Memorandum

To: WRIA 8 Salmon Recovery Council
From: WRIA 8 Technical Committee
Date: October 18, 2007
Re: Cedar River Flooding and Impacts to Chinook Survival

Summary

The WRIA 8 Salmon Recovery Council requested Technical Committee review of the potential survival impacts to Cedar River Chinook salmon from the November 2006 flood and recommend whether or not the current salmon recovery strategy for the Cedar River should be modified. To address concerns, the WRIA 8 Technical Committee reviewed smolt production estimates, Chinook salmon spawning data (including tributaries), evaluated scour potential from past Cedar River studies and elsewhere, and considered flow effects from the flood magnitude, duration and timing.

After the Election Day 2006 November flood, many were concerned about the effects of flooding in the Cedar River on Chinook and sockeye salmon. Flooding and associated high river flows can cause scour of river bed materials which can expose or bury incubating eggs, causing mortality. Scour tends to be more severe when river flow cannot not expand into floodplain areas, and results in reduced survival and lower spawning success for salmon. A preliminary estimate from Washington Department of Fish and Wildlife monitoring suggests that the November 2006 flood event reduced 2007 Chinook smolt production. The preliminary estimate of approximately 14,200 smolts (Kelly Kiyohara, WDFW, Personal Communication) is near the lower end of the annual production range, monitored between 1998 and 2005 (12,811-60,569 smolts). When compared to the 2006 escapement, the smolt production in 2007 indicates the lowest survival of smolts since 1998 (estimated to be <1% to the Cedar River smolt trap compared to the existing range of 1.2-8.8 % smolt survival). It is likely that production of Chinook salmon fry will also be low in 2007. Overall, the relative influence of the November 2006 flood on the success of the 2006 brood year will not be known until the surviving adults return to spawn over the next three to five years (2009-2011).

While 2006 flooding appears to have substantially affected Chinook egg-to-smolt survival in the Cedar River, the Technical Committee recommends maintaining the current Cedar River salmon recovery strategy that focuses on mainstem river habitat protection and restoration.

- Maintaining the current strategy focuses recovery actions within the preferred habitats of Chinook, which due to their large size; predominately use the mainstem Cedar River for spawning and incubation. Spawning surveys show that low numbers of Chinook use tributaries, and use appears to be mostly opportunistic by hatchery-origin fish.
- A number of WRIA projects increase flood plain areas and access, which is also important for reducing the severity of scour and hence egg mortality.
- While there are short-term negative impacts of flooding, there are also long-term flooding benefits from creation of new habitats, delivery of spawning gravels, and incorporation of woody debris for habitat formation.

A better understanding of the complex influence of flow and habitat on Chinook productivity can facilitate better management and decision-making, especially with respect to management of effects from peak flooding versus duration. On-going efforts by the Cedar River Instream Flow Commission and others to study flow, scour, and Chinook survival are highly supported.

Introduction

After the Election Day 2006 November flood, many were concerned about the effects of flooding in the Cedar River on Chinook salmon. While most western Washington rivers were affected by floods during November 2006, the extent of flooding was actually highly variable. Lowland streams that originate in foothills and the glacial Puget Sound plateau (many in urbanizing areas) were little affected because the intensity, location, duration and precipitation type (rain, snow, rain-on-snow) did not favor flooding. On the other hand, the Skykomish River, draining the North and South forks near the town of Index experienced the “Flood of Record” at Goldbar.

Locally, the magnitude of flooding on the Cedar River was great, but by no means extreme, especially compared to the historical record of peak flows (Figure 1). Nearby, in Kelsey Creek, Bellevue, the peak flow on November 6, 2006 was 282 cubic feet per second (cfs), a rather “small” event for this creek by recent observations. Relatively speaking, the Chinook salmon in this part of the watershed would have been impacted much less. The variability in flooding itself highlights the importance of Chinook salmon spatial distribution and life history variability that creates population resilience to events that may cause localized or temporary impacts, even large ones.

