Hiram M. Chittenden Locks

The following write-up relies heavily on the *Hiram M. Chittenden Locks/Salmon Bay Subarea Chapter* by Fred Goetz in the *Draft Reconnaissance Assessment – Habitat Factors that Contribute to the Decline of Salmonids* by the Greater Lake Washington Technical Committee (2001).

Overview

The Hiram M. Chittenden Locks (Locks) were constructed by the U.S. Army Corps of Engineers (the Corps) in 1916 and commissioned in 1917. The Locks were built as a navigation project to allow boats to travel from the marine waters of Puget Sound to the protected freshwaters of Lake Union and Lake Washington. The Locks are comprised of two navigational lock chambers: a large lock that accommodates both large and small vessels and a small lock used by smaller vessels. In addition to the lock chambers, the Locks include a dam, 6 spillway bays, and a fish ladder.

The Locks form a dam at the outlet of the Lake Washington and Lake Union/Ship Canal system that maintains a higher water level in the Ship Canal than in tidally-influenced Shilshole Bay. The level of the water upstream of the Locks is maintained between 20 and 22 feet above mean low low water (MLLW) during most years.

The Hiram Chittenden Locks — looking westward.

Operation of the navigational locks involves raising or lowering the water level within either the large or small lock chamber so that vessels may pass between the two waterbodies. The filling and emptying of the large lock chamber is achieved by use of a system of two large conduits that can either fill the entire lock or half of the lock. This is achieved by using a miter gate that divides the large lock chamber into two sections. Water is taken into the conduits via two culvert intakes located immediately upstream of the structure. Water is conveyed through each conduit and is discharged into the lock chamber through outlet culverts on each side of the chamber. The Locks include a series of six spillway bays to pass excess freshwater inflow over the dam until the level of the Ship Canal drops to 20 feet MLLW. This most commonly occurs in June.

Since the original construction in 1916, the Locks have been upgraded several times to improve both upstream passage for adults and downstream passage for outmigrating smolts. The improvements include the reconstruction of the fish ladder in 1976 to facilitate upstream migration of adults. A program to install up to four smolts flumes began in 1995 and was completed in 2000. The smolt flumes provide improved passage for outmigrating juveniles and have significantly improved smolt passage through the structure when water is available for their use.

Historical Modifications

Physical Changes

The Locks serve as a dam between the freshwater environment of Lake Washington and the marine environment of Shilshole Bay (Puget Sound). Construction of the Locks and the Lake Washington Ship Canal resulted in substantial physical modifications to Salmon Bay. Historically, Salmon Bay was a long, shallow, tidally-influenced, saltwater embayment of Puget Sound (Weitkamp *et al.* 2000). As part of the construction of the Lake

Washington Ship Canal, Salmon Bay was dredged and channelized into the Salmon Bay Waterway upstream of the Locks and Salmon Bay downstream of the Locks. Approximately 1,300 acres of nearshore and wetland habitats were lost in Salmon Bay as a result of this dredging (Weitkamp *et al.* 2000).

The construction of the Locks and Ship Canal effectively lowered the level of Lake Washington between 8 to 10 feet to the existing level of Lake Union and raised the level of the Salmon Bay Waterway. The mean elevation for the Lake Union/Lake Washington Ship Canal system and Lake Washington is 21.0 feet (+/- one foot) MLLW (Weitkamp *et al.* 2000) with elevations managed between 20 and 22 feet MLLW, although water levels in the Ship Canal and Lake Washington have occasionally dropped to as low as 18.5 feet MLLW. The available storage in Lake Washington is such that sufficient water can be stored to maintain an elevation of at least 20 feet MLLW approximately 70 percent of the time.

Other habitat modifications at the Locks include extensive shoreline hardening along both sides of the Locks and the armoring of the Salmon Bay Waterway both upstream and downstream of the structure.

Limnological Changes

The construction of the Locks resulted in the creation of an abrupt transition from a tidal, estuarine environment to a freshwater environment. Through dredging and construction of the Locks, Salmon Bay was converted into a deep freshwater channel. Salmon Bay downstream of the Locks has remained a tidally-influenced, brackish-water estuary.

