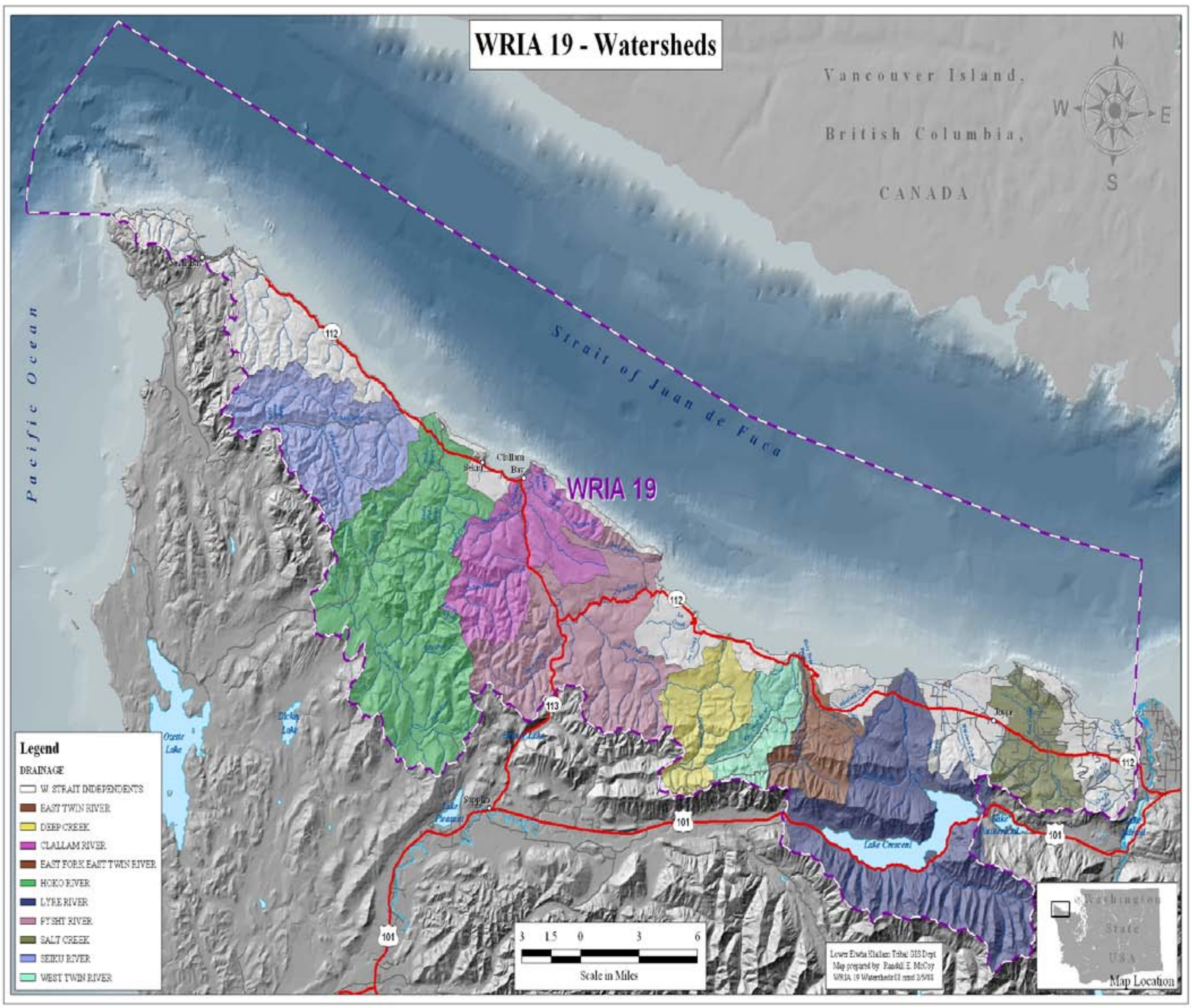
Habitat Committee Report on Western Strait of Juan de Fuca (WSJF) Coho Overfishing Concern

"Essential fish habitat means those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity."

Magnuson-Stevens Act § 3



Executive Summary

In 2005, 2006, 2007, and 2008 the Western Strait of Juan de Fuca (WSJF) stock of coho salmon fell short of its conservation objective of 11,900 natural spawners despite a preseason expectation that the conservation objective would be met. This review of essential fish habitat (EFH) relevant to Western Straits of Juan de Fuca (WSJF) coho was initiated by three consecutive failures of spawning recruitment for this coho stock. The Pacific Fisheries Management Council (Council) Salmon Technical Team (STT) has determined that harvest mortality was insufficient to have caused the spawning recruitment failure. Consequently, a review of EFH is appropriate to determine which non-fishing factors caused or contributed to the failure. The salmon fishery management plan (FMP) Amendment 14 on EFH requires the Council to make recommendations to correct non-fishing factors affecting salmon survival.

Accordingly, this report contains recommendations from the Habitat Committee for the Council's consideration. The HC focused on the specific physical and biological processes that may have contributed to reduced survivorship at different life stages, as well as a review of current regulatory mechanisms in place to minimize cumulative impacts to EFH imposed by current land use practices.

Ocean Condition

Local oceanic conditions during the first year of ocean rearing factored prominently in the low survivorship for WSJF coho returns in 2005-2008. While no specific research has been directed at WSJF coho survivorship during marine residence in the Strait of Juan de Fuca (SJF), inferences can be made from the substantial work surrounding West Coast Vancouver Island (WCVI) Coho and Chinook populations. It found that local oceanic conditions during the first year of ocean rearing factored prominently in the low survivorship for WSJF coho returns in 2005-2008. This report reviews the evidence for such impacts.

Freshwater Condition

Altered flow patterns (hydrological regime) in some drainage basins within the WSJF contributed to the decline of coho escapement from 2005-2008. Due, in part, to local land use practices that have highly altered the natural landscape in the WSJF. Higher peak flows and extended periods of reduced base flow condition likely contributed to reduced survivorship from egg to emergence (increased bed mobilization) and influenced overall fitness of rearing juveniles (reduced habitat availability). The following occurred:

- Results from the intensively monitored watershed (IMW) study of three WSJF drainage basins indicate that this altered hydrology contributed to the early entry and extended residence of coho smolts in the Straits, at a time when there is low food availability and increased predation risk during RY05-08.

- Optimal freshwater rearing conditions for WSJF coho, as identified by Physical Habitat Simulation (PHABSIM) modeling, were rarely met across the WSJF, but were substantially less in several major drainages. The worst conditions were found in the

Clallam River with 5% and 3% of optimal coho rearing condition for RY07 and RY08, Sekiu River was 40% for RY08, and Salt creek at 11% and 8% for RY07 and 08.

- Increased turbidity, due partly from road related runoff and poor management practices can adversely affect overall fitness, foraging success, and growth rate of rearing freshwater coho. In the Hoko River, the largest drainage in WSJF, turbidity exceeded levels where coho foraging is completely inhibited on 72, 43, and 46 days during freshwater residence of the RY05-08 coho populations, respectively.

Existing Regulatory Framework

The cumulative impacts of local land use practices and the failure of regulatory mechanisms to ensure full fishery resource protection likely contributed to this failure. While difficult to quantify in terms of freshwater survival rates, or separate out the impacts during these years of interest, as compared to other years, these impacts are the most ubiquitous in the WSJF and play a large role in the overall health of the WSJF Coho population.

