is over 250 years in age. While much of the older forest tends to buffer sections of the Koksilah River and its larger tributaries, many reaches now lack old forest buffers. Historic logging practices did not consider the importance of riparian buffers and trees were removed right to the water's edge. Reserve patches were not considered and extensive continuous clearcuts resulted.

Current logging practices are different though they still rely on the clearcut harvest system. Present-day practices include retaining reserves around streams and other features such as rock outcrops (Ken Epps and Molly Hudson, pers. comm.). While treed buffers are legally required on streams >1.5 m wide, only understory vegetation (i.e., shrubs) is required around smaller streams[5]. As earlier mentioned, current harvesting is primarily "2nd pass", as nearly all forests have been logged once since industrial forestry began. Determining when a forest is ready to be harvested depends on variables such as tree size, which will vary with the growing conditions of a site (Ken Epps and Molly Hudson, pers. comm.). Trees on good sites may be ready for harvest by 40 years old; most current day logging harvests trees between 40 and 80 years old (Ken Epps, pers. comm.). While "1st pass" logging removed large diameter trees, current harvesting removes much smaller trees.

**Figure 31. Current harvesting practices in the Koksilah River watershed. The area known as the Koksilah Old Trees is visible in the lower half of the photo.**

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[5] B.C. Reg. 182/2007, Private Forest Managed Land Council Regulation, *Private Managed Land Act.*

Management of logging debris has also changed over time. In early days, cutblocks were broadcast burned with the intent of burning up the logging slash that made tree planting difficult. Nowadays no broadcast burning occurs in the Koksilah watershed. On Island Timberlands properties, some of the slash is piled and burned while considerable volumes remain scattered within the cutblock (Ken Epps, pers. comm.).

**Figure 32. Current harvesting practices in the southwestern portion of the Koksilah River watershed. A tributary of the Koksilah River visible in the upper left corner of photo.**

On TimberWest properties, all slash is now left scattered in the cutblock. Also, legacy fallen logs are skidded around to keep them intact (Molly Hudson, pers. comm.). While the volume of retained wood in the harvest area is high, the piece size is much smaller than the historic large fallen logs.

Another disturbance affecting the current condition of forests in the Koksilah watershed was the introduction of white pine blister rust, a disease introduced from Asia in the early 1900s. White pine blister rust, in combination with bark beetles, killed 75% of the white pine in the Koksilah watershed (Collis and Alexander 1966). This once common tree species is now rare in the watershed although it may increase with the planting of disease resistant stock.

### *Roads and soil disturbance*

There are approximately 1,410 km of road in the Koksilah watershed (Figure 31). This includes maintained and overgrown forest roads, as well as paved and gravel roads used for agriculture and to access residential and industrial areas. Road density appears to be consistent across the watershed with an average of 4.5 kilometers of road for every square kilometer of land (Table 1). Approximately 3.6 km/km$^2$ of the roads are maintained and used while remaining roads appear overgrown with vegetation. Road density is slightly higher in the Glenora and Lower Koksilah sub-watersheds where forestry, agriculture, and residential areas converge. While important for access, roads can affect surface drainage patterns, release sediment into streams impacting fish habitat, and cause loss or fragmentation of wildlife habitat. With respect to protecting wildlife, it is estimated that maximum road density should be less than 1.9 km/km$^2$ and as low as 0.25 km/km$^2$ for some more sensitive species (Forest Practices Board 2015).

The forest road system in the Island Timberlands operating area is essentially complete and no major new road construction is likely (Ken Epps, pers. comm.). After construction, roads are maintained and left open for future forest management activities (e.g., planting, thinning, vegetation control, monitoring). It is unknown if any new roads will be developed in urban and rural areas.

**Table 1. Road density in the various Koksilah sub-watersheds**

| Assessment watershed | Watershed Area (km2) | Existing Road Density (km/km$^2$) | Overgrown Road Density (km/km$^2$) | Total Road Density (km/km$^2$) |
|---|---|---|---|---|
| Fellows | 33.8 | 3.0 | 1.1 | 4.2 |
| Glenora | 21.8 | 4.5 | 0.7 | 5.3 |
| Kelvin | 35.7 | 3.1 | 0.7 | 3.8 |
| Upper Koksilah | 84.9 | 4.3 | 0.5 | 4.8 |
| Middle Koksilah | 60.3 | 3.4 | 1.1 | 4.5 |
| Lower Koksilah | 35.2 | 3.7 | 1.1 | 3.8 |
| Mount Todd | 40.0 | 3.2 | 1.2 | 4.4 |
| Total | 311.7 | 3.6 | 0.9 | 4.5 |

As a result of historic and current land management practices, important structures like large trees, standing dead trees and fallen logs are uncommon in the landscape. Riparian forests and their structures are also less abundant. With fewer large trees in riparian areas, recruitment for large woody debris in streams is also lacking, affecting fish habitat and channel stabilization. Habitat for large tree and cavity-nesting species is declining. The following sections provide further detail with respect to some of the impacts of the land development history on specific values in the Koksilah watershed.

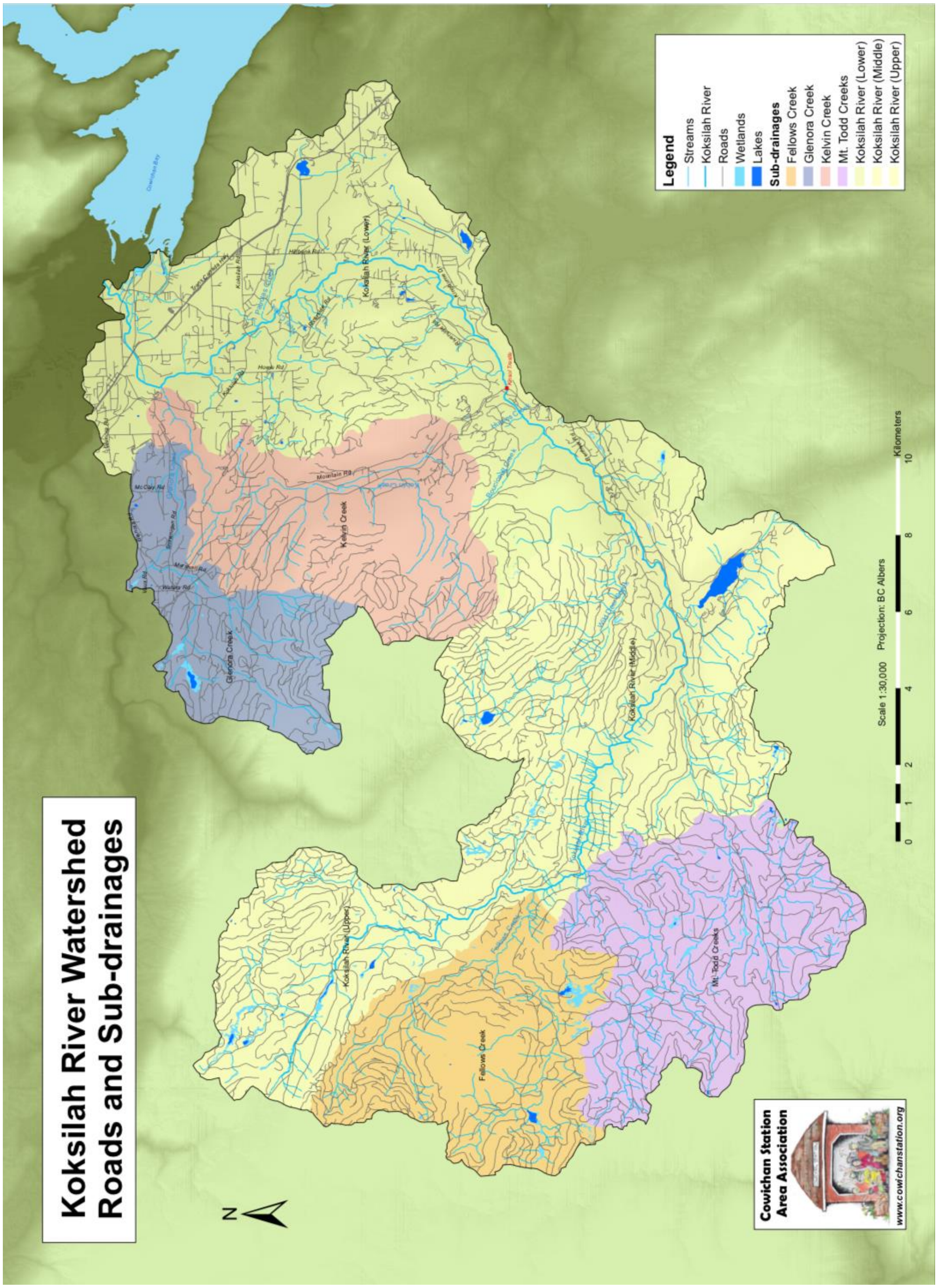


Figure 33. Condition of landscape connectivity in the Koksilah River watershed.

## Condition - Water Quantity and Timing of Flow

In recent decades, late-summer streamflow in the Koksilah watershed has been in decline. The river is reported to display "flashy" behaviour, rising and falling quickly in response to rainfall events. Such hydrologic characteristics threaten water supply and fish habitat, and may undermine channel stability and other stream characteristics. There is an interest in addressing these hydrologic dynamics to improve water supply and the well-being of the aquatic ecosystem. As discussed elsewhere in this report, a long history of human disturbance has resulted in extensive clearings for settlement and agriculture in the lower elevations, early-seral managed forests in the middle and higher elevations and a road density of 4.5 km/km$^2$, approximately 80% surfaced and 20% vegetated, with the roads well distributed throughout the basin. Why are these changes occurring? To what extent are land-use factors shaping the hydrologic dynamics? Can the dynamics be addressed by a change in land-use and/or through restoration? What measures are suggested? To help respond to these kinds of questions, an initial office-based assessment is presented here using publicly-available hydrometeorological and land-use data.

**Figure 34. Harvesting adjacent to riparian management area.**

### *Hydrologic Dynamics of Koksilah River*

Daily discharge in the Koksilah River has been measured consistently since 1956 by the Water Survey of Canada (WSC). It was also measured during 1915-1916. The annual pattern of streamflow reflects the pluvial (rain-dominated) nature of this hydrologic regime with an overall maximum flow during the winter and minimum in the late summer (Figure 35). Closer examination of patterns in long-term annual streamflow at this gauging site shed light on changes that may be occurring in this hydrologic regime. Figure 36 provides a time series of annual maximum flow at the WSC station. A small long-term mean increase of ~0.1% per year is indicated. Figure 37 suggests no trend in annual water yield during this period, though variability may be changing. (Water yield is calculated by summing the daily volumes discharged.)

