Lower Snow and Salmon Creeks and Estuary Integrated Restoration Strategy:

Alternatives for continuation of the comprehensive salmon and steelhead monitoring program

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November 2024

WEST FORK ENVIRONMENTAL

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Acknowledgments

We spoke with numerous individuals on multiple occasions in preparation for writing this report. We were humbled by the breadth and depth of their knowledge and experience in the area of salmonid population research and monitoring and their dedication to acquiring the data necessary to further the conservation of local salmon runs. Each person voiced a desire to see the strong data collection record established at the Snow Creek weir continue in the same or an equally effective manner. They all were firm in their statement as to the value of the Snow Creek program to inform management and recovery of salmonids in the region, and everyone we spoke with voiced support for the overall goals of the restoration work that is currently in conceptual stages.

Among those we spoke with are Mark Downen, Hood Canal, E Straits, E Jefferson, N Mason, W Kitsap District Biologist and his staff at Snow-Salmon Creek, research biologists at the WDFW, Joe Anderson and Neala Kendall, habitat and fish management biologists Randy Johnson and Aaron Brooks at the Jamestown S'Klallam Tribe, Roma Call, Natural Resources Director at the Port Gamble S'Klallam Tribe, Tim Abbe and Aaron Lee of Natural Systems Design. Our work was substantially benefitted from access to proceedings and materials produced for several meetings held by the Snow Salmon Forum and obtained through Alicia Olivas, Hood Canal Coordinating Council and Larry Lestelle, Biostream Environmental. Thank you everyone!

1.0 Historical Setting and Project Context

Until the last decade of the 19th century, Snow Creek was a tributary to Salmon Creek, joining approximately 0.5 mile above the head of Discovery Bay. However, early in the European settlement of the Snow and Salmon Creek basin the streams were decoupled creating two independent channel networks each flowing into Discovery Bay at separate locations along the eastern and western head of the bay. In order to drain wetlands and develop the valley bottom for agriculture, Snow Creek was relocated to follow the east side of the valley and routed directly into the southeast corner of Discovery Bay.

Another, but less geomorphically consequential channel realignment in the Snow Creek subbasin was made to Andrews Creek such that it now flows permanently into Crocker Lake. While the facts around this alteration are not entirely clear, it appears likely from existing landform evidence that Andrews Creek historically flowed across a substantial alluvial fan as it entered the valley from the west between Snow Creek and the Little Quilcene River, at times flowing for extended periods to the north or to the south, depending on debris conditions on the fan. The extensive scrub shrub and emergent wetlands in the north south trending valley between Snow Creek and the Little Quilcene probably served as a significant buffer or sink for sediment transported from the upper network of the Andrews Creek subbasin and also would have attenuated peak flows originating from that portion of the watershed (Tim Abbe personal communication).

The Snow Creek realignment resulted in cascading changes to hydrologic regimes and associated sediment transport and storage functions in both Snow and Salmon Creeks. Ultimately characteristics of the nearshore environments at the head of Discovery Bay were affected by these and other impediments to normal sediment transport and deposition. The effects of channel realignment were reinforced by the construction of rail and road infrastructure at the boundary of the valley and the bay, further imposing an already restricted physical interchange between the fresh and nearshore ecosystems. These changes have had long-lasting and detrimental impacts on the productivity of Snow and Salmon Creeks and their downstream nearshore systems.

Recent conservation concerns for the recovery of several anadromous salmonid species, including threatened summer Chum salmon, have resulted in an interest in restoring historical channel patterns and processes in the Snow and Salmon Creek basin. While some habitat restoration work has been done in both streams, as well as in the estuary and Discovery Bay, consideration is now being given to a more comprehensive, integrated restoration strategy for the area. The strategy is considered to be a key part of an updated recovery plan for the Hood Canal Summer Chum Evolutionarily Significant Unit (ESU). As such, it is viewed as important for both achieving recovery, and for maintaining a recovered status as climate change effects are increasingly manifested (Scott Brewer, HCCC, personal communications).

Conceptual ideas and alternative approaches are being developed through the Hood Canal Coordinating Council (HCCC), as a result of the “Snow Salmon Forum.” The forum, facilitated by HCCC, consists of a group of co-manager participants and other entities who come together to consider restoration needs for the Snow-Salmon watershed and estuary, as well as a need to ensure on-going, uninterrupted monitoring of salmon and steelhead in the watershed. Normally a restoration effort such as this would advance through a technical review process and be evaluated on its merits for ecological benefits, construction costs, public and stakeholder support and funding availability. However, in this situation there is an additional consideration that must be addressed – the ongoing research and monitoring at the Snow Creek weir. Since the weir is located downstream of where the historical Snow Creek channel was diverted to its current channel location, reconnection of the historical channel confluence between Snow and Salmon Creeks would isolate the weir.

2.0 Weir Operations

Snow Creek was selected by the Washington Department of Game in the mid-1970s as a watershed that could be intensively monitored to provide abundance estimates and help develop escapement goals for steelhead in the fisheries management realignment following the Boldt decision in 1974. In 1976, a permanent channel-spanning weir was constructed across Snow Creek at RM 0.8 that facilitated monitoring adult and smolt populations. The Snow Creek weir was constructed to facilitate fisheries research and has amassed an admirable record – comparable in length to the record collected on the Keogh River in British Columbia, Canada for steelhead and Coho salmon (Wilson et al. 2022). Data collected at the weir have been used to develop an understanding of steelhead recruitment patterns from lowland independent tributaries to Hood Canal and the Strait of Juan de Fuca. Snow Creek was used to set the threshold for the minimum basin size for demographically independent steelhead populations in the Puget Sound region (Myers et al. 2015). However, extension of the Snow Creek data to large river systems in the region with more complex habitat types and significantly greater opportunity for divergent life histories has its limits.

Early experiments with a "permanent" style weir in Salmon Creek at the same time weir operations began in Snow Creek were unsuccessful. This style of weir was intended to be maintained through high flows but did not have permanent concrete footings. Several of these kinds of wooden structure weirs were installed during this same period on other west end Olympic Peninsula streams and were also unsuccessful. Further comprehensive monitoring efforts were deferred in Salmon Creek until 1992 when temporary adult fences and traps were installed coincident with efforts to implement and monitor a summer Chum supplementation program. All monitoring in Salmon Creek is currently supported by temporary facilities including the adult trap.

After nearly 50 years of continuous operation, the monitoring program facilitated by the Snow Creek weir is still collecting data that informs fisheries management and salmon and steelhead conservation (i.e., adult and juvenile abundance, age structure of the populations, timing of life history events, and indices of stock productivity, including smolt to adult survival). But given the potential that Snow and Salmon Creeks may be reconnected at the historical channel junction through a comprehensive restoration plan, or potentially a natural channel avulsion, either of which would render the weir obsolete, consideration of a future without the weir could be insightful and would necessarily be an important part of that larger restoration planning effort.

While it is impossible to assign a time to a potential channel avulsion, fluvial geomorphologists and engineers with Natural Systems Design (NSD) have concluded that a channel avulsion may occur at some future time causing Snow Creek to rejoin Salmon Creek somewhere along its historical flow path (Tim Abbe personal communications). Figure 1 (courtesy of Aaron Lee of NSD) is a relative elevation model map (REM) of the Snow – Salmon Creek valley. Purple shading indicates lowest elevation lands and generally represents portions of the valley that were occupied by the historical Snow Creek channel and adjacent wetlands.

