Winter 2009

# Proposed Closure of Brannian Creek Hatchery: Environmental Impact Assessment

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Huxley College of the Environment

Environmental Impact Assessment

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Signature ______________________
Crystal Bogue

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February 25, 2009

Dear Concerned citizen,

This Environmental Impact Assessment (EIA) was performed as part of a class at Western Washington University during winter quarter, 2009. As a group we analyzed the possible closure of the Brannian Creek fish hatchery on Lake Whatcom. This includes an assessment of environmental impacts in relation to a proposal, an alternative, and a no action proposal.

We recommend the proposal and alternative as options to deal with the possible closure of the hatchery that supports Lake Whatcom's Kokanee population. During these difficult economic times it is important to consider all options and impacts. The alternative proposal has the most benefits for restoring naturally spawning Kokanee.

Our investigation is an attempt to analyze all reasonable possibilities and summarize major impacts to the natural and built environment. We hope it offers insight into the environmental and social implications of the possible Brannian Creek hatchery closure.

Sincerely,

The Brannian Creek Fish Hatchery EIA Team

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# Proposed Closure of Brannian Creek Hatchery

## Environmental Impact Assessment

*Prepared for:*

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Environmental Impact Assessment
ESCI 436
Huxley College of Environmental Sciences
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***Note:*** *This report represents a class project that was carried out by students at Western Washington University, Huxley College. It has not been undertaken at the request of any persons representing local government or private individuals. Nor does it necessarily represent the opinion or position of individuals from government or the private sector.*

# Fact Sheet

| | |
|---|---|
| Project Title: | **Environmental Impact Assessment on the Proposed Closure of the Brannian Creek Hatchery** |
| Description of Project: | The proposed action is the closure of the Brannian Creek Hatchery located on Lake Whatcom. The Washington Department of Fish and Wildlife have proposed this closure due to state budget cuts. |
| Legal Description of Location: | The location of the Brannian Creek Hatchery is in Township 37, Range 4N, Section 15 all within the Lake Whatcom watershed in Whatcom County. |
| Proposer: | Washington State Senate<br>P.O. Box 40482<br>Olympia, WA 98504 |
| Lead Agency: | Department of Fish and Wildlife, Washington |

Required Licenses & Permits:

| | |
|---|---|
| Hydraulic Project Approval (HPA) | State Fish & Wildlife Habitat Program |
| Archeological Excavation Permit | Community Development Office of Archeology and Historic Preservation |
| Forest Practices Approval | Natural Resources Regional Offices |
| NPDES permit | |

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- Elements of the Built Environment
- Alternative Action
- Conclusion
- Fact Sheet

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- Appendix A
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1220 N Forest St
Bellingham, WA 98225
Wednesday, March 11th at 5:00 PM

# Table of Contents

# List of Tables, Figures and Appendices

**Tables**



**Appendices**



**Figures**

# Summary


### Purpose

The purpose of this Environmental Impact Assessment (EIA) is to evaluate the potential impacts of closing the Brannian Creek kokanee hatchery located in South Bay Lake Whatcom. Due to a large budget deficit facing the state of Washington, the closure of several hatcheries managed by the Washington Department of Fish and Wildlife (WDFW) has been proposed as a possible cutback measure. This EIA investigates the positive and negative impacts associated with the proposed action of hatchery closure, an alternative action and if no action was taken. The assessment of impacts was done in accordance with the State Environmental Policy Act (SEPA). The proposed action closes down all hatchery operations at the Brannian Creek facility. The alternative action integrates a phased closure of the Brannian Creek hatchery facility with the construction of artificial spawning channels in tributaries. If no action is taken then the Brannian Creek hatchery facility is left in full operation.

### Site Description

The Lake Whatcom hatchery on Brannian Creek is located in the third and southern most basin of Lake Whatcom at the mouth of Brannian Creek. The egg-taking program at the hatchery is over 100 years old and has historically produced the largest number of hatchery-propagated kokanee in the country.

### Problem Description

In response to the large deficit facing the state of Washington Governor Christine Gregoire outlined a state spending plan in 2008 for 2009-2011 fiscal period. This plan outlined cutbacks in several areas of state spending including the proposed closure of several or possibly many of the Washington state hatcheries which would save around six million dollars (Senate Democrats of Washington State 2009). The plan specifically named Colville, Omak, Mossyrock, Arlington and McKernon as hatcheries that would not survive the budget cuts (Washington State Democrats 2008). However there is speculation that additional hatcheries may be closed.  Among these hatcheries are several located in Whatcom County including the Brannian Creek facility (Relyea 2008).

### Proposed Action

The proposed action calls for the closure of the Brannian Creek hatchery facility. The hatchery currently supplies Lake Whatcom with around 5 million kokanee annually and exports an additional 10-11 million eggs to other lakes around the state of Washington (Personal Communication, Larry Sisson Bellingham, WA). Due to degradation of kokanee spawning habitat in many of the tributaries of Lake Whatcom there is currently very low levels of wild spawning kokanee in Lake Whatcom (Looff 1994, Dominguez 1994). The small amount wild spawning kokanee in Lake Whatcom are likely to be directly dependant on the Brannian Creek hatchery for survival (Dominguez 1994, Mark Downen unpublished data). Therefore, without measures to increase wild spawning, the proposed closure of the Brannian Creek hatchery would likely result in extirpation of kokanee from the Lake Whatcom watershed.

## Alternative Action (Preferred Action)

The alternative action is a phased closure of the Brannian Creek Hatchery facility along with construction and implementation of artificial spawning channels similar to those implemented on Weaver Creek, British Columbia (Appendix A). Artificial spawning channels provide optimal spawning habitat by controlling for flow conditions and substrate composition. Brannian Creek, near the hatchery would be an ideal site for spawning channels due to the large number of kokanee which currently return. Spawning surveys conducted in 2002 revealed that Anderson Creek supported the largest number of spawning kokanee (Mark Downen unpublished data). Olsen Creek would be another logical choice given that it has been the least influenced through anthropogenic activity and has the fewest amount of height barriers (Ian Smith Personal Communication, Bellingham, WA). The implementation of spawning channels in Anderson, Brannian and Olsen Creeks would significantly increase wild spawning of the Lake Whatcom kokanee population as well as coastal cutthroat, which are also native to Lake Whatcom and are currently declining due to tributary habitat degradation (Dominguez 1994). Through increasing wild spawning, spawning channels would significantly benefit the long term viability of these species.

## No Action Alternative

Under the no action alternative, the Brannian Creek hatchery facility would remain in operation. The Brannian Creek hatchery facility currently supports the Lake Whatcom kokanee population (Personal communication, Larry Sisson WDFW Bellingham, WA). There are concerns; however, regarding the health of the hatchery spawned kokanee population in Lake Whatcom. Declines in numbers have been attributed in part to historic hatchery management practices. There is also concern regarding the susceptibility of hatchery spawned kokanee to pathogens which could be introduced to the watershed following the proposed fish ladder over the Middle Fork Diversion dam on the Nooksack River (Whatcom Salmon Recovery 2003).

## Recommendation

Although the presence of the Brannian Creek hatchery is critical for maintaining the current population of kokanee in Lake Whatcom, as well as maintaining kokanee stocks in other lakes, the declining numbers of both wild and hatchery reared kokanee coupled with the possibility of pathogen introduction and additional habitat degradation lead to speculation of the future of kokanee in Lake Whatcom. In order to ensure long term survival and viability the Lake Whatcom kokanee and coastal cutthroat populations we recommend the alternative action.

# Brannian Creek Hatchery Impact Matrix

Table 1. This decision matrix represents elements of both the natural and built environments affected by actions to the Brannian Creek Hatchery.

No Impact: **0** | Large Positive Impact: + +
Positive Impact: + | Large Negative Impact: - -
Negative Impact: - | Positive and Negative Impacts: + / -

| | | Proposed Action | Alternative Action | No-Action Alternative |
|---|---|---|---|---|
| NATURAL ENVIRONMENT | | | | |
| Earth | Geology | **0** | **0** | **0** |
| | Soils | - | + / - | +/- |
| | Topography | **0** | **0** | **0** |
| | Erosion | **0** | - | **0** |
| Water | Surface Water | **0** | + / - | + / - |
| | Runoff/Absorption | **0** | - | **0** |
| | Floods | **0** | + | **0** |
| Fish, Wildlife, and Vegetation | Unique Species | - - | + + | + / - |
| | Fish Migration | - - | + + | + / - |
| BUILT ENVIRONMENT | | | | |
| Land and Shoreline Use | Recreation and Aesthetics | - | +/- | + |
| | Historical/Cultural | - | + | + |

# History of Brannian Creek Hatchery

Since the early 1900s, Lake Whatcom kokanee have been managed for a state and nationwide egg source as well as to enhance and sustain the recreational fishery (Crawford 1979, Dominguez 1994). In 1907 local game managers built the hatchery at the mouth of Brannian Creek. It was managed by the Whatcom County Game Commission until 1933 when administration was taken over by the Washington Department of Fish and Wildlife (Mark Downen unpublished data). Historically the hatchery has been one of the largest suppliers of kokanee eggs in the nation. The record egg take was 33 million kokanee eggs in 1946-47. (Washington State Game Commission 1947) The high success of the Brannian Creek hatchery was attributed to the fact that kokanee are incubated and reared in natural stream water (Mark Downen unpublished data).

In the 1950s management began to select for earlier spawning fish to provide larger fry in the spring in order to meet the demands of the growing recreational fishery (Dominguez 1994). This resulted in declining stocking levels which eventually reached a low of around 5 million in 1972. This prompted several management strategies to increase juvenile kokanee survival (Mark Downen unpublished data). Since 1981 the stocking goal into Lake Whatcom has remained at 5 million (Looff 1994).

Currently the hatchery produces 15-16 million eggs annually. Five million of the eggs are generally stocked into Lake Whatcom, with the remaining eggs transported to stock other lakes (Personal communication, Larry Sisson WDFW Bellingham, WA). There are 36 lakes across the state of Washington which are stocked with kokanee originating from the Brannian Creek hatchery. Approximately two thirds of the states kokanee fisheries are dependent on periodic stocking from the Brannian Creek hatchery facility. Kokanee are Washington State's fourth most preferred game fish and contribute 36.7 million annually from both wild and hatchery fish. About twenty million (56%) of that is supported by the Brannian Creek Hatchery. (Lake Whatcom Management Program 2009)

There are several current problems which face hatchery spawned kokanee in Lake Whatcom. Genetic alteration through the elimination of late run kokanee has caused decreased juvenile survival as the fry emerge before their primary food source is abundant (Dominguez 1994). The proposed fish ladder over the middle fork of the Nooksack diversion dam could also potentially harm the hatchery operation. Currently kokanee eggs produced at the Brannian Creek hatchery facility are disease free (Personal Communication, Larry Sisson Bellingham, WA). Introduction of pathogens from anadromous fish, namely the IHN virus, could have potentially harmful impacts on the Brannian Creek hatchery run.

