Environmental Effects of Additional Flood Control on the Baker River

Prepared for

Skagit County Public Works
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EXECUTIVE SUMMARY

Puget Sound Energy (PSE) has invited representatives of local governments, tribes, agencies, environmental groups and the public at large to participate in the development of new terms and conditions that will be included in the utility's application to the Federal Energy Regulatory Commission for a new license to continue operating the Baker River hydroelectric projects. Among the various provisions being considered are flood control measures that would protect human and environmental assets downstream of the projects, while ensuring that dam safety and hydroelectric power generation are not unduly compromised.

Skagit County – a key stakeholder involved in the relicensing proceedings – has offered a flood control proposal that would achieve additional flood protection by modifying reservoir storage and operations. This report compares the current operations to the alternative flood control proposal, and analyzes and summarizes the potential environmental effects of implementing the latter.

Our analysis shows that the County's flood control proposal, if implemented, would provide tangible ecological benefits, notably for several species of salmonids that utilize the Skagit River downstream of the Baker River confluence. Moreover, we find that potential adverse impacts of modifying existing flood control procedures can be avoided or minimized, and would in any event be largely insignificant and discountable. While any change in flows or reservoir operations is likely to pose environmental trade-offs, our analysis and the supporting evidence suggest that any adverse impacts of adopting Skagit County's flood proposal would be outweighed by the benefits.

Our principal findings are summarized below; further detail is provided in the sections that follow.

Reservoir effects of additional flood control

- Early drawdown of reservoirs (prior to peak spawning) will reduce the incidence of redd dewatering in the drawdown-affected portions of tributaries and spawning areas along the reservoir shoreline. High reservoir levels promote spawning in areas along the reservoir shoreline that are subsequently dewatered and scoured by drawdown. By lowering the reservoirs at an earlier date, the number of redds constructed in vulnerable areas will be reduced. In the case of sockeye salmon, delaying release of spawners into the reservoir until drawdown is nearly complete can further minimize impacts.
- Additional drawdown during early autumn will expose several miles of tributary habitat that are currently inundated and of little value to spawning salmon, but provide spawning habitat while in a free-flowing state. Sockeye salmon, in particular, prefer to spawn in the lower reaches of tributaries in close proximity to lake rearing habitat. These areas are quite vulnerable to scour during high winter flows due to unconsolidated substrate and lack of vegetation, but this risk is not elevated or reduced by additional flood control.
- Currently, there is no evidence to suggest that reservoir volume (i.e., rearing capacity) or zooplankton production (i.e., food supply) is limiting fish production. Modest reductions in average reservoir volume are unlikely to significantly reduce salmonid production since there is an overabundance of food and space relative to the number of fish that rear

in the reservoirs. For example, it has been estimated that sockeye smolt production could be increased 2-3 fold in Upper Baker alone. Moreover, under current operations, reservoir volume during much of the flood-control season is frequently reduced to levels far lower than they would be under the County's proposal. Based on the foregoing, we conclude that, relative to current conditions, reservoir volume fluctuations expected under flood control alternative pose a negligible risk in terms their likely effect on salmonid production.

- Concerns regarding increased turbidity are not well-founded. Current operations regularly draw down the reservoirs well below the levels requested by the County. According to relicensing studies, turbidity levels are weakly correlated with project/reservoir operations, indicating that other factors, such as runoff, play a much more important role.
- Early fall drawdown may decrease the incidence of wind-induced wave erosion of vegetated shorelines during fall storms, thereby reducing sediment input and turbidity, and protecting riparian vegetation.
- Amphibians will experience no adverse impacts due to additional flood control, and may experience a modest benefit. Amphibians utilize ponds and wetlands along the reservoir shoreline for reproduction and early rearing during the springtime. Their survival is affected strongly by local habitat conditions, in particular water levels and temperatures, which are a function of surface water and groundwater interactions. Many of these ponds and wetlands are inundated and become inaccessible to amphibians as reservoir levels rise in the spring. The County alternative may delay the date, on average, on which reservoirs reach full pool, so that the highest-value amphibian habitat along the vegetated margins of the reservoirs remains intact and accessible for a longer period of time.

Downstream effects of additional flood control

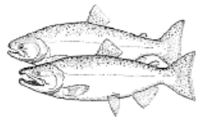
- The adverse impact of high flows, in particular those capable of initiating bed movement and scouring redds, on salmon egg-to-emergence survival is well documented for Skagit River stocks. Additional flood control will provide clear benefits by reducing the frequency and magnitude of scour events.
- Increased water releases during the fall (due to drawdown) may induce fall-spawning species to spawn higher along the channel margins. By moving redds away from the highest-energy portions of the streambed, the County's alternative would further reduce the potential for egg scour during winter freshets.
- Concern has been expressed that by inducing salmon to spawn further up along the channel margin, the risk of dewatering is increased. However, based on modeling studies, the effect of fall flows and on redd dewatering rates is tenuous at best. The highest dewatering rates in the HYDROPS model (using only five representative water years) occurred during the wettest and driest model years. Moreover, dewatering is disproportionately affected by the number of short (e.g., 48 hrs.), low flow events that occur during the period in question. Since short-term low flows are a common occurrence during any type of water year, it follows that the risk of dewatering will not increase under the County alternative.

- The species of greatest concern – ESA listed chinook salmon – faces the lowest risk dewatering due to its particular spawning habitat preferences, but is very strongly impacted by scour. By spawning in deeper, swifter waters within areas of larger substrate, chinook are generally less susceptible to dewatering than are other salmonids, pink or chum salmon, for example. Pink and chum are naturally more prone to dewatering risk, but both species – particularly pink salmon – are also very vulnerable to scour. From a consideration of the life history requirements of salmonids that spawn in the Skagit River and the probable physical impacts of higher autumnal flows, we conclude that any adverse effects to fall spawners, eggs and alevins that might result from dewatering will be more than compensated by the clear benefits of scour reduction.
- With or without additional flood storage, there is more than enough water available to augment flows during dry periods to minimize or eliminate serious dewatering events. The addition of flood storage will not appreciably reduce that ability from current levels, particularly for the shorter periods of time that pose the greatest risk. The ability to protect redds during incubation will also be bolstered by other flow management requirements. For example, minimum instream flow levels and ramping restrictions will provide substantial protection against short-term dewatering risk. The County's flood control alternative will not affect the capacity to implement other instream flow management measures.
- Additional flood protection, while reducing flood peaks, will not eliminate or appreciably reduce channel maintenance flows. Bank-full and higher flows occur on a regular basis in the Skagit River. The incremental decrease in the highest flows is not likely to significantly reduce the incidence of high-frequency, moderate magnitude events that are sufficient to maintain channel form and processes.

Opportunities for additional benefits and impact minimization

By calling for a flexible management framework that emphasizes environmental protection and enhancement alongside power production, the County's flood control proposal creates opportunities for attaining additional environmental benefits. For example, while flood protection is largely focused on buffering the highest flow events to minimize property damage and risks to humans, the proposed alternative offers the means for reducing the magnitude of higher-frequency, lower magnitude events as well. This may be desirable as part of an effort to reduce the scour effects of high flows on salmon redds. The benefits of such an approach should be weighed against potential impacts, such as further alterations to the natural flow regime in the basin.

Drawdown and refill operations can be tailored to avoid or minimize adverse impacts while magnifying benefits given existing conditions. For example, early reservoir refill (right after the end of the flood control season) would eliminate concerns regarding the inundation of spring-spawning steelhead redds in the drawdown zone by precluding spawning in vulnerable areas. Furthermore, the refill schedule could prioritize one reservoir or the other, depending on the environmental issues of interest.



1 INTRODUCTION

As a participant in the relicensing proceedings for the Baker River project, Skagit County has requested that changes in the flood protection protocol be included as part of the new operating license. Specifically, the County has asked that the reservoir drawdown occur earlier in the fall, with full drawdown completed by October 15. Also, the County has asked for an increase in the total amount of flood storage from 74,000 acre-feet to 150,000 acre-feet. The purpose of this report is to assess the environmental costs and benefits that are likely associated with a higher level of flood protection.

We have analyzed the environmental effects of a change in required flood protection levels in two geographical areas: 1) the reservoirs located above the dams (Baker Lake, Lake Shannon), and 2) the Skagit River below the Baker River confluence. Section 2 describes the physical and hydrologic changes to the reservoir environment and the Lower Skagit River as a consequence of additional flood control. Section 3 analyzes the environmental impacts (adverse and beneficial) on resources in the project reservoirs. Section 4 focuses on downstream impacts in the Skagit River.

2 HYDROLOGIC AND PHYSICAL EFFECTS OF FLOOD CONTROL

The following discussion describes the types of changes in hydrologic and physical conditions that may be attributable to flood control operations and specifically to the proposed additional level of flood storage.

2.1 Flood control effects on reservoirs

The proposed changes in flood protection can affect the condition of the reservoir environment in the following ways:

- Earlier drawdown results in lower average reservoir elevations during the September-November period.
- A higher mandatory drawdown volume results in a lower average reservoir elevation during the flood protection season (until March 1).
- Typically, reservoir refill occurs during the March-May period, although in practice, reservoirs tend to remain at low levels for several weeks after March 1. A greater amount of “hole” in the reservoir requires that either a higher proportion of inflow be devoted to reservoir refill in the spring, refill is initiated at an earlier date, or that the target date for complete refill be rescheduled for later in the spring.

A comparative analysis of current and proposed flood protection measures requires some understanding of current project operations relative to existing flood protection requirements. Currently, Puget Sound Energy (PSE) is required to provide 16,000 acre-feet of storage by November 1 and 74,000 acre-feet of storage by November 15, corresponding to a reservoir surface elevation of 711.56 ft (NAVD 88). However, average reservoir elevations between November 15 and March 1 are often much lower than the required level. In addition, Lake Shannon is substantially drawn down during the flood season, despite the absence of a specific flood-control requirement, primarily for reasons related to seasonal energy markets. Table 2.1 shows the average reservoir elevations and storage volume for five representative water years. The weighted average values are based on the same weighting factors used by the Aquatic Resources Working Group to represent the frequency of occurrence for each representative water year. Average flood-season storage is roughly 130,000 combined acre-feet between the two reservoirs across years.

Table 2.1. Average reservoir elevation and flood storage from Nov.15 – March 1 for five representative water years.

	2001	**1993**	**1995**	**2002**	**1996**	**Weighted Average**
	very dry	dry	normal	wet	very wet	
Baker Lake elev.	691.33	702.13	706.82	700.77	709.51	**704.16**
Baker flood storage	146,006	110,563	92,149	114,059	82,347	**101,942**
Lake Shannon elev.	385.85	422.64	435.34	432.38	433.37	**428.03**
Shannon flood storage	101,387	40,259	16,156	22,427	20,357	**29,491**
Total storage	247,393	150,821	108,306	136,486	102,704	**131,433**
Weighting factor	.077	.231	.462	.115	.115	

Figure 2.1 shows the reservoir elevation for Upper Baker during flood season (as well as September-October) for water years 1980-2002. The median value line is shown in bold. The flood control elevation is shown as a flat line. Figure 2.2 shows the reservoir elevation in Lake Shannon for the same period. Note that Lake Shannon does not currently have a 'hard' flood elevation constraint.