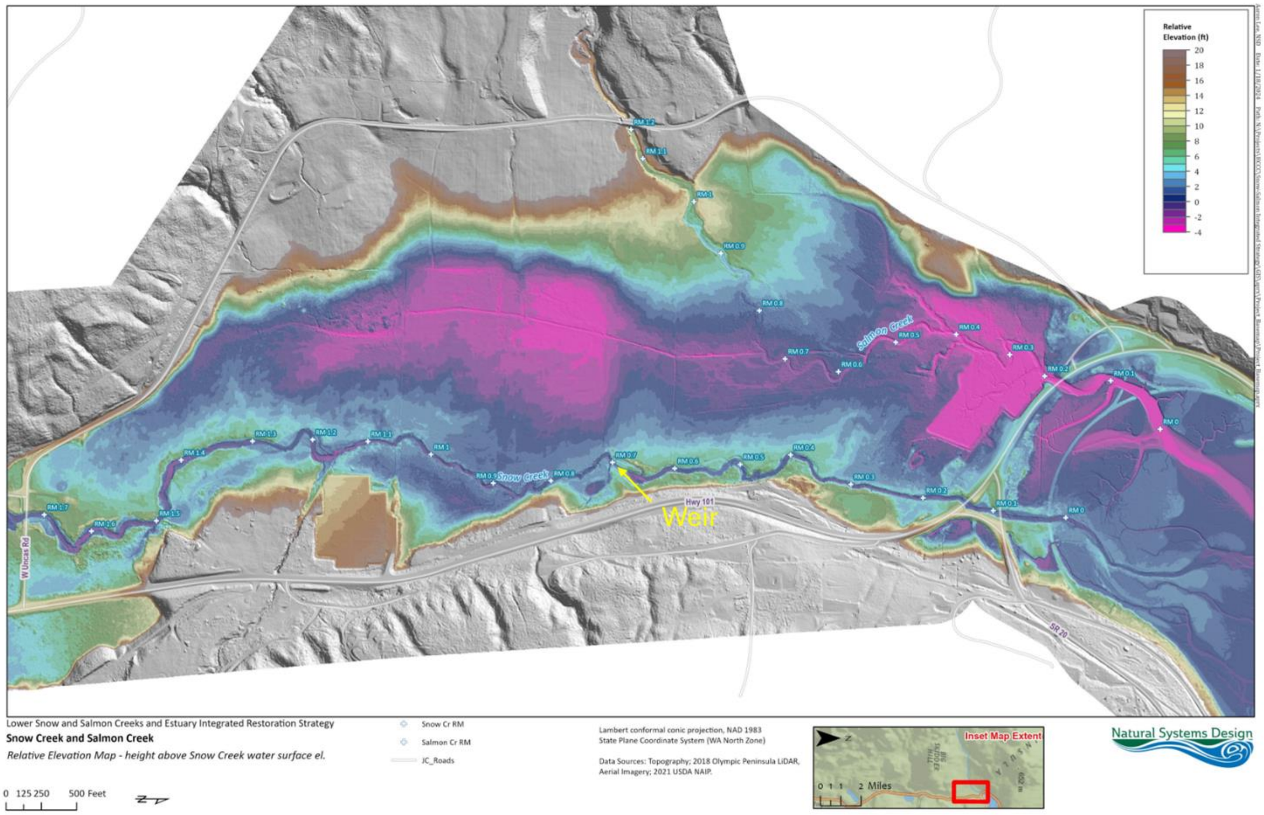

Figure 1. Relative elevation map of Snow – Salmon Creek lower valley.

3.0 Purpose and Limitations of Report

HCCC is currently engaged in a process to consider potential restoration options for the Snow-Salmon basin. This report is intended to provide information to inform that process. This report identifies possible alternative monitoring approaches that could be implemented as part of the overall restoration strategy being considered for the Snow-Salmon basin. The report does not make specific recommendations or endorse any specific course of action. Any decisions to be made on the future of monitoring fish populations in the Snow-Salmon basin are the exclusive purview of the State of Washington and tribal co-managers.

4.0 Information Needs and Objectives 1976 and 2024

When the Snow Creek weir was constructed in 1976 there was an information need that drove the objectives for the fledgling Snow Creek monitoring program. The primary objectives for the program were to support steelhead abundance estimation, help develop an understanding of steelhead life history in western Washington, and aid in the development of steelhead spawning escapement goals (WDG 1978). This information was acutely needed in the period of fisheries management realignment following the Boldt Decision of 1974.

In its early operation, the Snow Creek weir provided biologists an opportunity to collect needed steelhead life cycle data (i.e., adults in, sex ratios, juveniles out, age structure of adult and juvenile populations and timing of life history events), as well as basic production characteristics of the population. These data enabled estimation of important productivity metrics, including survival measures, both in freshwater and the marine environment. These were the objectives of the monitoring program then and they were addressed with a solution that was consistent with the technology of the day. The original objectives of the Snow Creek monitoring program have had continuing support across a broad audience over the years.

It bears noting that while the original objectives of the program were primarily focused on steelhead, it also enabled collection of significant life cycle and population dynamics data for both Coho and cutthroat (e.g., Johnson and Cooper 1986; Lestelle et al. 1993). Data collected at the Snow Creek research station have served in the development of important salmonid life cycle models in the Pacific Northwest, such as the EDT model (Mobrand et al. 1997; Blair et al. 2009).

Attempts at comprehensive upstream and downstream salmonid monitoring in Salmon Creek were made for several years when the program was implemented in Snow Creek—but these were largely unsuccessful. Subsequently, upstream trapping of adult summer Chum began in earnest in 1992 to support a supplementation project, and then expanded to trapping downstream Chum fry migrants in 2008. These successful efforts have continued to the present. The objectives of this work are to assess population dynamics of the Salmon Creek subpopulation of summer Chum and help evaluate habitat restoration efforts. The Salmon Creek summer Chum data set is recognized as being important for assessing the conservation status of listed summer Chum.

Now in 2024, after nearly 50 years of continuous operations in Snow Creek, there is another opportunity to review the information requirements and objectives for the entire Snow and Salmon Creek monitoring program. Management and information needs may have changed over the past 50 years given ESA and recovery planning considerations, climate change effects, changes in fisheries management, and other emerging issues. Moreover, the potentially major changes to the Snow-Salmon basin that may occur from comprehensive restoration activities or natural channel changes, warrant a review of objectives for assessing potential effects on the fish populations.

The development of a comprehensive restoration strategy for the Snow-Salmon basin and estuary (NSD, in preparation) affords an opportunity to review and affirm – and update as needed – the objectives for the monitoring program. Review of objectives are largely the responsibility of the State and tribal co-managers, though there is a need for recovery and restoration partners to weigh in. The monitoring program for the Snow and Salmon Creek basin is uniquely positioned to address key salmon response and recovery uncertainties, especially those related to linkages between the freshwater and nearshore marine ecosystems.

5.0 History of Monitoring Activities at Snow and Salmon Creeks

5.1 Monitoring Infrastructure

The permanent concrete footings of the Snow Creek weir and its steel beam panel supports ensure its permanence through the most extreme flow events (Figure 2, photo left). However, operational considerations are made during high flows, and for facility and worker safety, the upper panels are pulled at discharges greater than 200 cfs.[1] The weir interrupts natural transport of bedload through the system and prior to 2016 it was necessary to excavate sediment annually or semi-annually upstream of the weir and dispose of it off site. In 2016, the weir was retrofitted with sluice gates that are now opened at flows in excess of 85 cfs to facilitate transport of gravels and finer sediments past the weir, which is done typically after adult Coho migration has virtually ended in mid-December. Sediment accumulation in front of the weir can be problematic (Figure 2, photo right) but management of the weir is done to facilitate its transport on high flows. Concerns have been expressed about potential adverse effects downstream of the weir on incubating salmonid eggs and alevins (Larry Lestelle, Biostream Environmental, personal communications). However, it is noteworthy that sediment flushing typically occurs after summer Chum eggs have eyed, which provides a measure of protection to those eggs. Since Coho spawn primarily upstream of the weir and steelhead have typically emerged prior to flushing operations, there appears to be little concern for these species with respect to sediment management practices.

Fish sampling facilities in Salmon Creek are installed seasonally to capture adults and juveniles. In Salmon Creek the monitoring focus is on summer Chum that return at a time of the year when low flows make it easy to maintain a simple adult trap with temporary panels and a live box in the channel (Figure 3, photo left). Juveniles are captured using a small, inclined plane trap that is also easily installed on a temporary basis and can be managed on flows that occur during the fry outmigration (Figure 3, photo right). In this case the life history timing of the species of interest drives the selection of the monitoring infrastructure and temporary facilities serve this seasonal purpose well.

Figure 2. Snow Creek permanent full spanning weir newly constructed (circa 1978, photo let), and sediment accumulation in front of weir September 2023.

[1] Casey Sloth, WDFW biologist, notes that the need to pull panels is dependent on debris loads and is not only related to a specific discharge. In recent years, he notes that success has been achieved by opening panels only several inches to allow flow and debris to pass; this allows the weir to remain "fish tight". He further notes that the need to pull panels in the past 2 years have been infrequent and few data interruptions have occurred.

Figure 3. Salmon Creek adult fence trap 2023 (photo left) and incline plane trap used for collection of Chum salmon juveniles (photo right).

