CEDAR RIVER INSTREAM FLOW MANAGEMENT
September 5, 2001 IFC Committee Meeting

BIOLOGICAL MONITORING AND RESEARCH

❑ Objectives:

- Continue to increase our understanding of the relationships between stream flow and habitat conditions in the Cedar River, with an emphasis on chinook salmon and other naturally reproducing salmonids

- Support effective allocation of the "firm" and "non-firm" blocks of water during the summer

- Help guide the allocation of available water above guaranteed levels

- Help address several remaining technical issues that emerged in the later stages of the HCP development

PROPOSED SUPPLEMENTAL STUDY QUESTIONS

Background for Study Topics #1 and #2:

Instream flow management in the Cedar River during the late winter and spring is relatively complex. Managers attempt to balance a variety of objectives during this period including biological concerns in the reservoir and lower river, flood management, reservoir refill, ongoing municipal water supply and inflows to Lake Washington. The primary biological concerns during this time include salmon incubation, sockeye fry emigration, steelhead spawning and incubation, chinook rearing and emigration in the lower river and bull trout redd inundation and loon nesting in the reservoir. Substantial information is available to the Commission on all these biological topics with the exception of chinook rearing and emigration conditions. Collaborative PHABSIM analyses have been conducted in an attempt to describe the effect of stream flow on juvenile chinook rearing habitat. While helpful, these analyses are generally believed to be incomplete. In addition, we know relatively little about how Cedar River juvenile chinook deal with the effects of having had a large natural lake placed in their migration pathway.

Additional information will help the Commission better integrate the needs of juvenile chinook into the complex set of instream flow management considerations during the late winter and spring. Study Topics #1 and #2 are directed toward improving our understanding of the early life history of Cedar River chinook salmon and the effects of stream flow on life history patterns and survival**.** We would like to know what effects stream flow has on the early life history of juvenile chinook, and the effects of stream flow on rearing and emigration survival. We would also like to know the degree to which life history pattern effects survival from fry to smolt and/or adult.

Ideally, several data points, collected on an annual basis, could tell us most of what we might want to know about the relationships between instream flow management in the Cedar River and the behavior and survival of juvenile chinook. These data points may be very difficult or impractical to obtain but should be used as reference points when developing alternative investigative approaches.

1. Total number of chinook fry emerging from the gravel (or marked fry planted in the Cedar?).
2. Number of chinook successfully emigrating to Lake Washington as newly emerged fry.

3. Number of emigrating, newly emerged fry that are lost to predation or other sources of mortality during downstream migration to Lake Washington.
4. Number of larger "pre-smolts" successfully emigrating to Lake Washington.
5. By subtracting 2. + 3. + 4. from 1. we can potentially obtain an estimate of total in-river juvenile chinook mortality during rearing and subsequent "pre-smolt" emigration.
6. Survival of newly emerged fry emigrants from the time they enter the lake until they exit as smolts and overall survival until they return as adults.
7. Survival of larger "pre-smolts" from the time they enter the lake until the exit as smolts and overall survival until they return as adults.

Study Topic #1: The effects of stream flow on the migratory response of recently emerged chinook and sockeye fry and chinook fingerlings

Suggested Study Objectives:

- Investigate the effects of stream flow on the downstream migratory behavior of chinook fry and fingerlings.

- Investigate the effects of stream flow on the in-river emigration survival of chinook fingerlings and newly emerged sockeye fry.

Study Question 1a:

Are the numbers of recently emerged chinook fry that arrive at the fry trap in the Cedar River at Renton correlated with stream flow?

Potential study approach:

- Examine past and future daily chinook fry emigration data and flow records to ascertain the degree of correlation between stream flow and fry emigration.

Assumptions:

- At stream flows below scour thresholds, fry emergence from the gravel is independent of flow.

- The effects, if any, of interannual variations in spawning time can be sorted out of the analysis.

Study Question 1b:

To what degree does stream flow affect the in-river emigration survival of wild sockeye fry originating from different locations throughout the river?

Potential study approach:

- Continue to release marked sockeye fry at various locations throughout the lower river to assess the effect of longitudinal release location and instream flow on survival to the fry trap.

- To help assess the emigration survival of newly emerged chinook salmon fry and to better account for those chinook fry that are lost during emigration versus those that remain in the river to rear, the suggested study approach uses sockeye fry emigration mortality as a surrogate for newly emerged chinook fry emigration mortality.