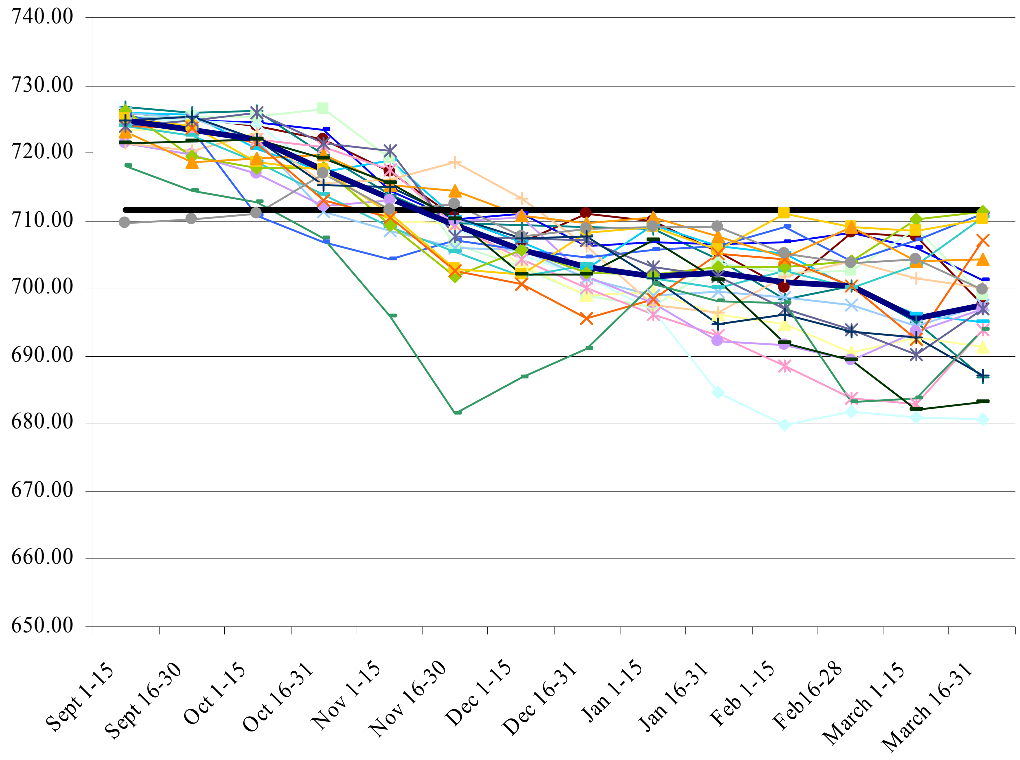


Figure 2.1. Reservoir elevation at Upper Baker during flood control season, water years 1980-2002. Median value series shown as bold line.

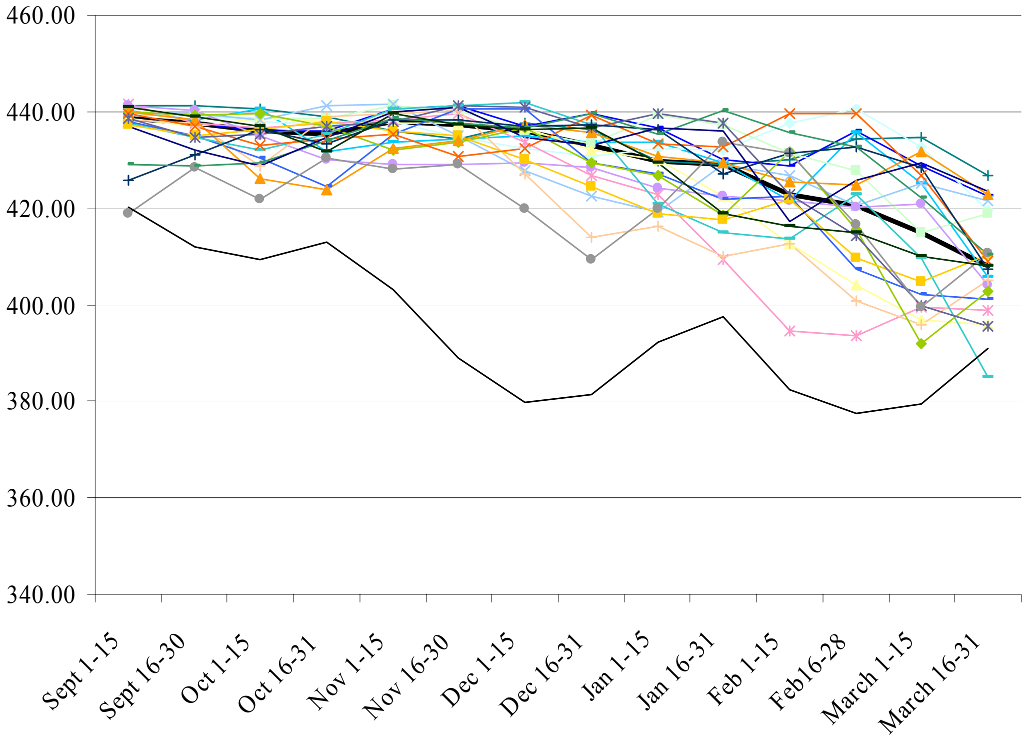


Figure 2.2. Reservoir elevation at Lake Shannon during flood control season, water years 1980-2002. Median value series shown as bold line. Water year 2001 is the outlier series of extremely low reservoir elevations.

Note that in both graphs, the reservoir elevation gets progressively lower on average throughout the flood-protection season. While gradual refill is apparent in the Upper Baker beginning in March, the Lake Shannon elevation continues to drop (on average) throughout the month of March.

An analysis of the daily reservoir elevation record shows that for the period 1975-2002, between October 15 and March 1, the total flood storage between both reservoirs exceeded 150,000 acre-feet on approximately 35% of all days in the record. Table 2.2 shows the exceedance statistics for total flood storage for this period.

Table 2.2. Exceedance statistics for total flood storage in both reservoirs, October 15 – March 1, 1980-2002. Storage volume calculated on the basis of end-of-day reservoir elevations.

Exceedance	Total Storage
0%	298,403
10%	232,169
20%	187,470
30%	164,910
40%	143,066
50%	126,213
60%	112,506
70%	100,501
80%	84,058
90%	51,592
100%	4,616

It follows that the impacts of a change in flood protection cannot be assessed simply as a function of the change in the required reservoir elevation (i.e., the ‘hard’ constraint). For example, when we assess the impacts of a reduction in reservoir volume, the task is not as simple as calculating the difference in volume between the two maximum reservoir levels. The data suggest that that approach may significantly overestimate the impact. However, it may also be true that with a new flood-elevation constraint, the projects will still be operated with more than the required amount of storage on average to allow more flexibility for desired power-peaking operations. In addition, due to the amount of required storage proposed by the County, it is likely that Lake Shannon would become an integral part of the flood-protection system, whereas to-date only Baker Lake has had a formal flood-storage requirement. It follows that a robust, quantitative assessment requires access to an operational model that adequately simulates the proposed conditions. As a result, the analysis in Section 3 (below) is substantially qualitative.

2.2 Flood control effects on downstream conditions

Flood protection measures result in changes in the Skagit River flow regime downstream of the Baker River confluence. The principal hydrologic changes can be summarized as follows, and are described in greater detail below:

- Due to earlier reservoir drawdown under a revised flood-protection scenario, discharges from Lower Baker will be higher on average (compared to current operations) during September and October. The precise timing and magnitude of potential flow changes during the drawdown period depend on the specific dates included in a flood control rule, the effects of other constraints (e.g., instream flow rules or pool-level requirements for recreational, aesthetic or cultural purposes), hydrologic conditions in a particular year, and operational choices made by Puget Sound Energy (PSE).
- The ratio of incubation flows to drawdown flows will be lower on average than under current operations. This does not necessarily mean that drawdown flows are higher

than incubation flows, but rather that the ratio is lower than under current operations. This may have implications for spawning by anadromous fish, as described below.

- During flood events (i.e., when the reservoirs are utilized for flood storage in an effort to lower the magnitude of the peak discharge), flows in the Skagit will be lower on average than under current flood operations. While this is almost certainly the case for particularly severe flood events, the magnitude of more frequent, moderately high-flow events may be reduced by a smaller fraction or not at all.
- If end-of-flood-season reservoir elevations are lower due to additional flood control, more water must be committed to refill the reservoirs after March 1, thereby reducing the contribution of the Baker River to flows in the Skagit. The timing and rate of refill can be adjusted to minimize impacts and maximize benefits.

The following discussion is intended to illuminate the limitations, trade-offs and operational realities associated with flood protection. A realistic assessment of the hydrologic impacts of flood control is a prerequisite to understanding the biological and ecological impacts and/or potential benefits.

The creation of flood storage during the fall months requires higher discharges from Lower Baker dam than under the current flood protection protocol. The required amount of storage can be achieved by either extending the duration of the drawdown period by beginning earlier or ending later, or the rate of evacuation can be increased through higher discharges. The County has asked for both more storage capacity and at an earlier date, similar to what is proposed in the IPP. This scenario likely requires that flood evacuation begin earlier than under current operations and that the average level of discharge is higher.

The ability to meet target levels for reservoir storage will depend on the hydrology of each individual water year, as well as the effects of other project-related constraints. For example, suppose that fall drawdown cannot begin until September 15 due to recreation or cultural concerns and the flood protection target is 150,000 acre-feet (AF) by October 15. Assuming a full pool in both reservoirs on September 14, Lower Baker would need to discharge approximately 2,520 cubic feet per second (cfs) on average around the clock, *in addition to natural inflow,* to meet the target. Furthermore, suppose that both September and October are especially wet, both in the 10% exceedance category for average monthly inflow at 2002 cfs and 3670 cfs, respectively. With the current Lower Baker turbine configuration, the project would have to operate at 100% capacity 24 hrs. per day in September (from the 15th to the 30th), and would need to spill a substantial amount of water in October in order to meet the target. Even with the proposed addition of two 750 cfs turbines, it would be difficult to meet the target in such a short period during a high-water year. Moreover, PSE is not likely to agree to spill water as a regular component of drawdown in the absence of threatening flood conditions. Any additional restrictions – such as maximum discharge limitations or minimum reservoir elevation constraints – further complicate the issue by narrowing the window for achieving the desired level of flood protection. For example, if Lower Baker discharges are strictly limited to a maximum of 3,600 cfs during September and October (as proposed in some recent HYDROPS simulations), under the wet-autumn scenario described above, the total flood storage achieved by October 15 would be less than 50,000 AF.

After reservoir drawdown is completed to the target level, less water is available for meeting minimum flow requirements in the event of a very dry winter. However, it should be recognized that this limitation is primarily an artifact of power-generation operations during the winter months rather than a hydrologic reality. The total active storage capacity (i.e., storage capacity above the minimum operating pool level) for the two reservoirs is roughly 295,000 AF. This means that under extreme low-water conditions, the project could augment natural inflows for a substantial period to achieve minimum instream flows, maintain desired incubation flows, etc. From a strictly mathematical perspective, the 145,000 AF of storage above and beyond the 150,000 flood protection level could provide approximately 610 cfs continuously for 120 days to augment inflow. As natural inflows from November-March rarely fall below 1200 cfs for a monthly average, the active storage component is hydrologically more than adequate to meet proposed minimum flows (1,100-1,200 cfs) for an extended period even under the most extreme conditions. However, other limitations on project operations may reduce the ability to augment prolonged low flows, such as minimum elevations for purposes of water quality protection.

By elevating discharges in the fall as a function of drawdown, the project increases the ratio of natural (or current) flows during the fall to those in the winter, on average. This poses a potential risk to spawning salmon as discussed below. Typically, based on statistical patterns of natural flows in the Baker system, average flows during the November-February period are higher than those in October. This is generally true whether one looks at the record for a 10% exceedance water year (i.e., all monthly flow are in the 10% category), a median year, or any other. A reconstructed record of natural inflow exceedance for the August-March period is provided in Table 2.3 [as excerpted from relicensing study documents].

Table 2.3. Exceedance statistics for the Baker River, based on reconstructed natural inflow records.

Month	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
August	4076	2650	2235	2106	1988	1824	1708	1506	1487	1400	1142
September	2993	2002	1760	1685	1555	1537	1416	1228	1170	1094	878
October	3844	3670	3054	2648	2181	1835	1599	1401	1280	1148	696
November	8124	5350	4887	3895	3509	2946	2775	2413	1852	1289	922
December	5831	4586	3820	3221	2693	2490	2249	2011	1648	1201	936
January	4549	3544	3104	2750	2644	2273	2109	1893	1521	1414	724
February	4922	3506	3297	2747	2276	1961	1837	1632	1471	1226	936
March	3669	2759	2408	2244	2097	1941	1813	1627	1544	1402	978

The difficulty lies in the fact that flows during the fall are not reliable predictors of flows during the subsequent winter. It is not unusual to have an exceedingly wet autumn followed by drier than average winter, nor to have a dry autumn followed by a moderately wet winter. However, as discussed below, extreme cases (i.e., extremely wet fall followed by an extremely dry winter and vice versa) are actually quite rare.