# Elements of the Natural Environment

## EARTH

### GEOLOGY

*Existing Environmental Condition*

Underlying the Lake Whatcom watershed are sedimentary rocks as well as the metamorphic phyllite. Since much of the parent material is Chuckanut Sandstone, gravel and sand are frequently encountered throughout the area. Chuckanut Sandstone is composed of coal, conglomerate, sandstone, and shale. (Lake Whatcom Management Program 2009)

During the time the neighboring Chuckanut Mountains were formed, Lake Whatcom became surrounded by hills. The lake was formed when glacial ice 5,500 feet deep advanced and retreated repeatedly, producing the lake's bathymetry. (Lake Whatcom Management Program 2009) When the last ice age ended 10,000 to 15,000 years ago, Lake Whatcom became isolated from marine waters, giving rise to kokanee. The lake originally drained into the South Fork of the Nooksack River which drains into Bellingham Bay (Figure 1). At that time sockeye salmon were able to reach the lake, but over time Lake Whatcom rose in elevation. The sockeye became trapped due to the formation of Whatcom Falls and continued to reproduce as land-locked sockeye, also known as kokanee.

*Proposed Action Impacts*

There would be no significant impacts on geology.

*Alternative Action Impacts*

There would be no significant impacts on geology.

*No Action Impacts*

There would be no significant impacts on geology.

### SOILS

*Existing Environmental Condition*

Soils in the Lake Whatcom watershed are generally well drained since sand and gravel dominate composition. The soil near the mouths of Brannian creek is called Wickersham Channery Silt Loam, and is very deep and well drained. It has formed on alluvium from phyllite and has been found over 60 inches deep. Permeability varies from moderate in the upper layers to very rapid in the lower layers. (Soil Survey of Whatcom County Area, Washington 1983)

The soil at the mouth of Olsen Creek is called Whitehorn Silt Loam and is very deep and poorly drained. It is over 60 inches deep and composed mostly of silt and sand loam. Since the soil is not very permeable, it has high water retention capacity. Erosion is not a concern because the water table is high through most of the year and runoff is slow. Soil 0.12 miles upstream from the mouth is called Kline Gravelly Sandy Loam; it is deep soil, moderately drained, and formed in mixed alluvium. Permeability is rapid making water retention capacity low and like Whitehorn Silt Loam it has a seasonal high water table. (Soil Survey of Whatcom County Area, Washington 1983) The risk for water erosion is low due to the absence of steep slopes along those sections.

*Proposed Action Impacts*

If the hatchery is closed the soils in the tributaries where kokanee spawn will be negatively affected (Figure 2). Kokanee travel up the tributaries of Lake Whatcom to spawn and then die, supplying an important nutrient source to the ecosystem. In the case of hatchery closure, nutrients from decaying salmon carcasses will no longer be present. These nutrients benefit photosynthetic organisms and microbes in the water as well as other animals further up the food chain. They also sink into nearby soils and provide soil nutrients for terrestrial plants.

*Alternative Action Impacts*

The Lake Whatcom watershed's upland soils are prone to erosion by landslides due to the steep topography in combination with loose conglomerate and shale deposits (Lake Whatcom Management Program 2009). Creating spawning channels would entail digging channels into the soil and potentially create a hazard.

<u>Mitigation</u>

Digging out of channels should be done during low precipitation months and after fry have started migrating back to the lake for the season. The best construction practices available should be used to minimize rutting and compaction of the soil. In addition to only doing construction during dry months, spawning channel locations should be restricted to the lower reaches of Brannian, Anderson, and Olsen Creeks where possible. The soil is much more stable and this would minimize wash-out and erosion of the spawning channels.

*No Action Impacts*

If the no action proposal is chosen the soils will be both positively and negatively affected. The tributaries where kokanee still spawn benefit from the nutrients from their carcasses after spawning. Creeks, including Olsen, Anderson, and Fir, get a boost of nutrients that would otherwise be lacking when the fish spawn and die. These nutrients benefit photosynthetic organisms and microbes in the water. (Living Landscapes 2002) They also sink into the nearby soils and are taken up by terrestrial plants. This benefits animals further up the food chain. Brannian Creek does not fall into this category since all kokanee brought into the hatchery are spawned and the carcasses go on to other local businesses for rendering into other products.

Negative impacts of the hatchery include the lack of fish spawning in Lake Whatcom's tributaries. The majority of kokanee travel to Brannian Creek and end up in the hatchery, unable to spawn naturally. If the fish were wild they would all instinctively travel upstream to spawn and die, delivering nutrients to the surrounding environment. The entire lake ecosystem suffers from the use of the hatchery. Fry grow up in Lake Whatcom by consuming available food and nutrients and then as adults are removed from that nutrient cycle, unable to give back what they used.

## TOPOGRAPHY

*Existing Environmental Condition*

The topography of southern Lake Whatcom and its tributaries is mountainous. During the last ice age, the massive volume and weight of the glacier that covered the region scoured away less resistant rocks and left behind the more durable ones. The hills surrounding Lake Whatcom and the three distinct basins defined by sills are present due to the resistance of the rocks. (Lake Whatcom Management Program 2009)

Basin three is the southernmost basin in Lake Whatcom at 321 feet above sea level with an average depth of 178 feet and a maximum depth of 328 feet (Figure 1). It contains 96% of the total water volume of the lake. To the southeast is Anderson Mountain at 3,364 feet and to the west is Lookout Mountain at 2,677 feet. To the south of Lake Whatcom is Mirror Lake, which is drained by Anderson Creek. Water from the Middle Fork of the Nooksack River is diverted into Mirror Lake, flows through Anderson Creek, and enters Lake Whatcom. (Lake Whatcom Management Program 2009)

*Proposed Action Impacts*

There would be no significant impacts on topography.

*Alternative Action Impacts*

There would be no significant impacts on topography.

*No Action Impacts*

There would be no significant impacts on topography.

## EROSION

*Existing Environmental Condition*

Erosion is not a major concern at the mouths of Olsen and Brannian Creeks. Runoff occurs slowly there because the topography is not steep. Sandstone is susceptible to erosion and it is possible on steeper slopes that erosion is a regular occurrence. Logging and urbanization have increased erosion over the last century.

Debris flows are a concern, especially along Olsen Creek. These catastrophes can destroy spawning habitat. Olsen Creek is noted for its lack of large woody debris, which has negatively contributed to scouring during annual high flow events (Dominguez 1994).

*Proposed Action Impacts*

There would be no significant impacts on erosion.

*Alternative Action Impacts*

The impacts would be the same as the impacts on soils.

*No Action Impacts*

There would be no significant impacts on erosion.

# WATER

## SURFACE WATER

*Existing Environmental Condition*

The Lake Whatcom watershed covers an area of about 56 square miles or 36,000 acres. This area includes the surface of Lake Whatcom, which is about 4,994 acres. (Lake Whatcom Management Program 2009) Movement of surface water in the Lake Whatcom watershed has been heavily influenced by human activity (Figure 4). Lake Whatcom is fed by two watersheds: the watershed surrounding the lake and the watershed on the Middle Fork of the Nooksack River. Water from the Nooksack is diverted in a tunnel through Bowman Mountain to Mirror Lake where it empties into Anderson Creek, then the lake. The City of Bellingham uses this outside water source to adjust water in Lake Whatcom, minimizing fluctuations in the lake's water levels to provide a consistent source of water. The Lake Whatcom watershed is fed by five main tributaries: Anderson, Olsen, Smith, Fir and Austin Creeks (Figure 1). All five tributaries have major water quality problems due to human impacts. Whether or not the habitat in any of the tributaries can maintain kokanee populations is questionable. Restoration of salmon habitat in the tributaries is an option, with Brannian, Anderson and Olsen Creek showing the most promise. (Personal Communication, Mark Downen, WDFW La Connor, WA)

*Proposed Action Impacts*

There would be no significant impacts on surface water.

*Alternative Action Impacts*

Brannian Creek is part of the Lake Whatcom watershed, which provides drinking water for the City of Bellingham and surrounding area (Pickett et. al, 2008). It is therefore very important that the implementation of any building in the watershed have no negative effects to this water source. The surface water quality, quantity, and movement of Lake Whatcom have been severely modified by human activity and construction. The construction of spawning tributaries within the watershed would have minimal impacts on the water quality of this water body, but the movement of existing water would be changed. The spawning channels would use water taken from the stream during periods of high flows and from the lake or a storage reservoir during seasons of low flows. Water needs to be from a consistent source, so the best option would be to supplement the stream water with a mix of water from rain catchment systems and Lake Whatcom. The impact on the original stream channel should be negligible in terms of water quality and quantity. During the time of construction these streams may be stressed by the diversion of water out of the channel. These impacts would be temporary.

Mitigation

The amount of sediment flushed into the lake would increase during the time of construction. Low impact construction methods such as check dams, tarp coverings and straw bale barriers should be implemented (Lake Whatcom Management Program 2009). Mechanical spills should be avoided or thoroughly cleaned up.

During high water flood events, the spawning channels should remain intact due to regulation of the amount of water to the channels. The channels should also have positive effects on the original stream channel during high flow events as they may prevent the scouring of the original channels through diversion of some of the water. Common practices should include monitoring of runoff to the lake for sources of excess nutrients and sedimentation.

*No Action Impacts*

If the no action proposal is chosen, kokanee will continue to be taken out of Brannian Creek, thus not allowing nutrients stored in the spent carcasses to return to the lake ecosystem. Maintenance of the property surrounding the hatchery will have an impact on surface water quality. Any method of controlling weeds and grounds maintenance will affect the surface water. If herbicides are used to control weeds such as blackberries, they will enter the water eventually. All disturbances occurring in that area will have an impact on the surface water, even driving into and out of the property.

Positive impacts of the no action proposal include no new disturbances to the local watershed. No construction means decreased erosion and runoff. Also the balance of organismal diversity and hence water quality will not change since the kokanee will remain a component of the system. Lack of changes to the current system will maintain the balance that is in place now.