One of the primary challenges in designing and operating the Locks is how to limit upstream salt water intrusion to the Ship Canal and Lake Union. The operation of the lock chambers, particularly the operation of the large lock chamber, allows denser salt water to intrude upstream of the Locks. A saltwater barrier and a saltwater return system reduce the amount of saltwater intrusion into the Ship Canal. The barrier is constructed across the forebay of the Locks and partially blocks the more dense saltwater from flowing toward Lake Union. The saltwater return system consists of a saltwater drain with an inlet at the bottom of the Ship Canal near the upstream end of the Locks. After entering the inlet, saltwater is conveyed back toward Puget Sound through a concrete conduit to a point just east of the dam structure. Here a "Y" joint splits the flow with part of it proceeding out directly below the Locks and part of it flowing to the fish ladder to provide additional attraction flows. This feature was added to the saltwater drain during reconstruction of the fish ladder in 1976. The lack of sufficient attraction flows was a primary reason for the reconstruction of the fish ladder to its present configuration.

Operation of the saltwater drain requires a large amount of freshwater. During the summer, water flowing through the saltwater drain represents about 67 percent of all water used during the low flow season. The saltwater barrier and saltwater drain reduce the impact of saltwater intrusion; however, during the summer period when the boat traffic is heavy and water levels are at their seasonal low, the saltwater drain may not be sufficient to limit salt water intrusion. When this occurs, a salt wedge intrudes into Lake Union and up to the Montlake Cut (Corps, 1999). This causes the Ship Canal immediately upstream of the Locks to become strongly stratified, with the denser, cooler salt waters occurring along the bottom while warmer fresh waters is limited to the upper areas of the water column (Simenstad *et al.* 1999).

Chinook Utilization of the Hiram M. Chittenden Locks

All Chinook salmon in the Lake Washington drainage must pass through the Locks twice, as outmigrating smolts and as adults returning to spawn. Historically, the Locks has been a partial barrier both to adult fish and outmigrating juveniles; however, the various fish passage improvements that have been implemented at the Locks have served to reduce the effect of this blockage and have increased the success of both adults and juveniles passing through the facility.

Adult Migration

Adult Chinook salmon migrating from ocean to upstream spawning grounds in the Lake Washington basin must negotiate passage through the Locks via one of four possible routes. Adult Chinook salmon can pass the Locks via the fish ladder, the large lock, the small lock, and the saltwater drain.

The goal of the fish ladder is to facilitate efficient migration of salmon through the Locks complex. In 1976, the fish ladder was rehabilitated to attract more fish and to ease upstream migration. Prior to rehabilitation, migration delay and passage problems at the Locks may have reduced the annual runs of Chinook salmon by up to 20 percent (WDF, 1971). Since rehabilitation in 1976 approximately 80 percent of all adult Chinook salmon use the ladder (Muckleshoot and WDFW, unpublished data) and about 20 percent of all adult Chinook salmon use the large lock.

Average residence times of fish at the Locks vary depending on their success ascending the fish ladder. In 1999, fish that successfully negotiated the fish ladder on the first attempt had an average residence time of 15 days at the Locks. Fish that were unsuccessful in negotiating the fish ladder the first time averaged 23.5 days residence time at the Locks. Time of day and tidal stage are known to affect upstream movement of Chinook through the fish ladder. These same factors influence fish movement in natural estuaries.

Juvenile Migration

Juvenile Chinook enter Lake Washington over an extended period from January through at least mid-July (WDFW, unpublished data) with two peaks of migration from tributary streams. A large downstream movement of Chinook fry occurs immediately after emergence in February and early March when small fry leave upper river areas and enter the lake. A second smaller peak occurs during May and June when larger juveniles migrate downstream to the lake as part of their migration to saltwater.

Seasonal outmigration timing for juvenile Chinook salmon at the Locks appears unique in comparison to juvenile Chinook outmitgration timing for other Puget Sound Chinook stocks. Saltwater migration through the Locks appears to occur later in the Lake Washington system. While outmigration in other Puget Sound tributaries can begin as early as March or April (Myers *et al.* 1998), no juvenile Chinook have been captured in March or April at the Locks and rarely have juvenile Chinook been found in early May. Based on a variety of data, about 5 percent of the Chinook juveniles pass the Locks in May, over 50 percent pass the Locks in June and about 40 percent pass in July. Most of the earlier migrating juvenile Chinook are of hatchery origin.