In selecting the set of five representative water years for analysis in the HYDROPS model, R2 Resource Consultants (2003) examined the discharge statistics for the Baker and Skagit systems between 1991 and 2003, focusing in part on the ratio of flows during the fall compared to flows during the subsequent winter, representing spawning and incubation periods, respectively. In a comparison of mean discharges during September-November (SepNovQ) and during the subsequent December-February (DecFebQ), the ratio DecFebQ:SepNovQ ranged from 0.78 to 2.16. In other words, incubation flows were substantially lower than spawning flows in some years, and over twice as high as spawning flows in other years. R2 also compared the mean October discharge (OctQ), representing peak spawning, to the lowest 7-day mean discharge during the December-February period (7QDecFeb) and found the ratio 7QDecFeb:OctQ to range from 0.49 to 1.93. By increasing fall flows during drawdown, either measure of the *incubation:spawning* ratio will be generally lower, the effect of which depends entirely on the combination of fall versus subsequent winter conditions.

In order to better understand the biological risks of high fall flows followed by low winter flows, we analyzed average flow statistics in a similar way, but for a longer time period. We calculated SepNovQ and DecFebQ for water years 1925-2002 for the Skagit River at Concrete. The exceedance statistics are provided in Table 2.4.

Table 2.4. Seasonal exceedance statistics for the Skagit River @ Concrete, water years 1925-2002.

Exceedance	Sept-Nov	Dec-Feb
100%	4865	6063
90%	7238	10254
80%	9169	11941
70%	9963	12872
60%	10467	14303
50%	11418	15082
40%	12445	15967
30%	13143	17041
20%	14741	18400
10%	16376	20121
0%	25037	29029

We then divided the record into 10% exceedance categories, i.e., 0-10%, 11-20%, etc., and analyzed the pattern of discharge exceedance sequences, i.e., the exceedance category of the SepNovQ compared to the category of the subsequent DecFebQ. Table 2.5 shows the number of years in the record for each fall flow → winter flow combination. Black shading indicates the most frequently occurring combination(s) for each fall flow category. The bold lines divide the fall flow exceedance statistics into three broader categories (i.e., driest 30%, middle 40%, wettest 30%) and the winter flows into two categories (i.e., driest 50% and wettest 50%) for discussion purposes.

Table 2.5. Matrix showing SepNovQ exceedance category and subsequent DecFebQ exceedance category for the Skagit River @ Concrete, WY 1925-2002.

Subsequent Mean Winter Flow Exceedance (Dec-March)

Mean Fall Flow Exceedance (Sept-Nov)

		Dry									Wet
		100-91%	90-81%	80-71%	70-61%	60-51%	50-41%	40-31%	30-21%	20-11%	10-0%
Dry	100-91%	4	1	3			1				
	90-81%	1		1	2	1					2
	80-71%	2		1	1	1	1		2		
	70-61%	1	1		2	1	1		1	1	
	60-51%		1			2		2	1	1	
	50-41%	1	3	1			1	1			1
	40-31%			1	1			1	1	4	
	30-21%		1			1	1	1	2	1	
	20-11%					1	2	2		1	2
Wet	10-0%			1	2		1	1			3

While there is a fair amount of variability in the record, the relationship between fall flows and subsequent winter flows is clearly not random:

- Generally, extremely dry fall months are followed by very dry or extremely dry winter months. The same is true for the wet fall-wet winter case.
- Eight out of nine years in the driest fall flow category were followed by lower than median winter flows.
- Of the sixteen years in the two wettest fall-flow categories, none were followed by winter flows in the two driest categories, and only one fell into the third driest category (i.e., 71-80% exceedance).
- For those years with fall flows in the driest 30%, 75% were followed by lower than median winter flows.
- For those years with fall flows in the wettest 30%, 74% were followed by higher than median winter flows.
- For those years with fall flows in the middle four categories (i.e., 31-70% exceedance), winter flows were highly variable, with 48% below median flows and 52% at or above median flows.

A comparison of mean monthly flows for a 3-month period is not a definitive index of hydrologic risk (as discussed further, below), but our analysis shows that extreme fall flows (both wet and dry) are positively correlated to winter flows and that worst-case scenarios (e.g., extremely wet fall followed by extremely dry winter) are in fact quite rare.

Following the completion of drawdown, one would expect the magnitude of high flows during the subsequent winter to be generally lower as a function of increased flood control. For the highest flows [i.e., flows that trigger Army Corps of Engineers (Corps) control of operations at Upper Baker], a greater amount of flood storage will reduce the magnitude of the flood peak and/or reduce the duration of peak-magnitude flows. However, for high-flow events that fall short of triggering Corps flood control procedures, it is not clear that a higher amount of required storage will necessarily translate to lower flows in the Skagit. In this scenario, whether PSE has a 74,000 AF or 150,000 AF storage requirement, the response to a period of high inflows may not differ. The point here is that while the magnitude of the highest, most damaging flows will be reduced by more flood storage, the consequences of lesser events are governed by operational decisions and the related requirements (if any) regarding the obligation to store flows during higher-frequency, lower magnitude events.

Recall from Section 2 of this report (i.e., Reservoir Impacts, Figures 2.1 and 2.2, Table 2.1) that actual flood storage frequently exceeds not only the required levels but also the amount requested by the County. This is especially true later in the flood control season. Consider a scenario in which the reservoir elevations correspond to a combined storage capacity of exactly 150,000 AF. If a high-flow event occurs, will operations be different with a 74,000 AF requirement compared to a 150,000 AF requirement? If there is any difference, it is likely that the higher amount of required storage will result in higher flows after the flood peak has passed, due to the need to return to the required level as soon as possible. Clearly, the operational response to high-flow events and the period that follows has a profound influence on subsequent flow levels in the Skagit River.

Finally, during the spring refill period, a greater amount of "hole" in the reservoir requires more water to be devoted to filling the reservoirs. This results in a decrease in outflow from Lower Baker. However, compared to current operations, more flood storage may not result in any change to springtime flows. A review of the end-of-day reservoir elevation data for Lake Shannon and Baker Lake shows that for energy-years 1976-2003, the mean reservoir elevations on March 1 were 416.38 and 696.91, corresponding to storage volumes of approximately 53,000 AF and 128,000 AF, respectively. It is not clear whether a lower, required reservoir elevation would push the average elevation across years even lower, but comparing the refill scenarios based on required flood elevations may be substantially meaningless.

An inspection of current operations also shows that refill does not generally begin until well after the March 1 end of flood control season. In fact, for energy-years 1976-2003, the average amount of total storage on March 31st is approximately 13,000 AF greater than on March 1st, primarily as a result of greater drawdown in Lake Shannon.

Other changes in the pending FERC license terms will also have a pronounced effect on operations, including the downstream effects of flood-protection. For example, the establishment of minimum instream flow and ramping requirements will substantially affect the management of project reservoirs.

3 RESERVOIR IMPACT ANALYSIS

The report covers the principal issues raised by the Washington State Department of Fish and Wildlife (WDFW) and other parties to date regarding reservoir-related effects of greater flood protection. The analysis of each issue will follow a structured format that identifies the primary implicit and explicit biological assumptions, analyzes these in the context of the Baker system, summarizes available information to support/refute the assumptions, and, where applicable, identifies information needs for reaching a definitive conclusion.

3.1 Reduced juvenile fish passage success during reservoir refill.

<u>Background and assumptions</u>: Juvenile salmonid outmigration in the Baker system occurs during the spring, beginning as early as mid-March, but with the vast majority of sockeye and coho migrants entering the juvenile traps in May. Sockeye migration typically tapers to very low levels by mid-June, whereas coho continue for several more weeks. Chinook migration is generally more irregular and their abundance is a small fraction of coho and sockeye abundance. If the projects are asked to commit a greater proportion of springtime inflow to reservoir refill (due to a greater "hole" for flood storage), then the "net" flow through the project is reduced. The working hypothesis is that lower "net" flow may retard juvenile movement through the reservoir, thereby causing additional delays, and possibly increasing the rate of 'residualism' (i.e., fish that do not leave the reservoir when they are supposed to and may spend their whole lives in the lake system). Sockeye salmon that remain in the freshwater system throughout their lives are known as kokanee. In some cases, juveniles may residualize and simply migrate a year later.

<u>Analysis:</u> The general argument is plausible that a filling reservoir may retard the rate of downstream movement for juvenile salmonids. Sockeye are likely less affected than other species by this scenario since they are inherently a lake-rearing species, accustomed to seeking out the appropriate lake outlet for purposes of migration. Very little hard data exists to firmly support the hypothesis for sockeye or for other species. A study on the Baker project (MWH, 2002) analyzed the statistical relationship between a number of variables related to project operations and the capture rates of juveniles in the Upper and Lower Baker traps. The study found no statistically meaningful relationship between any operational variables (such as reservoir elevation or outflow) and juvenile fish capture that would suggest any relationship to refill operations. However, numerous, significant deficiencies were noted in data quality, precluding the authors from ruling out the possibility of the existence of statistically significant effects. Also, the study did not include a regression between "net" flow through the project (i.e., outflow-inflow) and capture success, which may have been a better proxy for getting at the flood-refill question.

On the upper Lewis River in Southwest Washington, PacifiCorp (2003) conducted migration studies of radio-tagged juvenile coho salmon through Swift Reservoir in 2001. The fish were released near the head of Swift reservoir, a storage project like Baker, that measures roughly 15 miles in length, and features a substantial amount of seasonal drawdown. Although the reservoir has no existing juvenile collection facilities (and thus, no attraction pumps), 90% of tagged coho were detected near the face of the dam, with a median travel time of 3.6 days. While the study was not focused on reservoir refill as part of flood control operations, it suggested that coho salmon can readily find their way through a storage reservoir in an attempt to migrate. In that study, no fish were detected passing through the turbines. While coho are not typically a lake-rearing species in the wild, they are known to fare comparatively well as juveniles in a reservoir environment. The coho used in the Lewis River study were hatchery-raised and released into the reservoir at the onset of the study.

Addressing the residualism question is more problematic. One can argue that if overall passage success is reduced by flood protection, then it is logical that a higher rate of residualism would occur. However, even if compelling evidence is found to suggest that coho or sockeye may take longer to migrate under these conditions, it is not clear that a delay necessarily translates to high rates of residualism, particularly as these species generally fare well in reservoirs. It is more likely to be the case that residualism is more tightly linked to the rate of juvenile collection than to travel time.

Residualism – and the costs of migration delay in general – are likely most detrimental for chinook salmon. Chinook often migrate at a younger age and smaller size (particularly ‘ocean-type’ chinook), limiting their ability to navigate long reservoirs successfully. Chinook juveniles are known to be among the most difficult species to catch with juvenile collectors. However, due to their generally low current abundance in the Baker system and thus very limited trap data, it is not a straightforward task to assess the effect of the proposed changes in flood protection on chinook juvenile migration success. It should be noted that the effects on chinook juveniles are not a primary consideration for the Baker system reservoirs as the transport of chinook into the upper basin is not likely to continue in the future.

The effects of a change in the rate of reservoir refill due to added flood storage must also be considered against the backdrop of the broader fish-passage scenario. Juvenile salmonids of all species in the Baker tend to migrate mostly during the night, especially following dusk and prior to dawn. Power operations, on the other hand, are typically shut off during the night, except for during high-water conditions. It follows that even for current levels of reservoir refill during the migration season, there is likely little to no positive ‘net’ flow being created by hydro-operations during the most critical times of day. If it is the capture itself rather than the time-of-travel that is most important, then the change in flood elevation may not make any difference in actual juvenile capture success.

It should also be noted that the trap at Upper Baker is undergoing a substantial renovation, including a significant increase in attraction flow capacity. It is likely that these improvements will contribute to a major improvement in juvenile fish passage that would offset the effects, if any, of increased flood protection on juvenile fish passage success.