5.2 Past and Current Data Collection

Data collection for both Snow and Salmon Creeks has focused on fish in (adults) and fish out (fry/smolts) enumeration metrics. The collection of biological data such as sex, and age composition is facilitated by weir operations. The data record for Snow Creek is more complete and more rigorous than for Salmon Creek as a result of permanent weir operations. Years of collection and other general details for juvenile and adult data sets are provided in Table 1 below. What Table 1 does not show is the "second order" information such as smolt to adult return ratios (SAR) and spawner recruit (S/R) functions that are only possible if reliable count and age composition data is obtained. Presently these data are being collected at the permanent facility in Snow Creek and at seasonally installed and maintained traps in Salmon Creek (summer Chum only). These kinds of data are especially valuable for recovery monitoring and restoration planning and have been institutionalized in viable salmonid population (VSP) monitoring (McElhaney et al. 2000). Fish in and fish out monitoring projects, (such as exist for Snow and Salmon Creek) and that are run by the Washington Department of Fish and Wildlife (WDFW) provide an important mechanism by which to parse out the effects of freshwater versus marine survival on overall stock status. Furthermore, they help to assess effects of density dependence that occur in freshwater versus potential effects of density dependent survival in marine environments, most likely early in marine residency.

5.2.1 Snow Creek

The permanent weir is operated in Snow Creek year-round and is outfitted with adult panels August through March and juvenile panels April through July. The weir begins intercepting summer Chum in late August with that run winding down in early October as Coho begin to arrive. Coho are captured through early January when the steelhead upstream migration gets underway. The arrival at the weir of all three of these species is remarkably separate (Figure 4). The Coho and steelhead runs overlap by only about 2% at the end of the Coho and beginning of the steelhead run. Beginning in April, the weir is outfitted with juvenile panels to capture smolts with substantial overlap of Coho and steelhead in a typical western Washington spring smolt timing for these species.

Table 1. Historical adult and juvenile data collection in Snow and Salmon Creeks.

Stream	Location	Method	Years	Season	Species	Lifestage
Snow Creek	RM 0.8	perm. weir	1977 to present	Oct-May	STHD, COHO	Adult
	RM 0.8	perm. weir	1977 to present	Aug-Oct	CHUM	Adult
	RM 0.0-0.8	foot surveys	1976 to present	Oct-May	STHD, COHO	Adult
	RM 0.8-3.0	foot surveys	variable	Oct-May	STHD, COHO	Adult
	RM 0.8-1.6	foot surveys	1976 to present	Aug-Oct	CHUM	Adult
	RM 1.6-3.0	foot surveys	variable	Aug-Oct	CHUM	Adult
	RM 0.8	perm. weir	1976 to present	Apr-June	STHD, COHO	Smolt
Salmon Creek	RM 0.2	temp. weir	1977-1981	Aug-Oct	CHUM	Adult
	RM 0.2	temp. weir	1977-1982	Oct-May	STHD, COHO	Adult
	RM 0.2	temp. weir	1992-2002	Aug-Oct	CHUM	Adult
	RM 0.2	temp. weir	1978-1981	Mar-June	STHD, COHO	Smolt
	RM 0.3	fence trap	2002 to present	Aug-Oct	CHUM	Adult
	RM 0.3-1.6	foot surveys	1976 to present	Aug-Oct	CHUM	Adult
	RM 0.3-1.6	foot surveys	variable	Oct-May	STHD, COHO	Adult
	RM 0.3	Incline plane	2008 to present	Feb-May	CHUM	Fry

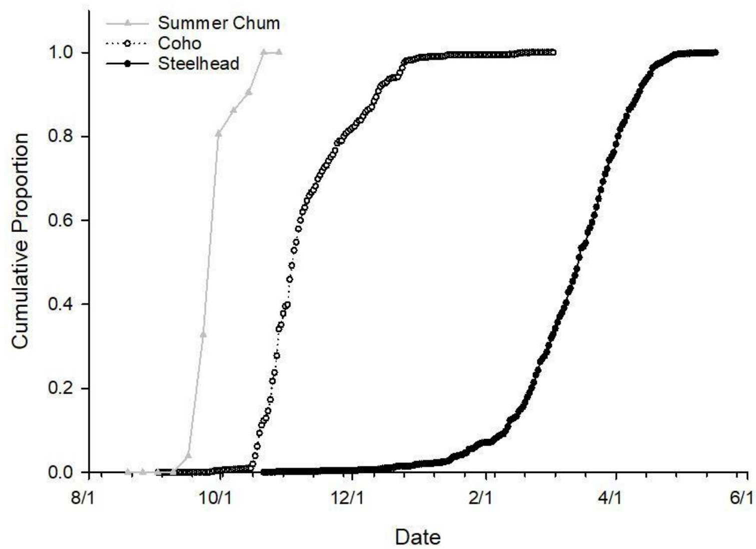

Figure 4. Cumulative proportion of returning adult captures for summer Chum, Coho and steelhead captured at the Snow Creek weir for period of record (data provided by WDFW).

Operation of the weir has enabled the recording of an extensive amount of biological data for both Coho and steelhead but less so for summer Chum since a significant proportion of the run spawns below the weir. Over the last 10 years on average 40% of the run has spawned in this lower reach (Mark Downen, WDFW, personal communications). While this distribution may be influenced by the weir, summer Chum spawner distribution in neighboring streams is similarly strongly skewed to lower stream reaches. These data have supported analysis of cohort abundance and adult run reconstruction for development of accurate SAR and S/R models. Other notable biological metrics such as sex ratios, number of females per redd, stream life of upstream migrants, number of repeat spawners, age at spawning, smolt size and productivity indices have also been collected. Use of PIT tagging is limited to tagging adult steelhead so that any untagged downstream kelts (i.e., adults that escaped upstream detection at the weir) can be added into adult return numbers. Similar abundance and biological data appropriate to Coho are collected, including enumeration of returning jacks.

Coho have a simpler juvenile and adult age structure and as such present a more straightforward data collection challenge than do steelhead.

5.2.2 Salmon Creek

There was a period of five years (1977-1981) when fish in, fish out monitoring for Chum, Coho, and steelhead in Salmon Creek was conducted at a temporary weir (Table 1). Subsequent to these efforts, the monitoring focus shifted to summer Chum only where adult capture is relatively easy owing to their arrival timing during annual flow minimas. Recovery monitoring for summer Chum is the main activity in Salmon Creek currently and an incline plane trap is operated February to May to quantify the summer Chum outmigration (Figure 3, photo right). Monitoring of fry migrations and modeling of total fry abundance has facilitated the development of SAR and S/R functions for this listed species. Limited spawning ground surveys have been conducted annually in Salmon Creek for Coho and steelhead up to the anadromous barrier at RM 1.6.[2] In recent years the lack of landowner permission has prevented full surveys up to the anadromous barrier. In December 2023, the HCCC was able to acquire the property in the vicinity of the barrier and place it into a conservation status, thus eliminating this restriction on important data collection in future years.

5.3 Uses of Data

5.3.1 Summer Chum Salmon

Salmon Creek has supported the majority of summer Chum production in the Snow-Salmon system with an average 2,300 spawners for years 2007-2019 (WDFW data). Salmon Creek long-term summer Chum monitoring provides enumeration of adults and estimation of fry outmigrants that contribute to freshwater and marine survival estimates. These data are used in recovery planning and elements of long-term monitoring are used for population models for other lowland systems where no data are available (WDFW personal communication). More recent studies evaluating the impact of climate change on timing of critical life history events, use survival estimates and migration timing of summer Chum in Salmon Creek to inform future model scenarios (Wienheimer et al. 2017).

5.3.2 Steelhead

The steelhead dataset developed at Snow Creek is one of the longest running records on the West Coast and data are used in modeling other lowland Hood Canal and Strait of Juan de Fuca systems. The data have recently informed a study of climate effects on salmon and steelhead phenological shifts that may be due climate factors (Wilson et al. 2023). The marine survival estimates have contributed to the Salish Sea studies[3] and determination of distinct population segments (DPS) or demographic units (Myers et al. 2015), which now form the basis for steelhead recovery monitoring under the Endangered Species Act. Escapement estimates from the Snow Creek weir are used to represent streams in the Sequim/Port Townsend area during preseason harvest planning conducted by the co-managers (District 15, Region 6 WDFW). Steelhead abundance and productivity data collected at Snow Creek has been used in assessment of viable salmonid population (VSP) parameters and modeling population viability (PVA) (McElhany and Payne 2006, Hard et al, 2013).

5.3.3 Coho Salmon

Coho annual smolt abundance and SAR estimates contribute to preseason run forecasting published annually

[2] Casey Sloth, WDFW biologist, has observed both Coho and steelhead spawners upstream of this point; he believes that at least in some years the upstream spawning extent may be closer to RM 2.0.

[3] https://marinesurvivalproject.com/wp-content/uploads/Puget-Sound-Hypotheses-and-Prelminary-Recs-SSMSP-2012-2.pdf

by WDFW (Litz 2023). Comparisons of productivity estimates can be made between Snow Creek and other Hood Canal and Straits intensively monitored watershed systems where annual smolt trapping is also conducted (notably Big Beef, Little Anderson, Seabeck and Stavis Creeks, East and West Twin Rivers, and Deep Creek). These data also contribute to ongoing assessments of Coho/steelhead interactions relative to environmental parameters such as flow regimes and temperature.