Wild fish first begin appearing in catches in early June with the peak outmigration period for wild Chinook juveniles occurring during mid to late June. Migration continues through early July. The combination of lake-rearing juveniles and delayed migration are hypothesized to be the cause of the unusually large Chinook smolts produced from the Lake Washington basin. Larger size may be beneficial as a result of increased ocean survival rates; however, more study is necessary on this issue.

Smolts may remain in the Locks for days to weeks. Larger smolts, such as steelhead or sockeye salmon, may move through the Locks in hours or days. Smaller smolts, in particular Chinook salmon, may remain in the Locks for weeks at a time, feeding and attaining size prior to entering Puget Sound. Large numbers (thousands) of juvenile Chinook may remain in the large lock chamber, feeding, for several days. Tagged juvenile Chinook have been known to pass through the smolt passage flumes, then return to the Ship Canal through either the small or large locks, and be passed a second time through the flumes (R2 Resource Consultants, 2000).

Habitat Requirements

Fish Access and Passage Barriers

(a) Adult Fish Passage

An important issue related to the Locks is the extent to which upstream migration of adult Chinook is delayed as a result of the facility. Migration delay may lead to increased energy expenditure, stress, susceptibility to disease, and altered spawning timing. The new fish ladder constructed in 1976 was designed to reduce migration delay and facilitate upstream migration based on the best available information at that time (Corps, 2000). In addition to the new fish ladder, the Corps has implemented some additional improvements including reconstructing the entrance to the fish ladder and enhancing the flow of water to facilitate the ability of adult fish to find the ladder.

A small number of adult fish may also pass upstream through the saltwater drain, but recent improvements in drain operation procedures are believed to minimize the use of this route. Fish attraction to the drain has been reduced by closing the drain during the summer when tides can exceed 7 feet and by operating the drain primarily at night when fewer adults migrate. In addition, adult Chinook may enter the intake of the saltwater drain on the upstream side of the Locks. Salmon entering the drain should be able to swim out of the six-foot diameter pipe. Use of the drain by adult Chinook is currently being investigated with hydroacoustics and video cameras as well as by tracking the movements of adults in the forebay (BioSonics, 2000; HTI, 2000).

Salinity in the entry pool to the fish ladder has been identified as a potential factor affecting attraction of fish to the ladder. Maintaining freshwater flows as a cue for homing Chinook is an important function of the fish ladder. Salinity in the ladder is influenced by operation of the saltwater drain, which transports a mix of salt and fresh water from above the Locks to the lower half of the fish ladder, and by tide stage (high salinity at high tide). Although studies of the effects of salinity on Chinook migration in the ladder have not been conducted, investigations on other salmonid species indicate that high salinity may discourage fish from using the ladder. High salinity is most typically a concern during the summer (July through September) when freshwater outflows from Lake Washington are at a seasonal low and less fresh water is available to mix with saltwater in the saltwater drain.

Since the reconstruction of the ladder, the primary issue related to passage appears to be less structural and more environmental. At the Locks, adult Chinook encounter an abrupt change from cooler, more saline marine water below the Locks to warmer, less saline water above the Locks. Also, Chinook encounter water currents below the Locks, but currents are negligible once they pass into the Ship Canal. In contrast, Chinook in a natural estuary would be free to move up and down the channel selecting preferable temperatures, salinity, and current velocities. At the Locks, there is less variability and less opportunity for Chinook to find more preferable habitat conditions.

Studies of tagged adult Chinook have shown that after migrating through the fish ladder, adult fish immediately move to the deepest part of the channel upstream of the saltwater drain. Researchers noted that the Chinook that passed upstream of the Locks held near the saltwater drain for long periods (average 19-20 days). Because of the intrusion of saltwater from Puget Sound, this area has the coolest temperatures and highest dissolved oxygen levels of any area for a significant distance upstream of the project. Fish entering the ladder in late July and early August had the longest residence times while fish migrating later in the summer had the shortest residence times. Between 1998 and 2000, the longest residence time for any tagged fish at the Locks was 52 days. Once they leave the Locks, most fish move through the Ship Canal in less than one day.