- The WSJF is dominated by commercial forestry (27% - 98% by watershed), much of which is regulated through the state's forest practice rules (Title 222 WAC). Though regulated under the state's forest practice rules, a recent evaluation by the Washington Department of Ecology (WDOE, 2009) for their effectiveness in bringing waters into compliance with state surface water quality standards is cause for concern. The Department found that the forest practices program lacked data that demonstrated whether current forest practice activities (such as timber harvest, road construction and maintenance, and fish passage barrier corrections) are improving conditions that will meet current state water quality standards. Furthermore, the department concluded, "After ten years, no studies have been completed or data collected that provide an indication of whether or not the forest practices rules are improving water quality or maintaining forested waters in compliance with the water quality standards. Similarly, data is lacking with which to conduct a thorough analysis of how effective operational and enforcement programs are in applying the forest practices rules."

- Washington Department of Fish and Wildlife (WDFW) conducted a pilot study in 2006 of compliance, implementation, and effectiveness of their Hydraulic Permit Approval (HPA) program including the WSJF area. This program, which issues permits for culverts and assures their proper design and function, is the primary mechanism used to ensure conditions necessary for coho passage (for both upstream and downstream migrating fish). The department concluded that "…the HPA program currently protects fish and fish habitat in large measure, and without the HPA program, we would see substantially more loss of fish life or habitat associated with the 4,000 projects permitted annually. However, they found that the agency's goal of achieving no net loss of habitat function and values is difficult to attain solely through the HPA permit process".

Outlook for future WSJF Coho runs may improve due to the following:

1. Marine survival indices including cooler sea surface temperatures and higher productivity of zooplankton prey in 2007 and 2008 suggest that conditions in the WSJF have improved substantially from 2003-2006. The strong relationship between zooplankton abundance and coho marine survival implies food availability for WSJF coho will improve and likely increase the numbers returning to spawn.

2. While estimates of the total escapement of WSJF RY09 coho have not been developed, early indications are it was a successful year with a large numbers of coho adults returning to spawn. Long term success requires that habitat availability and condition during years of spawner abundance maximize fresh water survival and outmigration.

3. Increase in salmon recovery efforts has led to significant habitat improvements in the WSJF. For instance, in the last few years many projects have successfully re-connected floodplain and estuarine habitat and modified channel morphology to improve riverine habitat complexity. These projects help create conditions that will increase survival through high-flow winter conditions, often a limiting factors for coho. Some examples of projects include :

- Acquisition and protection of Pysht River estuary
- Acquisition and protection of 22.5 acres of Pysht River channel migration zone.
- Engineered Log Jams (ELJs) in mainstem and S.F. Pysht River
- ELJ implementation in Hoko River
- Dike removal in Salt Creek estuary

Essential Fish Habitat Recommendations

1) Support efforts of the WDFW to improve HPA program, specifically the need for increased effectiveness and compliance monitoring of issued permits.

2) Support achievement of WDOE CWA Review milestones related to State of Washington Forest Practice program.

3) Support future restoration efforts in the WSJF that address limiting factors of coho salmon.

Habitat Committee Report on Western Strait of Juan de Fuca (WSJF)
Coho Overfishing Concern

Introduction

This review of essential fish habitat (EFH) relevant to Western Straits of Juan de Fuca (WSJF) coho was initiated by three consecutive failures to achieve the recommended escapement goal. The Pacific Fisheries Management Council (Council) Salmon Technical Team (STT) has determined that harvest mortality was insufficient to have caused the spawning recruitment failure. Consequently, a review of EFH is appropriate to determine which non-fishing factors caused or contributed to the failure. The salmon fishery management plan (FMP) Amendment 14 on EFH requires the Council to make recommendations to correct non-fishing factors affecting salmon survival. Accordingly, this report contains recommendations for the Council's consideration.

Essential Fish Habitat Description

<u>Freshwater Habitat</u>

The Western Strait of Juan de Fuca encompasses waters emptying to the Strait of Juan de Fuca west of the Elwha River, to the tip of Cape Flattery. The WSJF contains 27 salmonid-bearing watersheds that drain directly into the Strait of Juan de Fuca. The largest subbasin within the watershed is the Hoko River, followed by the Lyre, Pysht, Sekiu, and Clallam rivers.

Table 1. Western Strait of Juan de Fuca drainage basin areas (modified from Haggerty 2009).

Watershed	Basin Area (sq. mi.)	Percentage of WSJF
Colville, Whiskey, Field, Murdock, Joe, Jim, Butler, Falls, Olsen, Trettevick, Jansen, Rasmussen, Bullman, and Snow Creeks, Sail River, and Agency, Halfway, and Village Creeks	73.3	19.03
Salt Creek	19.1	4.96
Lyre River	67.9	17.63
East Twin River	13.6	3.53
West Twin River	12.6	3.27
Deep Creek	17.2	4.47
Pysht River	46.3	12.02
Clallam River	31	8.05
Hoko River	71	18.43
Sekiu River	33.2	8.62
Entire WRIA 19 area	385.2	100

The majority of the WSJF drains low elevation hills and mountains with maximum elevations ranging from 2,000 to 3,500 feet. The exception is the Lyre River subbasin, where maximum elevations approach 5,500 feet and a significant portion of the watershed is above 2,500 feet. The Lyre River subbasin is the only subbasin within WRIA 19 that contains alpine meadows and seasonal snow fields (Haggerty 2009). The climate varies widely throughout the WSJF, with higher annual precipitation to the west and at higher elevations (Figure 1).

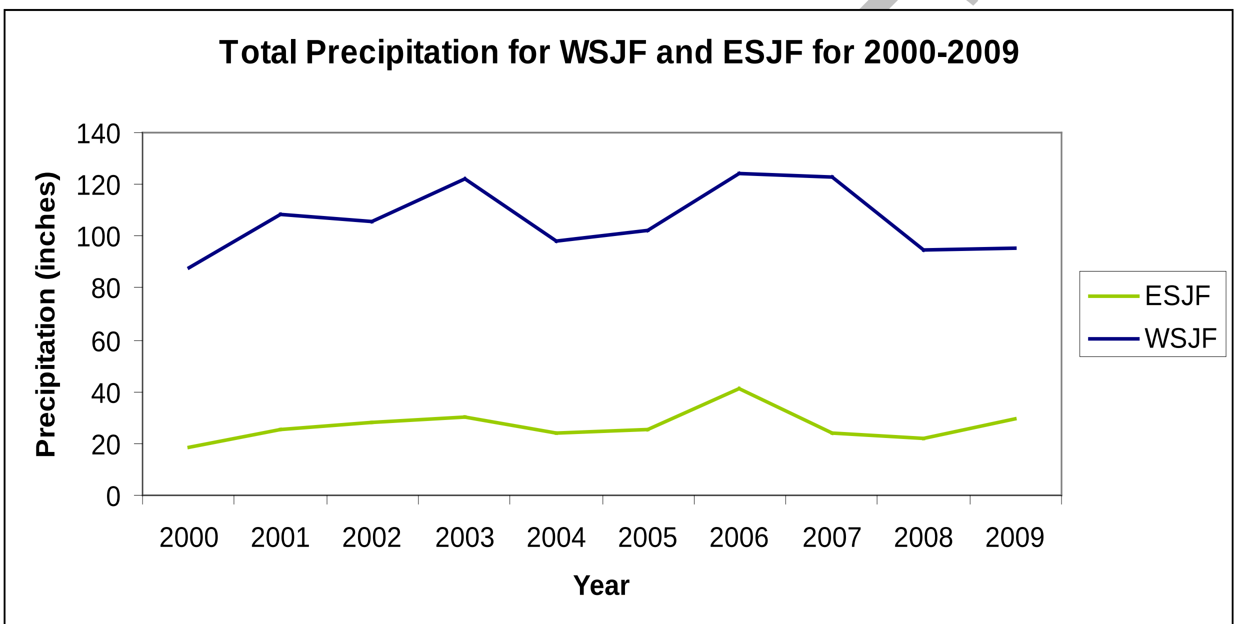


Figure 1. Annual total precipitation for the Strait of Juan de Fuca (PRISM 2010).