The analysis above is based on the premise that additional flood control translates to a greater “hole” at the end of the flood control season. As our analysis shows, this may not be the case. Average, combined reservoir capacity for the two reservoirs totaled approximately 180,000 AF on March 1st for energy-years 1976-2003, far more than the amount of storage requested by the County.

<u>Minimizing adverse effects:</u> There are options available that could reduce or eliminate potential negative effects on juvenile outmigration. For example, following the end of flood control season on March 1, reservoir refill could occur aggressively during the first month or 6 weeks, prior to the onset of substantial migration. In this way, the ‘net’ flow problem would be reduced during the most important migration period. Also, since fish production is

substantially higher in Upper Baker compared to Lake Shannon, the reservoir refill schedule could prioritize filling Baker Lake ahead of Lake Shannon. However, rapid refill may pose challenges for other resource interests, such as amphibian use of ponds in the drawdown zone, as discussed below.

3.2 Reduction in fish habitat for rearing in the reservoir due to decreased volume, leading to lower fish numbers.

Background and assumptions: Juvenile salmonids – sockeye in particular – rear in lakes during their freshwater residence period, prior to migrating out to sea. If reservoir volume is reduced, this hypothesis suggests that winter-rearing habitat will be reduced, leading to a reduction in fish numbers due to density dependence. In general, fish rearing capacity is most often modeled/described in terms of bottom-up processes. That is, the biomass of primary and secondary production (i.e., phytoplankton and zooplankton) are the key drivers of fish abundance, more so than physical space.

Analysis: This concern rests on the answer to the question: Is winter reservoir rearing habitat currently a limiting factor on fish production in the Baker system? Most of the available data suggest that it is not. Mazumder (2004) reported that based on current zooplankton levels, Baker Lake could potentially support 2-3 times more sockeye fry. Baker Lake juveniles leaving the system to enter saltwater are among the largest in the state, with lengths ranging between 72 and 266 mm, with an average length of 143.5 mm (Brood years '90, '94-'96) (Gustafson et al 1997). Not only are these smolts among the longest in the area, but overall mass is also greater than most other stocks (Mazumder 2004). In addition to their large size, a majority of Baker Lake smolts outmigrate after only one year of lake residence (Gustafson et al 1997). This pattern is generally associated with larger, healthier smolts. If habitat were a limiting factor, it is unlikely that fish leaving Baker Lake would be as robust.

Eggers (1978) argued that juvenile sockeye during the winter months stayed in deep waters with low light levels to minimize the risk of predation (Burgner 1991). Due to the energy reserves built up during the summer months, juveniles are able to spend a majority of their time in deeper waters to avoid predation. Not until the late winter months when energy reserves have been depleted do juveniles undergo extensive vertical migration to the surface to feed (Burgner 1991). Juvenile migration patterns in Baker Lake are largely unreported during the winter months. If juveniles are staying in the deep waters where metabolic needs are at their lowest levels, a decrease in reservoir surface area and volume may not have a great effect on juvenile winter rearing in the absence of other evidence suggesting the presence of density as a limiting factor.

It should be noted that a substantial increase in either natural production or hatchery outplants may elevate the importance of winter-rearing capacity. However, the driving factor will likely continue to be plankton abundance rather than reservoir volume.

Minimizing adverse effects: Measures described above for minimizing effects to juvenile migration are also applicable to the rearing capacity issue. Aggressive refill in the spring after March 1 would increase capacity at a time when the metabolic needs of juveniles are rapidly increasing. Also, due to lower densities of salmonids in Lake Shannon, refill priority could again favor Baker Lake in an effort to provide greater capacity in the early spring for that system.

3.3 Reduction in fish food supply, due to reduction in euphotic zone volume.

Background and assumptions: Most smaller fish, juvenile salmonids included, are wholly or partially planktivores, i.e., they eat plankton as a significant proportion of their diet. While fish largely feed on zooplankton, the total biomass of zooplankton is directly related to phytoplankton production. Large, nutrient-poor lakes can be substantially void of fish, while nutrient-rich systems can produce an abundance of fish in a relatively small space. The hypothesis in this case is that reduced reservoir volume translates to a reduced euphotic zone, resulting in less plankton production and consequently reduced growth or survival for fish.

Analysis: This issue rests on whether food availability during flood control season is limiting fish production. Current efforts to calculate lake sockeye carrying capacity is largely based on bottom-up theory (i.e., where nutrients and lower trophic levels control higher trophic population abundance). Due to the dependence on zooplankton through visual feeding in the limnetic zone, it has been widely established that these prey items serve as an index to determine the maximum sockeye biomass that a lake can support. Experimentation and models have been extensively utilized to explore the relationship between primary production (photosynthetic rate), zooplankton abundance, and the size of the euphotic zone depth (relating to feeding efficiency) and how these variables determine juvenile sockeye carrying capacity. The following models are available to determine fry biomass based on bottom up controls:

- Euphotic Volume (EV) (Koening and Burkett 1987)
  - $\mathbf{SB = -4.31 + 0.147\ EV}$
  - SB= 1000s of kg
  - EV= Mean euphotic zone depth(EZD) (m)* lake area (km^2)

- Euphotic Zone Depth (Koening and Kyle 1997)
  - $\mathbf{Ln\ SB\ (kg/km^2) = 5.45 + 0.95\ EZD}$
  - EZD= seasonal average euphotic zone depth

- Zooplankton Biomass (Koening and Kyle 1997)
  - $\mathbf{SB(kg/km^2) = -68.9 + 2.07ZB}$
  - ZB= seasonal mean total of zooplankton biomass (mg/m^2)

- Photosynthetic Rate (Hume et al 1996)
  - $\mathbf{PR = [(3.25 + 0.583\ PR) * (Lake\ area,\ km^2)]/10^6}$
  - 23,000 smolts per PR unit

Baker Lake is nutrient rich, with moderate to high total phosphorous levels (Mazumder, 2004). In addition to the abundant nutrients in the lake, total zooplankton abundance is comparable to other sockeye nursery lakes in the region [between <2000orgs/m^3 to 5000orgs/m^2 (1984-2000)] (Mazumder, 2004). Growth, over-winter survival and smolt size are strongly correlated with zooplankton abundance (Mazumder, 2004). Given that Baker River sockeye fry are among some of the largest in the region and that a majority of the juveniles are large enough to outmigrate after only one year of rearing (rather than 2-4 years), this indicates that zooplankton and nutrients are not currently limiting sockeye production. Due to the abundant nutrient and zooplankton levels and the historic numbers of individuals supported by the lake, it is largely believed that sockeye rearing in Baker Lake is not currently nutrient or zooplankton limited. As noted above, Mazumder (2004) reported that based on current zooplankton levels, Baker Lake could potentially support 2-3 times more sockeye fry.

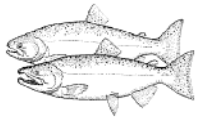
Also, bottom up models are not generally applicable to determine the effects of winter drawdown since very little food production occurs during the winter months. A majority of sockeye growth occurs during the spring, summer and early fall months when large zooplankton population booms occur. Studies have shown that winter feeding is minimal when zooplankton abundance decreases, with juveniles often experiencing 0 or negative growth (Berger 1991). This suggests that a reduction in winter euphotic zone volume is not a serious concern. It should be noted, however, that an early onset to drawdown (as recommended by the County) - and potentially a slower refill process - would reduce the euphotic zone somewhat in early spring and in the late fall. However, absent evidence that zooplankton abundance is limiting fish production, growth or survival, these impacts are likely to be minimal or nonexistent. Moreover, despite the official March 1 end-date for flood protection, in practice, the projects remain substantially drawn down for several more weeks due to seasonal power operations. This implies that there may be no significant effect at all to the spring euphotic zone that can be attributed to a greater amount of flood storage.

Mazumder (2004) raised one potential effect of winter water withdrawal on zooplankton levels and associated sockeye feeding. Depending on the stratification patterns of plankton and nutrients within the water column and the corresponding level of the turbine intakes, productive species and nutrients may be lost disproportionately, impacting production rates during the next summer plankton bloom season. No studies to support this hypothesis have been carried out to our knowledge. However, both reservoirs tend to experience turnover (i.e., thorough mixing due to the disappearance of temperature induced stratification) beginning in October and continuing through the early spring (PSE, 2004). This suggests that any disproportionate loss of nutrient rich water layers would occur, if at all, only during a small fraction of the flood-control season.

Minimizing adverse effects: Similar strategies apply in this case as above. If fish densities are higher in Baker Lake, it may make sense to refill the upper reservoir as a higher priority in order to provide maximum food production during the onset of spring plankton blooms.

3.4 Spawning success for fish in drawdown zone, both on the lakeshore and in tributaries.

Background and assumptions: Many species of fish may utilize the drawdown-affected sections of tributaries and/or the reservoir shoreline itself for spawning. Approximately 14



percent, or 5.4 miles, of the total linear feet of tributary stream habitat available to anadromous salmonids in the Upper Baker subbasin is located in the drawdown zone. Reservoir drawdown may dewater the redds of fall-spawning species, whereas inundation of redds constructed in the drawdown zone may cause harm to spring-spawning species. Moreover, complex patterns of lateral and vertical scour as well as sediment deposition profoundly affect spawning conditions in the drawdown portions of tributary deltas (R2 Resource Consultants, 2004).

One of the key factors to consider is the timing of reservoir drawdown (or refill) and the timing of spawning in affected areas. Sockeye spawn in numerous streams within the Baker system as well along the alluvial fans of incoming tributaries within Baker Lake, and potentially on suitable reservoir beaches. They are a fall-spawning species, beginning as early as mid-September, with peak spawning occurring during the late October to mid-November period. Coho and chinook salmon tend to spawn somewhat later in the fall, from October through December. Steelhead, rainbow trout and other trout species are typically spring spawners, with peak spawning occurring in April and May, occasionally extending into July. Spawning by salmonids in the spring is often triggered by the arrival of suitably warm water temperatures (6-9°C).

Results of sockeye spawning surveys in Baker Lake and associated tributaries suggest that approximately 40% of redds are located in the drawdown zone of tributary deltas or the lakeshore, although estimates range broadly from year-to-year (R2 Resource Consultants, 2004). The large majority of redds in the drawdown zone are located along the Upper Baker River delta, primarily within secondary distributaries, rather than within the primary distributary conveying the highest amount of flow. While poor visibility can hamper lakeshore spawning surveys, it appears that very few sockeye currently utilize those areas of the lakeshore for spawning that are not directly associated with the mouth of a tributary. For example, in 2003, despite a much higher than average number of sockeye spawners released into Baker Lake and a total of 339 redds observed in the drawdown zone, none were recorded along non-tributary associated portions of the lakeshore (R2 Resource Consultants, 2004; see Table 4-2 and Figure 4-3 in referenced document).

Redds constructed in the drawdown-exposed sections of tributaries are vulnerable to scour during high-flow events, although this is of course true to a lesser degree in all tributary reaches even under natural conditions. Since the drawdown sections of tributaries are typically inundated during the entire growing season, vegetation is largely unable to establish in and stabilize these areas. As a result, accumulated sediments are largely unconsolidated and highly vulnerable to scour.

<u>Analysis:</u> Under current flood protection operations, reservoirs remain substantially full well into the month of October, which coincides with the peak of sockeye salmon spawning season. For redds located on beaches in particular, reservoir drawdown causes dewatering in the absence of consistent groundwater input, leading to suffocation and death. Under current operations, early spawning often occurs at nearly full-pool elevations in Baker Lake (approximately 727 ft). By November 15, the reservoir is drawn down by roughly 16 vertical feet. As we have shown in the discussion at the beginning of the report, average levels fall well below the required flood control level, with an average elevation across years of approximately 702 ft. While the proposed change in flood storage does require a greater level of drawdown, the dewatering impacts for fall spawning may not be any greater, and

may in fact be somewhat reduced. Moreover, with a more aggressive drawdown schedule that calls for completion by October 15, a substantial portion of spawning may take place at a time when the reservoir is already at or near its flood protection threshold, resulting in less net drawdown during incubation. This is especially true for species spawning in the late fall, such as coho salmon. However, based on six years of spawner distribution data, the percentage of spawners utilizing the drawdown zone does not appear closely related to the date that drawdown begins (R2 Resource Consultants, 2004).