It is difficult to determine what role the Locks have on migration delays once Chinook have moved upstream of the facility. Water quality limitations, particularly low dissolved oxygen levels in the Ship Canal in the summer, appear to play a major role. This is discussed further in the water quality section. The initial theory, based on observations in 1998, is that residence time is a function of water temperature with fish holding at the Locks until near-surface temperatures drop below 22 degrees C (Fresh *et al.* 1999). However, studies in other rivers indicate that fall Chinook normally hold in estuaries for about one month (Wendler, 1959; Verhoeven and Davidoff, 1962; and Vernon *et al.* 1964). So some of the apparent migration delay may be normal behavior for fall Chinook.

(b) Juvenile Fish Passage

Neither the original construction of the Locks nor rehabilitation later included specific features to pass downstream migrating salmon and steelhead juveniles (smolts). Ongoing monitoring at the Locks and the availability of more recent coded-wire-tag data has indicated that the design and operation of the Locks has the potential to significantly affect year-to-year differences in salmon smolt-to-adult survival primarily as a result of this lack of facilities to improve survival for outmigrating juvenile Chinook (Corps, 1999; Seiler, WDFW, unpublished data).

In most years more than 2.5 million smolts will migrate through the Locks. A number of factors relating to fish health and development (smoltification) have been shown to influence survival. For example, injury (descaling, bruising) of smolts can increase delayed mortality (Bouck and Smith, 1976). Injury and stress can reduce the quality of outmigrants in terms of predator avoidance (Mesa, 1994; Schreck *et al.* 1997); preparedness for saltwater entry (i.e., smoltification; McInerney, 1964; Schreck, 1982, 1992), and disease resistance ability (Schreck, 1996; Maule and Vanderkooi, 1999; Maule *et al.* 1989). Since 1994, monitoring and evaluation coupled with smolt passage improvements have been used to improve the survival of juvenile salmon migrating through the Locks.

Fish passage improvements were completed in 2000 with full implementation expected by 2001 or 2002 through structural and operation changes.

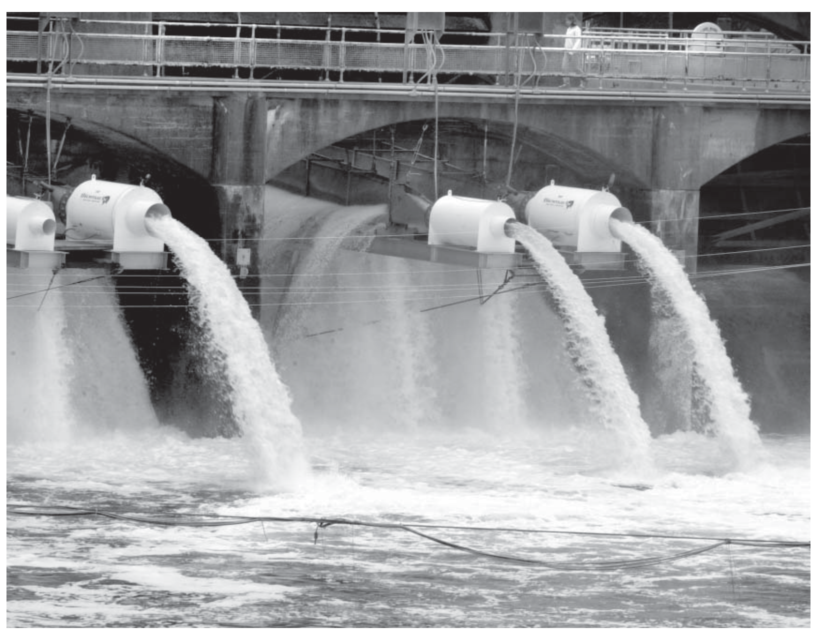
There are a combination of 12 different routes outmigrating Chinook smolts may use to pass through at the Locks. These include fish moving through the fish ladder, over the spillway, through the saltwater drain, or through the lock chambers and/or the culvert systems for both the small lock and the large lock chambers. Although 12 routes are possible, data collected over the past four years indicates that Chinook smolts are most likely to pass through one of three major routes: 1) over the spillway (via the smolt passage flumes or under the spillway gates), 2) through the large lock gates, or 3) through the filling culverts for the large lock. Both the fish ladder and saltwater drain appear to pass small numbers of migrating juvenile salmon. However, use of the saltwater drain may be higher during drought years when there is limited water available after early June to operate the smolt passage flumes or spillways. It is likely that few fish use the small locks.