6.0 Effects of Stream Restoration Alternatives on Current Monitoring Program

Three potential restoration alternatives for rejoining Snow and Salmon Creeks are under consideration. They differ principally in where a newly reconstructed Snow Creek channel would be diverted from the existing Snow Creek channel (Aaron Lee, NSD, personal communication) (Figure 5). All three alternatives rejoin Salmon Creek at approximately the same location. A fourth alternative, the no action alternative, is also a potential outcome of any comprehensive deliberation on this subject.

Alternative 1: Alternative 1 diverts Snow Creek from its present course at RM 1.3 (in the vicinity of where Snow Creek was channelized away from its native course) and directs a restored channel toward the center of the valley where the existing ditch alignment is located. From there the restored channel meanders northward to a junction with Salmon Creek approximately 2,500 feet upstream of Highway 101. This channel relocation renders the existing Snow Creek weir obsolete and requires redeveloping the Snow Creek monitoring program. All of the enumeration and fish handling tasks facilitated by the weir would need to be implemented differently. Alternative 1 also requires that the methods currently used for monitoring Salmon Creek adult and juvenile summer Chum would need to be scaled up to handle the additional flow of a restored Snow and Salmon Creek system.

Alternative 2: Alternative 2 diverts Snow Creek from its present course at RM 0.95 slightly downstream of where Snow Creek was channelized away from its native course and directs a restored channel toward the center of the valley where the existing ditch alignment is located. From there the restored channel meanders northward to a junction with Salmon Creek approximately 2,500 feet upstream of Highway 101. As with Alternative 1, this channel relocation renders the existing Snow Creek weir obsolete and requires a redevelopment of the Snow Creek monitoring program. All of the enumeration and fish handling tasks facilitated by the weir would need to be secured by other methods. Alternative 2 also requires that the methods currently used for monitoring Salmon Creek adult and juvenile summer Chum would need to be scaled up to handle the additional flow of a restored Snow and Salmon Creek system.

Alternative 3: Alternative 3 diverts Snow Creek approximately 1,000 feet downstream of the weir and takes a direct route (channel will be physically designed similar to Alternatives 1 and 2) across the valley to Salmon Creek, joining Salmon Creek at the same location as Alternatives 1 and 2. While this third option leaves the weir location unchanged and does not require the redevelopment of the monitoring program, the system remains vulnerable to an avulsion of Snow Creek in the vicinity of its historical floodway.

Alternative 4: Alternative 4 is the "no action" alternative and would require no adjustments in the current monitoring program.

A Changing Baseline: Should any of the active restoration alternatives be selected, there would be significant changes to the habitat. These changes would establish a new baseline or production potential for all species in the restored Snow and Salmon Creek basin. Since the inception of the Snow and Salmon Creek monitoring programs there have been direct and indirect interventions in both systems (to habitat and fish populations alike) that have probably, and in some cases demonstrably, influenced monitoring metrics. These events include the opening of access into Crocker Lake and Andrews Creek (especially influential for Coho salmon), channel reconstruction and in-channel cover enhancement with large woody debris in Salmon Creek, riparian restoration of the lower reaches of Salmon Creek, supplementation of Salmon Creek summer Chum, brood years 1992-2003, supplementation of Snow Creek Coho, brood years 1998-2003, debris placement in specific reaches of Snow Creek, corrections to several fish passage impediments, numerous land acquisitions, and restoration projects in Discovery Bay. In addition to these direct effects there have been indirect effects of the weir, primarily on sediment transport processes. And so, while the monitoring program at Snow Creek may be long standing, the physical and biological systems have been changing, sometimes in dramatic and abrupt ways as would be the case with any of the restoration alternatives.

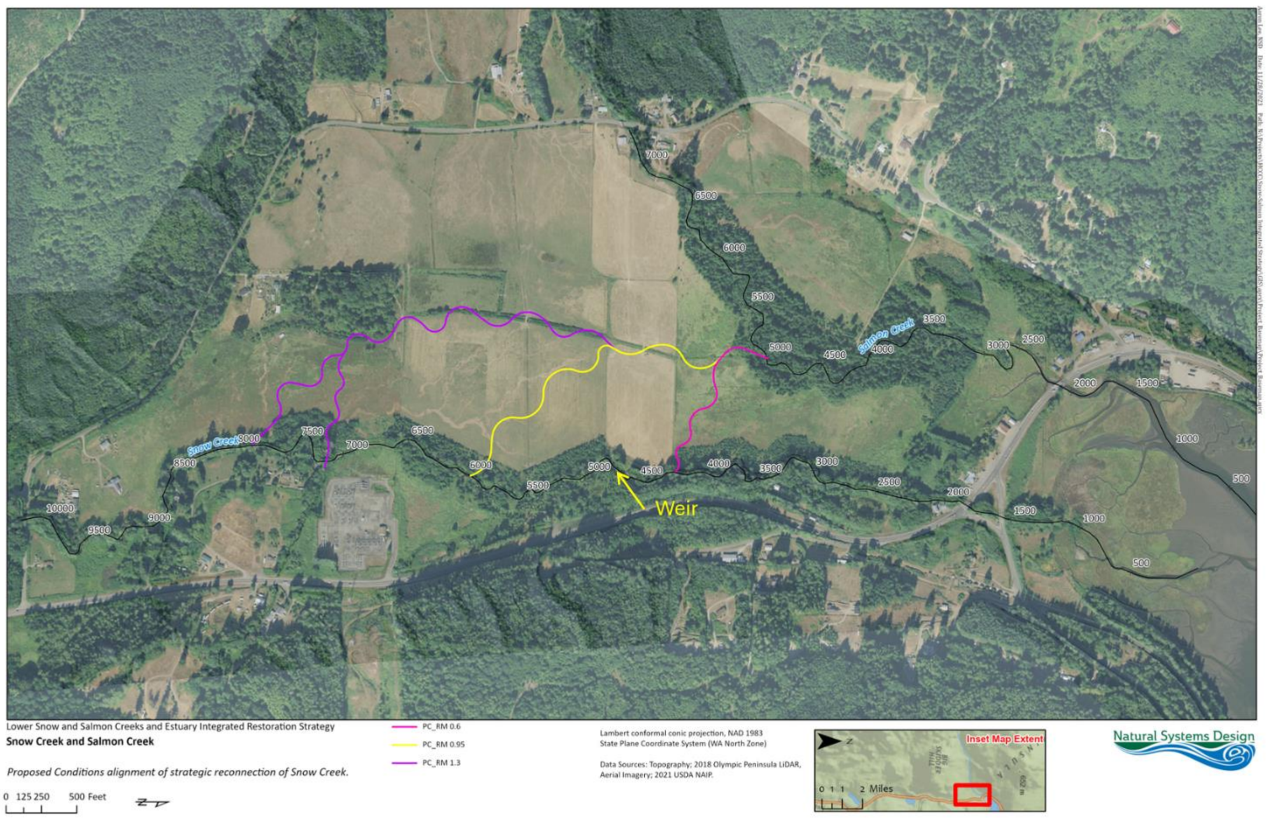

Figure 5. Proposed flow paths of three restoration options to reconnect Snow and Salmon Creeks and location of existing Snow Creek weir (NSD, in preparation).

7.0 Alternative Monitoring Methods

The alternatives being considered in a comprehensive restoration strategy for the Snow-Salmon basin, including a no-action alternative, provide an opportunity for co-managers to clarify the objectives and information needs of the monitoring program. It also provides an opportunity to consider the program's role in the bigger landscape of monitoring work being conducted at other locations within the Salish Sea region, including other fish in, fish out studies. Are the information needs of 2024 best served by collection of the same data as those identified in 1976? Should other scientific uncertainties also be considered that the Snow-Salmon Creek watershed is uniquely situated to address (e.g., the role of a restored nearshore system in the recovery of summer Chum)?

In this section we identify alternative monitoring methods in a general sense. We do not presuppose that these methods will be applied to a Snow Creek upstream of its junction with Salmon Creek or vice versa or that they would be applied to a rejoined Snow and Salmon Creek mainstem. It may make the most sense to develop an updated monitoring program whose major elements (adult and juvenile enumeration) would be focused below the restored confluence between Snow and Salmon Creeks. While this approach would not produce directly applicable numbers for continuation of the existing Snow or Salmon Creek data records, it's not immediately clear why that would be important since the rejoined systems and upstream restoration activities will usher in a different productivity domain for the basin that will be worthy of monitoring on its own merits. Regardless of where the key monitoring locations occur, the fish numbers will be coming from very different habitat complexes than prior to a reconnection and valley restoration. If it is desirable to monitor the Snow or Salmon Creek branches individually upstream of their new confluence, these same alternative methods can be applied. In suggesting these methods, we do not imply a particular study design, only a means of collecting the same or similar data as has been done through other methods over the last several decades in these two systems. However, it is important to understand that certain methods require complementary monitoring activities for optimal effect.