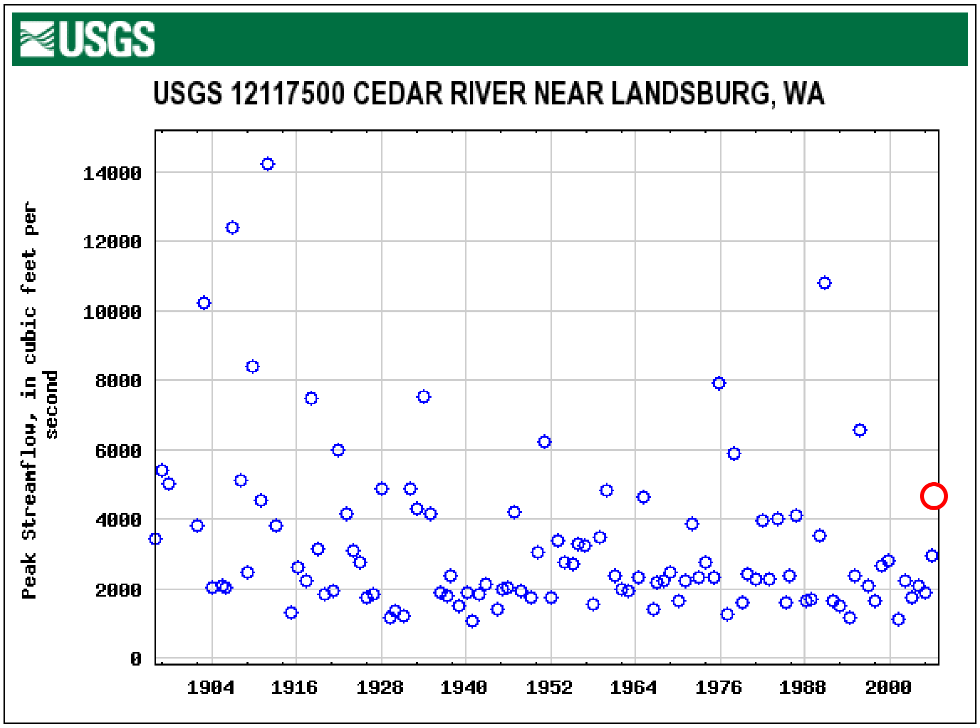

Figure 1. Cedar River peak flows at Landsburg. The last, larger open circle represents the daily average magnitude of flow (4310 cfs) November 9,2006. Although the instantaneous flow magnitude was greater than this value and also at Renton, Landsburg flows are shown here for historical flow context. Source – USGS.

<u>Flooding as a Habitat-Forming Process</u>

In natural alluvial channels, flooding plays a large role in forming and maintaining instream and floodplain habitat. Flooding recruits and transports sediment and woody debris, recharges shallow floodplain aquifers, and forces channel migration. In turn, these flood-related events help to create side channels, gravel bars, wide floodplains and other valley-floor habitat features, each of which helps to store flood waters and dissipate flood forces. As a result, flooding increases the complexity of floodplain and in-channel habitats. Plant community succession, as well as fish and wildlife reproduction, rearing, migration and refuge, rely upon the habitat-forming processes of floods in floodplains. Indeed, salmon in the Pacific Northwest evolved under highly dynamic periodic floods. When they occur at natural rates and magnitudes and in settings that allow for physical channel and floodplain responses, floods are essential to the long-term sustainability of salmon.

Unfortunately, the habitat forming processes (i.e., flow, sediment and woody debris) in the Cedar River are severely impaired as a result of bank armoring, levees, floodplain development, channelization, and flow regulation. The Cedar River occupies only 37% of its former pre-development active channel area (Collins et al. 2003), and 64% of its length is confined by revetments. Its channel width is less than half its historic width with fewer side-channels and less braiding (Perkins 1994). These changes exacerbate the effects of flood flows on egg-to-fry survival of salmon. In addition, Cedar River peak flows are managed to reduce impacts to incubating salmon and human activities and infrastructure in the floodplain (by limiting flood inundation), with resulting implications for flooding induced habitat formation and for stream bed scour.

Cedar River Chinook Spawning Distribution

Cedar River Chinook salmon primarily use the mainstem river for spawning (90-98% by year; Table 1). Among the lower Cedar River tributaries, spawning use is generally less than 5%. In 2006, a larger escapement year, only one Chinook salmon redd was observed among Peterson, Rock, Taylor and Walsh creeks combined. Since mass marking began, spawning in Cedar River tributaries and above Landsburg (2003-2006) generally indicates higher use by hatchery straying adults (although, preliminary data from fish passage at Landsburg in 2007 appears to be much lower). Although success by fewer fish using tributaries cannot be discounted as an important contribution to the overall population, other factors such as higher hatchery-origin spawning, variability in flows affecting seasonal access, and overall low abundance relative to the mainstem Cedar River, suggest contribution to population recovery will be based on annual circumstances and seeding of capacity that is driven by mainstem or hatchery abundance.