The climate as a whole can be characterized as temperate coastal-marine, with mild winters and cool summers. The majority of precipitation falls as rainfall from October through April. The eastern half of the watershed is much drier the western half. For example, the Salt Creek subbasin receives 35-55 inches of precipitation annually (McHenry et al. 2004), where as the Sekiu River subbasin receives 95-120 inches of precipitation annually (Lautz 2001). Subbasins such as the East and West Twin River and Deep Creek have intermediate precipitation levels averaging 75 inches per year (Stoddard 2002). Both the Eastern Strait of Juan de Fuca (ESJF) and WSJF had anomalous precipitation conditions during January and November of 2006 that would have likely had adverse effects on incubating coho during the ReturnYear (RY) 05 and the early run of RY06 (Figure 2). These conditions also would have impacted the rearing juveniles of RY04 and RY05.

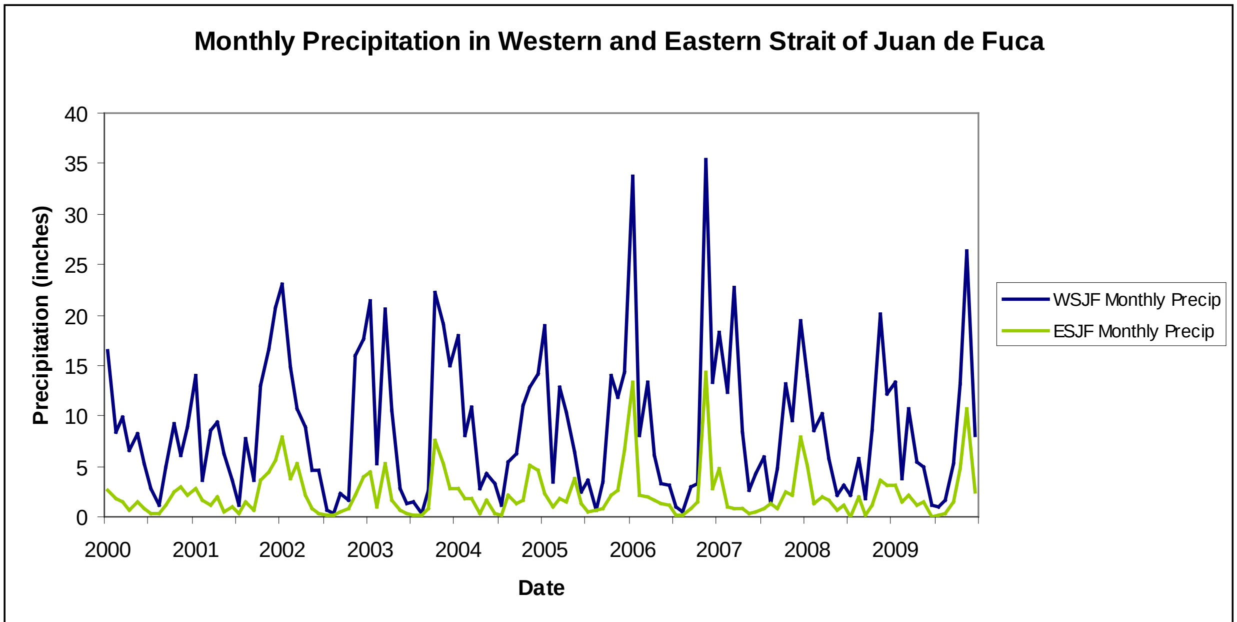


Figure 2. Monthly total precipitation for the Strait of Juan de Fuca (PRISM 2010).

The WSJF is a mix of sedimentary and basaltic volcanic rock types interspersed with glacial deposits. Bedrock units are generally orientated parallel to the Strait of Juan de Fuca, striking northwest in the western portion of the SJF and west-northwest in the eastern half. The rock units are generally youngest nearest the Strait of Juan de Fuca and oldest in the headwaters. Bedrock units are overlain by glacial deposits in many places throughout the watershed, but the most extensive glacial deposits occur closest to the Strait and/or east of the East Twin River. For example, glacial deposits occur across 18% of the watershed area but in the Salt Creek subbasin glacial deposits cover more than 35% of the basin (Haggerty 2009).

Optimal Coho Rearing Conditions (PHABSIM)

The WSJF Instream Flow studies were conducted by EES consulting using the Physical Habitat Simulation (PHABSIM) modeling approach, which is commonly referred to as the U.S. Fish and Wildlife Service Instream Flow Incremental Methodology (IFIM). Whenever feasible, the three-flow regression method was used to hydraulically model flows on the riffles; when necessary to extend the modeling range, the "one velocity-set" method was used to model either upward or downward.

Habitat Suitability Index (HIS) curves for coho life stages were provided by Ecology and WDFW in their most recent instream flow guidelines (WDOE, 2004). All life stages for coho salmon were used in the modeling effort.

Optimal freshwater rearing conditions for WSJF coho were modeled in 2005 (Blum 2005). The modeling effort used Physical Habitat Simulation (PHABSIM) to identify optimal flow conditions that would provide maximum rearing habitat for coho juveniles (Blum 2005). These conditions are rarely met across the WSJF, but were substantially less in several major drainages (Appendix A). The worst conditions were found in the Clallam River with 5% and 3% of optimal coho rearing condition for RY07 and RY08, Sekiu River was 40% for RY08, and Salt creek at 11% and 8% for RY07 and 08.

Water Quality Conditions (Turbidity)

In 2004 the Makah Tribe installed three continuous turbidity monitoring stations in the Hoko drainage to evaluate long-term trends of suspended sediment and the acute and chronic effects on salmon. Ecology has also installed turbidity monitoring stations in Deep, East, and West Twin rivers in 2006.

Increased turbidity (metric used as a surrogate for suspended sediment) due partly from road related runoff and poor management practices can adversely affect overall fitness, foraging success (Barrett et al. 1992; Sweka and Hartman 2001a), and growth rate (Shaw and Richardson 2001; Sweka and Hartman 2001b) of rearing freshwater coho. Recent research suggests that turbid conditions above 100 Nephelometric Turbidity Units (NTU) can reduce foraging success while conditions over 400 NTU inhibit foraging completely for coho salmon (Harvey and White 2008). In the Hoko River, largest drainage in WSJF, turbidity exceeded 400 NTUs on 72, 43, and 46 days during freshwater residence of the RY05-08 coho populations, respectively (Makah Tribe unpublished report).