- Use past work conducted by USFWS on the Cedar to determine the relative vulnerability of hatchery and wild fry to predation in the Cedar River. If the incidence of wild and hatchery fry in the stomachs of predators is similar to their relative abundance in the river, then vulnerability to predation is likely similar for the two groups. If not, then relative rates of predation can be adjusted to estimate independent predation rates for each group.

- Adjust, if necessary, wild fry emigration survival estimates using the results of the two investigations described above.

Assumptions:

- The relative incidence of hatchery and wild fry in the stomachs of fish predators in the Cedar River is an accurate representation of the total relative rates of emigration mortality experienced by wild and hatchery fry.

- Wild sockeye fry emigration mortality provides a reasonable approximation of the mortality experienced by newly emerged chinook fry during emigration from the river.

    - Newly emerged chinook fry are significantly larger than sockeye fry and may experience different predation rates.

    - Newly emerged chinook fry may behave differently than newly emerged sockeye fry and may therefore experience different predation rates.

Notes:

- Is there a potential “breakpoint” in the correlation between stream flow and emigration survival? For example: If the survival of fry that don’t make it to the trap on the first night after emergence is markedly lower than that of fry that do arrive at the lake on their first night; then one would expect a “breakpoint” effect at flow levels that are below the level required to get most of the fish to the lake on their first night.

- Because of the complex early life history of ocean–type chinook, it is difficult to assess the affects of stream flow on chinook fry emigration survival. Unlike sockeye, a significant portion of the emergent chinook fry population may elect to either rear in the river for an extended period of time before moving downstream, or may gradually move downstream over a period of several days. Therefore, it will be difficult to distinguish between mortality experienced during emigration and that which is experienced while rearing in the stream. The mortality of emigrating sockeye fry may possibly be an acceptable surrogate for the mortality of emigrating newly emerged chinook fry.

Study Question 1c:

Is in-river emigration survival of chinook parr correlated with stream flow?

Potential study approach:

- Capture, pit tag and release migrating chinook parr/smolts in the upper river.

- Recapture tagged migrating chinook parr/smolts in the screw trap near the mouth of the river in Renton.

Assumptions:

- Sufficient numbers of migrating chinook parr/smolts can be captured and marked to provide meaningful results.

- Migrating fish captured in the upper river are destined continue migrating to the lake within a relatively confined time period rather than interspersing relatively short migrations with extended periods of rearing.

- Pit tagging and associated handling does not significantly effect migration behavior or migration survival.

- Potential incidental take associated with capturing and tagging wild Cedar River chinook is permitted.

- Using coho smolt trapping efficiency as an acceptable surrogate for chinook smolt trapping efficiency

- The size threshold of 75 mm for pit tagged smolts will not significantly effect results.

<u>Study Topic #2:</u> The effects of size of juvenile chinook and timing of entry into Lake Washington on survival to smolt and/or adult

Suggested Study Objectives:

- Compare the in-lake survival to smolt of juvenile chinook that enter Lake Washington as newly emerged fry in February and March with those that enter the lake as fingerlings in May and June after an approximate in-river rearing period of 3 months.

- Compare the overall survival to adult of newly emerged chinook that rear in the river for up to approximately 3 months with newly emerged fry that move directly downstream into Lake Washington.

Study Question 2:

Is chinook survival to smolt and adult correlated with early life history strategy?

Study approach A:

- Continue to enumerate the number of chinook fry and parr/smolt that emigrate from the Cedar River.

- Recover otoliths from chinook carcasses in the Cedar River.

- Attempt to make use of otolith reading techniques to determine the relative proportions of the various juvenile life history patterns in adult chinook that return to the Cedar River. Recent work on the Skagit suggests that this approach can potentially yield useful results in some systems.

Assumptions:

- Banding patterns in otoliths recovered from adult chinook that have reared as juveniles in the river for an extended period before emigration can be distinguished from those that have moved quickly from the river and have reared as juveniles in the lake.

Note: While one early life history strategy may be a dominant contributor to the adult population over a set period of time, other life history patterns may also be important in ensuring that the population has the capacity to adapt to changing environmental conditions. A variety of life history patterns may help the population persist during periods of environmental anomaly that may adversely affect the normally dominant life history pattern.

Study approach B:

- Continue to enumerate the number of chinook fry and parr/smolt that emigrate from the Cedar River.

- Tag a cross section of the chinook fry outmigration with half-sized coded wire tags (CWT). This technique was successfully tested in 2000. The adipose fin is not clipped.