Table 1. Recent percentage distribution of Chinook salmon redds among major Cedar River spawning areas.

Year	2001	2002	2003	2004	2005	2006
Mainstem above Landsburg:%	0.0	0.0	4.5	3.9	2.7	4.6
Lower Cedar River Tributaries: %	2.0	4.3	5.4	4.1	2.4	0.2
Mainstem below Landsburg: %	98.0	95.7	90.2	92.0	95.0	95.2

Impacts of Flooding on Salmon

When thinking about the effects of flooding on salmon, the magnitude, timing and duration of the flood are important. Magnitude describes the peak of the flood and is when maximum flooding (inundation) occurs. As shown in Figure 1, peak flooding is easily quantified and generally is believed to represent a significant threat to salmon productivity, as a function of streambed scour (direct mortality) on incubating sockeye and Chinook salmon eggs. Migrant trap studies of Chinook in the Skagit River have shown a strong negative relationship between peak flow and percent survival. However, years of monitoring sockeye salmon fry production in the Cedar River shows that there is no readily interpretable relationship between survival (to the downstream trap) and annual daily peak flow up to 4000 cfs (Figure 2 data points from Kiyohara and Volkhardt 2007). The greatest uncertainty regarding effects of peak flow on survival occurs at or above 1800 cfs. It is possible that a threshold of effect may exist that limits spawning and incubation success under certain flood conditions and may resemble the hypothetical line fit shown in Figure 2. This line fit is based both on the existing variability and the likelihood of quickly declining survival as gravel is mobilized from flooding at some threshold level. This concept is supported by data from a scour monitoring study conducted in 1990. That study found that, over a range of burial depths form 0.25 feet to 0.75 feet, approximately 11% of the scour monitors were dislodged at flows between 1860 and 2170 cfs; 28% of the scour monitors were dislodged (regardless of burial depth) at flows less than 3000 cfs; and 60% of the monitors were not dislodged until flows exceeded 3500 cfs (data reported in: Final Report: Cedar River Instream Flow and Salmonid Habitat Utilization Study, Cascades Environmental Services, Inc. 1991, Section XII – Risk Zone Analysis). Referring to the survival data again, for flows greater than 4000 cfs (occurring every five to ten years), the relationship is highly influenced by one large flood event (>7000 cfs), which probably represents a very real effect on egg survival from gravel scour at that flood magnitude.

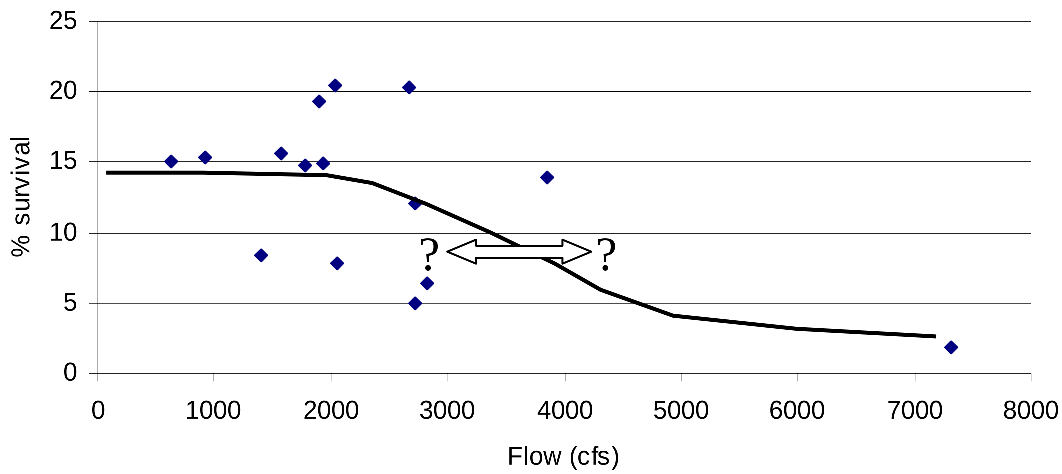

Figure 2. Depiction of alternative line fit to sockeye salmon survival data points from Kiyohara and Volkhardt (2007). Decreasing survival likely occurs relative to increasing flows, but where a “threshold” of effect occurs is unknown, but likely at flows no less than approximately 2600 cfs (1.5-year flood, Perkins Geosciences 2002).