Washington Department of Ecology Clean Water Act Assurance Review

Land use in the WSJF is dominated by commercial forestry which is regulated through the State of Washington Forest Practices Act. The Forest Practice Board is tasked with utilizing science-based recommendations from the Adaptive Management program to inform necessary rule changes to the Forest Practice rules.

The Adaptive Management program was created to provide science-based recommendations and technical information to assist the Forest Practices Board in determining if and when it is necessary or advisable to adjust rules and guidance for aquatic resources to achieve the resource goals and objectives of the Forests and Fish Report. The Forest Practices Board may also use this program to adjust other rules and guidance. There are three desired outcomes:

- Certainty of change as needed to protect targeted resources;
- Predictability and stability of the process of change so that landowners, regulators and interested members of the public can anticipate and prepare for change;
- Application of quality controls to study design and execution and to the interpreted results.

The Forest Practices Adaptive Management Program is a multi-caucus program that includes representatives from state departments (including Fish and Wildlife, Ecology, and Natural Resources), federal agencies (particularly National Marine Fisheries Service, U.S. Fish and Wildlife Service, and Environmental Protection Agency), forest landowners, county governments, the environmental community, and tribal governments.

Representatives of these caucuses participate on two key Adaptive Management Program committees established by the Forest Practices Board: the Forests and Fish Policy Committee (Policy) and the Cooperative Monitoring, Evaluation, and Research Committee (CMER). The function of Policy is to develop solutions to issues that arise in the Forest Practices Program. These issues may be raised by science reports on rule or program effectiveness or policy questions on implementation of forest practices. Solutions may include the preparation of rule amendments and/or guidance recommendations. The purpose of CMER is to advance the science needed to support adaptive management.

Under Washington state law (Chapter 90.48 RCW) forest practice rules are to be developed so as to achieve compliance with state water quality standards and the federal Clean Water Act (CWA). The Department of Ecology (Ecology) has been designated as the state water pollution control agency for all purposes of the CWA, and has been directed to take all action necessary to meet the requirements of that Act. The Clean Water Act Assurances (CWA assurances) granted by Ecology in 1999 as part of the Forest and Fish Report (FFR) expired June 30, 2009. The assurances established that the state's forest practices rules and programs, as updated through a formal adaptive management program, would be used as the primary mechanism for bringing and maintaining forested watersheds into compliance with the state water quality standards.

The CWA Assurances review completed by Ecology summarizes the findings on the progress the state's forest practices program is making in bringing waters into compliance with state surface water quality standards (Chapter 173-201A WAC) and the federal Clean Water Act. This review is being used as the basis for determining whether or not to extend the CWA assurances into the future.

The Department found that the forest practices program lacked data that demonstrated whether current forest practice activities (such as timber harvest, road construction and maintenance, and fish passage barrier corrections) are improving conditions that will meet current state water quality standards. Furthermore, the department concluded, "After ten years, no studies have been completed or data collected that provide an indication of whether or not the forest practices rules are improving water quality or maintaining forested waters in compliance with the water quality standards. Similarly, data is lacking with which to conduct a thorough analysis of how effective operational and enforcement programs are in applying the forest practices rules." (WDOE 2009).

Washington Department of Fish and Wildlife HPA Program

The state Legislature gave the Department of Fish and Wildlife the responsibility of preserving, protecting, and perpetuating all fish and shellfish resources of the state. To assist in achieving that goal, the state Legislature in 1943 passed a state law now known as the "Hydraulic Code" (Chapter 77.55 RCW). Although the law has been amended occasionally since it was originally enacted, the basic authority has been retained.

The law requires that any person, organization, or government agency wishing to conduct any construction activity that will use, divert, obstruct, or change the natural flow or bed of state waters must do so under the terms of a permit (called the Hydraulic Project Approval-HPA) issued by the Washington Department of Fish and Wildlife. State waters include all marine waters and fresh waters of the state, except those watercourses that are entirely artificial, such as irrigation ditches, canals and storm water run-off devices.

Damage or loss of fish and shellfish habitat results in direct loss of fish and shellfish production. The enactment of Chapter 77.55 RCW was recognition by the state Legislature that virtually any construction or work that affects the bed or flow of the waters of the state has the potential to cause habitat damage. The law's purpose is to see that needed construction or work is done in a manner to prevent damage to the state's fish, shellfish, and their habitat. By applying for and following the provisions of the HPA issued under Chapter 77.55 RCW, most construction activities and work that affect the bed or flow of state waters can be allowed with little or no adverse impact on fish or shellfish.

The major types of activities in freshwater requiring an HPA include, but are not limited to: stream bank protection; construction or repair of bridges, piers, and docks; pile driving; channel change or realignment; conduit (pipeline) crossing; culvert installation; dredging; gravel removal; pond construction; placement of outfall structures; log, log jam, or debris removal; installation or maintenance of water diversions; and mineral prospecting.

Major saltwater activities requiring an HPA include, but are not limited to: construction of bulkheads, fills, boat launches, piers, dry docks, artificial reefs, dock floats, and marinas; placement of utility lines; pile driving; and dredging.

It is important to emphasize that the above are only examples of major types of activities requiring an HPA and that any construction activity or work that uses, diverts, changes, or obstructs the bed or flow of state waters requires an HPA.

In 2006, Washington Department of Fish and Wildlife (WDFW) Region 6 completed a pilot study of compliance, implementation, and effectiveness of their Hydraulic Permit Approval (HPA) program. Region 6 includes all of the WSJF, thus these findings are readily applicable. Permits were appropriately conditioned for culvert size in 91% of projects, culvert slope in 64% of projects, and replenishing channel substrate inside the culvert in only 20% of projects. Permit applicants complied with the above conditions 38%, 57%, and 100% of the cases, respectively. The implementation success of these activities was uniform across all activities at 50% (WDFW 2007). The department concluded that "…the HPA program currently protects fish and fish habitat in large measure, and without the HPA program, we would see substantially more loss of fish life or habitat associated with the 4,000 projects permitted annually. However, the agency's goal of achieving no net loss of habitat function and values (WDFW POL-M5002) is difficult to attain solely through the HPA permit process" (WDFW 2007).

A more recently completed study showed that 30% of HPA permits issued to ensure fish passage resulted in barriers in relatively short time frames, and that some culvert design types may have performed more poorly than others (e.g., no-slope designs resulted in barriers in 45% of projects) (Price et al., 2010).

Nearshore

There is roughly 75.14 miles of shoreline beginning just west of the Elwha River out to Cape Flattery in Neah Bay. Along this shoreline are 19 stream-delta habitat complexes that vary in size and habitat composition (tidal marsh, tidal wetland, spits, etc) and range in degree of habitat alteration (Todd et al. 2006).

Most of these complexes west of the Pysht River are limited in natural habitat complexity, having little tidal marsh habitat nor significant channel networks. The mouths of these rivers (Hoko, Sekiu, and Clallam) tend to be completely exposed to high wave energy and seasonally will close off due to littoral sediment drift and low base flow conditions during the summer and early fall (Todd et al. 2006).