One of the challenges in choosing alternative methods to advance the Snow and Salmon Creek monitoring program is in selecting methods that are appropriate to the level of accuracy required for the management and research needs of the program. Prior to selection of alternative methods, it would be helpful if co-managers could define this aspect of the information needs. Up to this point, a complete census of the adult and juvenile populations has been the default standard for the weir. However, seldom are biologists able to achieve a complete census. In spite of this, data sufficient to determine SAR and S/R relationships are available from other populations where less intensive monitoring occurs. Monitoring methods suggested in the following section can mitigate adverse effects of restoration actions on the long-term monitoring program, aid in the determination of population viability, provide data for fisheries management, and set a new baseline for the restored system.

7.1 Adult Monitoring – Fish In and Biological Sampling

Alternative methods for counting adult fish into the Snow Salmon Creek system are:

1) **Resistance board weirs** – Resistance board weirs operate on principles of fish guidance by pickets but in the case of the resistance board weir rather than being attached to a rigid panel system, the pickets are buoyant plastic pipes attached at their base to a cabling system that is fixed along the stream bed (Tobin 1994; Stewart 2003). These systems are for adult collection only. As with other channel spanning weirs, fish are guided by the pickets into a one-way capture trap box where they may be removed for processing. A resistance board weir would require substantial annual effort to construct and maintain. The restored system would need to be evaluated to determine an effective installation location. If designed and sited appropriately, data similar to that collected at the current weir could be gathered for all species. However, as with any trap, unpredictable high stream flows would cause periodic gaps in data. But part of the appeal of a resistance board weir is that floatable debris washes over the weir, depressing the buoyant pickets, thereby reducing in-storm maintenance. Repair of any damage during high

water could only be done once flow subsides to manageable (wadeable) conditions.

2) **Temporary fence trap** – What we are terming a "temporary fence trap" is what is currently used in Salmon Creek to trap summer Chum (Figure 3, left panel). They are constructed of panels either of vertical pickets or coarse mesh that guide fish to a one-way trap box where they can be netted for processing. These traps are highly adaptable in small streams but are only effective in settings when trapping can be conducted on relatively low flows. This particular method would be effective for monitoring summer Chum adults but would not be useful for the other runs that return on higher flows (Anderson and MacDonald 1978).

3) **Resistivity counters** - Resistivity counters can be used to effectively enumerate adult salmonids. They operate on the principle that there is a difference in conductivity between the water and the body of a fish. This method requires that fish swim over a series of submerged electrodes where resistance in the electrical field is continuously recorded by a data logger. These systems require some guidance to direct fish over the electrodes and also must have a base for electrode attachment. Signals can be analyzed by different means to detect the passage of fish, to determine the direction in which the fish is moving, and to classify it by size according to the peak signal size. No distinction can be made for species or sex. However, in a system like Snow and Salmon Creeks where the runs of different species are temporally well separated, species may be inferred from timing to a large extent. Resistivity counters have been used successfully in the Keogh River in British Columbia and are in widespread use in Europe (McCubbing 2003; Love et al. 2012; Wilson et al. 2022)).

4) **ARIS sonar** – ARIS sonar scanners transmit sound pulses and convert the returning echoes into digital images. The high frequency pulses can be manipulated through the manufacturers proprietary software to produce high quality images of whatever is in the ensonified field, including migrating fish. This technology has been used effectively to monitor the migration of different salmonid species in rivers from CA to AK. The primary advantage of the technology is that it can operate in highly turbid water and does not require any guidance infrastructure, only that fish be within the sonar field of view which can be assured with proper positioning in the stream. These are key operational differences between the ARIS and the VAKI described below. The data can produce numbers of fish, time observed, direction of travel, and substantially accurate length observations. Species identification is possible only through inference of known timing and presence patterns, length, and behavioral profiles. Images of fish are only viewed and thus no biological data are collected except by inference from size, known timing data and behavior. The files provide a permanent record of run dynamics. ARIS sonar systems are relatively easy to install and operate, requiring only routine checks during operation to ensure all components are functioning and power is maintained (Helminen and Linnansaari. 2003; Broderson 2016; Nolan et al. 2023)(e.g., Figure 6).

5) **VAKI infrared scanner** – The VAKI Riverwatcher is an infrared scanner that transmits a curtain of infrared beams from a transmitting plate to a receiving plate. When the fish break these beams the unit registers a silhouette of the fish and a high-quality video camera records multiple pictures (Baumgartner et al. 2010). The typical application of the VAKI infrared scanner is in an engineered setting where fish movement is substantially controlled such as a fish ladder or guidance weir of some sort. Count data, species identification, migration timing and size can be generated from VAKI imagery and the digital underwater camera it is usually paired with. Advancing AI

technology is being embedded in the manufacturer software to automate counts of fish (Haas et al. 2024). The method would not be useful in scanning in a wide natural river setting but may have application for certain species that could be guided during low flows through the detection chamber. The VAKI scanner will work well in turbid water up to approximately 90-NTU. These levels of turbidity are common during winter and springtime high flow events in local Olympic Peninsula streams.

6) **Digital underwater cameras** – High quality underwater cameras are typically used in conjunction with VAKI scanners or other fishway counting chambers and can be used in isolation to document large-bodied salmonids (Deacy 2016). This is another method that relies on fish guidance infrastructure to funnel them into detectable range. As such, cameras may only be practical for species and times when flows are relatively low (e.g., summer Chum).

7) **Spawning ground surveys** – Foot surveys or spawner or spawning ground surveys, have been the default method for documenting salmon run size for years (Irvine 1993). In spite of all the technological developments to count fish, these surveys are still valuable, especially in natural systems where no permanent guidance facilities exist. A well-organized basin wide spawning ground survey system will have index reaches that receive regular survey effort throughout the spawning period and supplemental surveys that are conducted near the peak of the run in other areas known to support the species. Extrapolation of these data can yield estimates of the total number of spawners in the basin. These surveys can be used to collect biological data from dead fish in the case of semelparous species. Ages derived from scale or otolith analysis can be used to aid in Cohort reconstruction that is critical for spawner recruit analyses. Observations of spawning locations, spawn timing, sex ratios, genetic sampling and other important parameters are all facilitated by systematic spawning ground surveys (Wilson et al. 2020). Regardless of other counting methods, spawning ground surveys are an important activity for managers. Because of the diversity of biological data that can be obtained and subsequent results (e.g., genetics information), spawning ground surveys have a place in any monitoring program. Statistical methods of assessing bias and total redd counts are available (Murdoch et al., 2018).

8) **PIT tag antenna arrays** – PIT tags provide a unique identifier that can be applied and detected for the life of the fish. These 9- or 12-mm long tags can be applied internally by injection to juvenile salmonids at sizes greater than 60-mm. PIT tags contain no battery and are powered passively when they come into the presence of an electromagnetic field generated by an antenna array. The array and the tag are both tuned to the same frequency and the excitement of the tags antenna by the array's field causes the chip inside the tag to transmit the code for recording and storage by the transceiver that powers the array. Time stamped code detections may be downloaded manually at the controller at any time or can be recovered via a cellular modem. Adult abundance estimates are generated by knowing the proportion of smolts that are tagged and expanding the number of detections in the adult run by this proportion. It is possible that this approach may produce a slight underestimate of the adult run due to tag shed or differential survival between tagged and untagged fish, but all of these factors are well studied (Uthe et al. 2017). Age composition of the adult return can be determined because the year of tagging is associated with the tag code (Fryer 2007). So, in the case of steelhead, most tag codes at time of adult return will indicate fish have been at sea for two years but a few will

document a 3-year lapse since tagging. In this manner the PIT tag detection database can accumulate information that is useful in compiling life cycle models. In addition to marine survival and age at return, depending on when juveniles are tagged, a substantial amount of information on habitat use and instream survival and growth may be acquired through PIT tagging and detection at a smolt trap. Because so much can be learned from smolt detections and subsequent adult detections, a PIT tagging program is highly effective and reliable in a monitoring program. This technology does not work well in brackish water so permanent arrays need to be established upstream of tidal influence. The method requires maintenance of the antenna arrays, periodic replacement of electronics and power supply components. PIT tag technology is used widely in the Columbia basin to generate estimates of adult abundance and is instrumental in the development of life cycle models for Chinook and steelhead (IPTDSW (In-stream PIT-tag detection systems workgroup 2020).