## PUBLIC WATER

*Existing Environmental Condition*

Approximately half of Whatcom County residents' drinking water comes from Lake Whatcom. There are 250 private wells, and approximately 15 other small public water systems take water directly from the lake. There are two major water intakes in the lake and they are owned by the City of Bellingham and Lake Whatcom Water and Sewer District. These two municipalities serve 86,000 Bellingham residents, 5 neighboring water districts, a tribal nation, Sudden Valley, Geneva, and portions of North Shore and South Bay. (Pickett et. al 2008, Lake Whatcom Management Program 2009). Nutrient loading and eutrophication are major concerns on the heavily populated lake.

*Proposed Action Impacts*

There would be no significant impacts on public water.

*Alternative Action Impacts*

There would be no significant impacts on public water.

*No Action Impacts*

There would be no significant impacts on public water.

**RUNOFF/ABSORPTION**

*Existing Environmental Condition*

Many soils in the Lake Whatcom watershed are poorly drained and have high water tables. This makes them prone to runoff and flooding. In addition, Lake Whatcom is highly sensitive to nutrient loading that can result from this runoff.

*Proposed Action Impacts*

There would be no significant impacts on runoff/absorption.

*Alternative Action Impacts*

The impacts would be the same as the impacts on surface water.

*No Action Impacts*

There would be no significant impacts on runoff/absorption.

**FLOODS**

*Existing Environmental Condition*

Flooding and debris torrents have occurred in many Lake Whatcom's tributaries. Flooding occurs because many drainages are confined with steep walls and do not include floodplain, side channel and low gradient intermittent habitat. Sub basins in which major debris torrents have occurred in the last 100 years include Smith in 1917, 1946, 1971 and 1983, Austin in 1983, Blue Canyon tributaries in 1983, some South Bay tributaries in 1983 and Olsen in 1983. Such flooding contributes to destabilization of substrate, habitat destruction and reduction of cover. (Dominguez 1994)

*Proposed Action Impacts*

There would be no significant impacts on floods.

*Alternative Action Impacts*

The impacts would be the same as the impacts on surface water.

*No Action Impacts*

There would be no significant impacts on floods.

## FISH, WILDLIFE, AND VEGETATION

### UNIQUE SPECIES

*Existing Environmental Condition*

Fish

The Lake Whatcom watershed supports a variety of aquatic species including many recreationally important game fish. The populations of kokanee and coastal cutthroat trout likely colonized Lake Whatcom shortly after glaciation over 10,000 years ago. They have evolved in isolated conditions and are evolutionary significant units (ESU) of each species.

Kokanee (*Oncorynchus nerka*)

Kokanee are sockeye salmon which exhibit a different life history. Sockeye salmon, like many Pacific salmon are anadromous, meaning they migrate from marine to freshwater to complete their life cycle. Kokanee are sockeye salmon which inhabit freshwater lakes which have become landlocked (Ricker 1940, Dominguez 1994). They have evolved as distinct populations, fully adapted to freshwater existence (Groot 1991). Kokanee likely colonized Lake Whatcom following glacial retreat and were denied ocean access following the formation of Whatcom Falls around 10,000 years ago ( Dominguez 1994). Kokanee are native to the northwestern part of the United States and British Columbia as well as Siberia and Japan. In the state of Washington, naturally derived kokanee populations have historically existed in Baker Lake, Lake Chelan, Lake Ozette, Lake Sammamish, Lake Washington, Lake Wenatchee and Lake Whatcom (Crawford 1979, Groot 1991). Today Baker Lake, Lake Sammamish, Lake Washington and Lake Whatcom harbor the only native, naturally derived kokanee populations in the greater Puget Sound drainage (Mark Downen unpublished data).

Kokanee are generally smaller than sockeye due to the productivity differences of their freshwater and oceanic post rearing habitats (Gustafson et. al 1997). Lake Whatcom kokanee grow to lengths of ten to twelve inches and are generally smaller than other lakes (Personal communication, Larry Sisson, WDFW Bellingham, WA). They prefer deep, cool (50-59 degree Celsius) water. In Lake Whatcom, kokanee adults typically school around one hundred yards offshore and migrate around the lake (Dominguez 1994). The principle food source of kokanee is pelagic zooplankton and small insects (Groot 1991). Kokanee typically live between three and four years. Spawning generally occurs from October through January. In Lake Whatcom kokanee eggs are generally laid in October in lakeshore tributaries. Eggs require clean, cold, oxygen rich water and gravel streambed in order to fully develop. After about 100 days or 5 months the eggs emerge as alevins, which are fry with egg sac still attached (Figure 5). Alevins live off of the nutrients from the egg sac for two to three weeks; it is during this time where the kokanee develop a homing instinct which will eventually return them to their natal site. They emerge from the gravel as fry, and will remain in the tributary for another two to three weeks, facing upstream and eating small food particles which may be floating downstream. Finally the fry enter their lake habitat as fingerlings, usually sometime in April.

When the mature kokanee are ready to spawn, they undergo several biological changes. The body of the male kokanee becomes a brilliant shade of red and he develops a pronounced hook jaw called a kype with sharp teeth (Figure 5). The female becomes a reddish pink, with a green stripe down her side indicating that she is physically ready to spawn. After these changes occur, the kokanee stop eating and their flesh immediately begins to deteriorate. Kokanee return to their natal tributary to spawn in October. Schools of kokanee swim upstream and then, by using their homing instincts, select an ideal spawning site in close proximity to their birth site. Females and males pair off and the male guards the spawning site while the female fans the gravel with her tail, creating a depression in the gravel four to six inches deep called a redd. After the female deposits her eggs in the redd the male fertilizes the eggs with his sperm, called milt. Both parents then fan gravel over the eggs to protect them. This spawning process can occur several times but both parents are destined to die shortly after spawning, their carcasses becoming an important food source for scavenging animals and an important nutrient source for the stream. In Lake Whatcom, kokanee have historically spawned in Brannian, Olsen, Anderson, Fir, and Smith Creeks. (Dominguez 1994, Lake Whatcom) In addition to the natural spawning population, the Lake Whatcom kokanee population has been managed as an egg source as well as a recreational fishery since the early 1900s (Dominguez 1994). High kokanee abundances in the mid 20$^{th}$ century contributed to record egg takes of 33 million eggs in 1947 (Washington Game Commission 1947).

Unfortunately, both wild and hatchery kokanee runs have experienced dramatic declines. Wild spawning kokanee accounted for only 2% of total spawners in Lake Whatcom in 2001 and 19% in 2002 (Mark Downen unpublished data). Currently the Lake Whatcom kokanee population is supported by the hatchery, with little or no spawning occurring in the other tributaries (Looff 1994, Mueller et al 2001). Genetic analysis of wild spawning kokanee in Olsen Creek (Figure 2) has shown little variation between wild and hatchery spawned kokanee runs which suggest that the wild spawning kokanee population in Lake Whatcom may not be self sustaining (Mark Downen unpublished data).

Habitat degradation, including the loss of tributary spawning habitat, has been the primary factor leading to wild spawning kokanee declines. Timber harvesting and land development have removed riparian vegetation, causing increased summer temperatures which limits salmonid productivity. (Dominguez 1994) The low abundance of large woody debris (LWD), which is essential fish habitat, may be one of the primary reasons for the substantial decline of kokanee populations (Looff 1994). Some Lake Whatcom drainages are currently managed for removal of LWD. In most streams, historic spawning habitat has been adversely affected by debris torrents which scour the substrate, loss of LWD, and the inability of the stream channel to maintain gravel suitable for spawning. Excessive sedimentation can cause fine silt particles to cement particles in lower gradient areas, making it nearly impossible for female kokanee to construct redds and spawn successfully. (Dominguez 1994)

Hatchery derived kokanee populations have experienced dramatic declines as well. In the 1950s the entire late spawning run disappeared from the population. This is thought to be due to managers selecting for the early part of the run, which likely stemmed from pressure to set early season goals for egg take to meet the growing demands due to the excitement over abundant kokanee numbers. The result from this alteration is the emergence of kokanee fry into Lake Whatcom before the lake has established its algal blooms. (Dominguez 1994) This may have adverse effects on juvenile kokanee survival as zooplankton abundance, the food supply for kokanee, is directly dependant on algal blooms (Coveney et al 1977). As mentioned above, Lake Whatcom kokanee are generally smaller than kokanee from other lakes. Even kokanee from the Brannian Creek hatchery, when transported to other lakes, grow larger than kokanee in Lake Whatcom (Dominguez 1994). This suggests that kokanee growth is limited by nutrients in Lake Whatcom.

Other current threats to Lake Whatcom kokanee include the proposed fish ladder over the middle fork of the Nooksack River which could potentially introduce anadromous pathogens into the Lake Whatcom watershed. The IHN (infectious hematopoietic necrosis) virus causes acute and lethal disease of cultured and wild fish stocks (Anderson et al 2000). Additional studies have shown that Lake Whatcom kokanee show high susceptibility to IHNV (Garver et al 2006). The fact that the majority of kokanee in Lake Whatcom are hatchery spawned may increase their susceptibility because of the high aggregations at the mouth of Brannian Creek. Increased habitat heterogeneity and greater spatial diversity in kokanee populations will increase resilience to pathogens, including IHNV. (Mark Downen unpublished data)

Coastal Cutthroat trout (*Oncorhyncus clarki clarki*)
Coastal cutthroats are native to Lake Whatcom. It is believed that resident cutthroat populations evolved from post glacially isolated sea run cutthroat populations around 10,000 years ago (Dominguez 1994). Lake Chelan cutthroat were stocked into Lake Whatcom in 1901 and Toutle Creek cutthroat which were supplemented into Lake Whatcom in the late 1980s and early 1990s (Dominguez 1994). Current populations are likely of mixed origins from wild and supplemented stocks interbreeding with the Lake Whatcom population. Coastal cutthroat may exhibit four possible life histories. One form is anadromous; the other three are non migratory meaning they spend their entire life cycle in freshwater. The three freshwater spawning types are fluvial, adfluvial, and resident. Fluvial is when spawning and early rearing occurs in smaller tributaries and major growth occurs in mainstream rivers. Adfluvial is when spawning and early rearing occurs in smaller tributaries and major growth occurs in lakes or reservoirs. Resident is when the entire life cycle of the cutthroat is spent in small headwater streams. (Whatcom County Water Resources 2003, Dominguez 1994) Lake Whatcom cutthroat generally feed on small invertebrates and fish including juvenile kokanee. (Personal Communication, Ian Smith Bellingham, WA)

Lake Whatcom cutthroat generally spawn from December to mid June (Dominguez 1994). All migratory forms of cutthroat require similar spawning habitat. Unlike kokanee which die shortly after spawning, coastal cutthroat can spawn several times during their lifetime. Low gradient, low flow area with riffles and pools are ideal for spawning, while optimal rearing habitat requires large woody debris and overhanging banks (Whatcom County Water Resources 2003). Austin and Beaver Creeks are the most important cutthroat spawning streams in Lake Whatcom but Carpenter, Olsen, and Smith Creeks also contribute significantly to the Lake Whatcom cutthroat population (Dominguez 1994). Degradation of spawning habitat has caused significant declines in the Lake Whatcom cutthroat population. Sedimentation has been the primary cause, with fine grained particles inhibiting emergence of fry from redds which are dug in gravel (Dominguez 1994, Mark Downen unpublished data). Anthropogenic influences on tributary habitat include removal of riparian vegetation and large woody debris inputs. Bank armoring and channelizing prevent natural formation of pools and riffles and have also contributed to cutthroat declines. (Dominguez 1994) Further pressure on the cutthroat population is due to competition from non-native introduced species such as smallmouth bass and yellow perch.