The two largest estuarine complexes along the WSJF are the Pysht River and Salt Creek. Both estuaries have spit features and include substantial tidal marsh areas. At least half of the Pysht Estuary tidal marsh has been altered or converted to an upland vegetation type (Figure 3).

Figure 3. Pysht River estuary (WDNR 1995 photo; taken from Todd et al. 2006).

The Hoko river, largest drainage throughout the WSJF, has also seen significant alteration along the nearshore (Figure 4). The lower reach of the mainstem river is hypothesized to have been anthropogenically altered sometime between 1920 and 1940. The channelization of this lower meander would have been done as a “deliberate management decision to more efficiently transport logs through a significantly shorter and less sinuous reach of channel” (Todd et al. 2006).

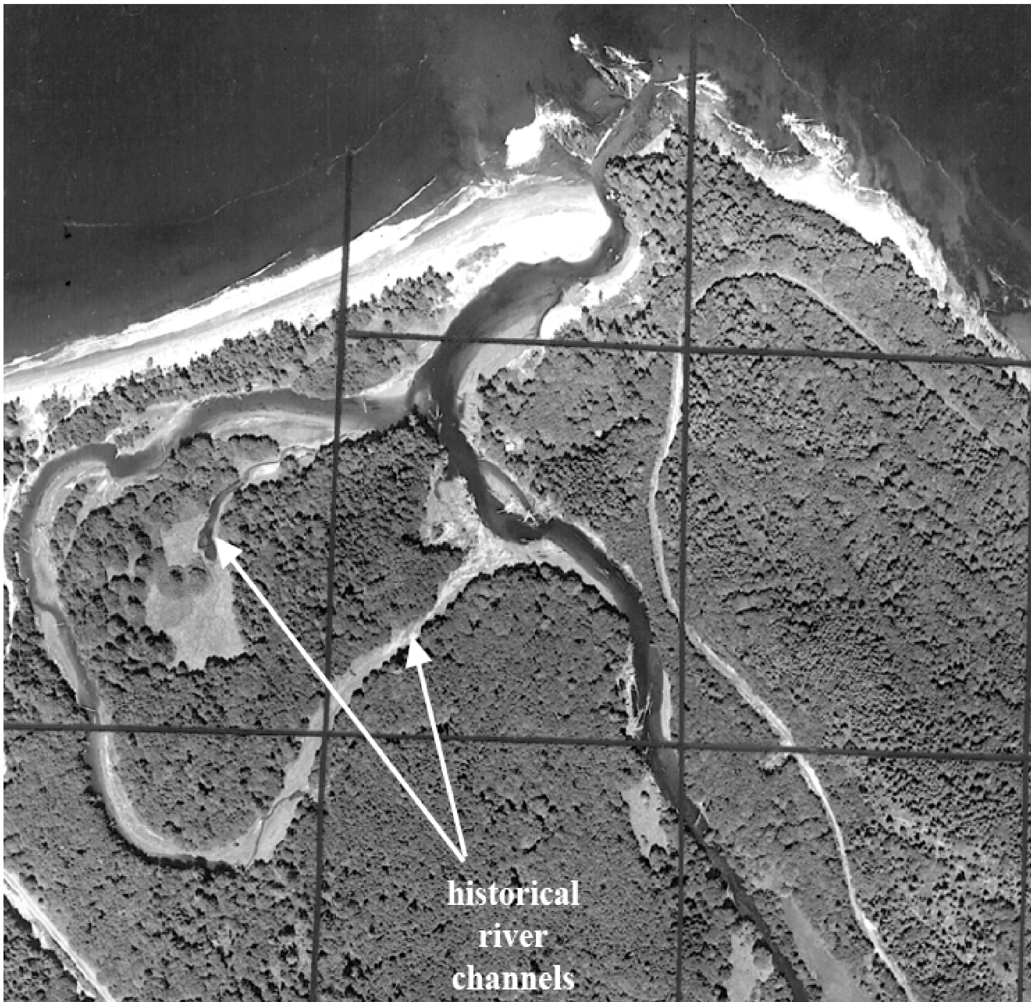


Figure 4. 1957 Aerial photo of the Hoko River mouth.

An additional modification to the nearshore is the roughly eleven miles of shoreline that is armored to protect Highway 112. The armoring extends from the east end of the Makah reservation to the Sekiu River. Impacts from this highway include potential destabilization of shoreline sediment sources and increases in landslide activity (Todd et al. 2006).

Intensively Monitored Watersheds (IMW)

The Intensively Monitored Watershed project is a joint effort of the Washington Departments of Fish and Wildlife and Ecology, NOAA Fisheries, EPA, Lower Elwha Klallam Tribe and Weyerhaeuser Company and is financially supported by the Washington Salmon Recovery Funding Board. The premise of the IMW project is that the complex relationships controlling salmon response to habitat conditions can best be understood by concentrating monitoring and research efforts at a few locations. Focusing efforts on a few locations, including drainages in the WSJF, allows enough data on physical and biological attributes of systems to be collected to allow the detection of the effects of restoration treatments on salmon production.

Coho utilization of nearshore habitat in the WSJF is not well understood. Only recent research (2005-2010) efforts have targeted the WSJF nearshore, and only indirectly focused on coho salmon. PIT tag data from coho salmon in the WSJF Intensively Monitored Watersheds (IMW) indicate that emigrating smolt move along the nearshore environment and re-enter freshwater habitat in adjacent drainages (Roni et al 2009). Tagged coho from the East and West Twin rivers were found to move between drainages in every year during the tagging study (2005-2009). In an effort to evaluate the spatial extent of this movement, PIT tag antennaes are proposed for Deep Creek, a drainage west of the East and West Twin rivers.

Subyearling coho emigrated from natal drainages as early as October. For example, peak emigration of Return Year (RY) 08 E/W Twin river juveniles occurred on November 6th, 2006 coinciding with the fifth largest recorded flood event since 1974. Of the 69 tagged adults that returned in RY07 and RY08, few have been adults from the fall emigrants (Roni et al. 2009), raising concerns regarding early entry and extended residence in the straits, especially with regard to food availability and increased predation risk.
In a broader study of WSJF nearshore utilization, RY08 Chinook smolts were collected from numerous nearshore habitats and found to be genetically linked to distant regional populations. Specifically, a genetic sub-sample of the Chinook smolts were found to be of Columbia River (48%) and Puget Sound (44%) origin. The remaining samples originated from the Washington Coast and Klamath River Reporting Groups (Kassler and Warheit, 2008). These findings illustrate the importance of WSJF nearshore habitat not only to local salmon populations, but to those populations moving throughout the region.

<u>Ocean Conditions</u>

The literature set for marine EFH and ecosystem studies is extensive. Much of the literature focuses on the relationship of OPI coho to the marine ecosystem. Logerwell et al (2003) showed significant relationships between survival to adults and pre-smolt winter sea surface temperatures, Spring transition date to upwelling ocean conditions, first ocean spring/summer ocean conditions (sea level), and first winter sea surface temperatures. Logerwell et al (2003) point out that these elements are independent. Good or exceptional survival brood years will experience most or all of these criteria in their favorable phase.

Hickey (2008) discusses the differences in productivity of the northern end of the California Current System and concludes there is a five-fold increase in average coastal chlorophyll concentration from Northern California to Southern Vancouver Island.