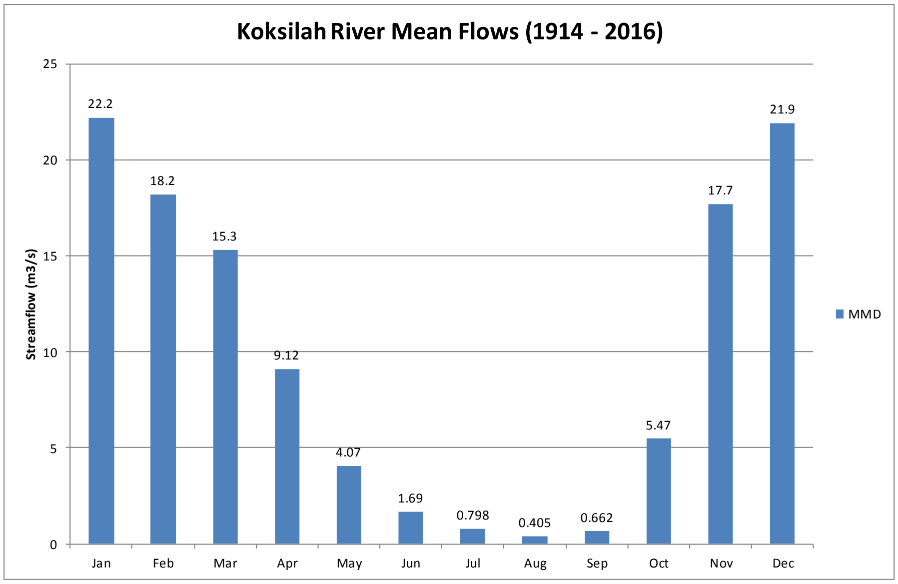


**Figure 35. Long-term average hydrograph for the Koksilah River at WSC Station 08HA003 (Plot courtesy of Matthew Macdonald at FLNRORD).**

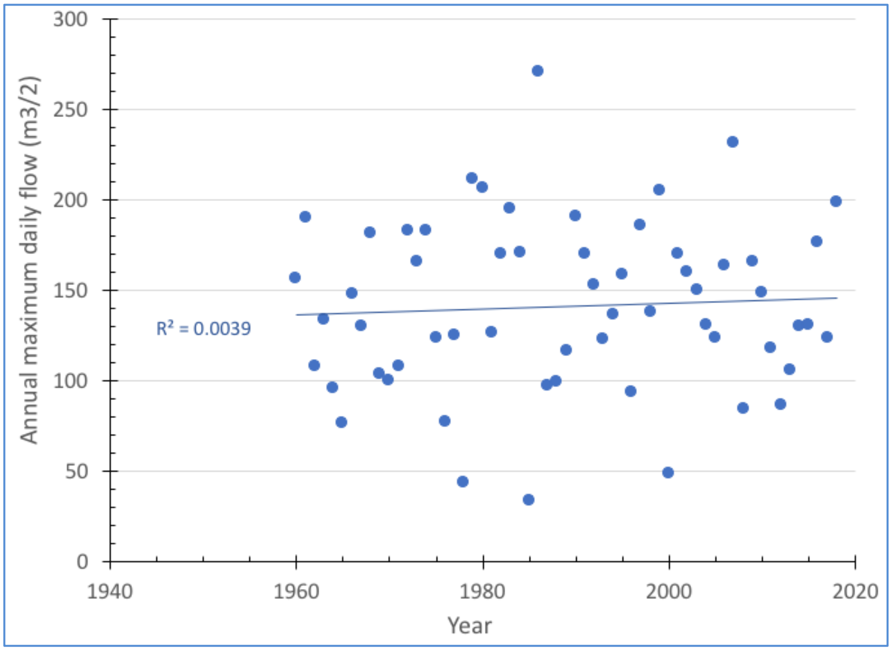


**Figure 36. Annual maximum mean daily flow (1960-2018) at WCS 08HA003.**

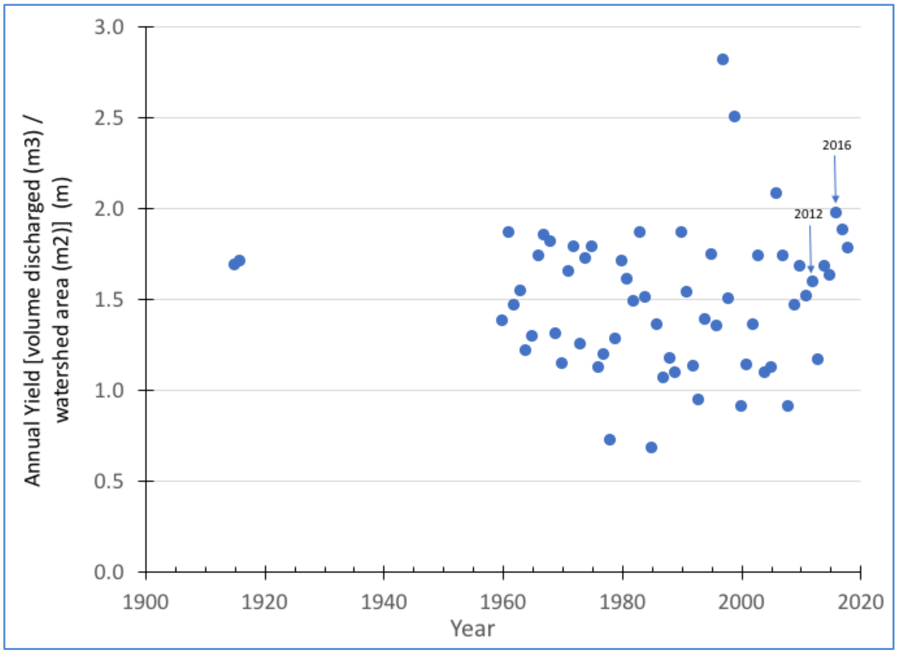
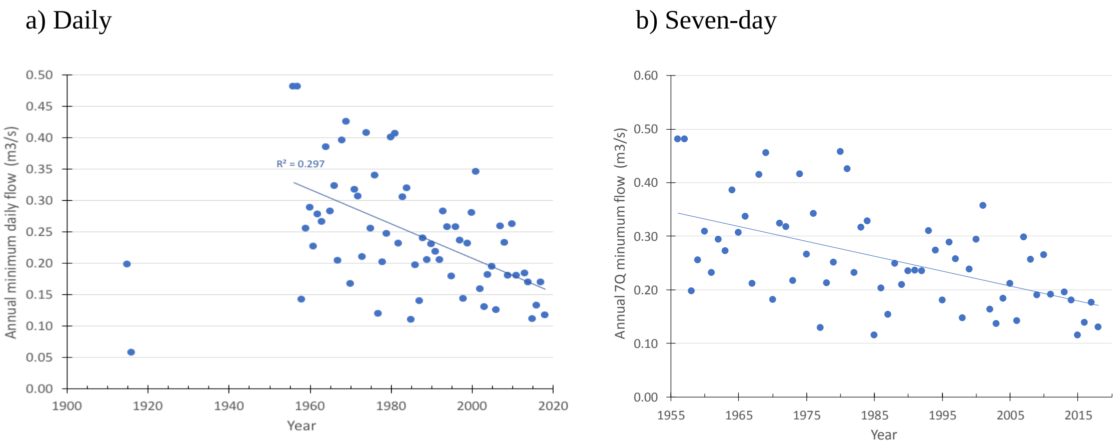


**Figure 37. Annual water yield (m, total annual discharge / watershed area at WSC 08HA003. (*Note: 2012 and 2016 are underestimates due to data gaps.*)**

These minor changes in annual maximum flow and basin yield contrast with characterizations of long-term trends in annual minimum flow. In Figure 38, both the annual minimum daily flow and seven-day low flow show a long-term mean decline of about 0.9% per year in addition to reduced variability. The decline appears to have accelerated in about 1985. This measured decline reflects the experience of the local community. Figure 39 shows increasing occurrence of the annual number of days with less than 0.3 m$^3$/s. These complementary descriptions of reduced water quantity clearly point to a sustained change in the summer flow regime. However, the decline in low-flow magnitude is apparently not being accompanied by a change in its timing (Figure 40). What might drive this change in summer water availability at the gauging site given the lack of change in these other flow characteristics? The following analyses attempt to shed light on this question.


a) Daily

b) Seven-day

**Figure 38. Minimum one-day and seven-day annual streamflow (1956-2018) at WSC 08HA003.**

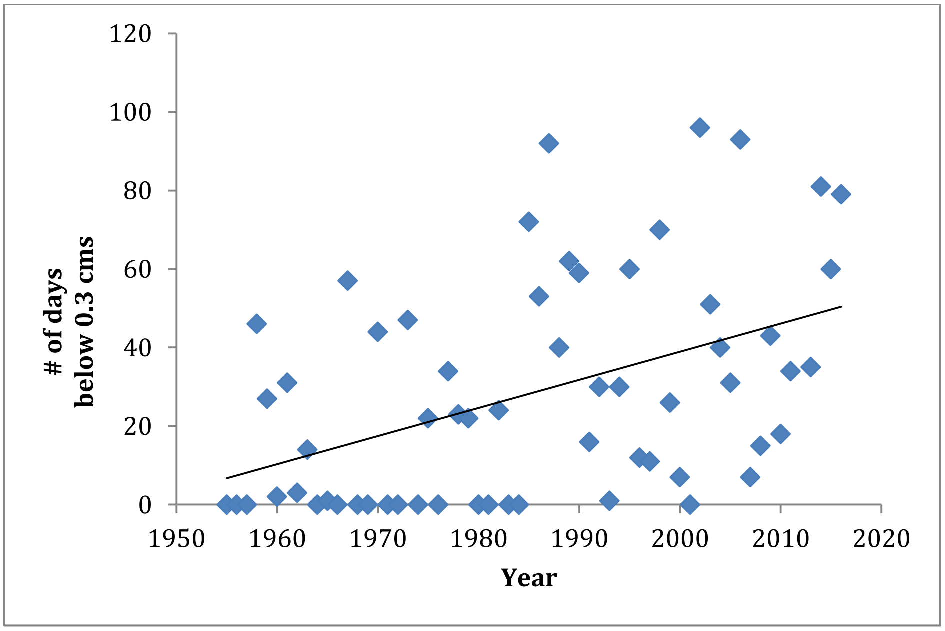


Figure 39. Number of days per year with streamflow under 0.3 m³/s at WSC 08HA003.

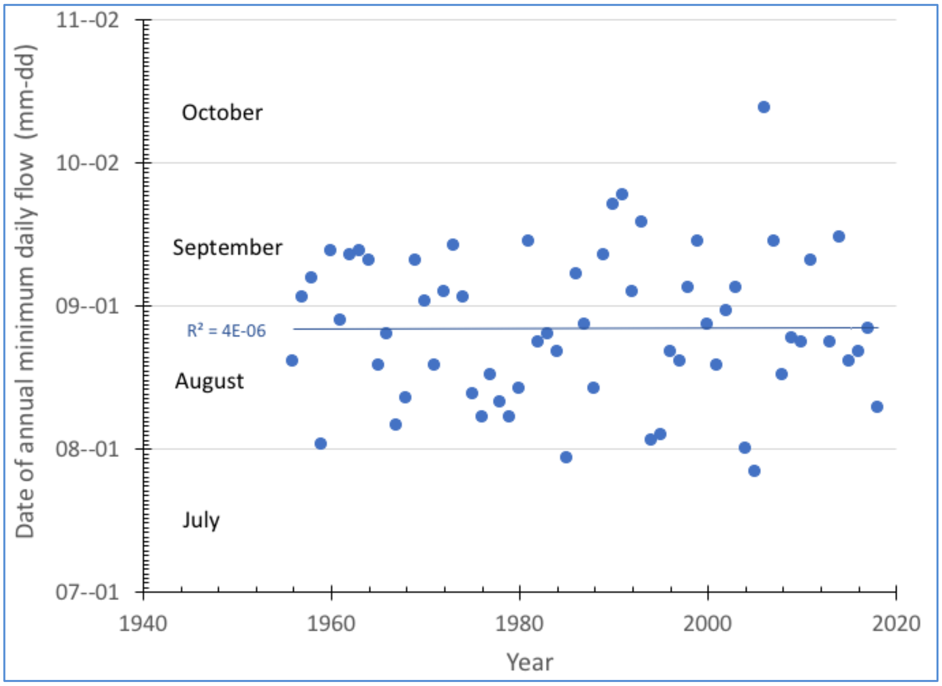
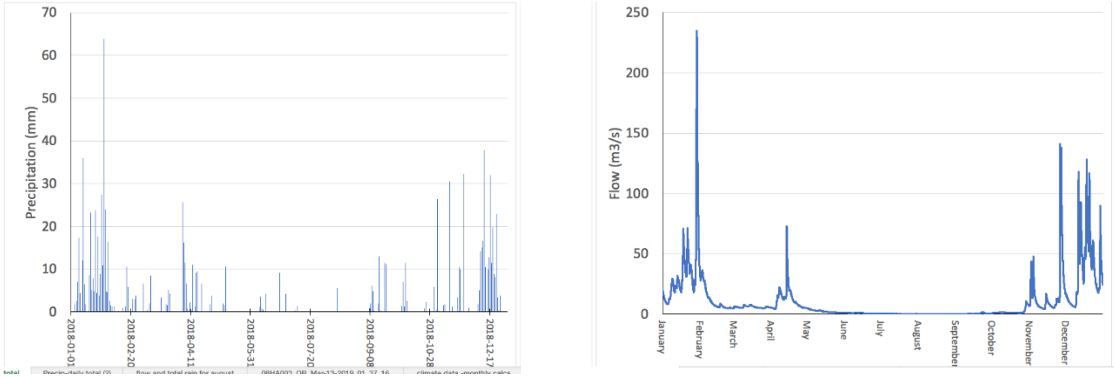


Figure 40. Date of annual minimum daily flow versus year for WSC Station 08HA003 for 1956-2018.