Native non-salmonids

There are a variety of native non-salmonid fish in Lake Whatcom including various species of sculpin (*Cottus* spp), longnose sucker (*Catostomus catostomus),* peamouth chub (*Mylocheilus caurinus),* and three spine stickleback (*Gasterosteus aculeatus).*

Non-native species

There are many non native fish that inhabit Lake Whatcom. Some of these species were illegally introduced such as the brown bullhead (*Ictalurus nebulosis)*, largemouth bass (*Micropterus salmoides),* pumpkinseed sunfish (*Lepomis gibbosus),* and yellow perch (*Perca flavescens).* Other non native species were introduced through stocking at various times in the 20th century. These include smallmouth bass (*Micropterus dolomieui),* which were introduced in 1983 and 1984 to support a fishery and attempt to control peamouth populations and rainbow trout (*Oncorhyncus mykiss)* that were introduced in the early 1900s. (Dominuez 1994, Lake Whatcom Management plan 2009) The warm water fishery in Lake Whatcom is quite popular but evidence exists that smallmouth bass prey on and compete with native salmonids (Mueller et al 1998).

Wildlife

The Lake Whatcom watershed provides habitat to a large variety of wildlife. As a result of human land use practices, several species once thought to exist in the watershed have been extirpated from the area. Some of the more notable species include the grizzly bear (*Ursus arctos horribilis),* northern spotted owl (*Strix occidentalis caurina*), wolverine (*Gulo gulo),* marbled murrelett (*Brachyramphus marmoratus*) , and elk (*Cervus canadensis*). Still there are currently 10 amphibian, 2 reptile, 125 bird, and 49 mammal species which are known to inhabit the area (Appendix B).Many of these species are listed in some form under the Endangered Species Act (ESA). (Lake Whatcom Management Program 2009)

Vegetation

Most of the Lake Whatcom watershed is under forested condition and is managed by either the State Department of Natural Resources or private timber companies. The forested area is mostly native, older second growth and third growth, with small areas of virgin old growth forest remaining. Most of the watershed is dominated by Western Hemlock (*Tsuga heterophylla*), and Douglas fir (*Pseudotsuga menziesii*). Some native hardwoods are also present, including red alder (*Alnus rubra*), black cottonwood (*Populus balsamifera*), and big leaf maple (*Acer macrophyllum*). There are limited wetland areas within the watershed. Riparian vegetation is critical in the watershed (Appendix C). It provides critical habitat for native wildlife and provides many indirect ecosystem functions such as lowering of stream temperatures through shading, providing cover, supplying LWD to the stream, and increasing slope stability. (Lake Whatcom Management Program 2009).

*Proposed Action Impacts*

Kokanee (*Oncorynchus nerka*)

The proposal will likely have devastating impacts on the Lake Whatcom kokanee population. Genetic testing revealed that there are no genetic differences between the wild spawning kokanee from Olsen Creek and hatchery reared kokanee from Brannian Creek (Mark Downen unpublished data). This further supports the hypothesis that wild spawning kokanee populations are dependent on the Brannian Creek hatchery for survival and without the persistence of hatchery stocking the wild spawning population would not be viable. The Lake Whatcom kokanee population appears to be directly related to hatchery stocking density (Dominguez 1994). Closure of the Brannian Creek hatchery facility would surely result in extinction of Lake Whatcom kokanee.

Coastal Cutthroat (*Oncorhyncus clarki clarki*)
Juvenile kokanee have been an important food source for coastal cutthroat (Personal Communication, Ian Smith Bellingham, WA). With native coastal cutthroat directly competing with smallmouth bass, removing kokanee as a food source for coastal cutthroat may diminish fitness of the cutthroat populations.

Non-native and non salmonids
It is difficult to predict the impacts to other species if kokanee were extirpated from Lake Whatcom. While some of these other species may directly interact with kokanee (i.e. smallmouth bass), these interactions are not well understood (Dominguez 1994). Given the large degree of uncertainty regarding the potential ecological effects of kokanee extirpation, there is the possibility of significant impacts to many or all aquatic species if kokanee were removed from the system. These may include impacts on complicated food web dynamics as well as nutrient contributions in spawning tributaries.

Wildlife
Salmon carcasses supply critical energy for a diverse array of terrestrial vertebrates (Cedarholm et. al 1999). Many terrestrial mammals and birds (Appendix B) inhabiting the watershed would lose a potential food source from wild spawning kokanee carcasses if the Brannian hatchery were to close and kokanee were lost from Lake Whatcom.

Vegetation
The proposed action would have minimal impacts on vegetation.

*Alternative Action Impacts*

Kokanee (*Oncorynchus nerka*)
The implementation of spawning channels would significantly benefit kokanee in Lake Whatcom by providing optimal spawning conditions regardless of additional tributary habitat degradation. Controlling for low flow conditions and gravel substrate, spawning channels in Brannian, Anderson and Olsen Creeks will provide Lake Whatcom kokanee with optimal spawning habitat that should continue support future populations and increase genetic diversity. Coastal cutthroat have similar spawning habitat requirements as kokanee. (Dominguez 1994) Implementation of spawning channels could also significantly benefit coastal cutthroat populations by providing optimal spawning conditions without posing the risk of sedimentation.

While the wild native kokanee population is re-establishing in the Olsen, Anderson, and Brannian Creek spawning channels, there may be a lag in population increase. A decrease in kokanee population could potentially have negative effects further up the food chain. The cutthroat trout that rely on the kokanee as a food source could be affected during this transitional period (Personal communication, Ian Smith Bellingham, WA). There may be adverse effects on riparian vegetation and wildlife during the construction period.

Mitigation

A phased closure will allow wild runs of this population to be re-established steadily. To minimize the declining of both kokanee and cutthroat trout populations, the final phase of the hatchery closure should not happen until the spawning channels are fully functioning with a sustainable number of kokanee spawning and hatching in them. Care should be taken that this population is not disturbed during any construction of spawning channels. Construction should not take place during spawning months, or while salmon redds are still present in the stream. Attempts should be made to prevent sedimentation of the original stream channels of Brannian, Anderson, and Olsen, as well as at the mouth of the streams where they enter Lake Whatcom. During the first four to nine years of operation, transplanting eggs from Brannian Creek to the spawning channel may be necessary to establish and sustain future kokanee runs. To mitigate negative impacts to riparian vegetation, low impact construction methods should be used and care should be taken to avoid displacement of riparian vegetation.

*No Action Impacts*

The hatchery supports unique, genetically distinct, isolated populations of kokanee and cutthroat. The survival of the kokanee population in Lake Whatcom is dependent on the hatchery. Without the hatchery the fish would not be able to spawn successfully, or in such great numbers. The kokanee are food for much of the cutthroat population in the lake. There could be potential negative effects on the cutthroat population if the kokanee population were to disappear.

While the hatchery currently supports the Lake Whatcom kokanee population, current declines in the hatchery spawned population have led to speculation as to the viability of the population (Personal Communication, Mark Downen, La Conner, WA). Historic hatchery practices such as selection for early kokanee runs have contributed to kokanee declines (Dominguez 1994). IHN virus susceptibility of hatchery spawned kokanee is also a major concern, especially if the relative proportion of hatchery spawned individuals in the population remains the same. If wild spawning levels continue to decline due to habitat degradation the dependence of Lake Whatcom kokanee on hatchery stocking will continue to increase. Without severe management intervention, genetic homogenization, and disease susceptibility will remain as lingering concerns to the health and viability of kokanee in Lake Whatcom.

**FISH MIGRATION**

*Existing Environmental Condition*

Same as existing conditions for unique species.

*Proposed Action Impacts*

The impacts would be the same as the impacts on unique species.

*Alternative Action Impacts*

The impacts would be the same as the impacts on unique species.

*No Action Impacts*

The impacts would be the same as the impacts on unique species.

# Elements of the Built Environment

## LAND AND SHORELINE USE

### RECREATION AND AESTHETICS

*Existing Environmental Condition*

Lake Whatcom is a beautiful place to live and play and must be preserved. Many lake inhabitants are fighting to reduce phosphorus inputs into the lake through gardening choices and the removal of pet waste. Other attempts to keep Lake Whatcom clean are targeted on people who use Lake Whatcom as a source of recreation. Since 2006, there has been growing legislation against two-stroke motors. There are also efforts made to maintain boats and prevent toxins from entering the lake. The tradition of fishing is one that dates back far in time for many cultures. The tribes have been using these rivers for sustenance before colonization. Many early settlers also fished for kokanee for recreation and for food. Fishing is a pastime of Americans, and for many people fishing and boating go hand in hand. A balance must be reached to preserve the water quality and fish habitat to allow for the possibility of healthy fish populations for current and future generations of fishermen. The tradition of fishing is one that dates far back in time throughout many cultures. The need to maintain healthy fish populations in Lake Whatcom is important to support recreational activities on the lake. Lake Whatcom supports a fishery for many species including native kokanee and coastal cutthroat trout, rainbow trout from the Whatcom Creek hatchery and introduced warm water species such as smallmouth and largemouth bass (Lake Whatcom Management Program 2009).

The boundaries of the surrounding watershed are formed by five mountains: Squalicum Mountain, Stewart Mountain to the Northeast, Anderson Mountain to the South, and Galbraith Mountain to the West. These mountains are covered with mixed evergreen and hardwood forests. (Whatcom Watershed Management 2009)

The hatchery is located on Brannian Creek, which is on the south end of Lake Whatcom in basin three. In the area of the watershed where the hatchery is located there are very few houses and other types of development. There is a secured entry on the side of hatchery that faces the lake. There is a gravel driveway that allows access to the building from the main road. The view from the hatchery is beautiful. The lake and the surrounding hills and mountains are clearly visible.