Smolt Passage Flumes and Spillway Gates

By late spring, the flow volume into the Ship Canal is usually reduced such that the spillway gates cannot be opened wide enough most days to safely pass smolts. Further, late spring and early summer inflow (May-July) to the Ship Canal appears to have been reduced since the late 1970s as a result of natural climate variability (Houck, 2000) and increased water demand within the basin (Horner and May, 1998). Prior to 1995, little or no water was spilled over the dam during most days in June and July. In 1995, a prototype low-flow smolt bypass flume was installed that used only 20-25 percent the water volume necessary to open a spillway gate 1.0 foot. In 2000, the prototype flume was replaced with the four smolt passage flumes capable of passing nearly the equivalent amount of water as would pass through a 1.0 foot spillway gate opening. Installation of these four flumes has allowed the Corps to increase their operational flexibility and to use water more efficiently for safe smolt passage within a wider range of available flows.

The primary concern with the smolt passage flumes is the potential lack of available water to allow operation of the flumes during the later part of June and July when most juvenile Chinook salmon are migrating through, or rearing below, the Locks. When water isn't available, Chinook and other smolts are forced to select other routes to exit the Locks. By this time in the migration season, juveniles are likely highly motivated to migrate from physiological cues or due to the increasingly high temperatures in the Ship Canal.

Spillway gates are typically mentioned as the preferred means to pass juvenile salmonids through water control structures (Williams et al. 1996). There are still periods in late spring when additional water must be spilled under the spillway gates at the Locks to maintain the maximum pool elevation. Water may also be spilled through the spillway gates to provide additional adult fish attraction during the late winter and spring adult steelhead migration. The minimum opening for the Locks spillway gates is 0.5-foot and they are currently operated at this level. At other water control projects (dams) in the Pacific Northwest, the minimum gate opening recommended for passing juvenile salmon is 1.0 foot (Williams et al. 1996). The difference between how the gates are operated at the Locks and at other projects does not appear to be a concern for fish survival.



Recently installed smolt flumes assist juvenile passage past the locks.

Large Locks

The large locks has been implicated as the primary source of injury and mortality for smolts passed through the Locks. The main concerns regarding juvenile salmon use of the large lock are: 1) entrainment into the filling conduits and culverts and subsequent injury and mortality during passage through the conduit system; and 2) predation of injured or disoriented smolts passed through the conduit system. Entrainment is a term for the "phenomenon of being carried along by turbulence" and is used to refer to the process in which juvenile salmon swim into, and then are swept through the filling conduits, culverts, or drain pipes at the Locks. Entrainment is important because juvenile fish can be injured or killed during this process if water velocities are high or there are obstructions such as barnacles or sharp bends in the piping that could injure fish.

Smolt passage improvements completed in 2000 and 2001 included actions to reduce entrainment of juvenile fish and to lower the rate of injury of fish that are entrained. As a result, entrainment of smolts into the large lock filling culverts has been dramatically reduced between 1996 and 2000. This is mainly due to two factors: installation and operation of the smolt passage flumes and reductions in the fill rate of the large lock chamber during each lock cycle. Lower fill rates have decreased water velocities in the filling conduits and culvert inlets. Reduced flow rates have lessened the likelihood of juvenile fish being attracted and entrained into the culvert inlets. In 1996, an average of 540 smolts were entrained per lockage event. In 1998, it was between 211 to 360 smolts per lockage event. These entrainment rates were with one flume (80 cfs) in place. With the addition of 4 new flumes (3 flumes operating most of the migration season) the entrainment rate in 2000 was reduced to 45-120 fish per fill. The average entrainment was 93 fish per fill or an average 83% reduction in the entrainment rate from 1996 to 2000.

A second objective of the improvements to the large locks was to reduce the injury rate of any smolts still entrained into the culvert intakes and deposited in the upper half of the lock chamber. In November of 1999, all of the conduits leading into and out of the large lock chamber were cleaned to bare concrete using a high-pressure wash to remove encrusted barnacles and other debris. As a result, in 2000 there was a 75 percent reduction in significant injury rates to fish entrained into the large lock chamber.