Ocean year 2005 saw poor conditions for salmon production. The ONI values averaged 0.4 from April to July (weakly warm), and downwelling occurred with southerly winds in mid-July. Hickey reports that productivity, as measured by chlorophyll, remained higher in the Northern end of the California Current during this event. Brood year 2003 Western Straits Coho, if they went straight west, experienced this set of ocean conditions.

The Canadian Department of Fisheries and Oceans Science Advisory Secretariat reports on the state of the Pacific Ocean provide graphs of copepod and euphasiid abundance for southern Vancouver Island (CDFO 2009). This information coupled with the methods of Logerwell (2003) provide a basis for predicting, or explaining as is the case for this review, marine survival of coho.

Strong predictive capabilities are found between the relationship of specific zooplankton species that require “cool” sea surface temperature (SST) and juvenile salmon survival rates. A marine survival index has been developed that related SST and zooplankton abundance to survival rates of several juvenile salmon species (State of the Ocean Report, SAS 2009). During the critical first year after ocean entry of the WSJF populations of concern (RY2005-2008) warm summer SST and low zooplankton abundance predominated, resulting in the index reaching a 30-year high in the summer of 2005 (Figure 11; State of the Ocean Report, SAS 2009).

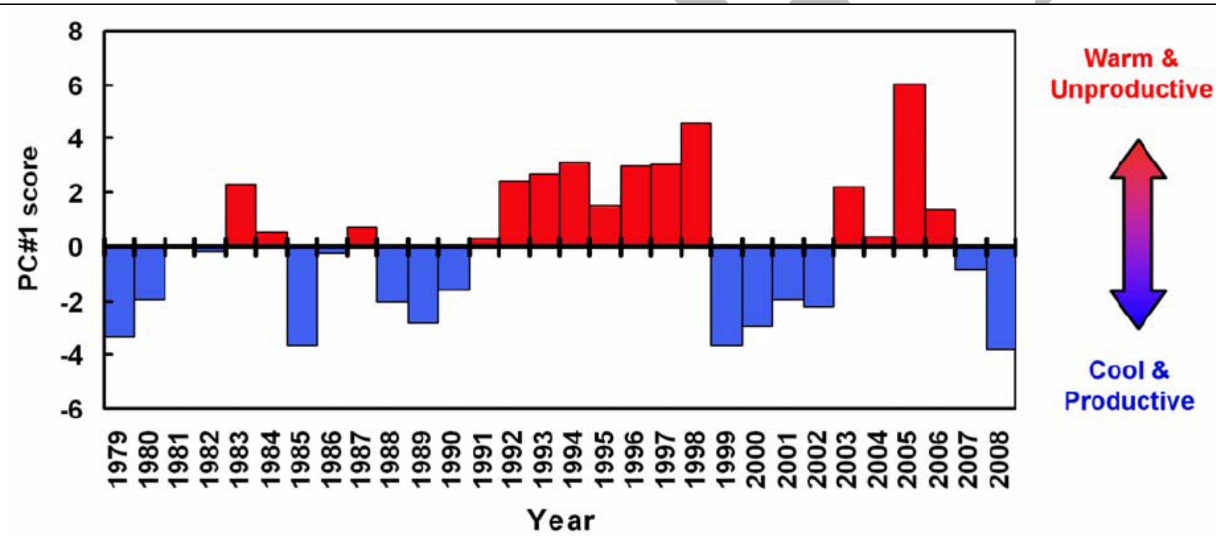


Figure 11. Time series of scores of the marine survival index in coastal waters off Vancouver Island.

Beetz (2009) finds wild coho marine survival responded to more physical and biological variables and in a weaker fashion than hatchery coho. She also shows that interior coho from Puget Sound and Strait of Georgia depend on ocean conditions of their first winter and second spring. Boreal shelf copepods were more strongly related to interior coho marine survival, while sub-arctic copepods were related strongly to coastal coho marine survival.

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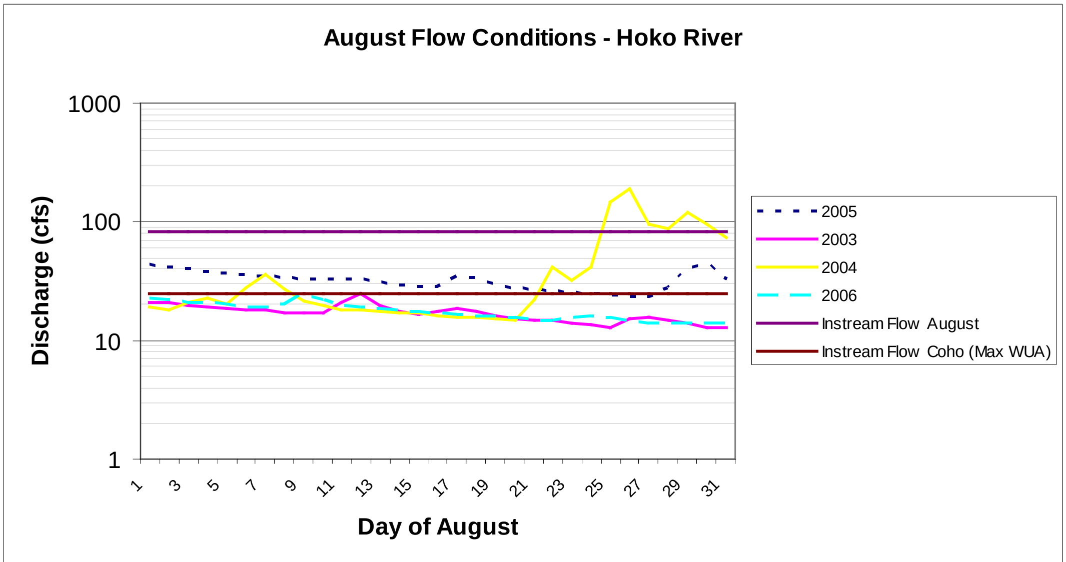
Appendix A


August Flow Conditions - Hoko River
Discharge (cfs)
1000
100
10
1
1
3
5
7
9
11
13
15
17
19
21
23
25
27
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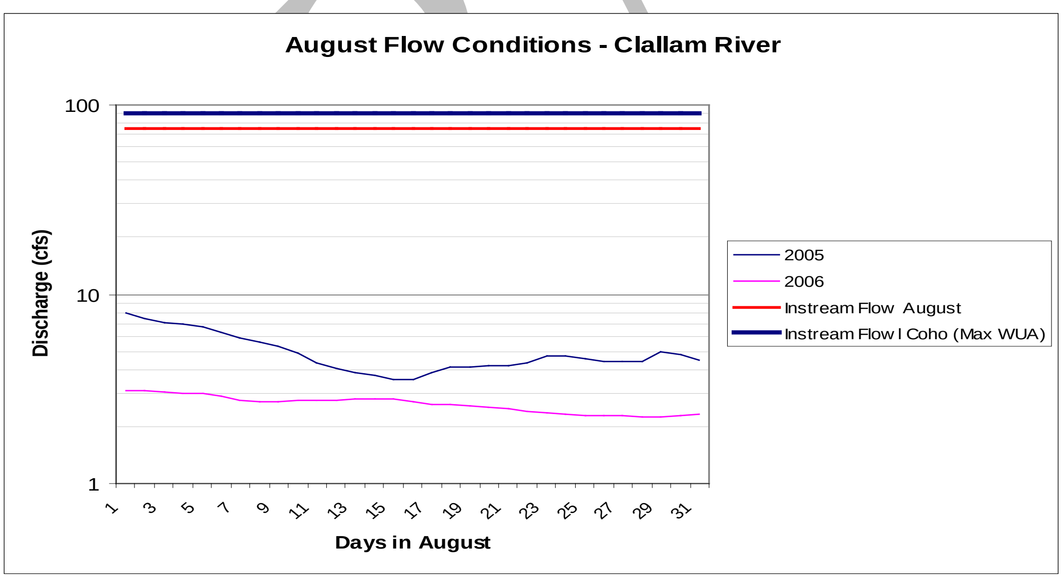
Day of August
2005
2003
2004
2006
Instream Flow August
Instream Flow Coho (Max WUA)