For Chinook salmon, the results may be similar, although data from the larger flood event (>7000 cfs in 1990) are not available for Chinook salmon (from data in Kiyohara and Volkhardt 2007). While the Chinook survival data presented by Kiyohara and Volkhardt (2007) provides useful estimates of egg-to-emigrant survival, it is much less useful as a measure of incubation (egg to emergence) survival. Because a significant number of juvenile Chinook remain to rear in the Cedar River for up to three months before emigrating (unlike most newly emerged sockeye which move to the lake within 24 to 48 hours after emergence from their redds), this survival data also includes the effects of natural mortality during this extended rearing period, after the completion of incubation in the gravel. The relationship between survival and peak flow in the Cedar River is further complicated by flow management that artificially reduces peak flooding but increases flow duration (see below) – representing a trade-off between flood responses that both have an influence on scour. Given continued uncertainty for management application, the Cedar River Instream Flow Commission, as part of its supplemental study program, is working to frame approaches to enhance our current understanding of flow and scour.

Flood timing is important seasonally because flooding may affect fish during spawning (as in 2006) and while incubating eggs are physiologically more susceptible to disturbance prior to water-hardening. The significance of these effects may be due in part to the timing of the flood, which occurred during a record rainfall event early in November. Only once (1906) since peak flow records have been kept (106 peak flood events dating back to 1896) at Landsburg has an event of greater magnitude occurred so early in November (Figure 3). It will be useful to review precipitation and temperature predictions of Pacific Northwest climate change, coupled with an assessment of river and reservoir management goals to evaluate potential effects to spawning, incubation and rearing success.