Redds constructed along alluvial fans may not be as vulnerable to dewatering as those on the lakeshore. Alluvial fans feature dynamic subsurface hydrology, even as surface waters recede. During average to wet autumns, tributary input is beginning to increase during the spawning season, providing additional input to eggs buried within the alluvial fan. While some risks of dewatering exist due to drawdown, these are likely lower than for beach spawning sites. Moreover, if the drawdown schedule is aggressive in September, the probability of spawning along the upper reaches of inundated alluvial fans may be substantially reduced. Dry year conditions may introduce elevated risks to alluvial fan spawning due to the delayed onset of a rise in tributary inflow. While a longer record of detailed surveys of redds along alluvial fans during a variety of flow scenarios would be helpful in the assessment of this issue, these are highly dynamic areas that undergo substantial alteration year after year. It follows that relationships between redd location and reservoir levels would likely change on a yearly basis.

One aspect of fall spawning and dewatering risk that we are unable to assess with current data is whether suitable gravel is available along beaches at extremely low reservoir levels. Historically, prior to the construction of Upper Baker, it is estimates that up to 95% of spawning occurred on natural beaches. However, the construction of the dam inundated these beaches by raising the water level by roughly 60 ft. A study by R2 Resource Consultants (2004) showed that suitable spawning areas are available on portions of the Upper Baker shoreline, but it is not clear how deep into the reservoir the gravel beds extend. Many of these areas are likely kept relatively free of fine sediment as a result of wind-induced wave action along the reservoir margin, but deeper areas are likely to have much poorer substrate quality. It follows that the availability of beach spawning sites may be limited to relatively full reservoir levels, making them highly vulnerable to annual drawdown of 30-40 feet during the winter.

Scour risk in the drawdown zone is affected by flood control operations. Scour is caused by drawdown itself as well as by post-drawdown high flows. Drawdown typically causes vertical scour due to the receding lake elevation and associated increase in tributary gradient. High post-drawdown flows, coupled with fluctuating lake elevations due to storm events or snowmelt, tend to cause both lateral and vertical scour, and in some cases, radical changes to the entire distributary network within a delta (R2 Resource Consultants, 2004). The County's proposal for earlier reservoir drawdown (i.e., prior to peak spawning) should decrease the incidence of drawdown-related redd destruction due to scour. High-flow related scour risk is likely unchanged by additional flood storage since current levels of drawdown regularly exceed proposed reservoir levels. Many of the drawdown sections of smaller tributaries feature log jams and other instream structures. Redds in these tributaries may not be as vulnerable to scour.

Spring spawners – such as steelhead and rainbow trout - face a different set of challenges related to flood protection. Inundation of redds in exposed tributary reaches by rising reservoir levels may cause intra-gravel flow to stagnate, leading to lower oxygen levels, increased siltation and reduced survival. During most years, suitable temperatures for trout spawning are not reached until reservoir refill is well under way (Baker River Relicensing Technical Study, A-01), reducing the risk of excessive inundation. As is the case for fall spawners, these vulnerable habitat areas represent a modest percentage of total available habitat. Steelhead in particular - which have a greater leaping ability than most other salmonids - have access to dozens of miles of superior spawning sites within the upper basin. Chinook and coho juveniles tend to emerge in the late winter and early spring, reducing the likelihood of inundation prior to emergence. The primary issue for spring spawners under both the proposed and current flood control operations is the timing of refill.

Minimizing adverse impacts: Some of the impacts of added flood storage can be ameliorated through strategic reservoir management. To minimize impacts to fall spawners, aggressive withdrawal should commence as early as possible to discourage spawning along upper elevations of reservoir beaches and alluvial fans. Again, prioritizing Baker Lake may make sense in an effort to protect the higher fish abundance and habitat quality in the upper basin. To alleviate scour effects along exposed sections of key tributaries, habitat restoration that includes placement of instream structures and possibly the re-creation of meanders may be worth pursuing, primarily in smaller tributaries. In the spring, aggressive refill should be utilized to eliminate spring spawning habitat that will subsequently be inundated by filling reservoirs. The current practice of maintaining relatively low reservoir elevations well after the March 1st end of the flood control season may expose a larger fraction of spring spawners to adverse effects of inundation.

3.5 Increased predation on fish in reservoirs, due to reduced volume.

Background and assumptions: Generally, one can argue that placing the same number of fish into a smaller volume of water will make the fish more vulnerable to predation. The search-efficiency of predators is likely to be higher, since fish are presumed to be closer together in this scenario.

Analysis: Despite this generally plausible and straightforward hypothesis, an analysis of this issue requires consideration of several interrelated factors, some of which have are discussed under separate headings in this report. Our analysis, again, focuses on lake-rearing salmonids. If the lakes are near their maximum capacity for juvenile salmonids, then this hypothesis has more weight, since densities are likely high to begin with. However, as our analyses of Issues #2 and #3 (above) suggest, this seems to not be the case in Baker Lake. If current densities are relatively low, then even with a reduction in reservoir volume, the average density of fish in those areas of the reservoir where fish are generally found may not be any higher. In other words, while the amount of suitable habitat may decrease as a function of volume, dispersion by fish that are currently at low density may not lead to greater predation success. However, if fish production increases through higher seeding of the lake or through improvements in fish passage and habitat conditions, then this issue may be more relevant. It should also be recognized that while an increased rate of predation is bad for the prey, it certainly is not so for the predator. Native char, cutthroat trout as well as terrestrial and avian predators may benefit from the concentration, if any, of juveniles as a function of reservoir volume reduction.

Predation, in general, is a major source of mortality for sockeye juveniles, particularly near points of artificial concentration, such as hatchery fry release sites or fish-passage ‘bottlenecks’ (see Cedarock 2004 for an analysis of the Baker system). Reservoir drawdown and refill does not amplify such ‘active’ concentration phenomena in any way, despite an overall reduction in volume.

The predation issue also depends on other factors, such as turbidity (see discussion of Issue #7, below). If turbidity is increased by added flood storage, then it may offset increases in predation due to improved capture success by reducing visibility.

One factor that cannot be fully analyzed at this time due to a lack of appropriate data is the influence of reservoir bathymetry. If, for example, reservoir drawdown either creates or eliminates shallow areas (which are more difficult to escape from as a prey-fish), then some changes (positive or negative) in predation pressure may occur. It should be noted, however, that the winter distribution of juvenile salmonids is likely concentrated in deeper areas (see Issue #2, above), so a change in bathymetry at the reservoir margins may not have any detectable effect on predation rates during that period.

3.6 Increased predation on fish in tributaries in the drawdown zone.

Background and assumptions: As the reservoir gets drawn down, the inundated lower reaches of tributaries get exposed. These sections often lack both vegetative and instream cover, thereby exposing fish to a greater risk of predation by avian and terrestrial animals. This issue rests on the assumption that fish that would otherwise utilize areas of greater cover (e.g., upland sections of a tributary) will move into these areas when they become available, or that they will be exposed while moving between the reservoir and tributary habitat.

Analysis: It is of course true that reservoir drawdown exposes otherwise inundated tributary reaches. In the case of very small streams, inundated portions are often filled with silt and little remnant channel may be recognizable. In these cases, exposing the reaches to winter tributary inflow may in fact improve habitat conditions by actively removing fine sediment, which in turn may attract fish to utilize the area. Larger tributaries maintain a recognizable channel even when inundated, due to the hydraulic force of tributary inflow. Some of the tributaries to Baker Lake, for example, are described as featuring cascades and log jams within the drawdown zone (Baker Relicensing Study, A-01).

Since the loss of tributary habitat is one of the greatest impacts of artificial reservoirs, it would seem that even seasonal exposure of inundated reaches may provide some meaningful benefits, depending on the channel condition. Tributaries of a sufficient size provide spawning habitat during low reservoir levels. This may be particularly important for stream-spawning species. In such a scenario, predation pressure may well increase over what may be expected in covered, vegetated areas. That increase must be weighed against the benefits of having the habitat available in the first place. Moreover, for certain avian and terrestrial predators, reservoirs can be substantially more difficult than streams in terms of fish-capture efficiency. It may be that increased predation pressure on fish is more than outweighed by the benefits to other species.

Minimizing adverse effects: It may be possible to improve cover conditions in exposed tributary reaches through the placement of instream structures, such as boulder complexes or submerged, anchored logs. During full-pool conditions, these would also provide increased cover in the reservoir, a benefit to numerous lake-rearing species. During flood protection season, instream structures may provide cover from predators, as well as increased habitat complexity. Concerns regarding potential boating hazards should be taken into account when planning in-reservoir habitat improvement projects, particularly in shallow areas.

3.7 Increased turbidity, due to drawdown, with impacts on euphotic zone and fish production.

Background and assumptions: As a natural function of riverine ecosystems, fine and coarse sediments are transported by streams due to a combination of hydrologic and erosional processes. When sediment-laden waters reach a reservoir, velocity decreases and sediments are deposited on the bottom of the lake. During extreme drawdown periods, layers of mostly undisturbed fine sediments at the lake bottom may become re-suspended through wave action, causing an increase in turbidity. Turbidity is a somewhat double-edged environmental factor. Episodes of high turbidity are natural, necessary components of aquatic systems, serving to distribute nutrients through the ecosystem. Excessive, persistent turbidity can substantially reduce light-penetration, thereby reducing primary productivity, despite high levels of nutrients. In artificial lake systems, or in systems where natural sedimentation rates are exceeded due to land-use practices, (e.g., Lake Shannon) fine sediments may build up over time due to poor flushing, despite periodic re-suspension.

Analysis: The basic concern (as described by Gary Sprague, WDFW) is that drawing the reservoirs down to lower than usual levels will expose new layers of otherwise undisturbed fine sediment. These sediments may get suspended, leading to seasonal increases in turbidity. While the general concern is valid, the turbidity increase would likely persist only during the first few years of the new flood control regime as repeated exposure should result in the movement of fine sediments out of the reservoir or into deeper portions.

Moreover, as indicated by the reservoir elevation analysis at the beginning of the report, the reservoir reaches very low drawdown levels with some frequency under current management. It is not clear how much difference the new protocol would make in terms of net displacement of fines. A more rigorous analysis would require detailed information on the distribution, size and abundance of fines in the reservoir, coupled with realistic assumptions regarding the nature of flood control operations (particularly between the two reservoirs) under a modified level of flood protection.

Apart from the resuspension of fine sediments at extremely low reservoir levels, it is not clear that reservoir levels have any noticeable effect on turbidity. HDR investigated the relationships between turbidity in Lake Shannon and the Lower Baker River and water levels in Baker Lake and Lake Shannon (HDR, 2004; draft memorandum, J. Oppenheimer, Environmental Scientist, HDR Engineering, Bellevue, WA, to N. Verretto, Fisheries Biologist, Puget, Bellevue, WA, dated November 27, 2002). HDR did not detect a direct relationship between either Lake Shannon or Lower Baker River turbidity levels and corresponding daily reservoir elevations.

As noted above, euphotic zone productivity is generally low during the winter months, and fish are generally not feeding very much due to reduced metabolic activity and naturally lower levels of food abundance. These factors point to the fact that reductions in euphotic zone volume during the flood season may not have a noticeable adverse effect in any case. Also, to the extent that predation pressure is linked to visibility, higher turbidity may even provide a modest benefit for juvenile salmonids rearing in the reservoir.

3.8 Decrease in foraging success of avian species, due to increased turbidity.

Background and assumptions: Birds are generally visual feeders. This implies that higher turbidity levels may make it more difficult to locate prey. This concern was raised by Gary Sprague (WDFW), based on his knowledge of an instance at a different project where loon feeding efficiency had been linked to turbidity.