9) **Genetic sampling (tGMR)** – Trans-generational genetic mark-recapture (tGMR) models represent a minimally invasive advance for estimating adult population abundance, at least for semelparous species (Rawding et al. 2014). Application of this method to species like steelhead is not practical since their carcasses are rarely recovered after spawning. This method relies on genotyping a sample of adults as the marking event and subsequent genotyping of juveniles and assignment of parentage as the "recapture" event. After applying QC methods to reduce inaccuracies and biases in data, estimates are modeled using calculations akin to traditional mark-recapture experiments. Costs and time constraints of these methods are within a reasonable range of routine monitoring budgets and may be of interest to co-managers for species other than steelhead moving forward (Rosenbaum 2024).

Methods 1-2 above produce counts and facilitate physical handling of the fish for collection of biological data (e.g., size, age, sex ratio, repeat spawning). Methods 3-8 are capable of producing counts, but do not uniformly facilitate handling of the fish. However, they can produce some biological data by virtue of remote data collection, such as length, timing and directional data (ARIS sonar) or pairing of data from specific individuals that were processed as juveniles, as in the case of PIT tagged fish. Method 9 enables investigation of many stock characteristics and is minimally invasive but as noted above is impractical for steelhead.

Figure 6. ARIS sonar in operation on Skookumchuck River, September 2023.

7.2 Juvenile Monitoring – Fish Out and Biological Sampling

Options for counting of juvenile fish out of the Snow Salmon Creek system are as follows:

1) **Incline plane traps** – Incline plane traps operate on the principle of entrainment of fish and debris over a slotted, perforated or screen covered incline plane or ramp that is framed between mesh sides (Todd 1994, Figure 7). Fish are directed into a mesh live box at the downstream edge of the incline and are held there for processing. Water velocities at the lip of the incline prevent fish from swimming out of the live box. Incline plane traps have been fabricated in many different sizes and often have a rotating drum at the back of the live box to pass debris out while retaining fish. Small incline plane traps are useful to collect data on fry abundance, timing and acquire biological data. The traps require routine field checks during operation to ensure optimal operation and well-being of fish. These traps are used in many salmon monitoring programs and established methods for estimating abundance are readily accessible and flexible to account for trap efficiency. Traps featured in Figure 7 were designed by West Fork to shed debris over a paddle wheel driven rotating drum screen and provide safe haven for fish in a baffled live box.

2) **Rotary screw traps (RST)** – Rotary screw traps are a device developed for capture of salmonid smolts constructed from 3 components groups: 1) perforated stainless mesh covered cone with internal solid vanes for rotational propulsion, 2) pontoon system for flotation and anchoring, and 3) frame and attachment components for raising the cone. Rotary screw traps are the smolt trap of choice for larger system trapping operations today, having replaced the large scoop traps which were an oversized incline plane trap in common use through the 1980's (Volkhardt et al. 2007). RST traps are still manufactured by the inventor and patent holder. Cones come in two diameters, 5 and 8 feet diameter. Adequate streamflow is needed to ensure proper speed of cone rotation. If an RST is used in a future monitoring program it may be possible to "engineer" a site on the new channel for optimal operation. The traps require routine field checks during operation and maintenance to ensure optimal operation and well-being of fish. These traps are used in many salmon monitoring programs throughout the range of salmon. A common statistical model (Baysian Time Stratified Population Assessment System (BTSPAS) for modeling abundance is available to account for trap outages and variable efficiencies (Bonner and Schwarz 2011). The five-foot RST featured in Figure 7 was operated by West Fork for the past 4 years on the Dickey River and is outfitted with panels to increase cone rotation and capture efficiency.

3) **Panel smolt traps** – Panel smolt traps were popularized by WDFW and tribal biologists on the Olympic Peninsula in the 1970's and their operation has been fine-tuned since. These traps feature hardware cloth or plastic mesh covered panels supported by metal fence posts, a temporary sandbag dam to increase surface area on the panels (thus slowing velocities across panels to avoid impinging fish), a plastic pipe to carry smolts into a baffled wooden live box. These traps are highly efficient and some of the panels in the "fence" are constructed to easily remove or "pop out" to accommodate unusually high flows. These traps are limited by stream size and this design may be impractical for a reconnected Snow-Salmon Creek owing to variability of spring flows.

4) **Electrofishing/trapping** – Juvenile Coho and steelhead could be captured in the stream using electrofishing or other capture techniques such as small seine. There may be specific habitat

reaches well suited to capture of juveniles where biological data could be collected and PIT tags applied.

Methods 1-3 above are capable of producing counts (fish out) and also provide the opportunity for collection of biological data (e.g., size, timing, scale or genetic sampling) and PIT tagging. Method 4 provides opportunities to associate juvenile production with habitat characteristics as well as tagging fish for future detection at an older age (smolts or adults).

Figure 7. Tandem incline plane fry traps with paddle wheel driven debris drums operating on the Skookumchuck River, January 2024 (photo left). Five-foot rotary screw trap operating on low flows in the spring of 2023, Dickey River. Installation is outfitted with panels to funnel water and turn cone faster for increased capture efficiency (photo right).

8.0 An Updated Monitoring Program: Pros and Cons, Losses, and Gains

An updated monitoring program for a restored Snow - Salmon Creek system may need to be a collection of complementary activities depending on the information needs and objectives that are identified. If a comprehensive restoration plan makes operation of the Snow Creek weir impractical, numerous alternative methods are available to maintain the longstanding data record. A review of some of the pros and cons of these methods is presented below (Table 2).

8.1 Adult Salmon and Steelhead Counts

As an alternative to a weir structure, adult Chum, Coho, and steelhead counts could be compiled with an ARIS sonar system. Once a suitable site is selected, this device is easy to install and operate and proprietary software from Sound Metrics facilitates counting fish, assigning directionality to all observations. The reviewer can produce precise lengths for as many fish as desired. This system is not capable of assigning species, but the primary runs of summer Chum, Coho and steelhead are well separated temporally, and knowledge of these differences could be applied for accurate counts (Figure 6). The main disadvantage of this system is that fish are not handled and consequently no biological data can be obtained. The principal advantage is that fish are free to migrate upstream to spawning areas without trapping and handling. There are no avoidance behaviors in response to a weir structure and on potentially large runs there is no concern for overcrowding in a trap box.

8.2 Juvenile Counts

Two trap types could be used for juvenile monitoring, an incline plane trap for fry and a rotary screw trap (RST) for smolts. Median outmigration of summer Chum fry is from mid-March to April 1 so some overlap would occur between trapping operations for fry and smolts. A choice could be made whether to use a RST from the beginning or use a fry trap in the early part of the fry migration and finish the monitoring of fry using the RST coincident with the early smolt monitoring or some other approach. Both these traps provide proven methods that will work well in a rejoined system if a suitable deployment site is located. It is possible that the locations for operating traps, especially the RST could be "engineered" during channel reconstruction so that adequate velocities are available for maintaining optimal revolutions of the RST cone. If some facilitation of the monitoring program though this type of action is needed, it should be considered a cost of infrastructure replacement necessitated by the restoration work. Steelhead smolts are strong swimmers and can be retained by a screw trap, but it must be operated optimally with adequate trap rotations created by streamflow. The advantages of these traps are that methods are established to estimate abundance while estimating trap efficiency and accounting for outages, and biological data can be collected. The disadvantages include need for routine checks of the trap, but this is not unlike what is required at the current weir.

8.3 PIT tagging and Stationary PIT Tag Antenna Arrays

A robust PIT tagging and detection program focused on tagging of juveniles (parr and smolts) can yield a variety of valuable biological data including, overwinter survival of Coho and steelhead parr, growth rate, age composition of adult population, and significant timing data of adult returns and marine survival rates. The last two points are predicated on detection of adults upon their return to the stream. Many monitoring programs in the Columbia River basin are constructing life cycle models and measuring adult escapement through the detection of adults PIT tagged as juveniles. Advances in recent PIT tag antenna technology permits long span pass-through designs that are less prone to damage and loss during high flows. The PIT tagging and detection portion of the monitoring program is one of the key approaches to collection of biological data that supports development of SAR and S/R relationships. Similarly, to finding a suitable fry/smolt trap site, a location for a stationary array should be considered that allows for a stable cross section of stream for antenna attachment and maintenance. Advantages of this method include stationary arrays would not have as high a potential to affect fish behavior as a trap structure and in conjunction with other methods, PIT tag returns generate timing, juvenile to adult survival data, evidence of repeat spawning, and age at return to spawn. Disadvantages include that juveniles must be marked each year to provide the continuous data record and the PIT tag system will require periodic checks and maintenance to reliably operate.