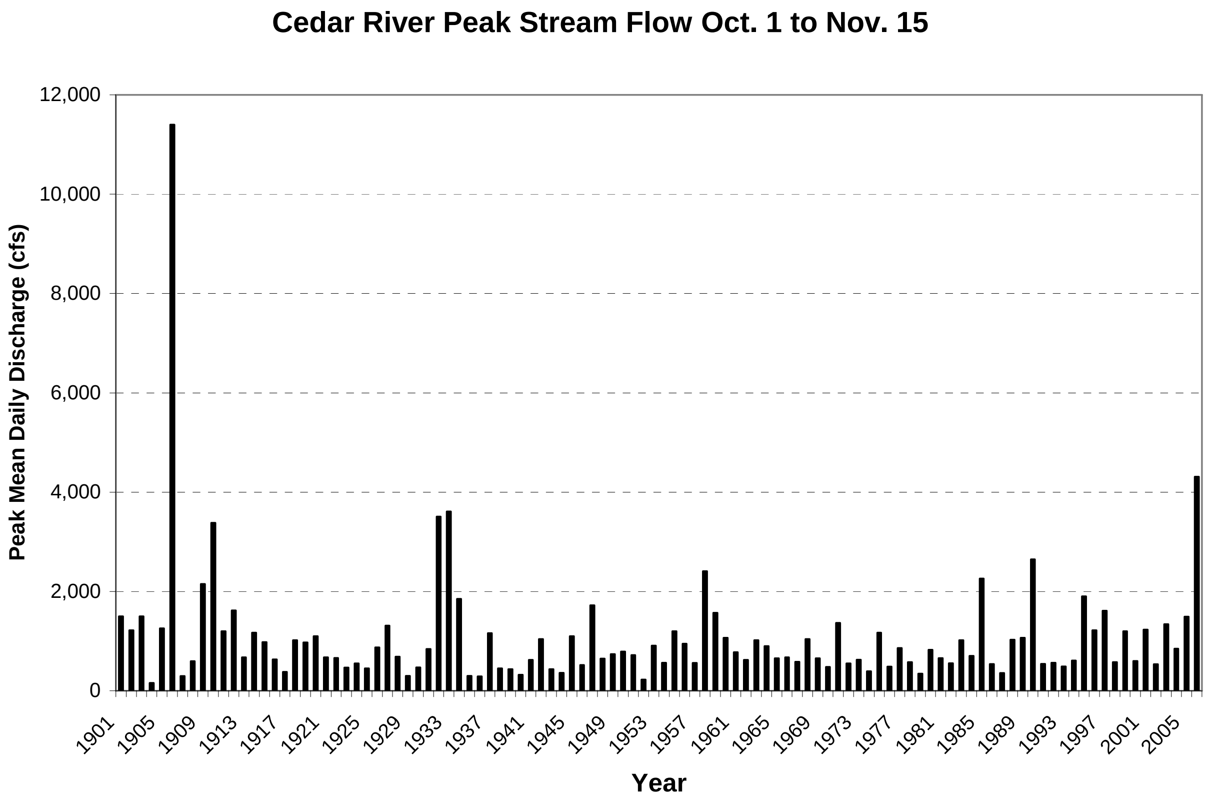

Figure 3. Historic summary of Cedar River peak mean daily discharge between October 1 and November 15. The November 2006 flood is represented by the last bar. USGS data from stream gage 12117500. Figure provided by Seattle Public Utilities.

Flooding duration can influence bed scour, streambank erosion, and channel migration, as well as have biological consequences because these impacts occur over a longer period of time, and habitats in more constrained or managed rivers are more likely to be negatively impacted. Revetments and levees that disconnect river channels from their floodplains, focus the “energy” (force x time) of a flood into the river’s main channel bed and banks. Conversely, unconstrained systems allow flood energy to dissipate into floodplains where flood inundation can create new habitats and reconnect old habitats with the main channel. Regulated flow regimes (often meant to mitigate the extreme magnitude of floods on people) may actually increase flooding duration that nevertheless acts to scour and erode rivers, especially if flows are artificially maintained at or near bankfull flow (where forces are at a maximum). Therefore it makes sense to estimate in-river survival based on flow duration as well as peak flow.

During the 2006 flood event, much flood water was stored above Chester Morse to limit peak flooding (Figure 4). After the storm, this stored water was released gradually to restore flood storage capacity prior to the arrival of subsequent storms. Although releases resulted in discharges that were well below the level of unregulated flows and below the actual peak flows that occurred during the storm event, actual discharge may have contributed to scour downstream. At Renton, discharge exceeded 4000 cfs for 8 days. Instead of one intense wave of flooding (with great inundation but briefer erosion potential), a lower flood magnitude was artificially sustained at levels (>4000cfs) problematic for scour over many days. This “trade-off” between peak flooding and duration (both contributing to scour potential) represents uncertainty for management application. The Instream Flow Commission studies are expected to inform flood control operations to potentially increase benefits to salmonids.

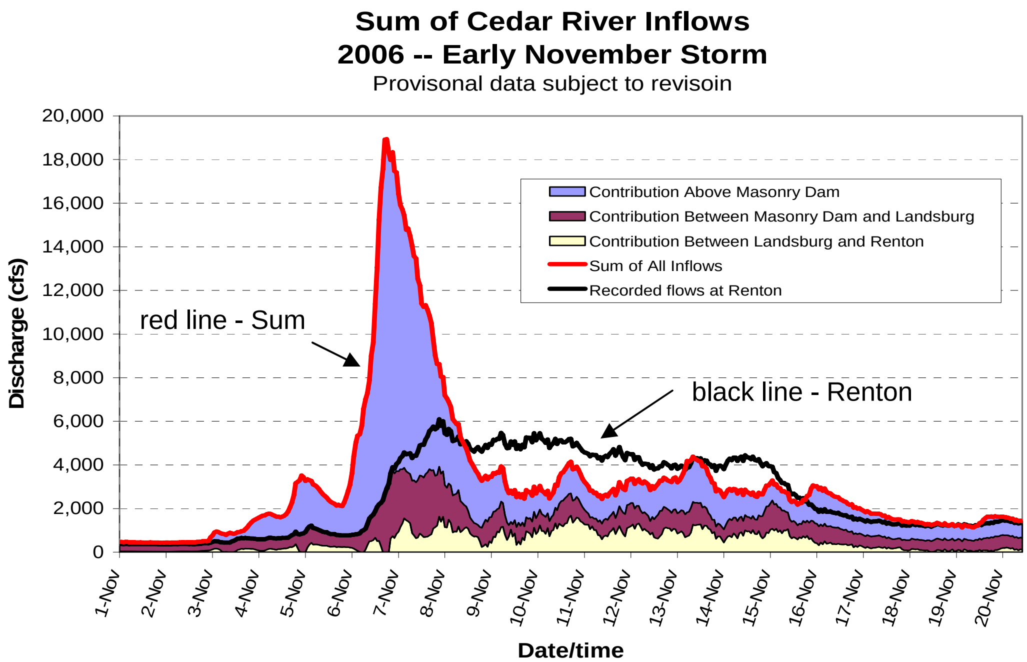

Figure 4. Cedar River November 2006 storm estimated inflow and discharge at Renton. Generally, the difference between the peak inflow (red line) and the actual discharge at Renton (black line) represents the reduction in flood magnitude due to storage at Chester Morse. The subsequent Cedar River flow at Renton (black line) that exceeds the inflow (red line) during the following days represents protracted flow duration. Figure provided by Seattle Public Utilities.