August Flow Conditions - Clallam River
Discharge (cfs)
100
10
1
1
3
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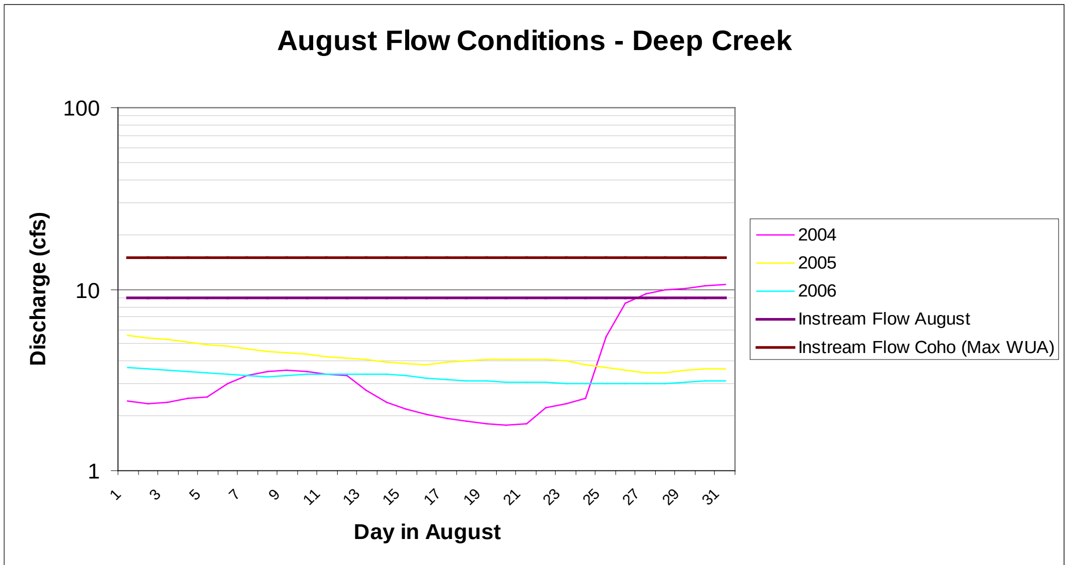
21
23
25
27
29
31
Days in August
2005
2006
Instream Flow August
Instream Flow l Coho (Max WUA)


August Flow Conditions - Deep Creek
100
10
1
Discharge (cfs)
1
3
5
7
9
11
13
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17
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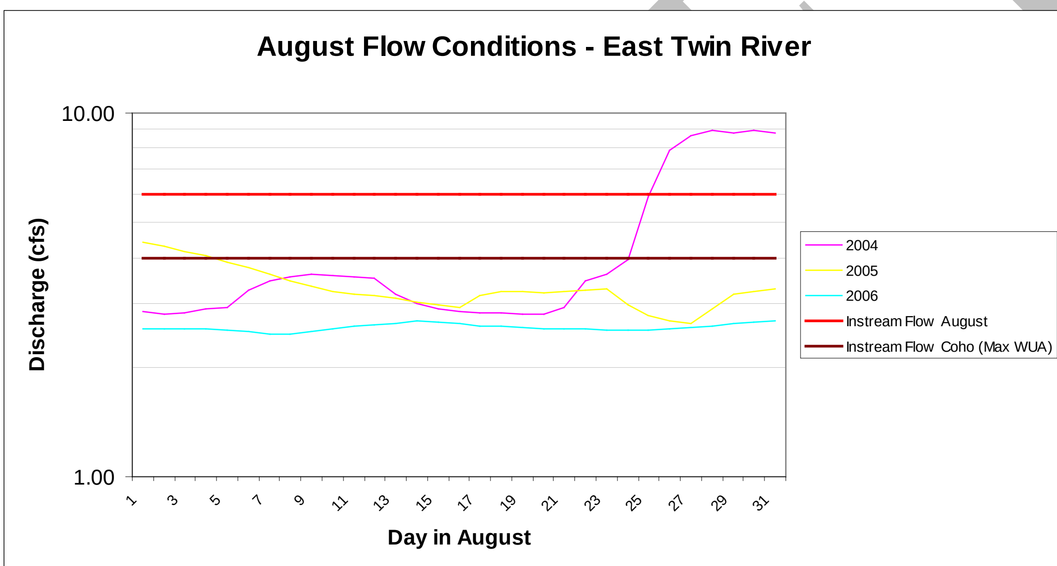
27
29
31
Day in August
2004
2005
2006
Instream Flow August
Instream Flow Coho (Max WUA)


August Flow Conditions - East Twin River
10.00
1.00
Discharge (cfs)
1
3
5
7
9
11
13
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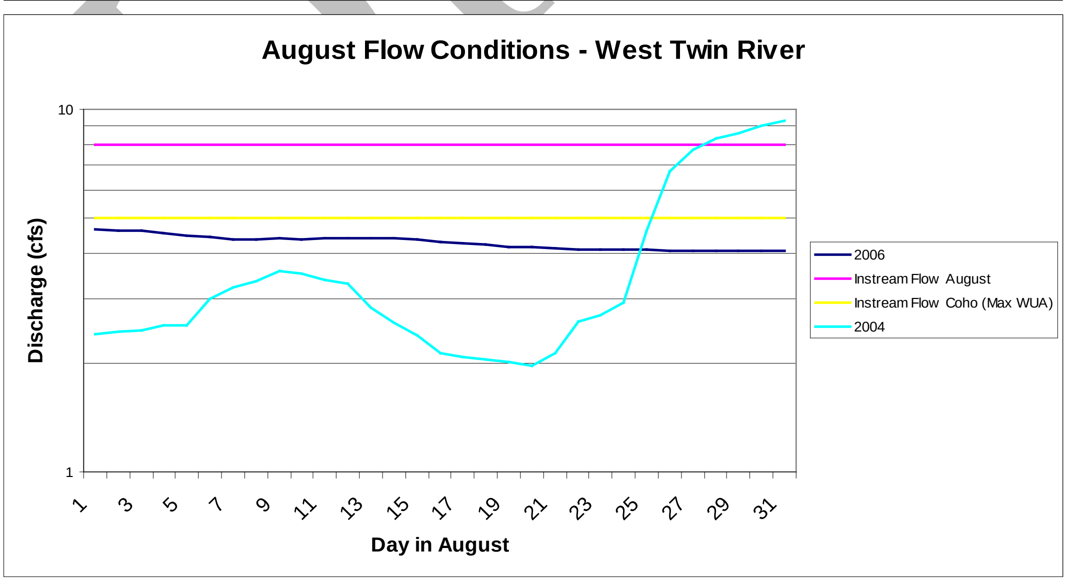
31
Day in August
2004
2005
2006
Instream Flow August
Instream Flow Coho (Max WUA)