While the reduction in injury rate for fish captured in the upper chamber is substantial, there is a data gap regarding fish injured after entrainment that are deposited in the lower lock chamber either during a "down lock" or during filling of the full lock. We know more fish are entrained during a full locking but we have no measure of entrainment during a down locking (both result in depositing juvenile salmon in the lower chamber). Pre-baseline injury values in the lower lock are up to 3 times greater (35%) than those reported in the upper lock chamber (10-15%). Barnacle regrowth is slightly higher in the lower chamber than the upper chamber. Whether barnacle removal could lead to a greater reduction in injury rates for the lower chamber is uncertain.

Water Quality

The saltwater–freshwater mixing area at the Locks is constrained and a significant salinity gradient is present across the Locks. During the summer period of heavy boating activity, the saltwater drain cannot keep up with the amount of salt water entering the freshwater system, and a salt water wedge intrudes into Lake Union and even up to the Montlake Cut. Saltwater intrusion and stratification can lead to low levels of dissolved oxygen upstream of the Locks and, at times, up through Lake Union. The anoxic conditions may have deleterious effects on benthic organisms. Several modifications have been made to the Locks to reduce saltwater intrusion above the Locks, including installation of the saltwater barrier and saltwater drain discussed above. However, some saltwater intrusion is still known to occur.

Temperature is a primary water quality consideration at the Locks related to Chinook. Higher temperatures may lead to increased predation rates, creation of a thermal water barrier, and direct mortality of adult Chinook salmon. Several studies indicate that high temperatures in the Ship Canal may delay adult migration. The adult Chinook salmon migration occurs during the most severe temperature conditions at the Locks and in the Ship Canal. Severe temperature gradients that occur at the Locks are uncommon in natural systems and are not found in most areas were anadromous fish migrate. Fish passing through this high gradient area may become stressed. Stress during this life history stage has unknown effects on Chinook behavior and survival. Increased water temperatures in the Ship Canal in June and July may adversely affect the migration route selected by smolts at the Locks with smolts selecting deeper depths as surface water temperatures increase beyond their temperature threshold. This may result in increased levels of entrainment through the saltwater drain or large locks conduit system.

Juvenile salmon (smolts) normally require a period of time to acclimate to marine waters. At the Locks, smolts are directly passed into the marine waters of Puget Sound. High temperatures are also known to affect the ability of smolts to transition to and grow in a saline environment. Potentially, a significant problem at the Locks is that as a result of high temperatures smolts are forced into the marine system before they are physiologically ready, and that may cause mortality in the estuary. The artificial estuary below the Locks is lacking most of the functions of a natural estuary. The numerous water outlets at the Locks diffuse the flows through the small estuary below the Locks, and little or no freshwater lens is formed during the late spring and summer low flow season. This freshwater lens is common in natural estuaries and provides a variety of salinity levels within the water column for Chinook to use during outmigration. Studies from other estuarine areas support the concept that some juvenile Chinook salmon life history types are dependent on low salinity conditions for a period of time prior to movement to marine waters.

Predation

Predation on salmon is often greatest at constrictions where fish aggregate. The major source of mortality from predation on juvenile Chinook salmon may come during migration through the Ship Canal and Lake Union system. Few if any freshwater fish predators such as bass or northern pike minnows have been captured within the immediate vicinity of the Locks. The primary known avian and mammalian predators on Chinook salmon are gulls, harbor seals, and California sea lions. Gull predation on juvenile Chinook in the lock chamber has virtually been eliminated since implementation of the slow fill procedures in 1999.

The numbers of harbor seals and California sea lions in Puget Sound have increased significantly in recent decades. Between 1985 and 1995, significant numbers of adult steelhead were consumed by sea lions. In 1996, NMFS authorized removal of several nuisance sea lions and subsequent predation rates on steelhead declined. Concurrent with removal of the nuisance animals, NMFS has been running an acoustic deterrent device (ADD) or acoustic harassment device (AHD) immediately downstream of the Locks. The ADD acts as a behavioral barrier to sea lions, emitting sounds in a frequency range that appears to exclude most animals from the Locks area (Fox *et al.* 1996). Sea lions have not been observed preying on salmonids near the Locks since 1999. Harbor seals are present in Puget Sound year-round and are more abundant than sea lions. They commonly attack salmon, but predation by harbor seals at the Locks has been infrequently observed. The numbers of juvenile Chinook taken by harbor seals is believed to be a small percentage of the run.