Regardless of the “trade-off” mentioned, scour likely was greatest in areas with high gradient and confinement (by levees or natural conditions). At these locations, the reduction in channel width likely results in deeper scour for greater duration at a given peak flow. The areas where salmon were least affected by scour would have been the tributaries, side-channels and otherwise lower-gradient, unconfined reaches of the lower mainstem Cedar River (supported by conclusions drawn from Perkins Geosciences 2002). These areas are also likely to provide the best rearing habitat. Since Chinook salmon spawn in the Cedar River (Table 1) among a range of gradient and confinement conditions, effects by exact spawning location are uncertain and incubation survival can also be affected by deposition (termed aggradation) of gravel scoured from elsewhere.

<u>Reducing the Impacts of Flooding – Implications for the Salmon Plan Strategy</u>

Given the spawning distribution of Cedar River Chinook salmon, increasing the priority of tributaries in the recovery plan strategy would not likely result in increased Cedar River habitat capacity, quality and quantity, nor contribute meaningfully to Chinook spatial distribution or diversity in the Cedar River. Although the Cedar River does not represent a completely natural system, restoration benefits will disproportionately accrue to the population for actions taken in the mainstem Cedar River. This does not imply that Cedar River tributaries are unimportant to Chinook salmon directly or indirectly (via flow, temperature, sediment and geomorphologic confluence interactions), however, projects in the mainstem will have more immediate and valuable benefits for Chinook.

The most important way to reduce risk to Cedar River Chinook incubation and rearing from flooding impacts is to increase mainstem floodplain capacity through such actions as levee removal, levee setback, and side channel enhancement. These actions would reduce flooding effects on incubating and rearing salmonids no matter what the flood control operations are likely to be, and improve the potential for habitat forming processes to function at a greater level in the Cedar River. A secondary response could be to minimize flooding through peak flow management if flooding duration below scour thresholds can also be accomplished. While reducing peaks flows through flow management can benefit incubating eggs, such activities can also impair other life stages (such as smolts) that need the habitat characteristics that flooding produces. Pursuing aggressive river restoration may allow for relaxed flood management for fish and offer the flood benefit of diverse and complex natural habitats that support the widest variety of species and life-history adaptations, and that contribute to the resilience of populations as well as the ecosystem itself.

Lastly, a better understanding of the complex influence of flow and habitat on Chinook productivity can facilitate better management and decision-making. The WRIA 8 Technical Committee supports on-going efforts by the Cedar River Instream Flow Commission and others to pursue studies of flow, scour, and Chinook survival. The Technical Committee also believes that it would be useful to investigate how flow and flooding affect the creation and connectivity of side-channels, as well as the role these habitats play in salmon productivity and in mitigating flooding effects. Monitoring the population provides fundamental information for assessing effects of annual disturbances (like the November 2006 flood) on early life stage survival and tracking the status and trends of the populations over time.

References

Cascades Environmental Services, Inc. 1991. Final Report: Cedar River Instream Flow and Salmonid Habitat Utilization Study. Section XII – Risk Zone Analysis.

Collins, B, A Sheikh and C Kiblinger. 2003. Historical River Channel Data for the Cedar River. Report to King County Department of Natural Resources and Parks.

Kiyohara, K. and G. Volkhardt. 2007. Evaluation of Downstream Migrant Salmon Production in 2006 from the Cedar River and Bear Creek. Washington Department of Fish and Wildlife Olympia, Washington 98501-1091.

Perkins Geosciences. 2002. Cedar River Gravel Study Phase 2 report. Prepared for U.S. Army Corps of Engineers, Seattle District and Jones and Stokes, Bellevue WA. August 2002.

Perkins, S.J., 1994. The Shrinking Cedar River -- Channel changes following flow regulation and bank armoring. In: Proceedings, Effects of Human-Induced Changes on Hydrologic Systems, American Water Resources Association 1994 Annual Summer Symposium, 1994, p. 649-658.