August Flow Conditions - West Twin River
10
1
Discharge (cfs)
1
3
5
7
9
11
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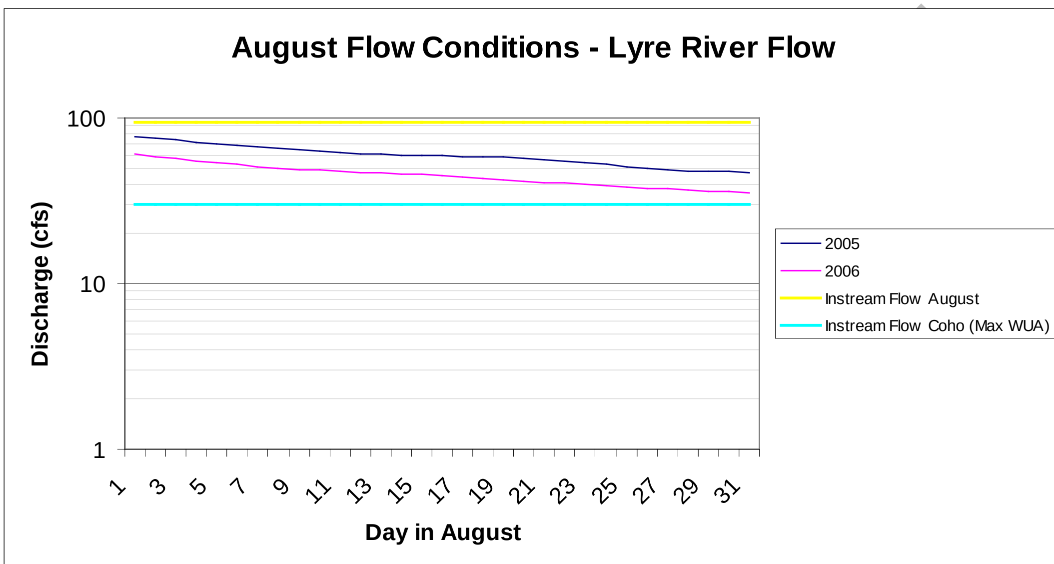
27
29
31
Day in August
2006
Instream Flow August
Instream Flow Coho (Max WUA)
2004


August Flow Conditions - Lyre River Flow
Discharge (cfs)
100
10
1
1
3
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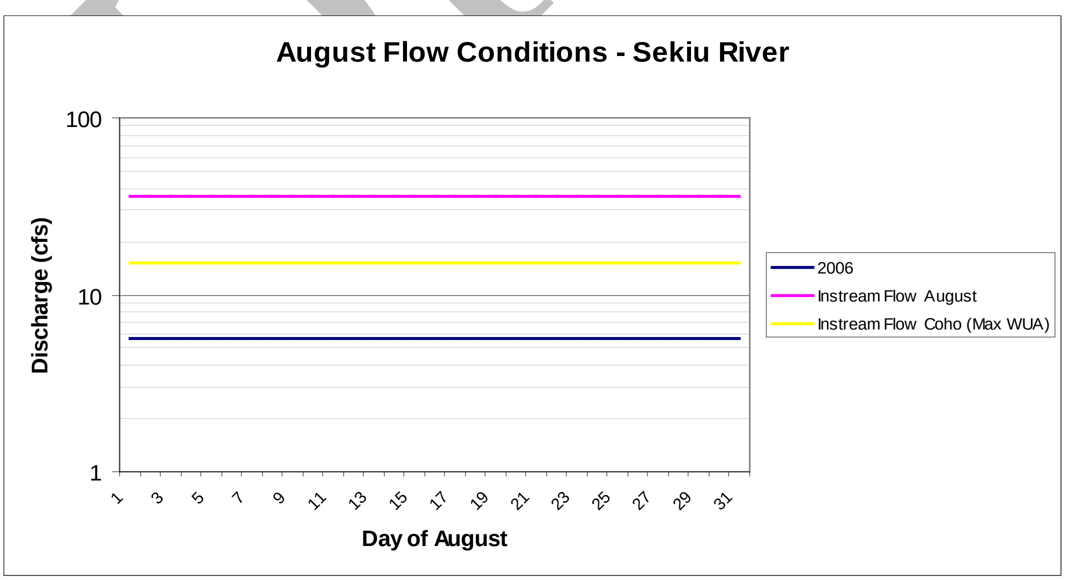
31
Day in August
2005
2006
Instream Flow August
Instream Flow Coho (Max WUA)


August Flow Conditions - Sekiu River
Discharge (cfs)
100
10
1
1
3
5
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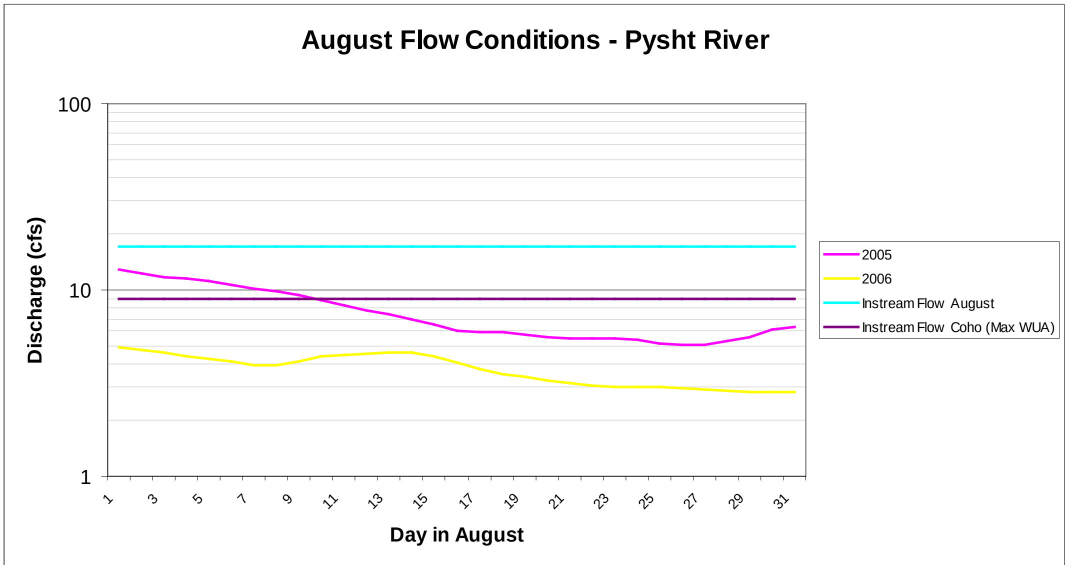
29
31
Day of August
2006
Instream Flow August
Instream Flow Coho (Max WUA)


August Flow Conditions - Pysht River
Discharge (cfs)
100
10
1
1
3
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21
23
25
27
29
31
Day in August
2005
2006
Instream Flow August
Instream Flow Coho (Max WUA)