8.4 Spawning Ground Surveys

Spawning ground surveys are used extensively to obtain adult escapement estimates for Coho, Chum and steelhead by Washington's fisheries co-managers. Useful data can be obtained for fish or redd counts and the utility of specific data types will vary by species. Accurate redd counts for example can be difficult to obtain under sustained high flow conditions that obscure redd morphology. This could be problematic for Coho that spawn during periods of highly variable winter flows although it is typically not for steelhead that spawn on a more benign flow regime. Reasonably accurate fish counts can be obtained for summer Chum that return on low flows. Regardless of the species, there is utility in spawning ground surveys for recovery of biological samples, timing and distribution of spawners. The pros for this monitoring method are that it has been successfully applied in Snow and Salmon Creeks, can be done in accordance with accepted co-manager field and analysis protocols, does not require fish guidance infrastructure that can be damaged during storms or handling of fish that can change behavior or distribution. Abundance estimates may be compromised by incomplete coverage due to private land ownership patterns, but complete network surveys are seldom achievable in any system nor is that necessarily the sampling goal. Reasonable data expansions and extrapolations are typically made to account for unsurveyed reaches or times.

8.5 Habitat and Juvenile Surveys

Recent stream restoration work (upstream of West Uncas Road) and the plans for the restoration of the historical connection have and would in the future change the habitat quantity and quality baseline of these systems. Physical habitat can be quantified with longitudinal habitat unit surveys. These data are needed to develop productivity indices that reflect current conditions. They serve as the template to understanding spawning and rearing habitat availability. Return of natural physical processes to the Snow – Salmon Creek system, including the nearshore environments of Discovery Bay are likely to create a new productivity domain that may affect fish distribution and abundance.

Table 2. Pros and cons of alternative monitoring methods that could be used in the Salmon-Snow Creek system to monitor summer Chum, Coho, and steelhead populations.

Method	Life Stage	Metric	Pros	Cons	Notes
Resistance Board Weir	Adult	abundance adult timing biological data (size, age, repeat spawning)	stable location for sampling abundance and timing	cost/permitting maintenance activities not conducive for volunteers potential trapping stress or changes to fish behavior interruption of natural stream processes	may be compromised at high flows, even more so than the existing Snow Creek weir.
Temporary Fence Trap	Adult	abundance adult timing biological data (size, age, repeat spawning)	stable location for sampling abundance and timing ability to collect biological data (size, age, repeat spawning)	difficult streamflow conditions during later Coho and steelhead migration for trapping good for summer Chum intensive staffing to keep operational	likely compromised during steelhead run due to streamflow summer Chum could be trapped in low flow
ARIS Sonar	Adult	adult abundance adult timing fish length	Ease of use low impact on fish requires no construction simple portable setup	need a stream cross section conducive to viewing tailends of run for Coho/steelhead potentially overlap of species species identification can be difficult unless applying known timing data	requires specialized equipment different data available for calculation of SAR no ability to collect age at spawning challenging to count milling fish or fish moving in groups

Method	Life Stage	Metric	Pros	Cons	Notes
VAKI Infrared Scanner	Adult	adult abundance adult timing fish length	good species identification and length data photographic evidence	requires in channel infrastructure to direct fish through scanner. operations >90 NTUs unreliable flow dependent	need right setting for this method (potential for summer Chum) typically used in engineered structures
Spawning surveys fish and redd	Adult	Fish and redd counts spawn distribution spawn timing biological sample (carcass) habitat use	Repeatable accepted protocols used in the Salmon-Snow system in past nonintrusive spawning distribution habitat use relative to restoration effort	streamflow constraints on visibility	redd counts can be used to compare abundance estimate from other methods carcass recovery possible for Chum and Coho but unlikely to be effective for steelhead (kelt rate is upwards of 50%)
Inclined plane trap	Fry	outmigrant abundance biological data (size, timing) genetics	tested trap used in Salmon Creek in past modeling can be used to estimate efficiency during trap outages	need appropriate location staffing required to operate	
Rotary screw trap	Smolt	Outmigrant estimate biological data (size, timing) genetics	modeling can be used to estimate efficiency during trap outages provides opportunity to PIT tag juveniles	need appropriate location to maintain trap revolutions staffing required to operate	unknown streamflow constraints on trap operation (June, late in migration) frequently used to generate juvenile abundance

Method	Life Stage	Metric	Pros	Cons	Notes
PIT Tagging	All	size at outmigration migration timing adult survival by juvenile traits age at spawning repeat spawning	can tag juveniles when trapped stationary array operates continuously no handling of prespawning fish, limited potential to affect behavior operation is not flow dependent	some tag mortality possible does not detect well in brackish water need stable stream cross section	need ongoing support periodic upgrades to antennas/cables and electronics
tGMR/Pedigree reconstruction	All	genetic sample size of fish	nonintrusive Coho/Chum carcasses can provide initial mark	not applied to steelhead yet access to adults is problematic (STHD)	need lab support

9.0 Monetary Costs of Alternative Methods

Estimated costs for alternative monitoring methods are based on our experience with the same or similar methods (Table 3). The exact cost required will depend on the final monitoring program components, staffing and other factors. Ranges are provided as considerable uncertainty exists with the exact application of most of these methods to this particular situation. It is possible that our estimates of cost include staffing flexibility that may not be available to government fisheries managers, such as a heavy reliance on the use of seasonal positions rather than full time technicians.

Table 3. Approximate costs of alternative monitoring methods.

Monitoring Methods	Initial Cost	Notes
Resistance Board Weir	$150,000	Weir and staffing year one
ARIS Sonar	$120,000 to $150,000	Includes cost of unit, set up, install and year one operation
VAKI Scanner	$165,000-to $200,000	Includes VAKI, guidance system, install and year one staffing
Temporary Adult Fence/Trap	$65,000 to $85,000	Fence, trap and staffing year one, summer Chum only
Incline Plane Fry Traps	$50,000	Includes two traps, install and operation year one
Rotary Screw Trap	$110,000 to $200,000	Includes estimated cost of 5-foot trap, install and year one operation
PIT Tagging	$225,000 to $325,000	Includes stationary antenna arrays on mainstem and both main branches, PIT tags and operation year one
Spawning Ground Surveys	$35,000 to $55,000	Year one staffing
Habitat Surveys	$24,000 to $36,000	Year one staffing

10.0 Conclusions

The following conclusions were reached after talking to numerous biologists familiar with the Snow-Salmon Creek monitoring program, perusing the data record ourselves, considering the restoration opportunities for the watershed and reviewing potential alternative methods for monitoring. These conclusions are not recommendations. The objectives and monitoring program content are the exclusive purview of State of Washington and Tribal co-managers.

1) The data record amassed from operations at the Snow Creek weir is impressive and has been instrumental in informing fisheries managers about basic steelhead biology and population dynamics within relatively small independent watersheds in western Washington.
2) Operation of a permanent weir is likely incompatible with a restoration goal of naturalizing sediment transport and deposition within tidal flats and nearshore marine environments at the head of Discovery Bay. Restoration of this habitat type is considered important for the full recovery of summer Chum.
3) Monitoring methods exist that can be implemented in lieu of the permanent weir program at Snow Creek. The data will differ in density and character, but if these methods were applied, as they are in other river systems where VSP and PVA assessments are conducted, there is no reason to believe they would be inadequate to serve the needs of the conservation and management community as they do elsewhere.
4) Some of the alternative monitoring methods listed in this report require a suitable fixed location for data collection, preferably one that is stable year to year. It is possible that these “soft infrastructure” needs could be woven into a final restoration plan such that alternative methods, such as PIT tag antenna arrays, might be implemented with more certitude than usual.
5) Technology is expanding rapidly, especially in the application of genetics to all metrics of VSP and while some applications such as tGMR are difficult to apply to steelhead because access to adult carcasses is unreliable by virtue of their life history, these techniques may yet prove valuable as a relatively non-invasive method of monitoring abundance and other run specific metrics.

11.0 References

Anderson, T. C. and B. P. MacDonald. 1998. A portable weir for counting migrating fishes in rivers. Fisheries and Marine Technical Report No. 733. Fisheries and Marine Services Branch, Department of Fisheries and the Environment, St. Johns, Newfoundland, CANADA.

Baumgartner, Lee, Mick Bettanin, Jarrod McPherson, Matthew Jones, Brenton Zampatti and Kathleen Beyer. 2010. Assessment of an infrared fish counter (Vaki Riverwatcher) to quantify fish migrations in the Murray-Darling Basin. Narrandera Fisheries Centre. Industry & Investment NSW – Fisheries Final Report Series No. 116.