- Tag a cross section of the smolt outmigration with a different tag. This could be a full sized CWT, a PIT tag, or any of a number of distinct marks. PIT tags would be advantageous for other studies in the basin and would be preferred.

- Interrogate juvenile chinook caught along the shore of Lake Washington for tags using a pit tag detector and a CWT detector. Fish can be released with minimal handling.

- Interrogate juvenile chinook caught at the Ballard Locks in a similar manner. WDFW is committed to sampling smolts at this location in order to estimate total smolt outmigration numbers.

- Sample all returning adults two, three, and four years after the juveniles are tagged.

Assumptions:

- As with any study of Cedar River chinook, the success of the endeavor is dependent upon the number of fish available. The largest assumption in this study is that enough fry can be tagged to allow for sufficient numbers to be subsequently recovered. This problem is mediated somewhat by sampling at several life history stages when the fish are more abundant. This is not possible with otolith sampling which depends on getting enough carcasses of returning adults two to four years later.

<u>Study Topic #3:</u> Distribution, abundance and habitat preferences of rearing juvenile chinook in the mainstem Cedar River, with emphasis on the interactions of these factors with stream flow

Suggested Study Objectives:

- Develop rearing habitat suitability criteria for appropriate size and age categories of juvenile chinook.

- Investigate the effects of stream flow on juvenile chinook rearing habitat suitability and availability.

- Investigate the effects of stream flow on juvenile chinook distribution and rearing habitat preferences.

Study Question 3a:

What is the preferred rearing habitat of juvenile chinook in the Cedar River and how is it affected by stream flow.

Potential study approach:

- Continue and expand ongoing juvenile rearing habitat assessment work to develop robust habitat suitability criteria for at least two size-classes of juvenile chinook.

- Integrate the habitat suitability criteria for each size-class with stream channel morphology and conditions at varying flow levels to asses the affect of stream flow on juvenile chinook rearing habitat availability.

Assumptions:

- Habitat preferences for rearing juvenile chinook can be characterized in a manner that supports a relatively accurate assessment of the effects of stream flow on available rearing habitat.

- Habitat preferences will incorporate the effects of predation risk and other factors that my influence habitat selection.

Study Question 3b:

What is the relationship between stream flow and connection to existing and potentially restorable off-channel areas and other important lateral rearing habitats?

Potential study approach:

- Delineate the location and relative abundance of potential off-channel and other important lateral and mid-channel juvenile salmonid rearing habitats. Determine the affect of stream flow on these habitats and the degree to which they remain connected to the main channel.

Assumptions:

- We can adequately characterize and quantify the relative value of different types of rearing habitat preferences for various sizes and species of juvenile salmonids.

<u>Study Topic #4:</u> Behavioral response of adult chinook and sockeye salmon to changes in stream flow and the operation of sockeye broodstock collection facilities

Suggested Study Objectives:

- Investigate the effects of stream flow on adult chinook in-river migration behavior.
- Investigate the effects of stream flow on adult chinook spawning site location.
- Assess the confounding effects, if any, of the operation of the Cedar River sockeye broodstock collection facility on adult chinook migration behavior and spawning site location.

Study question 4a:

What is the effect of stream flow on the temporal and spatial distribution of chinook spawning activity in the Cedar River?

Potential study approach:

- Continue ongoing chinook redd surveys throughout the river. Record spawning time, location, depth, velocity, 2-day (?) antecedent stream flow, water temperature, barometric pressure, rainfall and cloud cover.

Assumptions:

- Over time, the effects of stream flow on spawning distribution can be isolated from other factors that may influence time and location of chinook spawning.
- Sockeye broodstock collection activities do not significantly effect chinook spawning time and location.

Study question 4b:

What, if any, are the confounding effects of the sockeye broodstock collection activities on the temporal and spatial distribution of chinook spawning activity in the Cedar River?

- Continue to asses the distribution of adult chinook salmon and chinook salmon redds upstream and downstream of the sockeye broodstock collection facility to assess potential confounding effects, or lack thereof, of the facility on chinook migration and spawning distribution.

Study question 4c:

What is the effect of stream flow in the Cedar River on the spatial and temporal distribution of Cedar River adult chinook migration and final maturation in the Lake Washington Basin?

Potential study approach:

- Augment ongoing chinook redd surveys and live counts with snorkel surveys in key chinook holding areas. Record time, location at the time of siting, 2-day (?) antecedent stream flow, water temperature, barometric pressure, rainfall and cloud cover.