Flashiness of a river is a description of its responsiveness to rainfall events. Koksilah can be described as a "flashy" river because flows tend to both rise quickly due to significant rainfall and drop quickly thereafter. Figure 41 illustrates the close response between rainfall (a) and streamflow (b) in the Koksilah watershed. Figure 42 overlays the precipitation and streamflow during August 2018 indicating a high degree of runoff (rather than baseflow recharge). Flashiness is also consistent with a large difference in annual maximum and minimum streamflow: Koksilah streamflow ranges over five orders of magnitude in a calendar year. For example, just last year the maximum 5-minute mean flow was 235 $m^3/s$ on January 29th and the minimum was 0.0074 $m^3/s$ on August 10th. The high was associated with a large rain event on January 28th (63.8mm daily rainfall) and the minimum came after a relatively dry period. Many factors can contribute to responsive rainfall-runoff dynamics, for example, the absence of significant water storage in the Koksilah watershed. As discussed below, land-use factors can also contribute to flashiness.


a) Precipitation

b) Streamflow

**Figure 41. Close correspondence between (a) precipitation (ECCC Shawnigan Lake station) and (b) streamflow (WSC 08HA003 station).**

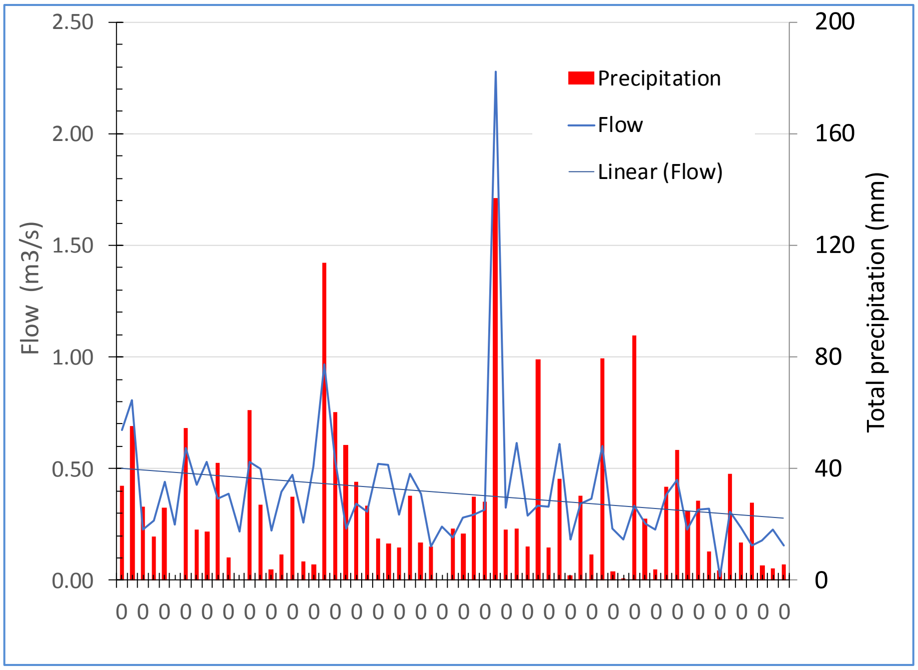


**Figure 42. Close correspondence between precipitation (ECCC Shawnigan Lake station) and streamflow (WSC 08HA003 station) during August 2018.**

### *Long-Term Changes in Precipitation*

To what extent might changes in extremes be brought about by long-term changes in climate including annual meteorological inputs? Figure 43 shows the total annual precipitation since 1912 at nearby Shawnigan Lake climate station, the station closest to the Koksilah watershed. An overall 25% *increase* in annual precipitation is suggested during this period of record or roughly 15% during the continuous period of record at WSC 08HA003. An unchanging water yield (Figure 36) during a period of increased precipitation inputs suggests the influence of factors beyond total precipitation – *e.g.*, seasonal distribution and short-term intensity of precipitation and effects of land-use activities. Both are discussed below.

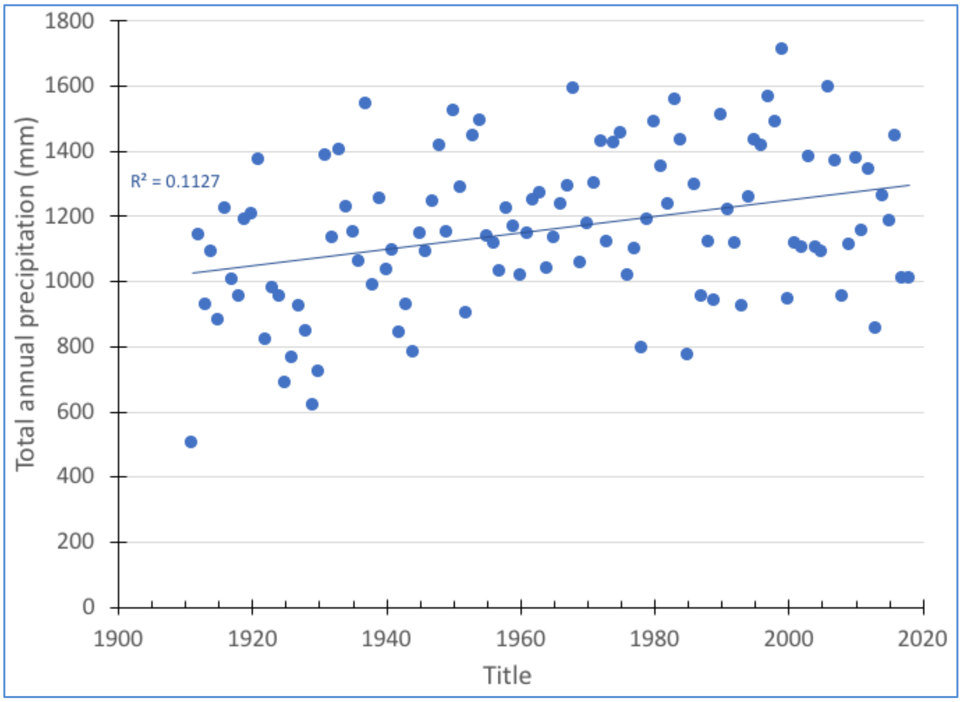


**Figure 43. Total annual precipitation at Shawnigan Lake climate station (Environment Canada & Co-operative Climate Network). (Note: *Values for 1960-1964, 1996, 2007, 2012, 2015-2018 may be underestimates due to missing daily values.)***

Figure 44 shows the long-term variation of annual maximum daily precipitation. Daily rainfall is a readily-available measure of rainfall intensity. This figure indicates a 35% increase in maximum daily precipitation with over a 25% increase occurring during the continuous period of record at WSC 08HA003. As maximum daily rainfall increases, maximum rainfall intensities over shorter time periods (e.g., one hour, ten minutes) would also be expected to increase, though not linearly. Higher rainfall intensities would tend to aggravate flashiness and thus reduce the likelihood of groundwater recharge. In light of the relatively consistent behaviour shown in Figures 35-37, increasing rainfall intensity may be at least a part of the explanation for the hydrograph changes shown in Figures 38 and 39. Further analysis would be needed including determination of short-term rainfall intensities and much closer analyses of long-term changes in rainfall-runoff dynamics and in relation to changes in surface condition.

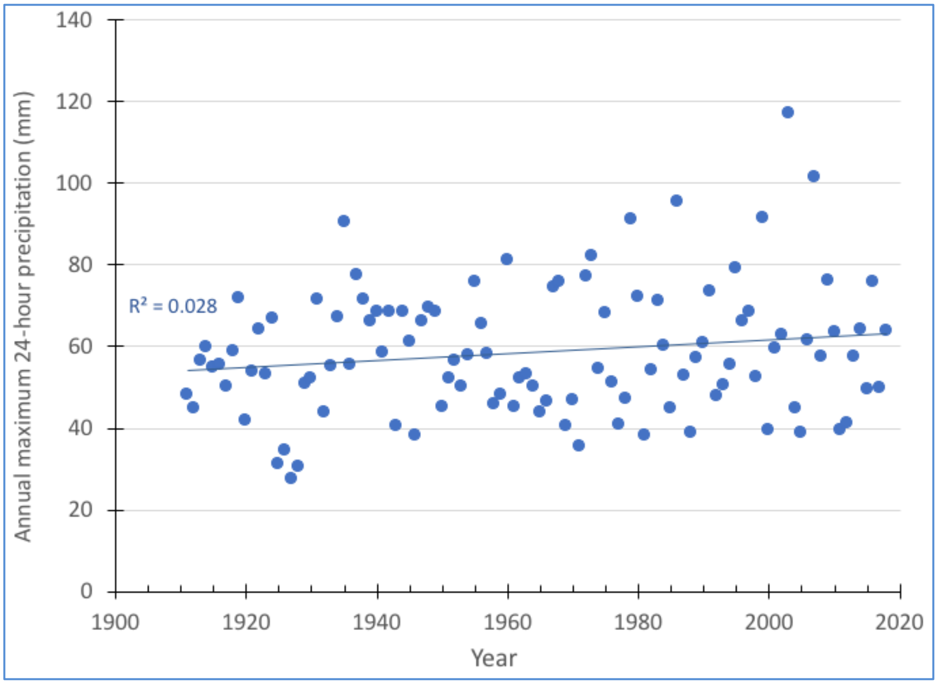


Figure 44. Long-term annual maximum daily precipitation at Shawnigan Lake climate station.

### Groundwater Condition

Water budgets have been calculated for 6 of the 11 aquifers occurring in the lower Koksilah watershed in areas used primarily for agriculture, rural residential, and forest management (Harris and Usher 2017). These water budgets help decision-makers evaluate where there is potential for additional water licences. Three of the aquifers are in bedrock, and three are in sand and gravel deposits.

Water deficits in bedrock aquifers can occur naturally during dry weather as there is often little water storage capacity. These deficits grow when water extraction occurs. Water deficits have been estimated for two of the bedrock aquifers; the remaining aquifer shows a surplus but is considered highly stressed (Harris and Usher 2017).

Water deficits are less common in surficial aquifers as they are readily able to store water in the porous sand and gravel materials (Harris and Usher 2017). Two of the aquifers are estimated to have a surplus, though one of them is considered highly stressed during hot dry years due to irrigation withdrawals. A water deficit has been estimated for the third aquifer.

Changes to groundwater flows are difficult to assess and impacts to aquifers downstream of disturbances can take decades to appear (Pike et al. 2010), therefore caution must be applied to these results.

### Land Use Change

Three data sources are examined to consider the potential influence of land use on hydrologic behaviour: consumptive water use, forest cover, and roads.

#### Consumptive Water Use

Provincial water licensing provides water licensing information that can be used to indicate the magnitude and rate of change of water licensing in the Koksilah watershed. Figure 45 shows the spatial layout of water licenses and wells in the Koksilah watershed (and downstream vicinity). Withdrawals are widespread both within the watershed boundary (of the hydrometric station) and downstream and adjacent to it. Wells outside of the watershed boundary may be drawing water from aquifers that contribute to baseflow measured at the hydrometric station and other points further downstream. There is a significant number of points of diversion above the hydrometric station (and even more below). These could be contributing significantly to the declining summer low flows, particularly during hot weather when water demand typically rises sharply.

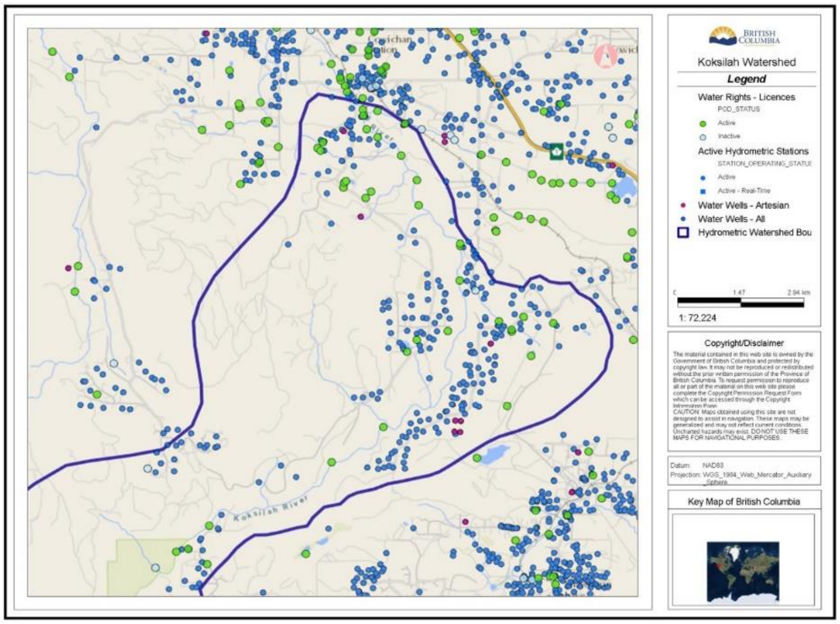


Figure 45. Mapping of surface points of diversion and groundwater wells.