Analysis: The diets of many birds include fish, aquatic invertebrates and aquatic plants. Carnivorous birds (such as loons), benefit from clear-water conditions in their attempts to capture mobile prey. Loons, for example, are known to prefer shallow, very clear lakes with minimal human disturbance (McIntyre, 1975).

Baker Lake and Lake Shannon are quite turbid during winter months under current conditions, particularly during the December-April period. Average monthly Secchi disk readings in December measured only 5 ft and 6.4 ft at Lake Shannon and Baker Lake, respectively (PSE, unpublished data, 2003). During some lakeshore spawning surveys, visibility was reported to be as low as 2 feet (R2 Resource Consultants, 2004). Turbidity levels are quite high due to a combination of natural characteristics of the basin, land-use practices (particularly forestry), as well as operation of the project reservoirs. As discussed above, the inability to flush sediment out of the reservoirs promotes high turbidity levels during the winter in particular.

It is difficult to gauge whether added flood protection would exacerbate turbidity in the short-term or long-term. As discussed above, the reservoirs are regularly drawn down well below current flood protection constraints. It is reasonable to assume, however, that increased flood protection would result in generally lower reservoir elevations during the winter. During the first few years of lower reservoir levels, turbidity may well increase due to the resuspension of previously undisturbed fine sediments. However, this effect may be alleviated over time by repeated exposure, suspension and redistribution.

We were not able to locate any quantitative studies linking turbidity to avian prey-capture success. It is also important to consider whether a small increase in turbidity over baseline levels will make a significant difference. If avian feeding is already significantly retarded by winter turbidity, it may be the case that an incremental increase is meaningless. Additional research may be required on this issue if it is considered to be of substantial importance.

Furthermore, these effects should be weighed against other potential benefits. It is conceivable that other impacts of added flood protection, such as the exposure of inundated tributary habitat, may increase the availability of other food sources, such as fluvial aquatic insects and tributary dwelling fish.

3.9 Amphibian impacts; decreases in reproduction success.

Background and assumptions: Many species of amphibians utilize the project area and surrounding forests, meadows, ponds, streams, wetlands and riparian corridors. Breeding season for some local amphibians begins during the winter and extends into the late spring.

Others may reproduce during summer months, particularly in year-round, forested pond habitats. The concern over amphibian reproductive success was raised by WDFW (Gary Sprague) and the U.S. Forest Service. During the spring, amphibians are reproducing in warm, shallow pools when the reservoir is drawn down. The eggs and larvae are subjected to cold water when the reservoir fills, significantly reducing reproductive success. It is known from amphibian surveys that ponds within the drawdown zone are utilized by some species (Baker River Relicensing Study, T-17). Greater drawdown may in fact increase the number of pools available, though the study indicated a strong preference by amphibians for pools with a significant proportion of vegetated margin, even in the drawdown areas. These sites are generally located at higher elevations. Moreover, adult amphibians are unlikely to travel long distances to new pools created further near the center of the reservoir by increased drawdown (Don Gay, U.S. Forest Service, personal communication, May 2004). It follows that increased flood control is unlikely to have any adverse effects on amphibian reproductive success compared to current flood control operations. In fact, if refill is delayed due to a larger "hole", some ponds may remain suitable for amphibian use somewhat later into the spring.

3.10 Section summary

This section analyzed the impacts of added flood protection on a variety of environmental values in affected project reservoirs. Most of the issues examined pose at most very minor adverse effects to resources of interest, and many impacts can be ameliorated through strategic management of flood storage between the two reservoirs.

It is important to consider current operational patterns as the benchmark for the comparison of effects. For example, several potential impact hypotheses are driven by the assumption that a greater amount of flood storage capacity will lead to a later or slower reservoir refill scenario. This is not necessarily the case. Under current operations, the reservoirs do not start refilling aggressively after the termination of the flood-control season on March 1. In fact, low levels may be maintained for several more weeks as a result of non-flood related operations. Moreover, at the end of the flood control season, the projects often feature more storage capacity than the County has requested. It follows that the amount of *required* storage may be largely irrelevant in considering the likely refill scenario.

The most significant change in reservoir management related to greater flood protection pertains to the timing and magnitude of the drawdown schedule proposed by the County. Earlier drawdown may in fact benefit fall spawners to some degree in that fewer redds will be subject to dewatering. However, more spawning may occur in the drawdown sections of tributaries. These sites may expose adults and redds to predation pressure and/or scour vulnerability. It should be noted that any increases in predation pressure should be considered a benefit to the predatory species. Impacts of scour occurring as a direct result of drawdown will be reduced by earlier reservoir evacuation. Scour risk due to high-flow events during the incubation period is not expected to change under the additional flood control scenario.

Issues regarding fish production – such as reservoir capacity and food availability – do not pose much of a risk at current levels of fish abundance. But if abundance is substantially increased through artificial production or through major improvements in fish passage, the situation should be closely monitored to detect density dependent effects if and when they

occur. However, against the baseline of current conditions with respect to natural and artificial production, the incremental decrease in average reservoir volume should not pose a significant effect to rearing capacity or food availability, particularly since the reservoirs are frequently drawn down beyond proposed levels under current operations.

4 DOWNSTREAM IMPACT ANALYSIS

This section analyses a variety of issues that have been raised as potential adverse impacts or benefits of increased flood control. Each analysis will draw upon the hydrologic analysis provided above as a basis for describing likely conditions in the Skagit River below the Baker confluence.

This discussion does not include a comprehensive analysis of HYDROPS output to date, although some results are cited herein. This is primarily due to the fact that the HYDROPS analysis is still a work in process as various scenarios are incorporated into more refined model runs.

4.1 Higher fall flows may allow salmon to spawn higher along the channel margins.

<u>Background and assumptions:</u> As described above, reservoir drawdown necessitates higher flows from Lower baker in the fall months. One result of higher fall flows is that salmon may spawn higher up along the channel margin. This may make redds more susceptible to dewatering, but less susceptible to scour.

When salmon spawn higher along the channel margin during higher flows, these redds become susceptible to dewatering at a greater rate than those constructed in deeper portions of the channel. In other words, as the water level recedes due to a combination of natural conditions and hydropower operations, some redds may become dry for a prolonged period, leading to high rates of egg mortality. The critical duration of dewatering depends on a number of factors, including air temperature, air moisture content, groundwater influence, etc. Eggs can generally withstand short periods of dewatering without high mortality rates. In the HYDROPS model, dewatering is defined as a continuous 48-hr period of during which water levels are at or below the level of the substrate at a redd site.

Winter scour due to high flows is strongly associated with poor survival. In the Skagit River, the magnitude of the highest discharge during the incubation period is strongly linked with subsequent chinook smolt production. Scour is a function of substrate size, substrate depth, flow velocity and other factors. Generally, scour is most likely to occur in the higher-energy portions of the channel, typically located in the middle rather than along the margins. While this is a simplification of actual hydraulic processes at a particular site, the general assumption is that redds along the margins are less likely to experience scour than those in the middle of the channel.

<u>Analysis:</u> Fall-spawning salmonids that utilize the Lower Skagit mainstem include chinook, chum and pink salmon. Coho are generally tributary spawners, although they may utilize side channels or sloughs associated with mainstem habitats for rearing or migration. Bull

trout, while also a fall-spawning species, are not known to utilize the Lower Skagit for spawning due to highly selective spawning habitat requirements.

Based on their spawn timing and habitat preferences, each species has a different level of vulnerability to the effects of scour and/or dewatering. Chinook salmon spawning in the Lower Skagit begins in early September and continues through mid-November, with a weighted mean spawning date of October 13. Compared to other species, chinook tend to select swifter (1-3 ft/sec velocity), deeper areas for spawning and in larger gravel (>6 inches) nearer to the middle of the channel. As a result, they are quite vulnerable to scour events during peak flows. As a result of higher average fall flows due to increased flood protection, the distribution of redds along the higher margins of the channel may reduce the percentage of chinook redds that are vulnerable to scour. The magnitude of this potential "benefit" depends on the distribution of suitable combinations of depth, velocity and substrate, as well as on the density of spawners utilizing the area. Furthermore, the incremental effect of flows associated with increased flood protection depends largely on the background flow level (i.e., whether the Skagit flowing at 15,000 or 45,000 cfs).

Chinook preference for deep, relatively swift waters for spawning reduces the likelihood of spawning in areas most likely to be impacted by dewatering. This is not to say that dewatering does not occur, but that the preference for mid-channel habitat areas of moderate depth creates an inherent buffer against dewatering during modest reductions in discharge. However, the severity of the problem depends largely on site specific bed profiles, substrate distribution and hydraulic characteristics. For example, Figures 4.1 and 4.2 [excerpted from Aquatic Resources Study A-09] illustrate the difference in dewatering risk for two transects that have been identified as fair (T-5) and good (T-12) chinook spawning sites. Transect 5 shows a relatively abrupt decrease (increase) in wetted width, particularly for discharges between 17,000 and 22,000 cfs. Transect 12, on the other hand, shows a much more gradual decrease (increase) in wetted width for all discharge ranges. Depending on the distribution of suitable spawning substrate, redds located in conditions similar to Transect 5 will likely be more vulnerable to dewatering than those in Transect 12 or similar sites.

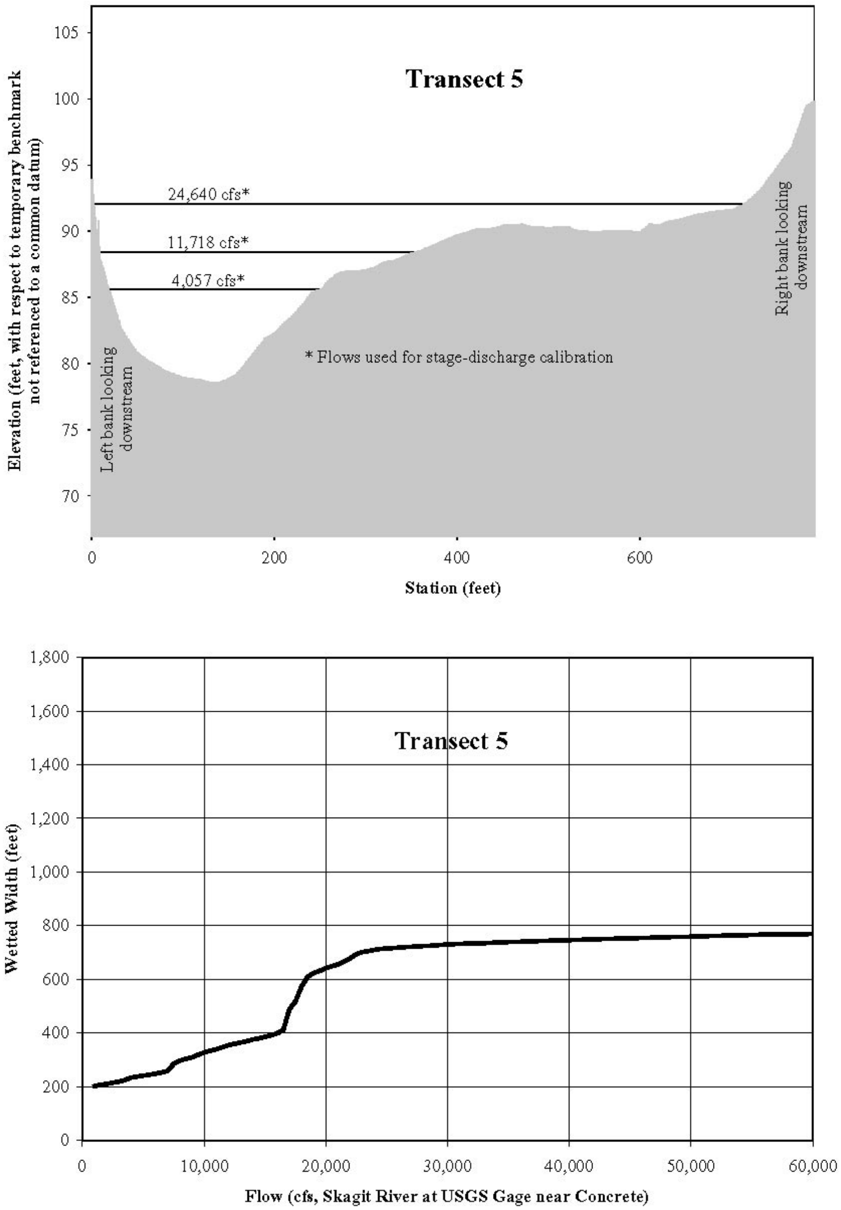


Figure 4.1. Excerpt from A-09. Transect profile and wetted width graph for Transect 5, rated as “fair” chinook spawning habitat.