Assumptions:

- Over time, the effects of stream flow on migration and final maturation can be isolated from other factors that influence adult chinook behavior just prior to spawning.

<u>Study Topic #5:</u> Analysis of the potential impacts of stream flow at Landsburg on water temperature at the mouth of the river and in Lake Washington

Suggested Study Objectives:

- Investigate the effects of stream flow as measured at the USGS gage below Landsburg on water temperature in the river near the river mouth at Renton.
- Investigate the effects of stream flow as measured at Renton on water temperature in Lake Washington.

Study Question 5a:

To what degree is water temperature in the Cedar River at Renton correlated with stream flow as measured at Landsburg within the normal range of stream flows and water temperatures that occur during the late summer and early fall?

Potential study approach:

- Review existing stream flow, water and air temperature records to assess the degree to which water temperature at the mouth of the river might be correlated with stream flow as measured at Landsburg.
- Reestablish water temperature measurements at the USGS stream gage below the Landsburg diversion.
- If deemed appropriate, use past and future temperature and stream flow data to model the effects of stream flow on water temperature in the Cedar River during the late summer and early fall.

Assumptions:

- The water temperature effects of changing riparian conditions, and possible alterations in groundwater input on stream temperature can be separated from the effects of stream flow.

Study Question 5b:

To what degree is water temperature in Lake Washington, including any localized effects associated with the Cedar River plume, correlated with stream flow as measured at Landsburg within the normal range of stream flows and water temperatures that occur during the late summer and early fall?

Potential study approach:

- Review existing stream flow, water and air temperature records to assess the degree to which water temperature in Lake Washington might be correlated with stream flow as measured at Renton.

- If deemed appropriate, use past and future temperature and stream flow data to model the effects of stream flow as measured at Renton on water temperature in Lake Washington during the late summer and early fall.

Assumptions:

- The water temperature effects of changing riparian conditions, possible alterations in groundwater input on stream temperature and stream flow elsewhere in the basin can be separated from the effects of stream flow.

- Water temperature is believed to be an important factor affecting fish.

Notes:

- Study question 5b will need to consider potentially complex and circulation patterns in Lake Washington. Investigations of this question may include collection of additional information on Lake Washington circulation patterns.

<u>Study Topic #6:</u> **Analysis of the potential effects of spring and early summer stream flows measured at Landsburg on water velocity vectors, water residence time, and the behavior and survival of emigrating juvenile salmonids in Lake Washington**

Suggested Study Objectives:

- Investigate the effects of stream flow (as measured at Landsburg), within the normal range of flows that might be expected in the spring and early summer, on velocity vectors and water residence time in Lake Washington.

- Investigate the effects of stream flow (as measured at Landsburg), within the normal range of flows that might be expected in the spring and early summer, on the behavior and survival of emigrating juvenile salmonids in Lake Washington.

Study Question 6a:

To what degree are velocity vectors and turnover rate in Lake Washington correlated with flow in the Cedar River as measured at Landsburg and Renton?

Potential study approach:

- Use historic Cedar River stream flow data and in-lake stratification and circulation information to model the effects of stream flow on potential velocity vectors along the shores of Lake Washington and the Ship Canal.

- Use historic Cedar River stream flow data and in-lake stratification and circulation information to model the effects of stream flow on lake turnover rate.

Assumptions:

- Circulation patterns in Lake Washington can be sufficiently characterized to adequately adjust for the effects of any "short circuiting" that may exist in the lake.

Study Question 6b:

What are the effects of stream flow in the Cedar River as measured at Landsburg and Renton, dishcharge at the locks, and lake level management on the behavior and survival of emigrating juvenile salmonids in Lake Washington, including the ship canal?

Potential study approach:

- Capture and mark juvenile salmonids as they exit the Cedar River. Attempt to recapture these fish in the nearshore area as the migrate through Lake Washington and as they pass through the locks.

- Attempt to correlate changes in distribution in the lake, migration time and survival to the locks with changes in Cedar River stream flow, changes in discharge at the locks and management of Lake Washington water level.

Assumptions:

- Sufficient numbers of fish can be appropriately marked and subsequently recaptured to provide statistically meaningful information.

- The effects of flow through the lake can be distinguished from other factors that may be effecting juvenile fish behavior and survival in Lake Washington.

<u>Study Topic #7:</u> Vulnerability of chinook salmon and sockeye salmon to redd scour

Suggested Study Objectives:

- Assess the relative overall effects of peak flows on chinook and sockeye redd scour.