Figure 46 shows the change in water demand from 1955 to the present in terms of both wells and licensed surface water withdrawals. The data for this plot have been compiled by Matthew MacDonald (FLNRORD) and include licenses below the hydrometric station. Although the total numbers shown include substantial withdrawals outside of the Koksilah WSC watershed boundary, they likely portray the pace of change of licensing specifically related to and potentially affecting the streamflow behavior portrayed in Figures 35 through 40. It is evident there was a strong period of increased surface demands through the 1970s culminating in a jump in the early 1980s and what looks like a limit being reached in about 1980. In addition, well construction accelerated from about 1970 until 1990 when the pace slowed somewhat, though continued to increase to the present day. The general period of greatest increase in demand from both surface and groundwater sources has changed in step with the declining low flow.

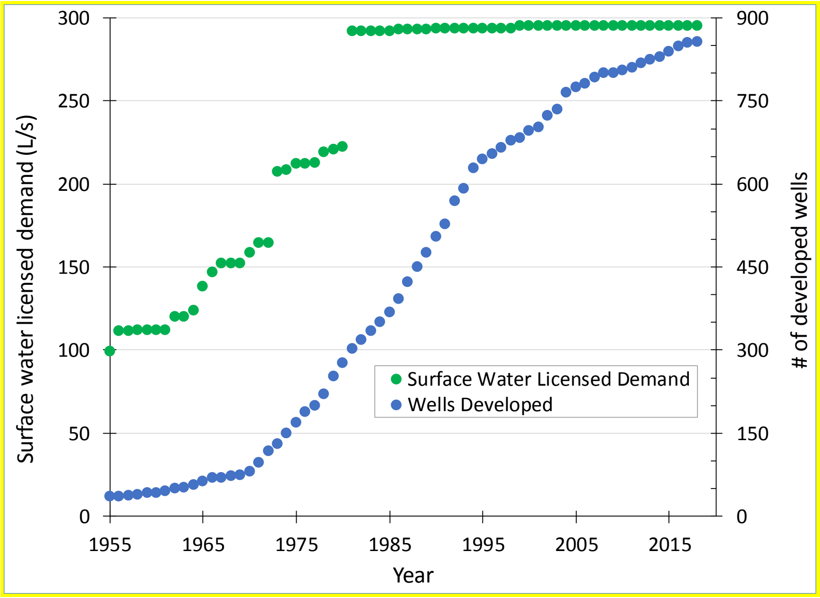


Figure 46. History of water licensing and wells.

Increased temperature during this period may be an aggravating factor causing water demand to further increase. It has been shown (Schreier *et al.* 2010) that when mean daily temperatures rise above a certain threshold, pressure due to irrigation demand rises sharply. Figure 47 shows the long-term temperature (annual daily maximum, minimum and mean) at the nearby Shawnigan Lake climate station. On an annual basis, mean temperature is rising and it is being driven by an increase in daily minimum temperature. As shown in Figure 48, during the month of August (a peak irrigation month) when low flows are observed to be at their lowest, Tmean is rising toward 20C. This suggests that there are increasing occurrences when Tmean is at or above 20C thus inducing accelerated pressures from irrigation. This highlights that human pressures may be exacerbated by climate change, leading to an acceleration of the impact on low flows.

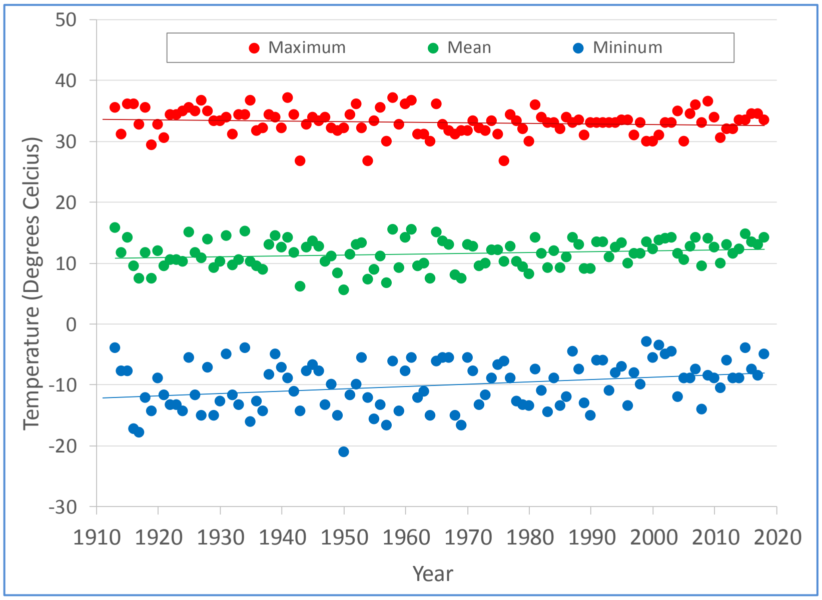


Figure 47. Annual minimum, maximum and mean air temperature at Shawnigan Lake climate station.

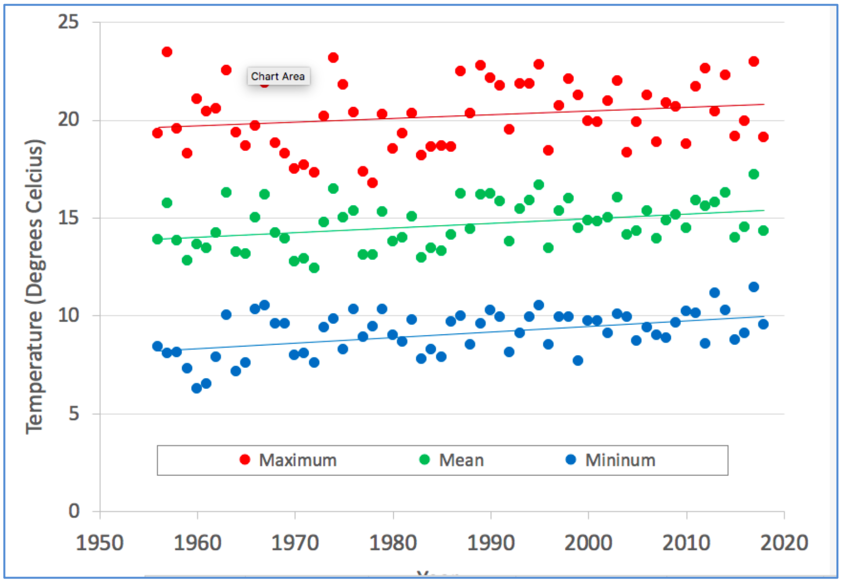


**Figure 48. August minimum, maximum and mean air temperature at Shawnigan Lake climate station.**

### *Forest Cover Change*

The assessment of forest cover change since 1940 to the present indicates that 50% of area above the gauging station is now under forest cover between 25 and 70 years old. These young forests transpire large volumes of water, removing it from the opportunity to contribute to streamflow. In those locations where forest cover has been completely removed and replaced with agricultural fields or unproductive land (e.g., landings, roads), those areas typically have faster runoff and discourage infiltration. The virtual absence of old forests results in a loss of moisture holding capacity and shade from summer heat. Overall, the current regime of forest management has the potential to be contributing to the decline in low flows.

### *Roads*

Roads intercept shallow subsurface flow, routing it to ditchlines and evacuating it efficiently to the stream network (Wemple 1994, 2003). The road network within the Koksilah watershed is well distributed and extensive. It is reasonable to infer that the road network within the managed forest land was built as the old forests on that land were harvested. A great deal of that harvest happened in the 1960s, 1970s and 1980s thus during that time, the road density likely increased significantly. As mentioned earlier, it now stands at 4.5 km/km$^2$ throughout the watershed. Such high levels of road density extend the drainage network throughout the landscape and strongly limit opportunities for infiltration of runoff, thereby encouraging flashiness, a loss of recharge, and ultimately a general decline in base flows.

## *Climate Disruption*

The increase in temperature and the decline in summer precipitation as earlier described are of concern given that these will strongly exacerbate the changes that are already well underway in the Koksilah River's streamflow (Figures 38 and 39). Significant snow accumulation may all but disappear in the Koksilah watershed through this century. Further, it is well understood that these projected changes in climate will be accompanied by increases in extremes both in terms of temperature and precipitation – notably, sustained summer periods without rainfall and higher intensity rainfall when rainfall does occur. These two examples are also problematic for exacerbating the decline in low flows. Although there may be more precipitation annually, its intensity and distribution during the winter means its potential benefit to aquifer recharge is not expected to compete with the losses associated with the other characteristics of the new climates.

## Discussion/Integration

A host of factors may be contributing to the observed continued decline in summer low flows at the Koksilah hydrometric station. A complex of land use, water withdrawals, climate change, (perhaps karst) and interactions among these appears to be creating the "perfect storm" for reducing summer water availability. Summer low flows are increasingly due to base flow alone. Runoff from rainfall events is rapid, thus limiting the opportunities for aquifer recharge. It is fortunate that this watershed is a priority to the provincial government in looking at linkages between the streamflow and groundwater.

Although additional data analysis would be needed to determine the relative roles of the various factors identified, there are steps that could be taken immediately to foster increased low flows during the summer season. (See next section.) Given the long-term persistence of climate change in creating downward pressure on summer water availability, it is highly recommended that steps be taken immediately to increase the hydrologic resilience of the watershed through restoration and changes in land-use. Creation of water storage opportunities may also be necessary, if/where practical.

## Outcomes and Further Work

### Summary of Key Findings

Summer low flow has been in general decline since about 1985 despite a long-term increase in annual precipitation.

The long-term change in low flow is likely being influenced by a range of factors most of which are negative, that is, making the summer flows go lower.

- Climate factors emphasise increased temperature and short-term rainfall intensity
- Potential land-use factors include water withdrawals (both surface water and groundwater), road density, and forest management practices.
- Increased temperatures may be interacting with licensed water demand to increase the demand just when the low flows are under the most pressure due to seasonal climate.

Additional work is needed to partition the relative magnitude of the potential causes so that appropriate measures can be identified in terms of changes in land use or implementation of watershed restoration.

### Further Work

Based on the above analysis and discussion, the following work is suggested to better partition and attribute cause for the decline in summer low flow:

- **Regional analysis to put the Koksilah flow regime in context.** It would be helpful to place the Koksilah watershed with a regional analysis to better understand the severity of its hydrologic regime.

- **Improved understanding of factors affecting base flow**. The pressures on groundwater recharge need to be better understood given the likely significance of groundwater to the Koksilah River's baseflow (i.e., summer low flow). Also, is there a cumulative effect from year to year affecting base flows? Determination of the hydraulic connection between the aquifers and river and of seasonal groundwater withdrawals are needed to determine aquifer budgets so that they can be related to changes in summer river flow.
- **Improved understanding of summer surface-water balance.** The pressures on the summer availability of water at the hydrometric station can be better quantified and partitioned. Components include a GIS analysis and field assessment to clarify the surface water demand above the hydrometric station and a more detailed analysis (perhaps using a hydrologic model) of the role of forest management and road density on rainfall-runoff dynamics. (This step may benefit from application of the Tableau Database Tool which facilitates separating base flow and storm flow in rivers and estimating potential water-withdrawals within a specific catchment on a monthly or seasonal basis based on water license and groundwater well location/type information.)

## Condition - Water Quality

As mentioned above, the lack of a large lake in the headwaters to regulate flows results in naturally low base flow rates (McKean 1989), which is the case in the Koksilah watershed. Summer flow rates for the Koksilah River are especially low (often 0.3 cms) and are a concern for fish survival, water supply for irrigation, and for sewage dilution affecting water quality (McKean 1989; BC MOE 1989).