*Proposed Action Impacts*

Kokanee contribute 36.7 million to the state’s economy annually. At least 20.7 million dollars of this amount is directly dependent upon the Lake Whatcom hatchery program and would be lost in the event of hatchery closure. Recreational kokanee fishing in Lake Whatcom and many other lakes in the Northwest United States would also be affected. (Whatcom Salmon Recovery 2003)

*Alternative Action Impacts*

The potential increase in kokanee populations due to increased wild spawning will significantly benefit the recreational kokanee fishery on Lake Whatcom for the long term. There is a large degree of certainty regarding the kokanee population during the transition period, and there is the possibility of decreases in the Lake Whatcom kokanee population while the spawning channel runs are being established. The closure of the hatchery also will adversely impact recreational fisheries on surrounding lakes which are currently stocked with kokanee from the Brannian Creek hatchery.

Mitigation

During the transitional period, lower catch limits should be placed on the recreational kokanee fishery to ensure that populations remain stable. A balance must be reached to preserve the water quality and fish habitat to allow for the possibility of healthy fish populations for current and future generations of anglers. Areas of the watershed that drain Brannian, Anderson, and Olsen Creeks should be designated as critical habitat and have minimal or no development within these areas. This measure is necessary in order to preserve adequate fish habitat within the spawning channels.

A small park or designated viewing area for spawning may be beneficial to help educate the public on the importance of protecting their watershed. A sign that explains the project and its objectives will also help educate the public.

*No Action Impacts*

Fishing is a very important part of the Lake Whatcom community. The kokanee population that is released by the hatchery greatly contributes to this. Without the hatchery, kokanee fishing would not be nearly as abundant as it is today.

**HISTORICAL/CULTURAL**

*Existing Environmental Condition*

The Brannian Creek facility has been in the current location for 102 years. The hatchery was operated by the Whatcom County Game Commission from 1907 to 1933. The Department of Fish and Wildlife took over operation of the hatchery in 1933. This hatchery has been the main source of kokanee for stocking lakes in Washington, Idaho, Oregon, Montana, and California. (Personal Communication, Larry Sisson, Bellingham, WA)

Lake Whatcom and its surrounding watershed have been culturally significant for hundreds of years to several Native American tribes. Before 1800 there were Stick Samish, Nooksack, and Saquantch peoples on the lake. There was a Nooksack village located at the south end of the lake known as Kaw-tchaa-ha-muk. Reveille Island, located within Lake Whatcom, contains evidence that it was used for ceremonies by Native Americans. After the turn of the nineteenth century, the Lummi tribes moved into the area and displaced the other tribes. (Moore 1973)

Relationship to existing land use plans and to estimated population

The Department of Fish and Wildlife owns the land that the hatchery operates on. The surrounding areas of the watershed are owned by the City of Bellingham, Lake Whatcom Water and Sewer District, and the Department of Natural Resources. Some of the land is managed for timber harvest. The land that borders Brannian, Olsen, and Anderson Creeks is zoned rural, rural forestry, commercial forestry, and recreation open space (Figure 3).

Currently there is a moratorium in place until March 19, 2009 on building within the Lake Whatcom Watershed. There will be a public meeting on March 12th that will determine whether the moratorium will be extended or not.

*Proposed Action Impacts*

Kokanee fishing in Lake Whatcom is a tradition that has deep roots. From Native American fish harvesting to modern recreational fishing, Lake Whatcom fish have proved an invaluable resource. Hatchery closure would not only impact the biological diversity found in Lake Whatcom, it would also end the tradition of kokanee fishing.

*Alternative Action Impacts*

The impacts would be the same as the impacts on recreation and aesthetics.

*No Action Impacts*

Kokanee are a unique and important species in Lake Whatcom. They are important to the fishing community and to the economy because of the revenue fishing brings in. From a cultural perspective the kokanee serve as food and sport. The fish also have historical significance. They have lived in Lake Whatcom since the last ice age and probably were harvested for food by natives. Since the early 1900s locals have taken interest in the survival of the fish.

# Conclusion

The proposal to close the Brannian Creek kokanee Hatchery has significant negative implications for many elements of the environment. One of the especially devastating effects will be the impact the closure will have on Lake Whatcom's kokanee population. If the hatchery on Brannian Creek closed, it would not be long before this population declined to unsustainable numbers. To worsen the situation, habitat degradation has already been a driving force in the decline of Lake Whatcom's kokanee population. Anthropogenic activities such as logging, housing development, and recreational activities are some of the causes.

This particular population of kokanee has not been listed as an Evolutionarily Significant Unit (ESU), but many experts believe that it should be (Personal Communication, Dr. Bodensteiner, Bellingham, WA). If this population was to disappear, it would become extinct. This would also negatively affect recreation, and historical and cultural preservation.

While the Brannian Creek hatchery facility is critical to support the current population of kokanee in Lake Whatcom, there are lingering concerns that remain about the long term viability of the species. The no action alternative is preferable to the proposal in that it would continue to support a population of kokanee. However, given the future uncertainties of susceptibility to pathogen introduction, high juvenile mortality due to early emergence, genetic homogenization of the hatchery run, and continued habitat degradation to wild spawning habitat the no action alternative may not be the best option to support a healthy, abundant kokanee population in the future.

An ideal solution would create a wild and sustainable population of kokanee in Lake Whatcom. The recommended action is a combination of a phased-closure of the hatchery and increasing natural salmon spawning habitat in the form of man-made spawning channels. The streams that have the greatest viability are Anderson, Olsen, and Brannian. Spawning channels could provide the opportunity for wild runs to be re-established. Depending on the specific conditions of each stream, restoration attempts may or may not be feasible, and could be costly and ineffective. The construction of ideal spawning habitat in the form of spawning channels is the most effective and guaranteed method of producing wild kokanee runs in Lake Whatcom. These channels will provide the optimal gravel for kokanee redds to be deposited and will be engineered with a monitered water source to protect the eggs safe from scouring caused by high flow events.

Most importantly, the creation of kokanee spawning habitat in the form of spawning channels will support a sustainable increase in Lake Whatcom's wild kokanee population. If this proves to be successful it will eliminate the state's reliance on the hatchery and have many positive effects on the environment as well as the kokanee population.

# Figures

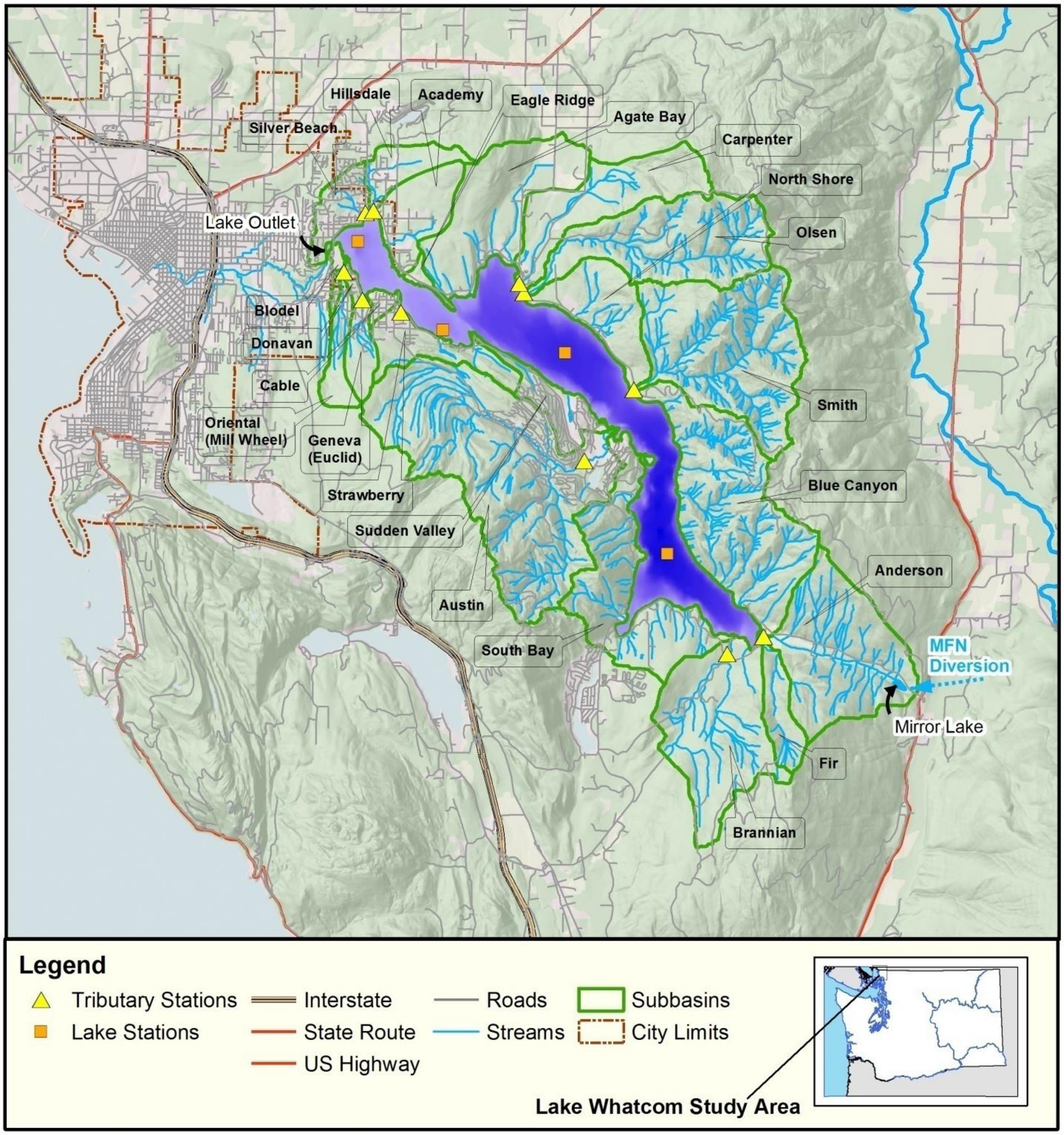


Figure 1. General Lake Whatcom map (Picket 2008).