- Investigate the degree to which redd location in the channel effects redd scour vulnerability.

Study Question 7:

To what degree is scour of chinook and sockeye redds correlated with the magnitude and duration of peak flow events in the Cedar River? To what degree is scour correlated with redd position in the stream channel?

Potential study approach:

- Continue current and past radio transmitter studies to estimate the flows at which specific redds at various locations in the channel scour to a depth that can impact incubating eggs and alevins.

Assumptions:

- Dislodgment of buried, neutrally buoyant radio transmitters is a sufficiently accurate surrogate for damaging bedload movement associated with peak flow events.

Study Topic #8: The potential effects of redd superimposition on the survival of sockeye and chinook eggs and alevins

Suggested Study Objectives:

- Investigate the effects of sockeye spawning activity on previously established chinook and sockeye redds.
- Assess the relative impact of varying spawning population size on the tendency for sockeye spawning activity to affect previously established chinook and sockeye redds.
- Investigate the effects of chinook spawning activity on previously established chinook redds.
- Assess the relative impact of varying spawning population size on the tendency for chinook spawning activity to affect previously established chinook
- Investigate the relationship between stream flow and the incidence of redd superimposition.
- Investigate how flow management might potentially help reduce the incidence of redd superimposition.

Study Question 8:

Does superimposition of sockeye spawning activity on or near previously established chinook redds result in significant mortality of incubating chinook salmon?

Potential study approach:

- Document the incidence of sockeye salmon spawning on or near previously established chinook redds. (Note: This data will not provide information on the degree, if any, of actual impact on incubating chinook caused by the activity of sockeye that may spawn on a previously established chinook redd).
- Continue to monitor juvenile production from the Cedar River and attempt to detect correlation between abundance of spawning sockeye and chinook egg to emigrant survival.
- Investigate the depth of egg deposition in chinook and sockeye redds.
- If deemed appropriate and useful, trap and enumerate chinook fry emerging from redds exposed to sockeye superimposition and those that were not.

Assumptions:

- Egg to emigrant survival is an acceptable surrogate for egg to emergent fry survival.

- Methods can be developed to deal with variations in fecundity and fertility in different redds.

- Effects of superimposition can be segregated from the effects of redd scour and other factors effecting egg to fry survival.

- We will be able to develop and implement acceptable methods of measuring chinook egg deposition depth.

Study Topic #9: Further investigations of the relationship between hydrologic features and the structure and function of instream and riparian habitats in altered stream channels

Suggested Study Objectives:

- Investigate the degree to which present instream flow and flood management practices on the Cedar River may result in variations from unregulated stream flow patterns

- Investigate the degree to which current channel conditions in the Cedar River vary from conditions prior to development especially in terms of hydraulic characteristics, meso- and microhabitat characteristics.

- Explore approaches for understanding the integrated effects of stream channel and stream flow alteration on habitat conditions in the Cedar River

Study Question 9a:

In what ecologically significant ways do present regulated stream flows differ from historic unregulated flows in the Cedar River?

Study Question 9b:

In what ecologically significant ways have physical alterations to the channel and riparian corridor altered hydraulic characteristics, fish habitat characteristics and sediment dynamics from conditions that were present in the system prior to development?

Study Question 9c:

How do the integrated effects of stream flow regulation and alteration of the stream channel and riparian corridor affect habitat conditions in the Cedar River?

Potential study approach:

- Adapt the Richter et al. (1996) method for assessing hydrologic alteration to the Cedar River and perform a subsequent analysis of the potential effects of hydrologic alteration on important ecological parameters with particular reference to key aspects of salmonid ecology and habitat preferences.

- Develop and implement a methodology for assessing the degree to which the channel of the Cedar River has been altered and the potential effects of alteration

- Develop and implement a methodology for integrating the results of the assessment of hydrologic alteration with the results of the assessment of stream channel alteration to help improve our understanding of the effects of stream flow on habitat conditions in the Cedar River.

Assumptions:

- The features of the natural hydrograph and associated ecological processes are important characteristics to be considered in assessing salmonid habitat preferences.

- Sufficient information can be gathered to adequately guide the scaling of natural hydrologic features and associated ecological processes to altered channels with altered ecological processes.

Additional Questions for Consideration:

At the 1/3/01 IFC meeting, the group agreed that, with the exception of the questions regarding the estuary, most of these additional questions have been incorporated within the existing 9 study topics and associated study questions.