Below the Locks, in west Salmon Bay and Shilshole Bay, a pilot study was conducted in spring and summer of 2000 to investigate the level of juvenile Chinook salmon predation by marine and anadromous fish (Footen 2000). The most abundant predators in this area were sea-run cutthroat trout, staghorn sculpin, resident Chinook or blackmouth, and native char (presumably bull trout). Although present, these predators do not appear to consume large numbers of smolts (relative to predation rates in the Ship Canal by smallmouth and largemouth bass). Initial estimates do not suggest that fish predation below the Locks is a significant source of mortality.

Preliminary Focus Areas

Based on the analysis above, the following table summarizes our understanding of the most significant factors for Chinook survival and fitness through the Locks.

Population Function	Requirements	Characteristic/ Condition	Processes	Constraints
Adult Upstream Migration	Successful Passage	Physical barrier with cool saltwater downstream and warmer freshwater upstream.	Freshwater input into Salmon Bay. Saltwater mixed into fish ladder water flow.	Warm surface water temperatures in Ship Canal and low dissolved oxygen levels. Adequate attraction water in fish ladder. Presence of locks as a barrier between salt and freshwater environments.
Juvenile Outmigration	Successful Passage	Physical barrier with cool saltwater downstream and warmer freshwater upstream.	Freshwater input (particularly through smolt flumes) into Salmon Bay downstream of locks. Improvements at locks to increase successful smolt passage.	Limited quantity of freshwater to operate smolt flumes during peak Chinook smolt outmigration period. Continued smolt entrainment into Locks filling culverts. Presence of locks as a barrier between salt and freshwater environments.

Among these factors, continued efforts to increase the safe passage of both juvenile and adult Chinook past the Locks and to reduce the effects of the abrupt transition between the marine and freshwater environments emerge as key focus areas.

Fish Passage Improvement Projects at the Locks

Habitat improvement projects should focus on improving those habitat qualities that the science indicates will likely provide the greatest benefit for fish. Habitat restoration projects will be monitored whenever possible. Monitoring will track those critical variables that will help the City to assess effectiveness in meeting project objectives. The City will seek to design and monitor habitat restoration projects that create benefits for multiple species, where this practical and where doing so does not undermine the main objectives of the project. The following table notes projects which have already been completed and projects which might be considered and notes the benefits for fish which each project may create.

Project Name Project Cost or estimate Status of Project	Project Description	Habitat Requirement Successful Passage	Transition
Barnacle removal $63,000 annually Underway	Annual scraping of sharp-edged barnacles from the filling culverts' interior walls	Minimize abrasion injury and mortality to juveniles entrained into the culverts	
Motors to control filling rate Underway	Installation of new variable speed motors on the large filling culverts	Allow slower filling rates	
Smolt Slides $725,000 Completed	Installation of smolt slides	Pass juvenile salmonids over the dam	
Strobe Lights $399,000 Installation completed	Installation of underwater strobe lights	Frighten juvenile salmonids away from the entrances of the filling culverts	

Addressing Uncertainties

Biological Indicators

This system is unique in the degree to which the natural system has been altered. It will be important to monitor the effects of new and ongoing passage improvements to increase salmonid survival and fitness. This system is also unique because there have been so many studies on the Locks system by various agencies and organizations during the past seven years. Because a significant number of improvements have already been implemented, an immediate opportunity exists for measuring how survival for Chinook can be quickly affected by short-term actions.

Key research and assessment issues include:

1. Continue evaluation of implemented improvements related to smolt passage through the Locks. Monitoring and evaluation occurred in 1996, 1997, 1998, 2000, and will occur again in 2001.
2. Determination of the best usage of available freshwater through the Locks to provide maximum smolt passage. In most years there is little available water for spill after mid to late June.
3. Investigate ways to increase the amount of freshwater available for fish passage in late June and July.
4. Further investigate ways to improve the saltwater/freshwater interface for both adult and juvenile passage.
   a. Evaluate salinity levels upstream of the Locks
   b. Evaluate freshwater input into Salmon Bay downstream of the Locks
   c. Evaluate salinity levels in the fish ladder for upstream migration
   d. Evaluate adult use of the saltwater drain into the Locks

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