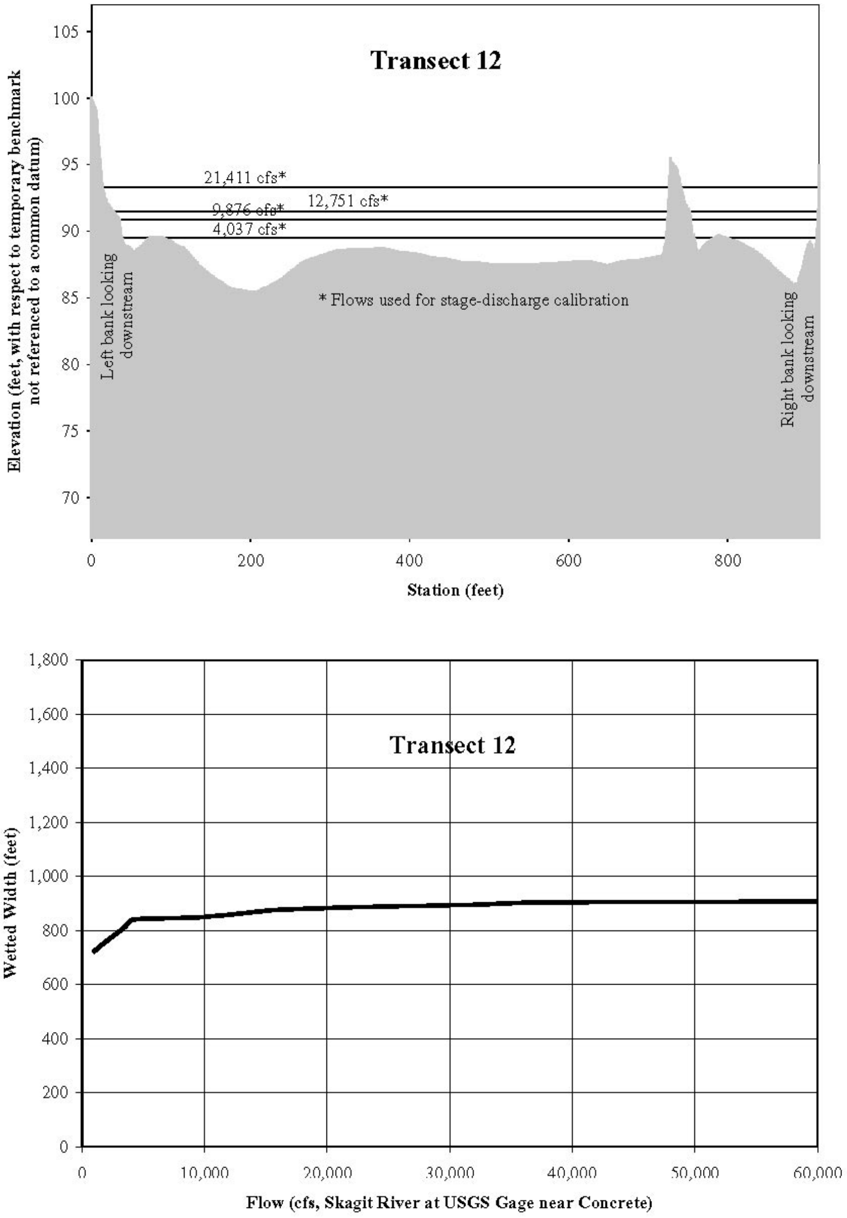


Figure 4.2. Excerpt from A-09. Transect profile and wetted width graph for Transect 12, rated as "good" chinook spawning habitat.

In the case of chinook, scour is likely to produce greater adverse impacts on average than dewatering. This conclusion is supported by the HYDROPS results which consistently show a greater impact from scour. For example, in the PSE.20 model run, scour reduced the reach averaged, transect weighted effective spawning width by approximately 15%, while dewatering reduced effective width by a comparatively low 6%. Similar patterns are evident in nearly all model runs to date. These results are based on an analysis of five representative model years, weighted by their respective likelihood of occurrence. Individual water years may feature substantially different relative effects of scour and dewatering, depending on annual hydrologic patterns. For all five model years, dewatering effects were relatively constant, ranging from a 5-8% reduction in effective channel width, with the wettest and driest model years (1996, 2001) producing the highest dewatering rates. On the other hand, scour risk is substantially elevated during wet model-years, with rates of 24% and 45% for water years 2002 and 1996, respectively, whereas the drier model-years featured rates of 2-6%.

The pink salmon population in the Skagit is the largest in Washington State, with recent odd-year generations averaging in excess of 500,000 spawners. Pink salmon spawning in the mainstem Skagit begins in early September and continues through late October. Their preference for somewhat lower spawning velocities than chinook, in addition to smaller spawning substrate, leads pink salmon to spawn closer to the channel margins, though mid-channel spawning is not at all uncommon. As a result, pink redds may be more vulnerable than chinook to dewatering, but less so to scour. It should be noted, however, that smaller-sized substrates are mobilized by lower magnitude discharges. It follows that scour risk may still be high, but the relative magnitude of these effects may be different than for chinook. HYDROPS results for PSE.20 indicate an approximately 15% loss (reach averaged, transect weighted) of effective channel width due to scour and nearly 27% for dewatering. Year-to-year variability is quite high. For example, water-year 1996, which featured a very wet fall and very wet winter, showed HYDROPS scour losses of 73% of effective channel width, in addition to 31% loss due to dewatering. In general, for pink salmon, model results suggest that wet years substantially increase scour risk (e.g., from a minimum of 7% in WY 2001 to 73% in WY 1996), whereas dewatering risk is relatively constant (e.g., 18-32% across model years without a clear pattern).

Chum salmon tend to spawn in low-velocity portions of the stream, but are large enough in body size to enable spawning in relatively large gravel. They utilize tributaries as well as mainstem habitats for spawning, often in shallow, low-energy side-channels that feature groundwater seeps and/or upwelling. Chum spawn later in the season on average than most other fall-spawning species, beginning in late October and continuing until late December, with a late November peak. Chum spawn timing provides protection from fall dewatering as well as many early-season scour events. The combination of spawning site and substrate preference, as well as spawn timing, suggests that chum salmon are likely to be more vulnerable to dewatering than to scour, although a distinct preference for areas with springs and seeps may reduce the lethal effects of dewatering (e.g., by extending the duration of the lethal exposure period). The HYDROPS model results support this conclusion. Scour effects are generally very low, ranging from 0-5% for the four driest water years, and rising to 19% in 1996. This value is substantially lower than those for other species. Dewatering risk is much more variable, with HYDROPS values ranging from 13-45% reductions in effective channel width, with the lowest impacts produced by the driest and wettest water years. These results are not surprising in the context of chum spawning habitat preference. Shallower side channels and stream-margin habitat types are highly variable year-to-year. In other words, the spawning habitat utilized in a dry year will be substantially different from habitat utilized in a wet year, unlike chinook, for example, which are oriented to the deeper parts of the channel.

In particularly dry years, higher flows during the September-October period (assuming an Oct.15 target date for flood storage) would likely benefit both pink and chinook salmon by increasing early-season spawning habitat. Depending on flow conditions during the subsequent incubation period, pink salmon may experience an elevated dewatering risk if flows remain low. Due to chinook spawning site preferences (described above), significantly elevated dewatering risk would likely occur only in very unusual circumstances. Further HYDROPS analyses of a more diverse representation of water years may provide some insight into this issue.

It is important to note that any dewatering risk posed by additional flood control is dwarfed by the impact of daily and weekly fluctuations resulting from power production operations. A reliable instream flow regime coupled with reasonable ramping requirements will likely have an immense effect of dewatering risk. Moreover, the benefits of reduced scour due to a reduction in peak flows should exceed the adverse impacts of higher fall flows.

<u>Minimizing adverse effects:</u> It is clear that higher fall flows may have both beneficial and adverse impacts to spawning salmon in the Lower Skagit. The nature of the impacts depends on both the existing flow conditions when flood storage evacuation begins, subsequent unpredictable flow conditions, the rate of discharge and other factors.

For chinook salmon, dewatering risk is best minimized by creating flood storage on an aggressive schedule as early as possible in the fall. Ideally, the majority of the elevated flows will have occurred prior to the spawning season. However, in extremely dry years, it may be beneficial to spread out elevated flows over a longer period to provide additional spawning habitat. If flood evacuation must occur during (rather than prior to) the chinook spawning season, the magnitude of elevated discharge should take into account identifiable thresholds in the discharge vs. wetted width relationship at key spawning sites. Moreover, to the extent possible, elevated discharges should continue around the clock as much as possible. This reduces the diel variability of flows to a more natural level and reduces the likelihood of dewatering.

4.2 Reducing flood peaks reduces egg mortality due to scour.

<u>Background and assumptions:</u> Peak flows are associated with lower rates of egg-to-migrant survival, presumably due to scour. Beamer and Pess (1999) investigated the relationship between peak flows during the egg incubation period for chinook and subsequent recruit-to-spawner ratio in the Stillaguamish and Skagit basins. The study concludes that:

- The relationship between egg-to-fry migrant survival and flood-recurrence interval is an exponential one. This means that survival is very sensitive to annual peak flow magnitude, and that changes in flood recurrence interval due to land-use effects or other factors can pose substantial adverse consequences.
- For high-flow events with a 20-year recurrence interval or greater between 1974 and 1990, no wild chinook stocks in either basin “replaced themselves”, i.e., none had a recruit/spawner ratio greater than 1.0.
- More importantly, “replacement failure” occurred >30% of the time as a whole, suggesting that much smaller high-flow events (e.g., 2-year events) may have deleterious consequences. There are of course many other contributing factors, such as harvest management.

The study does not postulate a specific mechanism for the negative relationship between peak-flow and egg-to-fry migrant survival, but many are possible. These include egg scour, suffocation due to silt and others.

It is important to consider the high flow-survival relationship in the context of many other factors. For example, if the extent of spawning habitat has been reduced due to siltation or other factors, then the spatial distribution of redds is likely to be more restricted compared to historical conditions, with a greater proportion located in mid-channel. This means that a higher proportion of redds will be vulnerable to the effects of anomalously high flows.

Also, as a result of harvest management practices and habitat conditions, the average sizes of chinook and other salmon have decreased substantially in the past several decades. This means that spawners are likely to construct shallower redds in smaller-sized substrate, increasing vulnerability to high flows.

While we can develop a relatively accurate estimate of high flow recurrence intervals for the 1 to 5-year interval or possibly the 10-year interval in some basins, one must keep in mind that we do not have very many data points for estimating longer-interval events. This means that inferences about the relationship between certain long-interval flow events and chinook survival should be made with caution. This is particularly important given the exponential shape of the relationship.

The apparent negative impact of high-frequency events (e.g., 2-year flood) is particularly worrisome. This suggests that vulnerability to high-flows has substantially increased over time, and may also point toward the likely relative importance of various mechanisms. For example, it seems unlikely that high-frequency events would precipitate substantial bed load movement and scour across the majority of spawning areas, unless those areas have substantially changed over time. This suggests that other factors, such as streambank erosion and subsequent siltation, as well as spawning habitat availability and distribution, may be equally important as causal mechanisms.

A recent study by Seattle City Light (SCL) biologists shows that the highest densities of spawning chum and pink salmon in their study area occur in the upper most reaches of the Skagit River below SCL's Diablo dam. The authors suggest this is associated with a reduction in the frequency and magnitude of flood flows (Conner and Pflug in press). Although there are many factors that contribute to survival of salmonids, flood control seems to play an important role in early egg-to-smolt survival.