- What is the relationship between the flow at Landsburg and flow through the Ship Canal?
- What is the relationship between flow at Landsburg and the availability of water at the Locks for operating the smolt slides?
- What is the relationship between the flow at Landsburg and the slope of the salinity and temperature gradients in Shilshole estuary?
- What affect does an abrupt salinity/temperature gradient in the estuary have on returning adult chinook? On outmigrating smolts?
- What is the relationship between flow at Landsburg and travel time of chinook smolts migrating through Lake Washington and the Ship Canal?
- Does the relative abundance of adult sockeye salmon in the Cedar River have a significant effect on adult chinook salmon spawning site selection.

Study Question Prioritization Summary Table

Summary of responses from 7 out of 9 participants. Total scores represent the sum of the number of individual ratings for a specified priority level multiplied by appropriate point designation.

SUPPLEMENTAL STUDY QUESTION	HIGH (3 points)	MEDIUM (2 points)	LOW (1 point)	TOTAL POINTS
TOP PRIORITY: ***≥ 18 points and no "Low" ratings***				
Study Question 2: Is chinook survival to smolt and adult correlated with early life history strategy?	3,3,3,3,3	2,2	--	**19**
Study Question 3a: What is the preferred rearing habitat of juvenile chinook in the Cedar River and how is it affected by stream flow?	3,3,3,3,3	2,2.5	--	**19.5**
Study Question 3b: What is the relationship between stream flow and connection to existing off-channel areas and other important lateral rearing habitats?	3,3,3,3	2,2,2	--	**18**
Study question 4a: What is the effect of stream flow on the temporal and spatial distribution of chinook spawning activity in the Cedar River?	3,3,3,3,3,3	2	--	**20**

SUPPLEMENTAL STUDY QUESTION	HIGH (3 points)	MEDIUM (2 points)	LOW (1 point)	TOTAL POINTS
MEDIUM/HIGH PRIORITY: ***≤ 18 points, ≥ 15 points and ≤ 2 "Low" ratings***				
Study Question 1a: Are the numbers of recently emerged chinook fry that arrive at the fry trap in the Cedar River at Renton correlated with stream flow?	3,3,3,3,3	2	1	**18**
Study Question 1b: To what degree does stream flow effect the in-river emigration survival of wild sockeye fry originating from different locations throughout the river?	3,3	2,2,2,2	1	**15**
Study Question 1c: Is in-river emigration survival of chinook parr correlated with stream flow?	3,3	2,2,2,,2.5	1	**15.5**
Study question 4b: What is the effect of stream flow in the Cedar River on the spatial and temporal distribution of Cedar River chinook migration and final maturation in the Lake Washington Basin?	3,3	2,2,2,2,2	--	**16**
Study Question 7: To what degree is scour of chinook and sockeye redds correlated with the magnitude and duration of peak flow events in the Cedar River? To what degree is scour correlated with redd position in the stream channel?	3,3,3,3,3	2	1	**18**
Study Question 9a: In what ecologically significant ways do present regulated stream flows differ from historic unregulated flows in the Cedar River?	3,3,3,3	2,2	1	**17**
Study Question 9b: In what ecologically significant ways have physical alterations to the channel and riparian corridor altered hydraulic characteristics, fish habitat characteristics and sediment dynamics from conditions that were present in the system prior to development?	3,3,3,3	2.5	1,1	**16.5**

SUPPLEMENTAL STUDY QUESTION	HIGH (3 points)	MEDIUM (2 points)	LOW (1 point)	TOTAL POINTS
Study Question 9c: How do the integrated effects of stream flow regulation and alteration of the stream channel and riparian corridor affect habitat conditions in the Cedar River?	3,3,3,3,3	--	1,1	**17**

SUPPLEMENTAL STUDY QUESTION	HIGH (3 points)	MEDIUM (2 points)	LOW (1 point)	TOTAL POINTS
MEDIUM/LOW PRIORITY: ***< 15 points, > 10 points and ≤ 2 "High" ratings***				
Study question 4c: What, if any, are the confounding effects of the sockeye broodstock collection activities on the temporal and spatial distribution of chinook spawning activity in the Cedar River?	6	6	2.5	**14.5**
Study Question 6b: What are the effects of stream flow in the Cedar River as measured at Landsburg, dishcharge at the locks, and lake level management on the behavior and survival of emigrating juvenile salmonids in Lake Washington, including the ship canal?	6	2	4.5	**12.5**
Study Question 8: Does superimposition of sockeye spawning activity on or near previously established chinook redds result in significant mortality of incubating chinook salmon***?***	3	4	4	**11**