Water quality is especially important in the Koksilah River because of the many ways the water is used including for drinking, aquatic life, irrigation, industry, recreation, wildlife, and livestock (Pommen 2004; Obee 2011), as well as for cultural use by the Cowichan people. As previously noted, cultural bathing pools are especially important, although many have become polluted (Hul'qumi'num Treaty Group 2005). In addition, a 2001 survey found that 60% of Quw'utsun' people used fish in streams, rivers, and lakes within their territory (Hul'qumi'num Treaty Group 2005). Thus, protecting water quality (and quantity) for the survival of fish is imperative for Quw'utsun' culture and food security.

In response to concerns over low summer flows and their impacts, in 1989 the BC Ministry of Environment established water quality objectives for the Koksilah River, under authority of the *Environment Management Act*, with the intent to protect water quality for the most sensitive water uses (BC MOE 1989). These objectives were later updated in 2011 (Obee 2011). Possible sources of contamination identified early on included older septic systems, dairy farms, the CVRD incinerator and landfill, a gravel washing operation, agriculture and urban surface run-off, and forestry operations in headwaters (BC MOE 1989, Pommen 2004). Water quality objectives (WQOs) were established to address these suspected sources of contamination and included microbiological contaminants, dissolved oxygen, turbidity, suspended residues, and dissolved copper, lead and zinc.

Levels of microbiological contaminants have consistently exceeded WQOs since monitoring began in 1988 (Pommen 2004, Phippen 2007, Dessouki 2010, Obee 2011, Smorong and Epps 2014). Between 1971 and 2003, WQOs were exceeded for fecal coliforms 80% of the time, 88% for E. coli, and 77% for enterococci (Pommen 2004), with elevated fecal coliforms and E. coli possibly linked to agricultural activities (Obee 2011). This contamination is not only a concern for drinking water and cultural use, but also for irrigation, recreation, and shellfish harvesting in the estuary. A goal to actively reduce bacterial contamination has been set, in part, to re-establish shellfish harvesting in the estuary (Obee 2011). A decline in fecal coliform levels was noted between 2012 and 2013, possibly due to outreach activities in the agriculture community with respect to practices around manure storage and spreading (Smorong and Epps 2014) in combination with ideal autumn conditions for the safe spreading of manure.

Dissolved oxygen in the river is important to ensure juvenile and adult fish populations are not stressed (BC MOE 1989). The WQO established for dissolved oxygen has also been regularly exceeded (Pommen 2004, Phippen 2007, Dessouki 2010, Obee 2011). In evaluating 33 years of data, Pommen (2004) determined that the WQO for dissolved oxygen in the Koksilah River was not met during June to September 91% of the time. WQOs were also not met during the winter in more recent years (Dessouki 2010, Obee 2011). This is suspected to be a result of a combination of low flows, higher water withdrawals for irrigation, increased nutrient loading from agriculture and subsequent algae growth, and increasing water temperatures.

Turbidity and total suspended sediments in the Koksilah River have also often exceeded WQOs (Pommen 2004; Dessouki 2010; Obee 2011) possibly due to agriculture and/or stormwater run-off (Obee 2011). At one site, phosphorous was elevated likely due to agricultural run-off and/or aging septic systems along the river (Obee 2011). During low flows, the algae that feed off of the phosphorus can degrade aquatic habitats.

Of the 11 aquifers in the Koksilah watershed, water quality was rated for three located in the lower Koksilah watershed floodplain (#186, #187, and #188, as shown in Figure 4) (Barrosa et al. 2013). These aquifers are stacked upon one another. The upper two aquifers recharge via rainfall and the Cowichan and Koksilah Rivers. All three aquifers are hydraulically connected to these two rivers (Barrosa et al. 2013). While water quality has been rated “excellent” for all three aquifers, the uppermost aquifer is considered highly vulnerable to contamination as the water table is high and it is topped by permeable sands and gravels (Carmichael 2014; Barrosa et al. 2013). It is the only aquifer rated as “vulnerable” in the entire watershed.

Land use and activities on the surface have the potential to affect water quality. Common land uses in the areas of overlap between this uppermost aquifer and the surficial part of the Koksilah watershed are agriculture and agriculture-residential mix (Barrosa et al. 2013). Other land uses above this aquifer include gravel extraction and the Koksilah Business Park which is occupied in part by transport companies, auto repair, construction, recycling, and waste disposal. The former Koksilah landfill, closed since 1997, is located in this area, along Koksilah Road (Barrosa et al. 2013).

## Condition - Fish

Recent fish observations are presented in Figure 50. Glenora Creek and Kelvin Creek provide habitat for several fish species including Chinook Salmon, Chum Salmon, Coho Salmon, Rainbow Trout, Cutthroat Trout, and Steelhead (BC MOE 2018b, BC MOE 2018c). The Koksilah River supports the same fish species as well as anadromous Cutthroat Trout and winter run Steelhead (BC MOE 2018a). Coho Salmon have been observed in Wild Deer Creek (Tim Kulchyski, pers. comm.) while Rainbow Trout are known to occur in Wild Deer

Lake. Threespine Stickleback commonly occur in Busy Place Creek while Coho Salmon and Cutthroat Trout have also been observed there (Kathy O'Donnell, pers. comm.).

Escapement data provided by the Department of Fisheries and Oceans shows that prior to 1992 Coho Salmon and Chum Salmon were more abundant than Chinook Salmon. Average counts for each species between 1953 and 1992 were 5188 Coho Salmon, 4475 Chum Salmon, and 233 Chinook Salmon. In a 2018 swim survey starting 5 km above and ending at Bright Angel Park, 135 adult Chinook Salmon, 850 Chum Salmon, and a few Coho Salmon were counted (Tim Kulchyski, pers. comm.). These numbers were considered good when compared to recent years.


Figure 49. Marble Falls is a partial barrier to fish passage.

With respect to stream gradient, the best fish habitat occurs in the lower portions of the watershed (Figure 50). Salmon species prefer stream gradients less than 7%, although they can occur in streams with up to 10% slope (Peter Tschaplinski, pers. comm.). As earlier mentioned, Marble Falls is considered a barrier for most salmon passage, restricting their access to potentially suitable habitat upstream Figure 49). However, Chinook Salmon were observed about the falls in 2018 (Tim Kulchyski, pers. comm).

There have been many attempts to enhance the fishery resource in the Koksilah watershed. Records show that stocking in the Koksilah River began in 1902 and included species such as Atlantic Salmon, Rainbow Trout, Cutthroat Trout, Brook Trout, and Steelhead (BC MOE 2018a). Cutthroat Trout were stocked in Kelvin Creek beginning in 1929 (BC MOE 2018b). Stocking of Keating Creek with Cutthroat Trout and Rainbow Trout occurred intermittently between 1918 and 1994 (FFSBC 2018). Between 1962 and 2002, Wild Deer Lake was stocked with over 32,000 Rainbow Trout (FFSBC 2018). Brown Trout were introduced into the watershed between 1932 and 1935 and successfully established (Fish and Wildlife Branch 1967). By the 1960s, the Koksilah system was recognized as a moderate sport fishery for Steelhead, Brown Trout, and Cutthroat Trout (Fish and Wildlife Branch 1967).

Attempts were also made to increase the salmon fishery in the Koksilah watershed as it was determined that spawning and rearing habitat existed above the Marble Falls fish barrier. In 1980 a fishway was installed to allow for fish passage over the falls; however, it was unsuccessful in providing passage for salmon (Figure 51) (Brian Tutty, pers. comm., BC MOE 2018a).

In another attempt, a "Coho colonization" research trial was initiated in 1986 to determine if the Coho fishery could be enhanced by introducing fry into suitable habitat above the fish barriers (Burns et al. 1988). Fry were salvaged from Glenora and Kelvin Creeks in areas that would typically dewater during summer low flows. The salvaged fry were then released above the barriers in Kelvin Creek and Grant Lake. Survival was assessed the following spring and the trial was considered successful with 16.4% and 18.9% fry survival in Grant

Lake and Kelvin Creek and Grant Lake, respectively. In addition, the smelts that emerged from Grant Lake were considerably larger than expected, likely due to the high nutrient content of the lake (Steve Baillie, pers. comm.).

Figure 51. Fish way constructed to improve fish habitat.

Efforts to improve fish habitat in Sh-hwuykwselu have been occurring for years (Kathy O'Donnell, pers. comm.). Hundreds of students have helped inventory fish populations and with the planting of riparian areas on several stream sections. Inventory work shows a very productive Threespine Stickleback population while Coho and Cutthroat Trout numbers have dramatically declined.

It has been recognized for decades that long term salmon production is at risk in the Koksilah watershed. Concerns over the status of fish populations date as far back as 1932 when Quw'utsun' elder Qwulsteynum expressed his fear that, like the decline he witnessed in duck population, "soon the salmon will be gone too" (Hill 2011).

Dramatic declines in salmon abundance have been observed throughout coastal BC (mainland and Vancouver Island) since the 1990s, declining sometimes by >90% (English et al. 2008)[6]. High harvest rates into the 1990s contributed to this decline; however, low smolt survival in marine environments and degradation of freshwater habitats are considered the primary causes. Also, in the Koksilah-Cowichan system, predation of Coho and Chinook in the estuary while waiting for adequate flows to begin upstream migration is another source of decline. Further complicating efforts to re-establish Coho, the hatchery fish have lower survival rates than wild stocks (English et al. 2008).

Many of the wild Steelhead stocks on Vancouver Island, including the Cowichan River system, have also declined significantly since the early 1990's (Lill 2002). In 2002 Steelhead in the Koksilah River were classified as "conservation concern" because stocks were only at 10-30% of their habitats' capacity. However, it is also believed that there is rehabilitation and restoration potential in the Koksilah River to increase Steelhead numbers (Lill 2002).

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[6] Escapement data for Chum, Chinook, and Coho in the Koksilah River spans from 1953 to 1992 when the downward trend in abundance began.

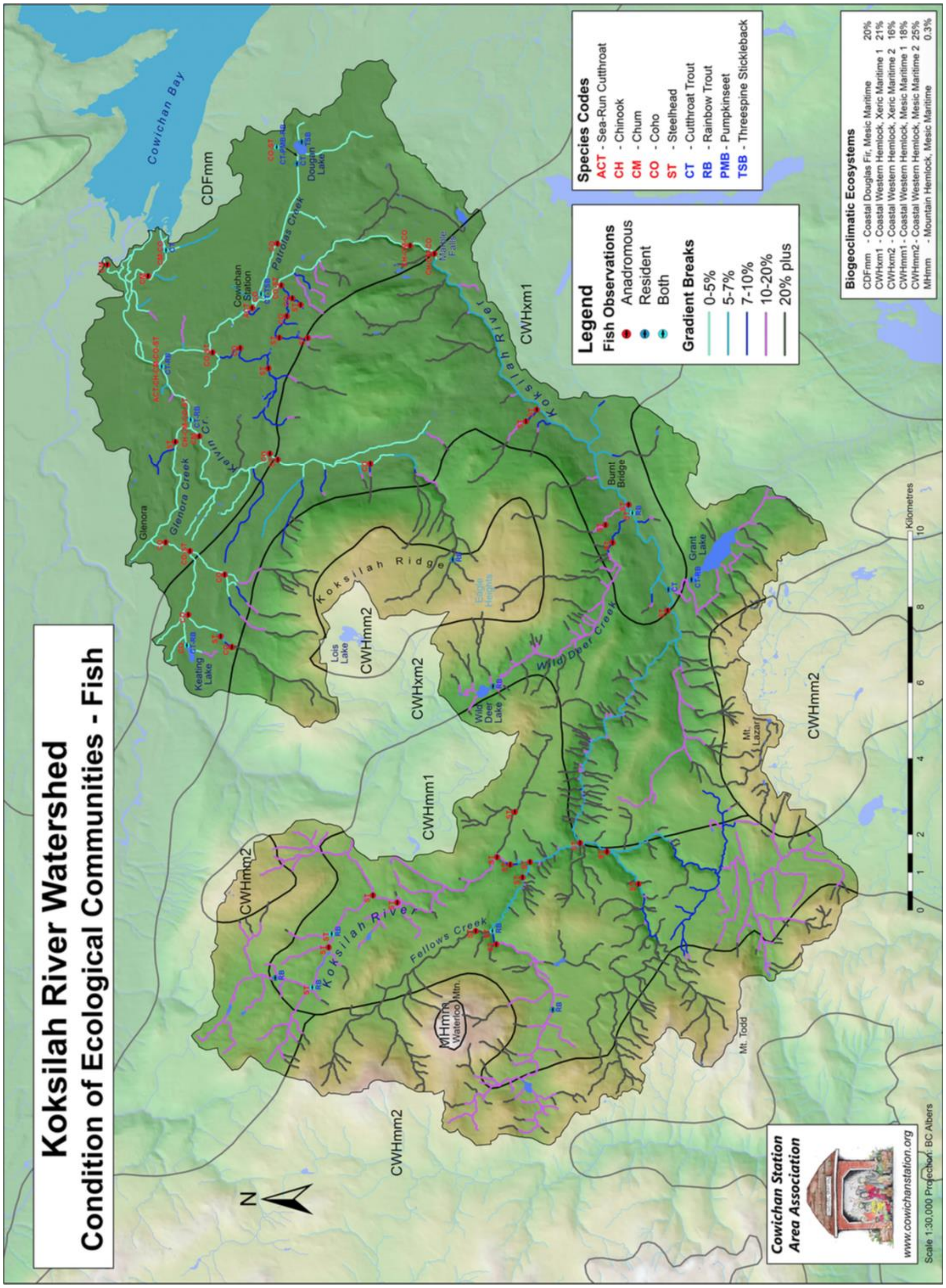

Figure 50. Fish occurrence and habitat in the Koksilah River watershed.