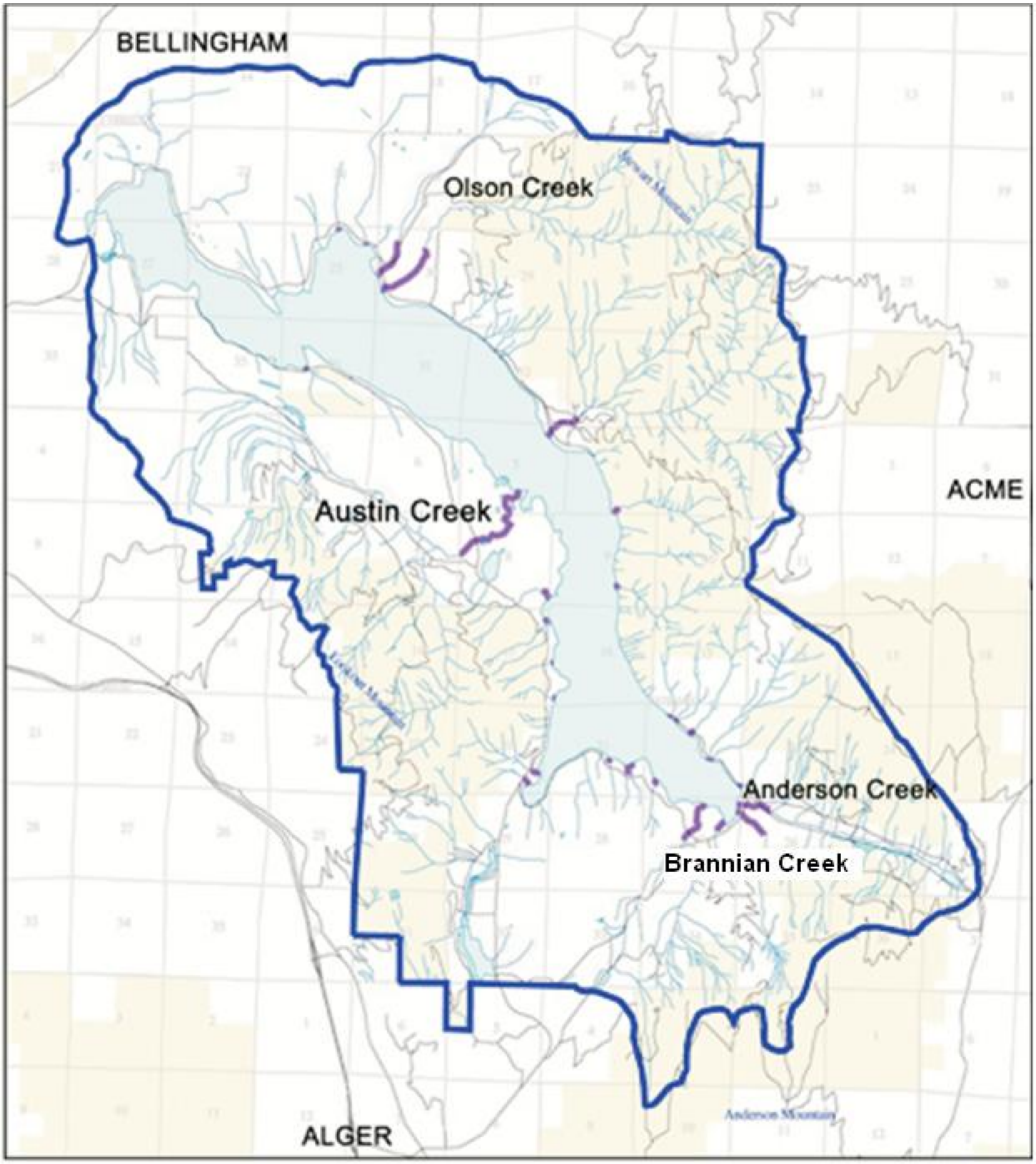


Figure 2. Current distribution (shown in purple) of kokanee in Lake Whatcom tributaries (Whatcom Salmon Recovery 2003).

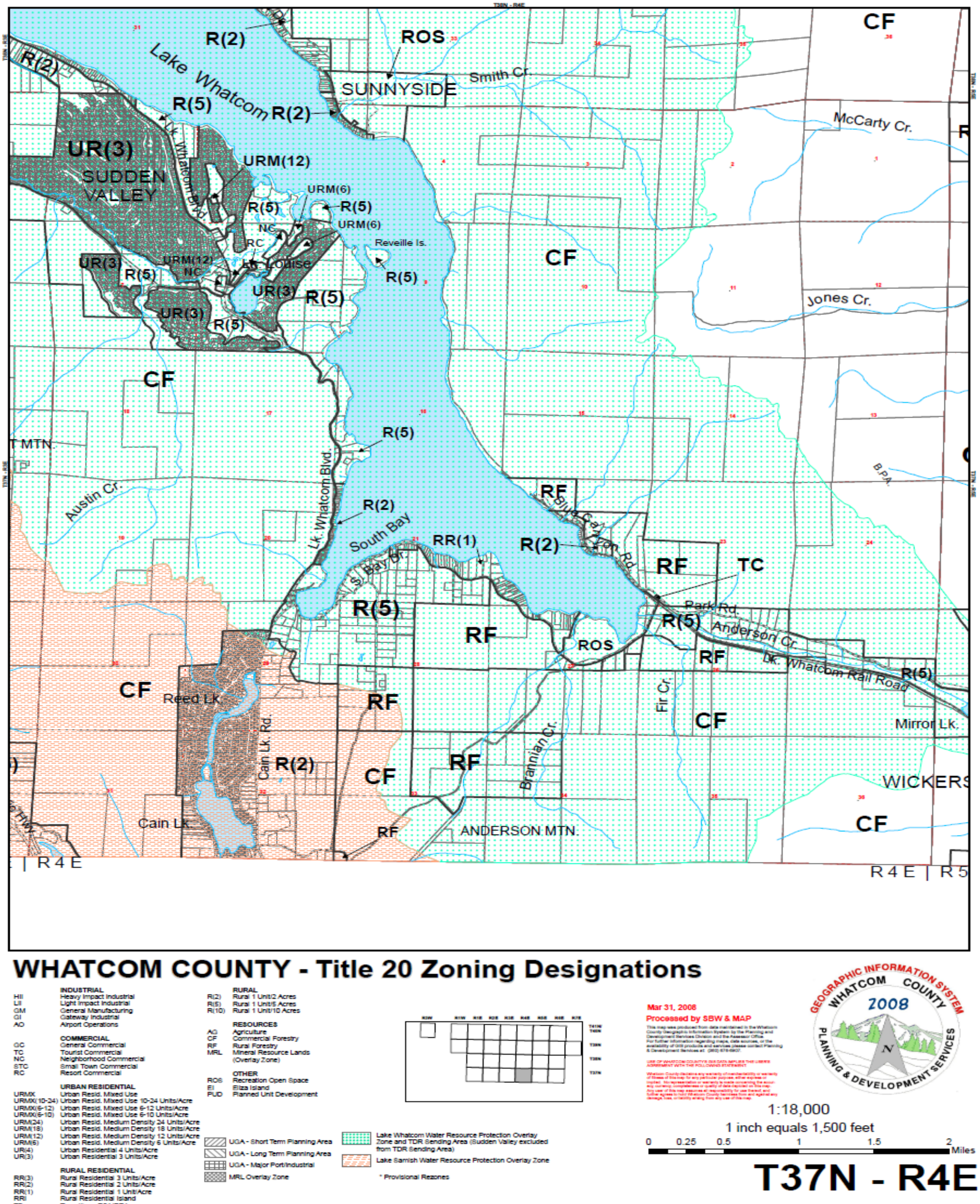


Figure 3. Map showing Lake Whatcom zoning (Whatcom County Planning and Development Services 2009).

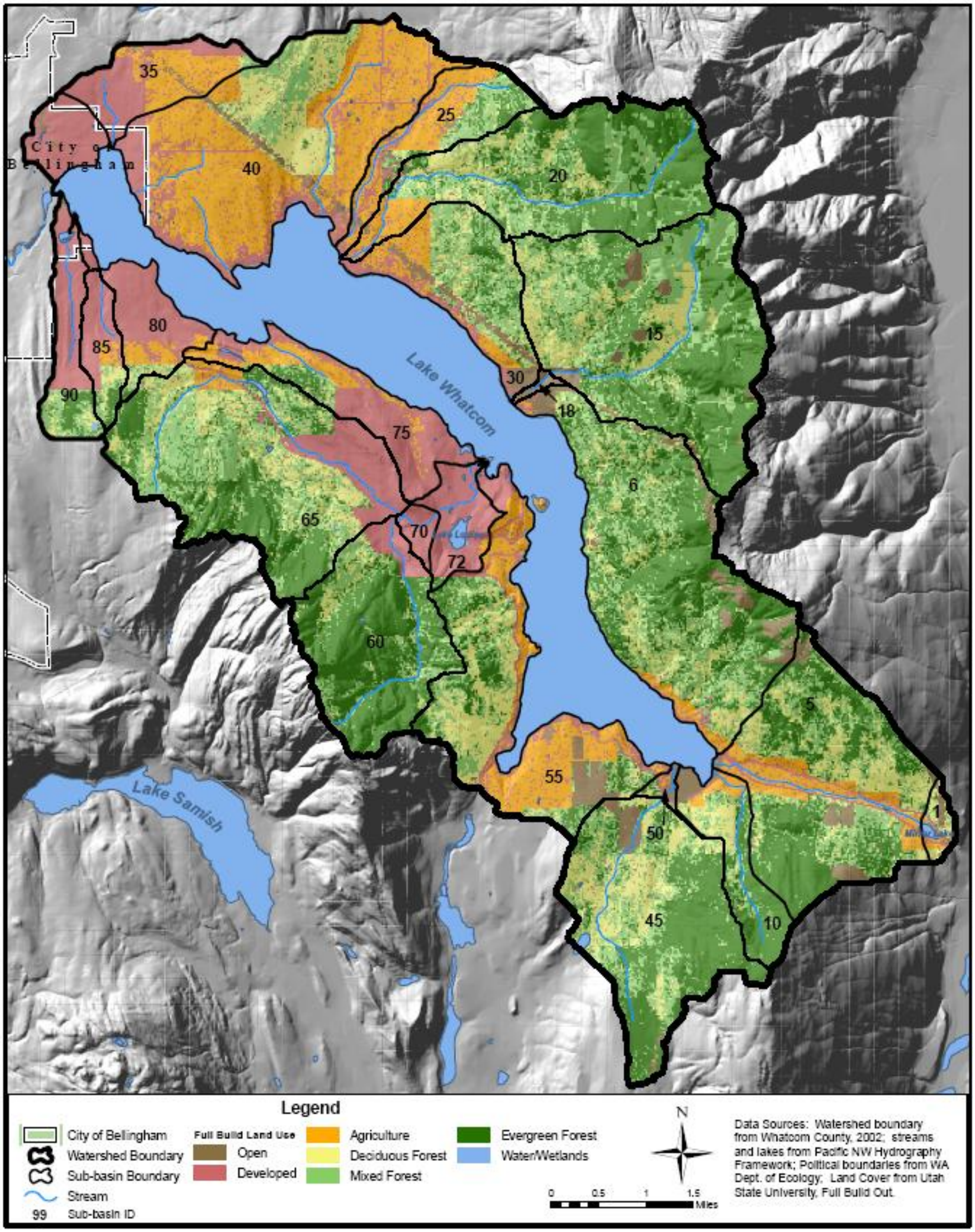


Figure 4. Lake Whatcom watershed landuse (Pickett et. al 2008).