SUPPLEMENTAL STUDY QUESTION	HIGH (3 points)	MEDIUM (2 points)	LOW (1 point)	TOTAL POINTS
LOWEST PRIORITY: ***≤ 10 points and no "High" ratings***				
Study Question 5a: To what degree is water temperature in the Cedar River at Renton correlated with stream flow as measured at Landsburg within the normal range of stream flows and water temperatures that occur during the late summer and early fall?	--	2	7	**9**
Study Question 5b: To what degree is water temperature in Lake Washington, including any localized effects associated with the Cedar River plume, correlated with stream flow as measured at Landsburg within the normal range of stream flows and water temperatures that occur during the late summer and early fall?	--	2	6.5	**8.5**
Study Question 6a: To what degree are velocity vectors and turnover rate in Lake Washington correlated with flow in the Cedar River as measured at Landsburg?	--	4.5	5	**9.5**

SUPPLEMENTAL STUDY QUESTIONS

Study Scoping Outline

Study Topic #1: The effects of stream flow on the migratory response of recently emerged chinook and sockeye fry and chinook fingerlings

Study Objectives:

- Investigate the effects of stream flow on the downstream migratory behavior of chinook fry and fingerlings.
- Investigate the effects of stream flow on the in-river emigration survival of chinook fingerlings and newly emerged sockeye fry.

Study Question 1a:

Are the numbers of recently emerged chinook fry that arrive at the fry trap in the Cedar River at Renton correlated with stream flow?

Scope Elements

1. Work with Dave Seiler, WDFW, to obtain all past daily Cedar River chinook fry emigration estimates for the early part of the emigration period between late January and early to mid-April.
2. Obtain daily mean stream records for corresponding periods during the emigration.
3. Identify a range of appropriate statistical tools that may be used to examine the degree to which fry emigration rate is correlated with daily mean stream flow.
4. Apply appropriate statistical tools to evaluate the relationship between stream flow the number of emigrating chinook fry.

Study Question 1b:

To what degree does stream flow affect the in-river emigration survival of wild sockeye fry originating from different locations throughout the river?

Scope Elements

This study will use measurements of the number otolith-marked hatachery sockeye fry that successfully migrate downstream to the Cedar River fry trap to estimate the emigration survival of newly emerged, wild sockeye and chinook fry.

Study year 1: Effect of stream flow on the emigration survival of newly emerged sockeye fry.

1. Use chilled water at the Landsburg sockeye hatchery to place 9 different otolith marks on 9 distinct groups of at least 250,000 hatchery sockeye fry each. The first 3 groups should originate from 3 consecutive eggtake days during the first third of the spawning period, 3 groups from 3 consecutive eggtake days during the mid-point of the period and 3 groups from 3 consecutive days during the last third of the spawning period.

2. At a single release point near the middle of the river, release one marked group of fully developed, newly emerged fry during each of three consecutive nights night during the first third of the emigration period. During the first night provide stream flows of approximately 260 cfs (as measured below Landsburg), during the second night provide flows of approximately 550 cfs and on the third night provide flows of approximately 860 cfs. Perform the same release schedule during the mid-point in the emigration period and again during the last third of the emigration period.

3. Using the existing WDFW fry trapping program, enumerate the number of differentially marked fry arriving at the trap.

4. Using appropriate statistical tools, quantify the effect of stream flow on emigration survival.

Study year 2: Effect of longitudinal location on the emigration survival of newly emerged wild sockeye fry.

1. Use chilled water at the Landsburg sockeye hatchery to place 9 different otolith marks on 9 distinct groups of at least 250,000 hatchery sockeye fry each. Three groups should originate from the same eggtake day during the first third of the spawning period, 3 groups from the same day at the mid-point of the period and 3 groups from on the same day during the last third of the spawning period.

2. On a single night during the first third of the emigration period, release one differentially marked group of fully developed, emergent fry at each of 3 different locations spread throughout the river. Perform the same release schedule at the mid-point in the emigration period and again during the last third of the emigration period. Attempt to maintain stream flows at approximately the same level during each night of release and for 48 hours after the release.

3. Using the existing WDFW fry trapping program, enumerate the number of differentially marked fry arriving at the trap.

4. Compare the effect of longitudinal release location in the river marked fry survival to the fry trap. Use appropriate statistical methods to quantify the effect of longitudinal release location on emigration survival.