Conditions in Koksilah River that threaten fish populations include extreme low flows, increasing water temperatures, high water demand for agriculture, urban development, logging, and reduced sewage dilution rates during low flows (BC MOEP 1986, Tutty 1984, McKean 1989, Lill 2002). Extended low stream flows delay upstream fall migration, leaving Chinook waiting in the estuary while being susceptible to predation by seals and sea lions (CWHCI 2016). Lack of adequate cover, large woody debris, and deep pools in the lower reaches of the Koksilah River also reduce spawning and rearing habitat quality. Habitat was lost in the Cowichan-Koksilah floodplain when important side channels were eliminated during urban and agriculture development (CWHCI 2016). And, more recently, increasing blue-green algae in the lower Koksilah River pools may inhibit rearing of trout and salmon by clogging their gills and reducing ability to locate food.

**Figure 52. Wild Deer Creek in the Koksilah watershed.**

While water temperatures in the Koksilah River have generally remained sufficiently cold to meet fish habitat requirements, recent data are showing a possible warming trend. Between 1971 and 2003, the cold water temperature requirement of 19°C for most species was met (Pommen 2004). Kelvin Creek has had very low temperatures (17°C), providing a cold water refugia for juveniles (Tutty 1984). However, recent data are showing that summer water temperatures in Koksilah River are exceeding thresholds required by some species (Obee 2011, Dessouki 2010). While many fish species are absent in summer, when water temperatures are highest, Steelhead and Coho are present. Steelhead often remain in the river for two years and require water temperatures at or below 19°C for rearing. Coho remain in the river up to three years and require water temperatures at or below 17°C. There is concern that water temperatures in the Koksilah River may continue to rise due to climate change and continued removal of streamside vegetation during forestry, agriculture, and urban development activities. In a study on the west coast of Vancouver Island, mean monthly summer stream temperatures increased 5°C following riparian harvesting, although some of this increase is climate-related (Tschaplinski and Pike 2017 and references therein). A change of this magnitude in the Koksilah system would further impact Steelhead and Coho populations.

## Condition - Wildlife

The Koksilah watershed is home to many wildlife species, some of which are considered "at risk" as their numbers decline and habitat is lost. Based on a search of the BC Conservation Data Centre dataset (BC CDC 2018), there are 30 vertebrate and 30 invertebrate species of conservation concern possibly occurring in the Koksilah watershed. This includes 14 vertebrate and 13 invertebrate species identified as threatened or endangered by the BC Ministry of Environment and/or Environment Canada.

Many of these species (and others) have been observed in the watershed during inventory work or by wildlife enthusiasts (Table 2, 3) (Figure 54). Bird counts conducted in Koksilah Provincial Park alone have identified 90 bird species (BC MWLAP 2001). Mammals observed in the park include Roosevelt Elk, Black Bear, Cougar, Wolf, Mink, Marten, and Black-tailed Deer. Amphibians include Red-legged Frog, Rough-skinned Newt, and Western Red-backed Salamander (BC MWLAP 2001) all of which require riparian forest habitat. The Ensatina Salamander has been observed in the Koksilah watershed (Figure 54) and is usually found in old growth habitats (Bunnell et al. 1999).

**Figure53. Black bear (*Ursus americanus*) in the Koksilah watershed.**

At the community event as part of this project, residents reported seeing a Northern Saw-whet Owl in the Koksilah Ancient Forest and Marten near Wild Deer Lake and Grant Lake Creek. One resident reported observing a Barn Owl in the watershed, which is on the BC Red list (threatened or endangered) and is classified as threatened by the federal government.

Since most of the Koksilah landbase is private managed forest, other wildlife species of conservation concern may have been recorded but this information is not publically available.

**Table 2. Vertebrate species of conservation concern observed in the Koksilah watershed.**

| Common name | Scientific Name | BC List[7] | SARA | Info. Source |
|---|---|---|---|---|
| Northern Goshawk, laingi subspecies | *Accipiter gentilis laingi* | Red | Threatened | 1 |
| Green Heron | *Butorides virescens* | Blue | - | 1 |
| Great Blue Heron | *Ardea herodias fannini* | Blue | Special Concern | 3 |
| Band-tailed Pigeon | *Patagioenas fasciata* | Blue | Special Concern | 3 |
| Barn Swallow | *Hirundo rustica* | Blue | Threatened | 3 |
| Western Screech Owl | *Megascops kennicottii kennicottii* | Blue | Threatened | 3 |
| Barn Owl | *Tyto alba* | Red | Threatened | 4 |
| Olive-sided Flycatcher | *Contopus cooperi* | Blue | Threatened | 3 |
| Northern Red-legged Frog | *Rana aurora* | Blue | Special Concern | 1 |
| Western Toad | *Anaxyrus boreas* | Yellow | Special Concern | 2,3 |
| Sharp-tailed Snake | *Contia tenuis* | Red | Endangered | 2 |
| Roosevelt Elk | *Cervus elaphus roosevelti* | Blue | - | 3 |

1 – BC Conservation Data Centre. 2014. Occurrence Report Summary. BC Min. Env. Available: http://maps.gov.bc.ca/ess/hm/cdc, (accessed Jun 6, 2018).
2 – DataBC 2018b, Incidental Wildlife Observations
3 – BC MWLAP 2001
4 – Reported by community member

Four of the 5 invertebrate species of concern recorded in the watershed are endangered or threatened (Table 3). The Dun Skipper, a small brown butterfly, has been observed at Burnt Bridge next to Koksilah Provincial Park, along the TransCanada Trail, and along the tracks near Cowichan Station (BC CDC 2014a,b,c). The Dromedary Jumping Slug has been observed at Eagle Heights (BC CDC 2014d) while the Warty Jumping Slug was located near Keating Lake (BC CDC 2014e).

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[7] BC red list = threatened or endangered; BC Blue list = special concern

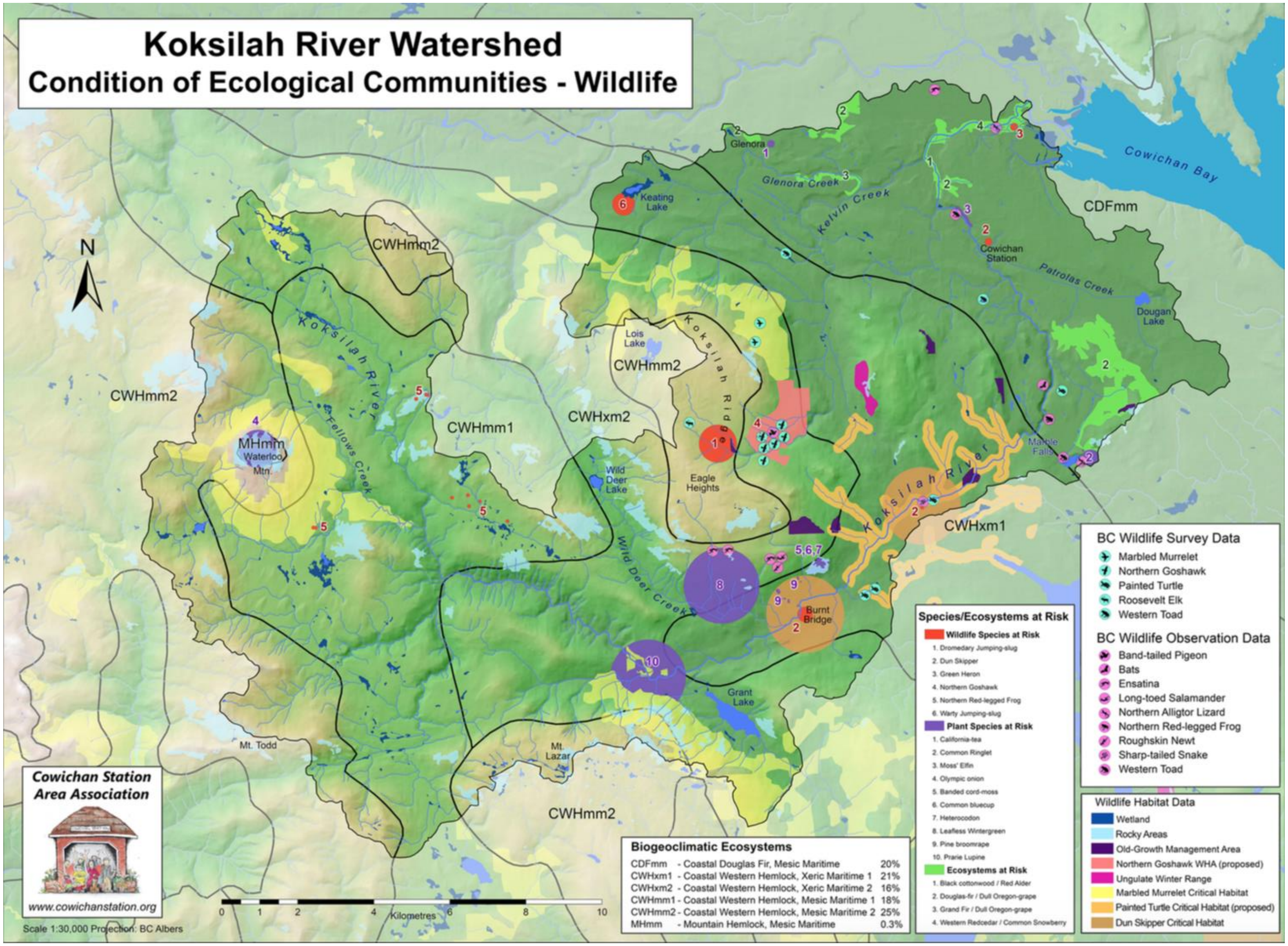

Figure54. Wildlife observations and habitat occurrence in the Koksilah watershed.

**Table 3. Invertebrate species of conservation concern observed in the Koksilah watershed.**

| Common name | Scientific Name | BC List | SARA | Info. Source |
|---|---|---|---|---|
| Dun Skipper | Euphyes vestris | Red | Threatened | 1 |
| Warty Jumping-slug | Hemphillia glandulosa | Red | Special Concern | 1 |
| Dromedary Jumping-slug | Hemphillia romedaries | Red | Threatened | 1 |
| Common Ringlet, insulana subspecies | Coenonympha tullia insulana | Red | - | 1 |
| Moss' Elfin, mossii subspecies | Callophrys mossii mossii | Blue | - | 1 |

1 – BC Conservation Data Centre. 2014. Occurrence Report Summary. BC Min. Env. Available: http://maps.gov.bc.ca/ess/hm/cdc, (accessed Jun 6, 2018).

These and other vertebrate and invertebrate species occupy a wide range of habitats some of which are in short supply. Therefore a number of habitat designations have been established in order to protect remaining habitat or to promote recovery of certain wildlife species (Figure 54). An Ungulate Winter Range has been designated under the *Forest and Range Practices Act* (FRPA) to protect Black-tailed Deer and Roosevelt Elk habitat during forest operations on provincial Crown land. No new road building or harvesting is permitted within this area. A Wildlife Habitat Area has also been proposed under FRPA with the intention to protect the habitat surrounding known Northern Goshawk nests (Table 2 above) during forest operations on Crown land.