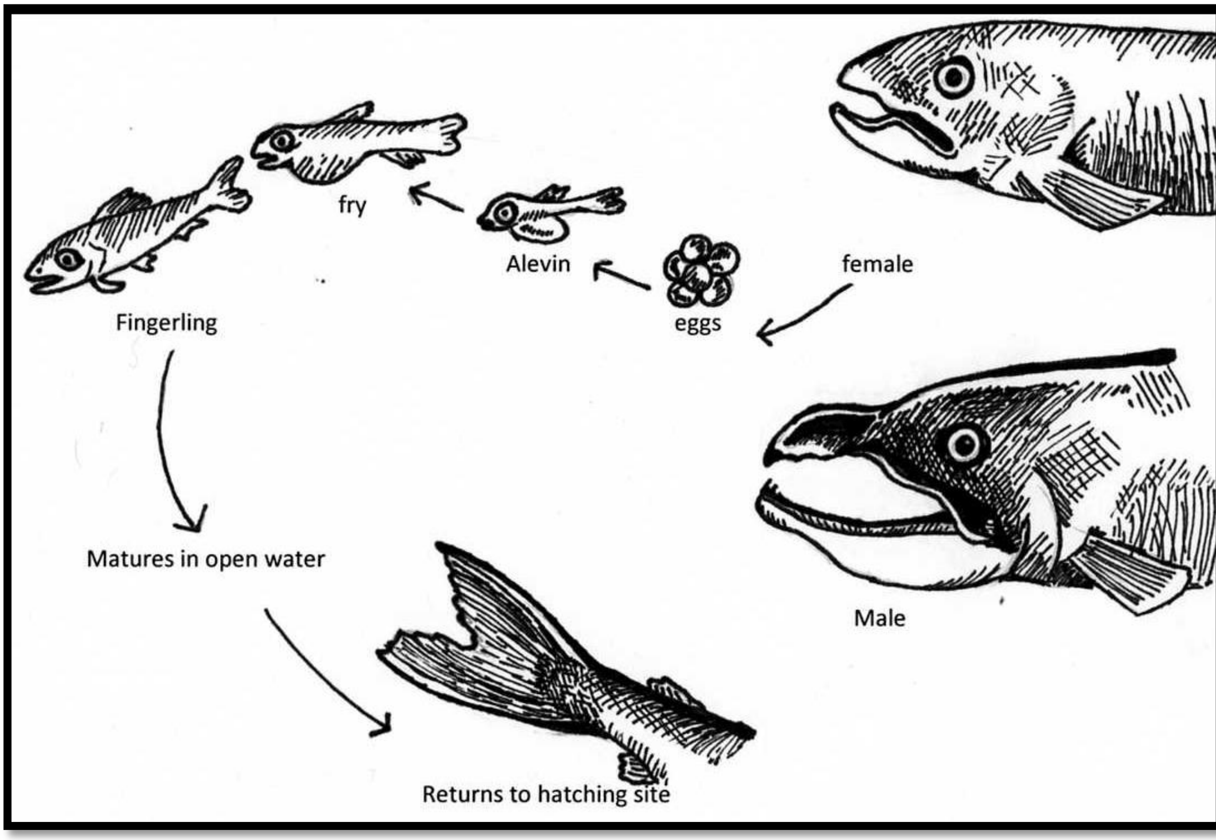


Figure 5. Diagram of life cycle of wild kokanee. The female kokanee fans her tail to dig nests called redds into the gravel streambed of lakeshore tributaries. The male guard as the female deposits an average of 1,000 eggs into the redd. Both the male and female fan gravel over the eggs. Newly hatched fish are called alevins and still have part of the yolk sac attached. They will live off the remaining nutrients in the yolk sacs and remain in the gravel. After the nutrients are absorbed, the young fish are referred to as fry. Fry remain in their natal streambed and feed on particles and small invertabrates that may be drifting downstream. After reaching over an inch in length the fry become fingerlings and migrate into their adult habitat. Kokanee generally live three to four years. When they are ready to spawn, both the males and females undergo several biological changes. They return to their natal site to spawn and die and then their carcasses become important food and nutrients for riparian animals and vegetation. (from: Whitney and Wydowski 1979, Utah Division of Wildlife Resources, picture by Sean Naman)

# Glossary

**DNR-** Department of natural resources

**DOE-**Department of Ecology

**ESA-** Endangered Species Act

**ESU-** Evolutionary significant unit

**FE**- Federal endangered species

**FSC**- Federal Species of Concern

**FT-**Federal threatened species

**IHNV-** infectious hematopoietic necrosis virus

**LWD –** Large woody debris

**LWMP-**Lake Whatcom Management Plan

**WDFW-** Washington Department of Fish and Wildlife

**SC-** State Candidate species

**SE-** State endangered species

**SEPA-**State Environmental Policy Act

**SM**- State monitored species

**ST-** State threatened species

**Adfluvial-** Life history strategy in which adult fish spawn and juveniles subsequently rear in streams but migrate to lakes for feeding as subadults and adults. Pertaining to flowing water. Movement toward a river or stream.

**Alevin-** Larval salmon that have hatched but have not yet completely absorbed their yolk sacs and usually have not yet emerged from the gravel.

**Anadromous-** Fish that ascend rivers to spawn. Migrations are usually cyclical and predictable based on the species. In the Pacific Northwest, many species of the salmon are anadromous.

**Bathymetry-** The measuring of water depth, mainly of seas and oceans but sometimes of deep lakes.

**Conglomerate-**A rock type that consists of a composite of particles of varying sizes.

**Debris Torrent-**A rapid channelized flow of water and debris down a drainage basin.

**Eutrophication-**A process where water bodies receive excess nutrients that stimulate excessive plant and organism growth.

**Extirpation-** Local extinction

**Fingerling-** A young fish of about 10 cm length, also: an immature fish, less than one year old, or any fish too small to be of marketable size.

**Fluvial-** Pertaining to rivers, flowing; pertaining to fish that live in or migrate between main rivers and tributaries.

**Fry-** A young fish at the post-larval stage. In Salmonidae the stage from end of dependence on the yolk sac as the primary source of nutrition to dispersal from the redd.

**Kline-** A type of soil that is well drained and moderately deep, formed on alluvium, with slopes 2-8%.

**Kype-** Curved or hooked jaw of male salmon.

**Loam-**Soil composed of sand silt and clay in relatively even concentrations.

**Metamorphic-** A type of rock transformed by heat and pressure creating physical and/or chemical changes.

**Milt**- The seminal fluid; gonads (testes) from male fish. When released into the water often creats a cloudy effect, either over a small area or in massive spawning visible from the air.

**Nutrient Loading-**A process by which nutrients are taken up by an ecosystem. In water bodies nutrient loading can lead to eutrophication.

**Old growth**- A type of forest that has attained a high level of age and maturity and has unique biological features.

**Phyllite-** Metamorphic rock composed mainly of quartz, sericite mica, and chlorite whose parent material is slate.

**Permeability-**A property where something can be pervaded by liquid.

**Redd-** Depression, usually a pit or a trough in the stream gravel, dug in preparation for, or during, spawning. Eggs are laid,fertilized and covered with gravel, larvae are hidden in the redd. The eggs are oxygenated by the current.

**Sedimentary rock-**A rock type formed by the deposition and consolidation of sediments.

**Sill-**A tabular pluton that has intruded between older layers of rock

**Whitehorn-** A type of soil that is poorly drained and very deep. They are formed on volcanic ash, loess, glaciofluvial deposits, and glaciomareine drift with slopes 0-2%.

**Wickersham-** A type of soil that is well drained and deep, formed on alluvium derived from phyllite with slopes 0-8 %.

**Zooplankton-** Animals (mostly microscopic) which drift freely in the water column.

# Appendix A

## Implementation of Spawning Channels at Weaver Creek in British Columbia, Canada.

### History of Weaver Creek

Weaver Creek is a tributary of the Fraser River in British Columbia, Canada. Canada has a long history of salmon enhancement which began at Weaver Creek in 1885 with the transplant of sockeye salmon (*O. nerka*) eggs into nearby streams. Salmon were especially abundant in the 1800s, and produced more than enough fry to replenish their numbers as well as satisfy the commercial need for salmon. At this time, up to eight million eggs were available from Fraser River alone to transplant to other rivers and streams throughout British Columbia. (Canada 2006)

Between 1943 and 1959 approximately 20,000 sockeye salmon returned to spawn in Weaver Creek each year. Between 1960 and 1968 the number of returning salmon decreased to approximately 12,000 salmon annually. This decrease in population numbers is attributed mainly to the destruction to spawning habitat and loss of eggs in gravel beds in Weaver Creek due to flooding and extensive logging in the watershed of the Fraser River. (Canada 2006)

As the numbers of spawning sockeye decreased, the numbers of sockeye caught by commercial fisheries decreased over this same time period from approximately 94,000 salmon to 24,000 fish (Canada 2006).