Analysis: The relationship between peak flows and recruitment failure is one of the few well-documented relationships between a particular environmental condition and chinook production in the Skagit Basin. Although the specific mechanisms are likely related to multiple drivers (e.g., high flows combined with smaller fish and poorer habitat conditions), reducing flood peaks should provide a tangible benefit to chinook and other salmon species that spawn in the mainstem Skagit. While the influence of the Baker River is relatively modest relative to total discharge in the Skagit (approximately 18% annually), the exponential relationship between peak flows and egg-to-migrant survival suggests that even modest decreases in peak flow may provide significant benefits.

4.3 Low pool levels may retard ability to augment flows during very dry winters.

Background and assumptions: If reservoir pool levels are maintained at a low level due to flood protection, less water is available to augment incubation flows. This issue is particularly relevant during the alevin life-stage prior to emergence from the gravel. The risk of dewatering is greater (i.e., shorter lethal period) at this stage than at any other.

Analysis: As discussed above, a shortage of water to provide incubation flows is likely to occur only during the driest winters, and is largely preventable through appropriate operational safeguards. The active storage capacity of the reservoir provides a substantial amount of flow-augmentation potential, if the capability for such augmentation is established as a priority. Based on our historical analysis of discharge patterns on a seasonal scale, winter flows (DecFebQ) that are substantially lower than fall flows are extremely unlikely. However, short-term anomalies may of course occur and may subsequently threaten egg or alevin survival. These conditions could conceivably be addressed through specific short-term augmentation protocols.

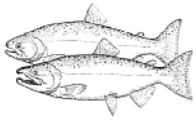
As previously discussed, under current flood protection operations the reservoirs are frequently drawn down far below required levels, especially in the late winter (February-March). It is difficult to assess whether increased flood protection would pose an additional risk to flow augmentation potential since current operations do not closely track existing constraints. At most, increased flood protection would pose a minor increase in augmentation risk, primarily during the early rather than late winter period (i.e., when current operations are likely to result in lower average reservoir elevations).

4.4 Reducing flood peaks may reduce the effectiveness and/or frequency of channel maintenance flows.

Background and assumptions: The importance of channel shaping and maintaining flows is garnering increasing attention among instream flow practitioners, particularly in basins that are substantially influenced by hydroelectric operations. These are flows of a magnitude that create and shape side-channels, mobilize substrate, cause some areas to erode while others accrete, provide sediment to surrounding riparian areas, recruit large woody debris, and a number of other critical functions. Some parties to the Settlement discussions have raised the concern that reducing peak flows (via greater flood protection) will decrease the frequency and/or magnitude of channel maintenance flows.

Magnitude and variability of flows is one of the most significant factors in determining biological and physical factors within a river system (Tockner et al 2000). Peak flows serve to scour substrate, reconnect floodplain habitats, and promote spatial and temporal temperature variability, promoting the re-establishment of native biodiversity (Stanford et al 1996). Essential physical habitat is formed through periodic disturbances, by resetting the system through the formation of new channels, scouring vegetation, blocking some side channels and creating new habitat (IFC 2002). Additionally, high flows serve to flush sediment and substrates to benefit habitat by removing pool scour and bed load deposition from riffle areas. These occasional extreme flow events impact the river system biologically by reducing non-native aquatic and riparian species presence within the system, in addition to meeting the required flow events for some species life history strategies.

Traditionally, the focus on instream flows originating from dam complexes has concentrated on the minimum amounts of water necessary to preserve habitat parameters for some key species. With the lack of high flows in some regulated systems, many channel maintenance functions are lost, particularly the flushing of sediment (IFC 2002). Current instream flow



regimens are now beginning to focus not only on minimum instream flows, but also on the variation of flows required to restore basic physical and biological conditions in the stream channel and, where feasible, its associated floodplains.

The Instream Flow Council recognizes two types of increased flow regimes to improve biological and physical conditions within regulated river systems: channel maintenance and channel flushing flows. Maintenance flows mimic a natural ecological function that is imperative to native species associated with the river environment (IFC 2002). These flows serve to maintain, preserve and restore stream channels, through the movement of sediment present in the system, adjusting streambed and bank capacity and morphology, and improving native aquatic and riparian species health and habitat. Flushing flows are shorter term increased flows that are important in the removal of fine sediments from gravel spawning areas.

Three methodologies are typically utilized to determine channel forming discharge quantities: bankfull discharge, specified recurrence interval discharge and effective discharge (Copeland et al 2000). Bankfull discharges are the maximum discharge that the channel can convey without flowing onto its floodplain. Specified recurrence interval discharge typically falls between the mean annual and five year peak flows. Effective discharge is defined as the discharge that transports the largest fraction of the average annual bed-material load. All three methods have constraints, and may not be appropriate in all watersheds. Further, due to the inherent variability in watershed conditions, physical characteristics of sites, and data/funding constraints, more than one method should be utilized to determine the appropriate channel forming flow.

While several methods exist to determine the appropriate channel forming flow, traditionally, bankfull discharge is the most often utilized determinant. Bankfull discharge is considered the breaking point between channel forming and floodplain forming discharge (Copeland et al 2000). Under bankfull conditions, it is believed that the channel undergoes a minimum flow resistance and produces the most sediment transport over time. In general, bankfull discharges in stable channels have been found to occur over a 1.5 year recurrence flood magnitude, but this number can vary greatly depending upon watershed conditions (Copeland et al 2000, IFC 2002, Petts 1996).

Peak channel forming flows do not need to occur every year to maintain habitat complexity and channel health. While channels are altered by a wide range of flows, bankfull flows are typically required to make major scale river alterations at the bankfull level on a 1 to 2.5 year interval (Copeland et al 2000). In river segments where increased flows can be released without having extreme detrimental effects on downstream human populations, release of channel forming flows should occur in accordance with natural runoff timing in the catchments (Stanford et al 2002).

<u>Analysis:</u> Flood stage of the Skagit River near Concrete is listed by the National Weather Service as being 28.0 ft (61,768 cfs), with a bankfull height of 27.5 ft (Between 57,500 cfs and 60,060 cfs) (NWS 2004). When a bankfull stage of 27.5 ft is reached at this gaging station, the area would undergo some localized flooding of low elevation farm land. If the river reaches a flood stage of 28 ft (61,768 cfs), minor flooding of lowland roads and farms from Rockport to Sedro Woolley will occur.

Between 1990 and 2002, the Skagit River flow gauge near Concrete recorded approximately 22 days, over 5 different water years, as having flows high enough to be considered a flood event (USGS 2004). Of these 22 flood days, 11 days would have been considered to be of flood magnitude without any input from the Baker River system. An additional 3 days would have been below flood stage, but above the bankfull stage, necessary for channel maintenance.

Between water years 1980-2002, bankfull flow conditions occurred during the September-February period in 12 of 13 years. The duration of the events varied, from one day to five days. The distribution of events by duration is shown in Figure 3. The average duration of bankfull flows during this period is 2.1 days. The average discharge across all events is approximately 80,800 cfs.

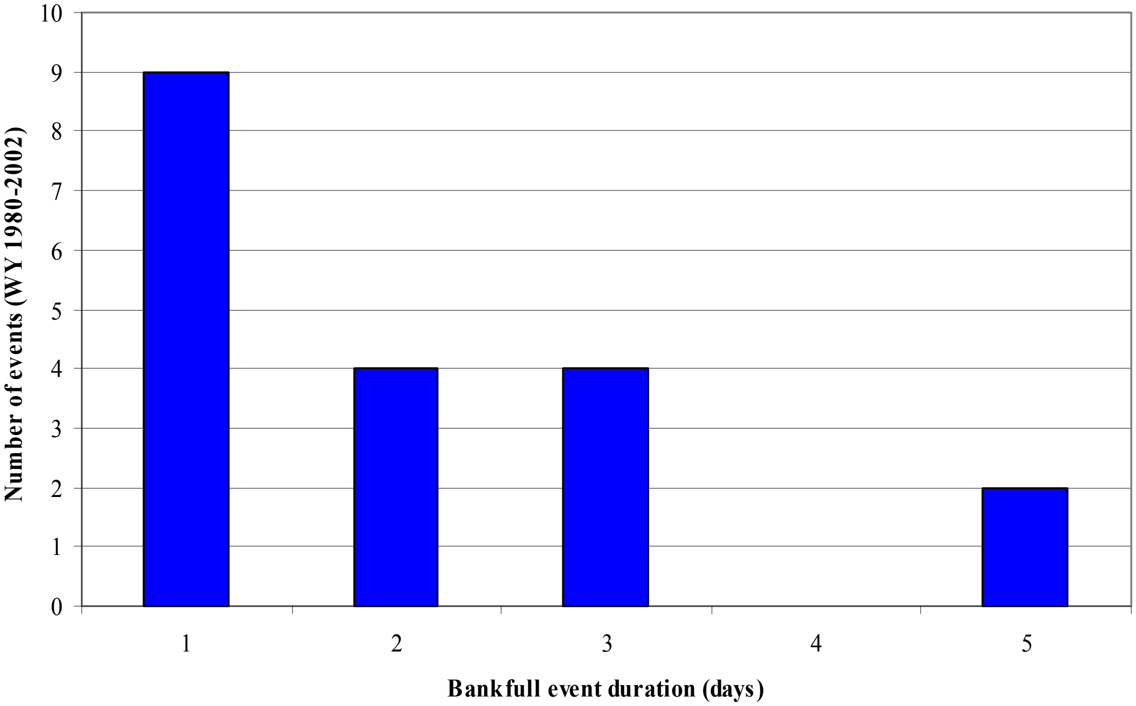


Figure 3. Number of bankfull events (>58,000 cfs) and event duration for the Skagit River @ Concrete, water years 1980-2002.

The record of flood events in the Skagit River between 1990 and 2002 and bankfull discharges between water years 1980-2002 illustrate that flow pulses of sufficient strength to reconfigure channel habitat and perform channel maintenance do occur regularly within the Skagit River system. An increase in Baker River flood protection will reduce the magnitude of the highest peak flows, but these are generally well in excess of what is required for channel maintenance.

4.5 Section summary

The primary downstream effects of additional flood control are higher average flows in the fall during reservoir drawdown and lower peak flows during the winter. Spring flows are likely unaffected compared to current operations, since March 1 storage averages approximately 180,000 AF, far more than the amount of storage requested by the County. Moreover, refill is often not initiated until much later in the spring.

Higher fall flows allow spawners to distribute more broadly in the river channel by gaining access to suitable areas near the channel margins. If flows during the incubation period are substantially lower than spawning flows, dewatering of redds may occur. However, dewatering risk posed by additional flood control is dwarfed by the effects of daily and weekly fluctuations in flow caused strictly by power production operations.

Dewatering risk posed by additional flood control can be minimized by initiating drawdown at an early date and maintaining reasonably steady flows throughout the drawdown period. The occurrence of an extremely dry winter following an extremely wet fall is very rare. However, irrespective of the “type” of water year, short-term periods of lower flow will occur. Hydrologically, the amount of active storage in the project reservoirs is adequate – with or without additional flood control - to effectively augment flows during anomalously dry conditions.

Chinook are less affected by dewatering than other species in the Skagit due to their spawning habitat preferences. Scouring of redds poses a much more serious concern for chinook and likely for other species as well.

Loss of redds due to scour can be reduced with additional flood control. Spawners may select redd sites that are further along the channel margins, thereby reducing their exposure to scour. The primary effect (and purpose) of flood control is to reduce peak flows in areas downstream. The negative correlation between high peak flows and egg-to-migrant survival is one of the few well-quantified relationships between a specific habitat condition and a direct environmental effect in the Skagit Basin. We expect that the reduction in scour attributable to additional flood control will more than offset any minor increases in the risk of redd dewatering.

Despite reducing peak flows by a modest but significant increment, the incidence of channel-maintenance flows is not likely to decrease appreciably. Flows in excess of what is required for channel maintenance occur quite frequently in the Skagit Basin. The decrease in peak flows attributable to flood control at the Baker project is not sufficient to markedly reduce the frequency of these events.

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