Critical Habitat under the federal *Species at Risk Act* has been identified in the Koksilah watershed for Marbled Murrelet, Dun Skipper, Northern Goshawk laingi subspecies[8], and Little Brown Myotis, offering protection of habitat on both public and private lands. Additional Critical Habitat was recently proposed for Painted Turtle (Figure 54). Land owners and managers have the responsibility to protect Critical Habitat to allow for the recovery and survival of these threatened or endangered species.

Other important and common habitat features include wetlands and rock outcrops (Figure 54). Wetlands are especially important for amphibian species including the Blue-listed Northern Red-legged Frog, which has been observed near several wetlands. Some of the older forest patches on provincial Crown land, the largest being 30 ha, have been mapped as Old Growth Management Areas (OGMAs) though there is no legal order in place to ensure they are protected. Although very small, these OGMAs may provide some protection of habitat features for some wildlife species.

Furthermore, although not legally designated in any way, the Lower Koksilah River, Glenora Creek, Kelvin Creek, and Dougan Lake have been recognized as offering good migration and wintering habitat for waterfowl (McKean 1989). As earlier mentioned, the estuary provides important habitat for migratory and overwintering sea birds.

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[8] The mapping file for Northern Goshawk critical habitat was not available in time for inclusion on the maps in this report.

## Condition - Plants

Plant life varies across the many ecosystem types in the Koksilah watershed. Rare plants have been found in some of the more unique ecosystems. Based on a search of the BC Conservation Data Centre dataset, there are 32 vascular plant, six nonvascular plant, and four fungus species of conservation concern possibly occurring in the Koksilah watershed. This includes 19 species identified as threatened or endangered by the BC Ministry of Environment and/or Environment Canada.

Nine vascular plant species of conservation concern have been observed in the Koksilah watershed, four of which have not been seen in several decades (Table 4, Figure 54). Many of these plants have been identified in Koksilah Provincial Park or the Eagle Heights area.

**Table 4. Vascular plants of conservation concern observed in the Koksilah watershed**[1]

| Common name | Scientific Name | BC List | SARA | Comments |
|---|---|---|---|---|
| Pine broomrape | *Orobanche pinorum* | Red | - | Located in Koksilah Provincial Park and areas north and northwest. |
| Common bluecup | *Githopsis specularioides* | Red | - | Several hundred Common bluecup plants observed at Eagle Heights. |
| Prairie lupine | *Lupinus romeda* | Red | Endangered | Last observed in 1973. Road improvements, residential development, logging, and invasive plants are threats. |
| Howell's violet | *Viola howellii* | Red | - | Observed in Shawnigan watershed with possible overlap into Koksilah watershed. Last observed in 1957. |
| Macoun's groundsel | *Packera macounii* | Blue | - | Observed at various times since 1912 at Koksilah watershed boundary near Shawnigan Lake. Last observed in 1956. |
| Heterocodon | *Heterocodon rariflorus* | Blue | - | Observed about 300 plants on Koksilah Ridge above Koksilah Provincial Park and at Eagle Heights. Located at seepage sites. |
| Leafless wintergreen | *Pyrola aphylla* | Blue | - | Observed in Eagle Heights area. |
| California-tea | *Rupertia physodes* | Blue | - | Around 100 plants observed on private property near Glenora Road. |
| Green-fruited sedge | *Carex interrupta* | Blue | - | Historical observation. Last observed near Cowichan Bay. |

[1] B.C. Conservation Data Centre. 2014. Occurrence Report Summary. B.C. Ministry of Environment. Available: http://maps.gov.bc.ca/ess/hm/cdc, (accessed Jun 6, 2018).

One nonvascular plant of conservation concern has been observed in the Koksilah watershed. Banded cord moss (*Entosthodon fascicularis*) is designated special concern by the BC Conservation Data Centre and under the federal *Species at Risk Act*, and may be threatened by hikers (BC MOE 2018).

## Condition - Ecological Communities

Ecological communities across the watershed vary in composition across the different aspects, elevations, soil types, and moisture conditions. Based on a search of the BC Conservation Data Centre dataset, there are 52 ecological communities of conservation concern possibly occurring in the Koksilah watershed. This includes 29 ecological communities identified as threatened or endangered by the BC Ministry of Environment. Seven ecological communities have been recorded in the Koksilah watershed, five of which are classified as threatened or endangered (Table 5). The remaining two are classified as special concern. All of these ecological communities occur in the lower elevation very dry Coastal Douglas-fir ecosystem. Other ecological communities of conservation concern may occur on the higher elevation private managed forest areas; however, this information is not publically available.

**Table 5. Ecological communities of conservation concern observed in the Koksilah watershed.**

| Common name | Scientific Name | BC List | Info. Source | Comments |
|---|---|---|---|---|
| Black cottonwood – red alder / salmonberry | *Populus trichocarpa – Alnus rubra / Rubus spectabilis* | Blue | 1 | On floodplain of Koksilah River. Mainly in rural residential. |
| Western redcedar / common snowberry | *Thuja plicata / Symphoricarpos albus* | Blue | 1 | On floodplain where Cowichan and Koksilah Rivers meet. Surrounded by agriculture and rural residential, with urban nearby. |
| Douglas-fir / dull Oregon-grape[4] | *Pseudotsuga menziesii / Berberis nervosa* | Red | 1 | Largest listed Ecological Community in Koksilah watershed. Located on mid to lower slopes of Cobble Hill Mountain. Surrounded by farmland, rural residential, and transportation corridors. |
| Grand fir / dull Oregon-grape[5] | *Abies grandis / Berberis nervosa* | Red | 1 | On Glenora Creek extending to confluence with Kelvin Creek. Forest, agriculture, rural residential and gravel pit nearby |
| Douglas-fir – Arbutus[7] | *Pseudotsuga menziesii – Arbutus menziesii* | Red | 2 | Not mapped by BC CDC, but identified by BC Parks. |
| Garry oak/ Ocean spray[7] | *Quercus garryana / Holodiscus discolor* | Red | 2 | Not mapped by BC CDC, but identified by BC Parks at Eagle |

| Common name | Scientific Name | BC List | Info. Source | Comments |
|---|---|---|---|---|
| | | | | Heights. |
| Arbutus/ Hairy manzanita[7] | *Arbutus menziesii / Arctostaphylos columbiana* | Red | 2 | Not mapped by BC CDC, but identified by BC Parks at Eagle Heights. |

1-B.C. Conservation Data Centre. 2014. Occurrence Report Summary. B.C. Ministry of Environment. Available: http://maps.gov.bc.ca/ess/hm/cdc, (accessed Jun 6, 2018).

2-MWLAP 2001

Many of these species and ecological communities of conservation concern are at risk because of changes to their habitat from land use. For example, many species have already disappeared from agricultural lands in general due to the requirement for food production (Bunnell et al. 1999). Past and current forest practices and land development activities create a landscape lacking structural diversity required by many species. For example, breeding and foraging habitat is often lacking for cavity nesting species; amphibian population declines often follow a loss of large downed wood, dense overstory, and deep litter layers. In general, loss of old growth throughout the landscape reduces the abundance of amphibians and cavity nesting species (Bunnell et al. 1999).

## Climate Change

As discussed earlier, projections for climate change vary by scale and scenario. While it is not possible to anticipate any particular outcome with absolute certainty, the consequences of the potential changes summarized below (in addition to impacts to low flows discussed earlier) are severe enough to warrant a great deal of precaution. It is also important to note that while the outcomes below are presented as discrete topics, they are, in fact, deeply interconnected.

### Natural Disturbance

Fire is the dominant form of natural disturbance in the Koksilah watershed. As noted above, fire intervals in recent history ranged from 350-1000 years. As global warming results from climate change however, it has been suggested that the Koksilah watershed may revert to conditions present thousands of years ago, when fires were more frequent (Brown 2015). Further, it is projected that the length of the fire season across the Georgia Depression eco-province, which includes the entire Cowichan region, is expected to increase from 30 to 52 days of the year (Haughian et al. 2012), and monthly severity ratings to increase up to 60% (BC MFLNRO 2016).

Other disturbance agents, such as insects may also become more prevalent. For example, the western hemlock looper, an insect that causes severe foliar damage and tree mortality amongst western hemlock, western redcedar and Douglas-fir (Government of BC, undated), may have more frequent outbreaks in response to the expanded range of western hemlock trees and more frequent drought (Ministry of FLNRO, 2016). Given that a significant portion of the Koksilah watershed is comprised of the Coastal Western Hemlock biogeoclimatic zone, such outbreaks could significantly alter ecosystem composition, structure and function, not unlike the impacts of mountain pine beetle outbreaks in the interior of BC.

### Ecosystem Shifts

As a result of the predicted warming in the Cowichan region, the entire Coastal Western Hemlock biogeoclimatic zone is predicted to shift 200-300 m higher in elevation, and 35-55 km further north (BC MFLNRO 2016). Meanwhile, the range of suitable climate for the Coastal Douglas fir biogeoclimatic zone is not expected to change significantly (BC MFLNRO 2016). At a finer scale however, pockets of very wet or very dry ecosystems, such as those dominated by western redcedar and arbutus, will likely decline (BC MFLNRO 2016).

While a 3 degree Celsius temperature increase does not sound like much, consider that 6,500 years ago, the climate in British Columbia cooled by 2-4 degrees Celsius, the results of which led to replacement of oak woodlands by conifer forests (Pellatt and Gedalof 2014). In other words, the same degree of temperature change led to a drastic shift in forest composition and structure (Pellatt and Gedalof 2014), however stretched over a period of 1000s of years. In contrast, current projected temperature increases are expected to occur in less than 50 years. The full extent of compressing this level of change into a much smaller timeline is unknown. It is expected, however, that such temperature changes could alter the timing of important environmental events, causing a breakdown in ecological relationships, such as predation and pollination, while invasive species will likely become more prevalent in response to both warming and increased disturbance (BC MFLNRO 2016).

## Summary

Xwulqw'selu (Koksilah village) is likely the namesake of what is now called the Koksilah River in the English language. There are many other Hul'q'umi'num' names for places in the Koksilah Watershed--names that existed long before colonists arrived, and which convey the deep history and connection that the Quw'utsun' people have with this place. The relationships that the Quw'utsun' people have with the Koksilah watershed are an integral part of its ecological character, which has changed dramatically since the onset of European settlement.

Historically, most of the watershed was covered with old growth Douglas-fir forests with diverse and abundant structures such as large trees, standing dead trees, and downed wood. Low elevation forests were open growing while middle and upper elevation forests were more moist and dense. Upper elevation wetlands and the few small lakes regulated water flows to some extent, although not to the same degree as would a large lake. Consequently, the Koksilah River has experienced high peak flows following big storms and low flows in dry summer months. Salmon occurred primarily in the low gradient stream reaches below Marble Falls, while the strong swimming Steelhead managed to reach further up the Koksilah River for spawning. Wildlife species were diverse making use of the varied and abundant structures and ecosystem types.

European settlement resulted in privatization of most of the land in the Koksilah watershed. Over 97% of the watershed has since been disturbed by anthropogenic activities—the effects of which are being amplified by climate change. In addition to changes on the land base, changes in freshwater and marine environment have also been documented. Declines in surface water quality and quantity have become more obvious, the number of low flow days per year is increasing, and water yield in summer is declining. Increases in contaminants, sediments, and water temperature as well as decreases in dissolved oxygen are impacting water quality. Declines in salmon and Steelhead populations have accelerated in the past decades. In addition, several plant and wildlife species as well as ecological communities are now threatened or endangered. Important habitat structures such as large trees, standing dead trees, and downed wood are becoming rare in the landscape. Many important values in the Koksilah watershed are at risk of becoming severely compromised, while others have already been pushed to the edge.

Nature's resilience is well known and protected networks can support natural processes to restore composition, structure and function of the watershed. The next phase of work will focus on developing a protected landscape network for the Koksilah watershed, as a blueprint for strategically organizing community-led stewardship and restoration efforts.

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## Appendix 1. Spatial Analysis Methodology

Available public data were collected and evaluated for accuracy and overall usefulness to the goals of the project. The following is a summary of the methods and data used to produce the seven thematic maps and associated summary tables included in this report. Methods are presented by map:

Ecological Character

The hypsoshade background was created by overlaying elevation values onto a DEM-derived hillshade.