### Habitat Enhancement

In order to reverse the decline in numbers of salmon, Canada decided to take immediate action and rehabilitate the spawning habitat of Weaver Creek. To provide additional spawning habitat for *O. nerka*, a spawning channel was built beside Weaver Creek in 1965. This channel is a shallow stream with a gravel bottom and sloping sides built up with rocks. The channel is about 2,900 meters long and caters to the needs of both sockeye salmon and Pink salmon (*O. gorbuscha)*. This channel provides much more spawning habitat than the original streambed alone, and has a controllable source of clean water to avoid destruction during flood events. (Canada 2006)

### Salmon Recovery

Between the years of 1965 and 1997, the Weaver Creek channel released almost 1 billion sockeye, 80 million chum (*O. keta*), and 10 million pink salmon. The run of sockeye today is more than 200 times the size of the run from Weaver Creek prior to 1965. Approximately 80% of redds in the spawning channel produce healthy fry, compared to 8% that succeed in Weaver Creek. The main reasons for this dramatic change is the ideal spawning habitat including clean water and gravel that the spawning channel provides. (Canada 2006)

# Appendix B

**Amphibians**

northwestern salamander (*Ambystoma gracile*)
Pacific giant salamander (*Dicamptodon ensatus*)
Oregon Ensatina (*Ensatina eschscholtzi oregonensis*)
western redback salamander (*Plethodon vehiculum*)
Roughskin newt (*Taricha granulosa*)
western toad (*Bufo boreas*) FSC; SC
Pacific tree frog (*Hyla regilla*)
tailed frog(*Ascaphus truei*) FSC; SM
red-legged frog (*Rana aurora*)
bullfrog (*Rana catesbeiana*)

**Reptiles**

northwestern garter snake (*Thamnophis ordinoides*)
common garter snake (*Thamnophis sirtalis*)

**Birds**

common loon (*Gavia immer*) SS
pied-billed grebe (*Podilymbus podiceps*)
eared grebe (*Podiceps nigricollis*)
western grebe (*Aechmophorus occidentalis*)
double-crested cormorant (*Phalacrocorax auritus*)
great blue heron (*Ardea herodias*)
green-backed heron (*Butorides striatus*)
Canada goose (*Branta canadensis*)
wood duck (*Aix sponsa*)
green-winged teal (*Anas crecca*)
mallard (*Anas platyrhynchos*)
northern pintail (*Anas acuta*)
gadwall (*Anas strepera*)
American wigeon (*Anas americana*)
ring-necked duck (*Aythya collaris*)
lesser scaup (*Aythya affinis*)
common goldeneye (*Bucephala clangula*)
bufflehead (*Bucephala albeola*)
hooded merganser (*Lophodytes cucullatus*)
common merganser (*Mergus merganser*)
turkey vulture (*Cathartes aura*)
osprey (*Pandion haliaetus*)
bald eagle (*Haliaeetus leucocephalus*) FT; ST
northern harrier (*Circus cyaneus*)
sharp-shinned hawk (*Accipiter striatus*)
Cooper’s hawk (*Accipiter cooperii*)
northern goshawk (*Accipiter gentilis*) FSC; SC
red-tailed hawk (*Buteo jamaicensis*)

golden eagle (*Aquila chrysaetos*) SC
American kestrel (*Falco sparverius*)
merlin (*Falco columbarius*) SC
peregrine falcon (*Falco peregrinus*) FSC; SE
gyrfalcon (*Falco rusticolus*)
blue grouse (*Dendragapus obscurus*)
ruffed grouse (*Bonasa umbellus*)
Virginia rail (*Rallus limicola*)
sora rail (*Porzana carolina*)
American coot (*Fulica americana*)
killdeer *(Charadrius vociferus*)
spotted sandpiper (*Actitis macularia*)
common snipe (Gallinago gallinago)
ring-billed gull (*Larus delawarensis*)
glaucous-winged gull (*Larus glaucescens*)
rock dove (*Columba livia*)
band-tailed pigeon (*Columba fasciata*)
mourning dove (*Senaida macroura*)
common barn owl (*Tyto alba*)
western screech owl (*Otis kennicottii*)
great horned owl (*Bubo virginianus*)
snowy owl (*Nyctea scandiaca*)
northern pygmy owl (*Glaucidium gnoma*)
barred owl (*Strix varia*)
long-eared owl (*Asio otus*)
northern saw-whet owl (*Aegolius acadicus*)
common nighthawk (*Chordeiles minor*)
black swift (*Cypseloides niger*)
Vaux's swift (*Chaetura vauxi*) SC
rufous hummingbird (*Selasphorus rufus*)
belted kingfisher (*Ceryle alcyon*)
red-breasted sapsucker (*Sphrapicus ruber*)
downy woodpecker (*Picoides pubescens*)
hairy woodpecker (*Picoides villosus*)
northern flicker (*Colaptes auratus*)
pileated woodpecker (*Dryocopus pileatus*) SC
olive-sided flycatcher (*Contopus borealis*) FSC
western wood-pewee (*Contopus sordidulus*)
Pacific slope flycatcher (*Empidonax difficilis*)
tree swallow (*Tachycineta bicolor*)
purple martin (*Progne subis*) SC
violet-green swallow (*Tachycineta thalassina*)
northern rough-winged swallow (*Stelgidopteryx serripennis*)
barn swallow (*Hirundo rustica*)
gray jay (*Perisoreus canadensis*)
Stellar's jay (*Cyanocitta stelleri*)

American crow (*Corvus brachyrhynchos*)
common raven (*Corvus corax*)
black-capped chickadee (*Parus atricapillus*)
chestnut-backed chickadee (*Parus rufescens*)
bushtit (*Psaltriparus minimus*)
red-breasted nuthatch (*Sitta canadensis*)
brown creeper (*Certhia americana*)
Bewick's wren (*Thryomanes bewickii*)
house wren (*Troglodytes aedon*)
winter wren (*Troglodytes troglodytes*)
marsh wren (*Cistothorus palustris*)
American dipper (*Cinclus mexicanus*)
golden-crowned kinglet (*Regulus satrapa*)
ruby-crowned kinglet (*Regulus calendula*)
Townsend's solitaire (*Myadestes townsendi*)
Swainson's thrush (*Catharus ustulatus*)
American robin (Turdus migratorius)
varied thrush (*Ixoreus naevius*)
cedar waxwing (*Bombycillia cedrorum*)
northern shrike (*Lanius excubitor*)
European starling (*Sturnus vulgarus*)
solitary vireo (*Vireo solitarius*)
Hutton's vireo (*Vireo huttoni*)
warbling vireo (*Vireo gilvus*)
orange-crowned warbler (*Vermivora celata*)
Nashville warbler (*Vermivora ruficapilla*)
yellow warbler (*Dendroica petechia*)
yellow-rumped warbler (*Dendroica coronata*)
black-throated gray warbler (*Dendroica nigrescens*)
Townsend's warbler (*Dendroica townsendi*)
MacGillivray's warbler (*Oporornis tolmiei*)
common yellowthroat (*Geothlypis trichas*)
Wilson's warbler (*Wilsonia pusilla*)
western tanager (*Piranga ludoviciana*)
black-headed grosbeak (*Pheucticus melanocephalus*)
potted towhee (*Pipilo erythrophthalmus*)
chipping sparrow (*Spizella passerina*)
fox sparrow (*Passerella iliaca)*
song sparrow (*Melospiza melodia*)
golden-crowned sparrow (*Zonotrichia atricapilla*)
white-crowned sparrow (*Zonotrichia leucophrys*)
dark-eyed junco (*Junco hyemalis*)
red-winged blackbird (*Agelaius phoeniceus*)
Brewer's blackbird (*Euphagus cyanocephalus*)
brown-headed cowbird (*Molothrus ater*)
purple finch (*Carpodacus purpureus*)

house finch (*Carpodacus mexicanus*)
red crossbill (*Loxia curvirostra*)
pine siskin (*Carduelis pinus*)
American goldfinch (*Carduelis tristis*)
evening grosbeak (*Coccothraustes vespertinus*)

**Mammals**

Virginia opossum (*Didelphis virginiana*)
Pacific water shrew (*Sorex bendirii*)
water shrew (*Sorex palustris*)
vagrant shrew (*Sorex vagrans*)
Trowbridge's shrew (*Sorex trowbridgii)*
shrew-mole (*Neurotrichus gibbsi*)
Pacific mole (*Scapanus orarius*)
Townsend's mole (*Scapanus townsendii*)
big brown bat (*Eptesicus fuscus*)
silver-haired bat (*Lasionycteris noctivagans*)
hoary bat (*Lasiurus cinereus*)
California myotis (*Myotis californicus*)
Long-eared myotis (*Myotis evotis*) SM, FSC
little brown myotis (*Myotis lucifugus*)
long-legged myotis (*Myotis volans*)
Yuma myotis (*Myotis yumanensis*) FSC
Townsend's big-eared bat (*Plecotus townsendii*) FSC; SC
coyote (*Canis latrans*)
red fox (*Vulpes vulpes*)
black bear (*Ursus americanus*)
raccoon (*Procyon lotor*)
river otter (*Lutra canadensis*)
striped skunk (*Mephitis mephitis*)
ermine (*Mustela erminea*)
long-tailed weasel (*Mustela frenata*)
mink (*Mustela vison*)
spotted skunk (*Spilogale putorius*)
mountain lion (*Felis concolor*)
bobcat (*Lynx rufus*)
black-tailed deer (*Odocoileus hemionus columbianus*)
mountain beaver (*Aplodontia rufa*)
northern flying squirrel (*Glaucomys sabrinus*)
Townsend's chipmunk (*Tamias townsendii*)
Douglas' squirrel (*Tamiasciurus douglasii*)
beaver (*Castor canadensis)*
bushy-tailed woodrat (*Neotoma cinerea*)
deer mouse (*Peromyscus maniculatus*)
southern red-backed vole (*Clethrionomys gapperi*)
long-tailed vole (*Microtus longicaudus*)
Oregon vole (*Microtus oregoni*)

Townsend's vole (*Microtus townsendii*)
muskrat (*Ondatra zibethicus*)
house mouse (*Mus musculus*)
Norway rat (*Rattus norvegicus*)
Pacific jumping mouse (*Zapus trinotatus*)
porcupine (*Erethizon dorsatum*)
pika (*Ochotona princeps*)
snowsh`oe hare (*Lepus americanus*)
eastern cottontail (*Sylvilagus floridanus)*

# Appendix C

**Native Riparian Vegetation**

Willows (*Salix* spp)
Red elderberry (*Sambucus racemosa*)
Snowberry (*Symphoricarpos albus*)
Pacific ninebark (*Physocarpus capitatus*)
Vine maple (*Acer circinatum*)
Serviceberry (*Amelanchier* spp)
Red osier dogwood (*Cornus sericea*)
Mock orange (*Philadelphus virginalis*)
Wild rose (*Rosa acicularis*)
Snowbrush (*Ceanothus velutinus*)
Oceanspray (*Holodiscus discolor*)
Hardhack spiraea (*Spiraea tomentosa*)
Flowering red currant (*Ribes sanguineum*)
Black hawthorn (*Crataegus douglasii*)
Salmonberry (*Rubus spectabilis*)
Thimbleberry (*Rubus parviflorus*)
Tall Oregon grape (*Mahonia aquifolium*)
Red alder (*Alnus rubra*)

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