Blair, G.R., L.C. Lestelle, and L.E. Mobrand, 2009. The Ecosystem Diagnosis and Treatment model: a tool for assessing salmonid performance potential based on habitat conditions. Pages 289-309 in E. Knudsen and J. Michael, Jr., editors. Pacific salmon environment and life history models: advancing science for sustainable salmon in the future. American Fisheries Society, Symposium 71, Bethesda, Maryland.

Bonner, S.J. and C.J. Schwarz. 2011. Smoothing population size estimates for time-stratified mark- recapture experiments using Bayesian P-splines. *Biometrics*, 67(4): 1498-1507.

Broderson, N. B., B. C. McIntosh, and C. T. Pfisterer. 2016. Feasibility of estimating salmon abundance in the Kuskokwim River using sonar, 2014 and 2015. Alaska Department of Fish and Game, Regional Information Report 3A, 16-06, Anchorage.

Deacy WW, Leacock WB, Eby LA, Stanford JA. 2016. A time-lapse photography method for monitoring salmon (Oncorhynchus spp.) passage and abundance in streams. Peer J. 2016 Jun 14;4:e2120. doi: 10.7717/peerj.2120. PMID: 27326378; PMCID: PMC4911955.

Fryer, J.K. 2007. Estimation of Mid-Columbia Summer Chinook Salmon escapement and age composition using PIT tags in 2006. Columbia River Inter-Tribal Fish Commission Technical Report 07-2. Portland, OR. 40p.

Haas, Christian, Philipp Klaus Thumser, Michael Hellmair, Tyler J. Pilger and Martin Schletterer. 2024. Monitoring of Fish Migration in Fishways and Rivers—The Infrared Fish Counter "Riverwatcher" as a Suitable Tool for Long-Term Monitoring Water 16(3).

Hard, Jeffrey, James M. Myers, Edward J. Connor, Robert A. Hayman, Robert G. Kope, Gino Lucchetti, George R. Pess, Anne R. Marshall, and Bradley E. Thompson. 2013. Puget Sound Steelhead Technical Recovery Team (PSSTRT). 2013. Viability Criteria for Puget Sound Steelhead. Final Review Draft. 373 p.

Helminen, J and T. Linnansaari. 2003. Combining Imaging Sonar Counting and Underwater Camera Species Apportioning to Estimate the Number of Atlantic Salmon and Striped Bass in the Miramichi River, New Brunswick, Canada. North American Journal of Fisheries Management 43:743–757.

IPTDSW (In-stream PIT-tag detection systems workgroup). 2020. Report to NOAA Fisheries for 5-Year ESA Status Review: Snake River Basin Steelhead and Chinook Salmon Population Abundance, Life History, and Diversity Metrics Calculated from In-stream PIT Tag Observations (SY2010-SY2019). January 2020.

Irvine, J. R., J. F. T. Morris, and L. M. Cobb. 1993. Area-under-the-curve salmon escapement estimation manual. Can. Tech. Rep. Fish. Aquat. Sci. 1932: 84 p.

Johnson, T.H., and R. Cooper. 1986. Snow Creek anadromous fish research. January 7, 1985 – June 30, 1986.

Progress report, project no. AFS 124. Submitted to the U.S. Fish and Wildlife Service. Washington Department of Game, Anadromous Game Fish Investigations. Port Townsend, WA.

Lestelle, L.C., M.L. Rowse, and C. Weller. 1993. Evaluation of natural stock improvement measures for Hood Canal Coho salmon. TR 93-1, Point No Point Treaty Council, Kingston, WA.

Litz, M.N.C. 2023. 2023 Wild Coho Forecasts for Puget Sound, Washington Coast, and Lower Columbia. Washington Department of Fish & Wildlife Science Division, Fish Program. 57 pp.

Love, D.C., D.J. Reed, and R.D. Harding. 2012. Steelhead trout production studies at Sitkoh Creek, Alaska, 2003– 2009, and 2009 and final report. Alaska Department of Fish and Game, Fishery Data Series No. 12-82, Anchorage.

McCubbing, D.J.F. 2003. Fish Counter Enumeration of steelhead and rainbow trout on the Bonaparte River in 2003-Post Fishway Redesign and Operational Improvements. Instream Fisheries Consultants. Vancouver B.C.

McElhany, P., M.H. Rucklelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units. NOAA Technical Memorandum NMFS-NWFSC-42.

Mobrand, L.E., J.A. Lichatowich, L.C. Lestelle, and T.S. Vogel. 1997. An approach to describing ecosystem performance "through the eyes of salmon". Canadian Journal of Fisheries and Aquatic Sciences 54: 2964-2973.

Myers, J.M., J.J. Hard, E.J. Connor, R.A. Hayman, R.G. Kope, G. Lucchetti, A.R. Marshall, G.R. Pess, and B.E. Thompson. 2015. Identifying historical populations of steelhead within the Puget Sound distinct population segment. U.S. Department of Commerce. NOAA Technical Memorandum, NMFS-NWFSC-128.

Nolan, J., E. Partee, J. Jacobs, R. Nelson. 2023. Technical Report: 2021-2022 Sonar Derived Chinook Salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*) Estimates for the Smith River, Del Norte County, California. Tolowa Dee-ni' Nation, Smith River, CA.

Rawding, D.J., C.S. Sharpe, and S.M. Blankenship. 2014. Genetic-Based Estimates of Adult Chinook Salmon Spawner Abundance from Carcass Surveys and Juvenile Out-Migrant Traps. Transactions of the American Fisheries Society, 143:55-67.

Rosenbaum, S. W., May, S. A., Shedd, K. R., Cunningham, C. J., Peterson, R. L., Elliot, B. W., & McPhee, M. V. 2024. Reliability of trans-generational genetic mark–recapture (tGMR) for enumerating Pacific salmon. Evolutionary Applications, 17, e13647. h t t p s : //d o i .org/10.1111/eva.13647

Stewart, R. 2003. Techniques of installing a resistance board fish weir. Alaska Department of Fish and Game, Regional Information Reportm3A03-26, Anchorage, AK.

Tobin, J. H. 1994. Construction and performance of a portable resistance board weir for counting migrating adult salmon in rivers. U. S. Fish and wildlife Service, Kenai Fishery Resource Office, Alaska Fisheries Technical Report Number 22, Kenai, Alaska.

Todd, G. L. 1994. A lightweight inclined-plane trap for sampling salmon smolts in rivers. Alaska Fishery Research Bulletin. 1(2):168-175.

Uthe, P., B. Knoth, T. Copeland, A. E. Butts, B. J. Bowersox, and J. Diluccia. 2017. Intensively monitored watersheds and restoration of salmon habitat in Idaho: ten-year summary report. Idaho Department of Fish and Game Report 17-14.

Volkhardt, G. C., S. L. Johnson, B. A. Miller, T. E. Nickelson, and D. E. Seiler. 2007. Rotary 437 screw traps and inclined plane screen traps. Pages 235-266 in D. H. Johnson, B. M. 438 Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O'Neil, and T. N. Pearsons. 439 Salmonid field protocols handbook: techniques for assessing status and trends in salmon 440 and trout populations. American Fisheries Society, Bethesda, Maryland.

WDG (Washington Department of Game). 1978. Cooperative Agreement #14 – 16 – 0001 – 6345 IFC between the United States Fish and Wildlife Service and the Washington State Game Department. Progress Report, June 30, 1978. Olympia, WA.

Weinheimer, J., J.H. Anderson, M. Downen, M. Zimmerman, T. Johnson. 2017. Monitoring climate impacts: Survival and migration timing of summer Chum Salmon in Salmon Creek, Washington. Transactions of the American Fisheries Society, Vol 146 (5):983-995.

Wilson, J., T. Buehrens, D. Rawding, and E. Olk. 2020. Estimates of Adult Fall Chinook Salmon Spawner Abundance and Viable Salmonid Population Parameters in the Washington Portion of the Lower Columbia River Evolutionarily Significant Unit, 2013-2017. Washington Department of Fish and Wildlife, Ridgefield, Washington.

Wilson, K.L., C.J. Bailey, T.D. Davies, and J.W. Moore. 2022. Marine and freshwater regime changes impact a community of migratory Pacific salmonids in decline. Global Change Biology 28:72–85.

Wilson, S.M., J.W. Moore, E.J. Ward, C.W. Kinsel, J.H. Anderson, T.W. Buehrens, et al. 2023. Phenological shifts and mismatch with marine productivity vary among Pacific salmon species and populations. Nature Ecology & Evolution 7: 852–861. doi: 10.1038/s41559-023-02057-1