The slope grid was calculated from the DEM after filling any voids that may have been in the original data, then it was divided into 3 slope classes: 0-40%, 40-60% and >60%. The three slope classes were combined with the soils data to define areas as having "Potential for Movement" and "Potential for Disturbance" using the following criteria:

| | **Potential For:** | |
|---|---|---|
| **Surficial Geology (Material type & Expression)** | **Movement** | **Disturbance** |
| Cv – Colluvial veneer | >60% | |
| Cvb – Colluvial veneer blanket | >60% | |
| F - Fluvial | | |
| F(G) – Glacio fluvial | | |
| F(G)h – Glaciofluvial hummocky | | |
| F(G)t – Glaciofluvial terraced | | |
| Fp – Fluvial plain | | All >40% |
| Fs-V – Fluvial steep slope, gullied | All | |
| Fv – Fluvial veneer | | |
| Mb – Moraine (till) blanket | >60% | |
| Mb-V – Moraine (till) blanket, gullied | All | |
| Ob – Organic blanket | | All <40% |
| Ob-R – Organic blanket, rapid mass movement | All <40% | |
| Ov – Organic veneer | | All <40% |
| W(G)b – Glaciomarine blanket | >60% | 0-60% |
| Wb – Marine blanket | | All <40% |

Data indicating “Gully Potential” was derived from a report and map produced by terrain specialist R.H. Guthrie (2005), and published by the BC Ministry of Environment. The Gully Potential map depicts a combination of slope and soils data, and identified potential gullies as “terrain that contains erodible sediments deeper than 1 m, on slopes steeper than 25%, for more than 100 m .”

The report is Vancouver Island Geomorphology: Extended Legends to Nine Thematic Maps. The full report can be found here: https://www.researchgate.net/publication/305401780

Bedrock and Talus were identified using the Vegetation Resource Inventory (VRI) published by Forest Analysis and Inventory Branch of the Province of BC in June, 2018. This updated VRI includes private lands on southern Vancouver Island. Bedrock was mapped where it constituted over 40% of the polygon area. All non-vegetated features of Talus were also selected.

Wetlands were identified using the Freshwater Atlas (FWA) mapped wetlands. New, modified or missing wetlands were identified using air photo interpretation of aerial photos from ESRI World Imagery and orthophotos obtained from the Capital Regional District. SPOT infrared imagery was also used to verify features and check positional accuracy.

Aquifer Vulnerability data was obtained from the Province of BC. Only high and medium vulnerability aquifers were selected for display on the map.

Biogeoclimatic Subzone Variants data were obtained from the Province of BC.

| Data Layer | Source | Scale |
|---|---|---|
| Digital Elevation Model (DEM) | Province of BC | 25 m |
| Biogeoclimatic Zones (BEC). Version 10 | Province of BC | 250,000 |
| Hypsoshade (from DEM) | Province of BC | 25 m |
| Slope (%) from DEM | Province of BC | 25 m |
| Terrain Stability | Province of BC | 50,000 |
| Gully Potential | Province of BC, Guthrie (2005) | 50,000 |
| Karst Potential | Province of BC | 250,000 |
| Vegetation Inventory Resource (VRI) | Province of BC | 20,000 |
| Freshwater Atlas (FWA) Wetlands | Province of BC | 20,000 |
| ESRI World Imagery | ESRI | varies |
| Aquifer Vulnerability | Province of BC | varies |

## Non-Forestry Lands

This map was created using publicly available zoning data provided by the Cowichan Valley Regional District (CVRD). Zoning data was overlaid with a grayscale hillshade derived from the DEM, streams and lakes from FWA and BGC lines.

| Data Layer | Source | Scale |
|---|---|---|
| Hillshade from Digital Elevation Model (DEM) | Province of BC | 25 m |
| CVRD Land Use Zones | Cowichan Valley Regional District (CVRD) | not specified |
| Freshwater Atlas (FWA) Streams and Lakes | Province of BC | 20,000 |
| Biogeoclimatic Zones (BGC). Version 10 | Province of BC | 250,000 |

## Forestry Lands

Parcel Survey Fabric data obtained from the Province of BC was used as a base map to align property information from other sources. Forestry zones obtained from CVRD data were classified as follows: woodlots, BC Timber Sales (BCTS) operating areas, Island Timberlands and TimberWest. To simplify the map, some road right-of-way polygons were not shown.

| Data Layer | Source | Scale |
|---|---|---|
| Parcel Survey Fabric | Province of BC | varies |
| TimberWest Lands | TimberWest | not specified |
| MFU 19 Boundary (Island Timberlands, 1997) | Sierra Club BC | 20,000 |
| Woodlots | Province of BC | 20,000 |
| Parks | CVRD | not specified |
| Forestry Zones | CVRD | not specified |
| Biogeoclimatic Zones (BGC). Version 10 | Province of BC | 250,000 |
| Freshwater Atlas (FWA) Streams and Lakes | Province of BC | 20,000 |

## Condition of Ecological Communities: Fish

Three datasets were combined to develop stream gradients: 1) elevation data from 20-metre contours; 2) DEM; and 3) the Freshwater Atlas stream network. Where stream segments crossed over two contour lines, the gradient was calculated as 20 metres / length of segment. Where there were stream confluences or headwaters between contour lines, the DEM value was used to calculate the gradient.

Gradient breaks were established at four different elevation intervals (5, 7, 10 and 20 metres), then the stream segments were assigned the break elevation value by using an upstream trace routine.

Fish Information Stream Summary (FISS) Observation data were selected for 9 species of interest, including 5 anadromous and 4 resident species. These were mapped with different icons and labels.

Some fish observations above Marble Falls were not displayed because they were a result of an attempted stocking program that did not establish a run.

The background is a hypsoshade map with BGC variants added.

| Data Layer | Source | Scale |
|---|---|---|
| Hillshade from Digital Elevation Model (DEM) | Province of BC | 20,000 |
| Slope from Digital Elevation Model (DEM) | Province of BC | 20,000 |
| Contour Lines (20-metre interval) | Province of BC | 20,000 |
| Freshwater Atlas (FWA) Stream Network | Province of BC | 20,000 |
| Fish Information Stream Summary (FISS) Observations | Province of BC | 20,000 |
| Fish Information Stream Summary (FISS) Obstacles | Province of BC | 20,000 |
| Biogeoclimatic Zones (BGC). Version 10 | Province of BC | 250,000 |

### Condition of Ecological Communities: Wildlife

Wildlife-related data were collected from Provincial and Federal Government sources for Species at Risk. Species at Risk data were split into three classes for display: wildlife, plants and ecosystems. Not all species in the Species at Risk inventory were displayed.

The Western Painted Turtle Habitat map was obtained from the "Recovery Strategy for the Western Painted Turtle (*Chrysemys picta bellii*) Pacific Coast population in Canada", available here: http://www.registrelep-sararegistry.gc.ca/document/default_e.cfm?documentID=3273. The map image featured in the report was georeferenced and digitized to create a usable digital map overlay.

Areas in the watershed identified by the Province of BC as Old-Growth Management Area, Wildlife Habitat Area and Ungulate Winter Range were included on the map.

The method for identifying wetlands and rocky areas (bedrock and talus) data are described in the Ecological Character map methodology.

| Data Layer | Source | Scale |
|---|---|---|
| Hypsoshade (elevation and hillshade combined) | Province of BC | 25 m |
| Biogeoclimatic Zones (BGC). Version 10 | Province of BC | 250,000 |
| Vegetation Resource Inventory (VRI) | Province of BC | 20,000 |
| FWA Wetlands, Streams and Lakes | Province of BC | 20,000 |
| Old-Growth Management Areas (OGMA) | Province of BC | 20,000 |
| Wildlife Habitat Areas | Province of BC | 20,000 |

| Data Layer | Source | Scale |
|---|---|---|
| Ungulate Winter Range | Province of BC | 20,000 |
| Species and Ecosystems at Risk | Province of BC | varies |
| Western Painted Turtle Habitat (Proposed) | Government of Canada | 160,000 |
| Critical Habitat for Federally-Listed Species at Risk | Government of Canada | varies |
| Wildlife Species Inventory Survey | Province of BC | varies |

Condition of Landscape Connectivity & Historical Forest Condition

| Data Layer | Source | Scale |
|---|---|---|
| Vegetation Inventory Resource (VRI) | Province of BC | 20,000 |
| Forest Cover Map (1954) | BC Forest Service | - |
| Interim Forest Cover Series (oub. 1957 - from photos 1954-1955) | Province of BC | 126,720 |
| Landsat MSS (1972) | US Geological Survey (USGS) | 60 m |
| Landsat TM (1985) | USGS | 30 m |
| Landsat L8 (2018) | USGS | 15 m |
| ESRI World Imagery (aerial photos, age varies) | ESRI | 30 cm - 1 m |
| SPOT satellite (2004 pan-chromatic, 2006 multi-spectral) | Province of BC | 5 m |
| Planet Explorer online image viewer | Online | 3 m |
| Google Timelapse (1985-2016) | Google | 30 m |
| CRD Orthophotos (2013-2017) | Google | 30 cm - 50 cm |
| High Resolution Forest Change for Canada "Time Series" (1985-2015) | Government of Canada | 30 m |

The following steps were applied to develop the Historical Forest Condition map series.

The six map panels are presented as a continuous time series, however it is important to note that the data used to create each map varies—largely due to advancements in mapping technology between 1954 and 2018. Consequently, three historical time periods were used as “starting points” for analysis: 1954, 1972, and 1985.

### 1954

In 1957 the BC Forest Service produced the forest cover map based on interpretation of air photos from 1954-1955. Information provided by the 1954 map is the coarsest in detail, and provides the least amount of information regarding "Immature" forest. Specific age groups within "Immature" forest are not noted. This map clearly identifies "Old" forest and then-logged "Old" forest, however, and distinguishes between immature forest following fire and immature forest following logging.

A hardcopy of the map was used as the primary reference, while a copy digitized by The Wilderness Society in 1990 was used to identify immature forest and not-satisfactorily-restocked (NSR) areas. For the purpose of the Koksilah ecosystem-based assessment, the immature forest age class was divided into two sub-classes: "logged", and "natural" (likely due to disturbance from fire). Historical fire data obtained from DataBC (MFLNRORD 2018) was used to confirm extent and age of the burned forest area.

### 1972

Landsat multispectral (MSS) satellite imagery was available from 1972, and is one of the earliest satellite-based remote sensing image collections available. These images provided a clear indication areas logged during that time period. Cross-referencing the locations of logged areas against the 1954 map, indicates that logging conducted between 1954-1972 was exclusively in "Old" forest stands. Forest identified as "Immature" in 1954 continues to be classified as such in 1972, due to the limited age information provided by the 1954 map for this class. Areas previously classified as "Old-logged" in 1954, become "Very Young" in 1972.

### 1985 - 2018

In 1985 improved Landsat imagery (i.e., Thematic Mapper, or TM) became available and allowed for composite images to be analysed on a pixel by pixel basis—the process used during this project to determine change in forest cover between 1985 and 2007 (i.e., to produce the 1985, 1996, and 2007 maps). Pixel values were matched to forest cover polygons provided by Vegetation Resource Inventory data, using a "majority rule" (i.e., the most commonly occurring pixel value in a polygon was assigned to that polygon). SPOT and Landsat 8 satellite imagery were used to continue the pixel-based change in forest cover analysis from 2007 to 2018. In addition to the Landsat and SPOT imagery, time series data obtained from Natural Resources Canada and images viewable online through Planet Explorer were also used to assign and/or confirm age class interpretations.

Specific age ranges assigned to "Young", "Immature", and "Mature" age classes vary between years, in general due to the challenge of using datasets that vary in technological origin, data resolution and detail. More specifically in the case of this project, lack of specific age data for forest noted as "Immature" in the 1954 map and the use of three different time periods as starting points for analysis, presented challenges. "Mature" forest, however, is consistently noted as >140 years across all six time periods, and is based on the extent of "Mature" forest mapped in 1954. This baseline data allowed for a confident comparison of "Mature" versus "Immature" logging between 1954 and 2018, and production of the Annual Rate of Logging graph displayed at the bottom of the Historical Forest Condition map series.