5. Use spawning survey data to determine the approximate distribution of sockeye redds in the Cedar River. Using the relationship between release location and emigration survival developed above, estimate the survival of rate of wild sockeye fry that emigrated during each of the three test nights.

6. Develop and implement a representative predator sampling program during each night of release to enumerate the number of wild and hatchery sockeye found in the stomachs of the major predators. Compare the relative proportions of wild and hatchery fry in predator stomachs with the proportions of wild and hatchery fry captured at the fry trap.

Study Question 1c:

Is in-river emigration survival of chinook parr correlated with stream flow?

Scope Elements

1. Using a screw trap, capture an appropriate number emigrating chinook smolts at a location near the mid-point of the river. On each of several nights, each with significantly different stream flows between 260 and 800 cfs, mark and release all captured fish with a distinct, externally detectable mark.

2. Recapture and enumerate the number of migrating smolts at the screw trap in Renton. (Note that, depending on the rate of emigration, marked smolts could continue to arrive at the trap for several days or more after release).

3. Radio tag a representive number of chinook smolts at the mid-river trap location and monitor their downstream movements to the fry trap. (Potential for tracking in the lake also).

Study Topic #2: The effects of size of juvenile chinook and timing of entry into Lake Washington on survival to smolt and/or adult

Study Objectives:

- Compare the in-lake survival to smolt of juvenile chinook that enter Lake Washington as newly emerged fry in February and March with those that enter the lake as fingerlings in May and June after an approximate in-river rearing period of 3 months.

- Compare the overall survival to adult of newly emerged chinook that rear in the river for up to approximately 3 months with newly emerged fry that move directly downstream into Lake Washington.

Study Question 2:

Is chinook survival to smolt and adult correlated with early life history strategy?

Scope Elements

Study approach A: This approach would attempt to use differential otolith banding patterns in stream-reared and lake-reared fry to distinguish between fish displaying these two different life history patterns and detect differences in survival.

- Compare otoliths from a sample of early Cedar River chinook smolt emigrants with smolts or presmolts captured at approximately the same time in Lake Washington.

- If the otolith banding patterns are different enough to accurately distinguish between the two like history types archive the samples;

    - Develop and implement a sampling program to recover otoliths from chinook spawning carcasses in the Cedar River.

    - Examine the otoliths and attempt to distinguish between fish that reared in the stream from those that reared in the lake.

- Use the sampling results to estimate the contribution of each life history type to the total adult population. Compare this estimate to the estimate of the number of fish in this cohort that migrated from the Cedar as fry and as smolts to derive an estimate of the relative survival rate for each life history pattern.

Study approach B: This approach would use marked fish to estimate the relative survival rate of the two life history strategies.

- Tag a cross section of the chinook fry outmigration with half-sized coded wire tags (CWT). This technique was successfully tested in 2000. The adipose fin is not clipped.

- Tag a cross section of the smolt outmigration with a different tag. This could be a full sized CWT, a PIT tag, or any of a number of distinct marks. PIT tags would be advantageous for other studies in the basin and would be preferred.

- Interrogate juvenile chinook caught along the shore of Lake Washington for tags using a pit tag detector and a CWT detector. Fish can be released with minimal handling.

- Interrogate juvenile chinook caught at the Ballard Locks in a similar manner. WDFW is committed to sampling smolts at this location in order to estimate total smolt outmigration numbers.

- Sample all returning adults two, three, and four years after the juveniles are tagged.

<u>Study Topic #3:</u> Distribution, abundance and habitat preferences of rearing juvenile chinook in the mainstem Cedar River, with emphasis on the interactions of these factors with stream flow

Suggested Study Objectives:

- Develop rearing habitat suitability criteria for appropriate size and age categories of juvenile chinook.

- Investigate the effects of stream flow on juvenile chinook rearing habitat suitability and availability.

- Investigate the effects of stream flow on juvenile chinook distribution and rearing habitat preferences.

Study Question 3a:

What is the preferred rearing habitat of juvenile chinook in the Cedar River and how is it affected by stream flow.

Scope Elements

- Develop robust habitat suitability indices for juvenile chinook in the Cedar River that incorporates velocity, depth, substrate, cover, edge preferences, backwater preferences, meso-habitat characteristics and predator abundance. Suitability criteria should be developed for at least two distinct size classes of fish including newly emerged fish and fish that have reared in the river for at least 1 month.

- Develop and employ a quantitative modelling tool to measures the manner in which the amount of preferred juvenile rearing habitat varies with stream flow for each fish size category selected.

Study Question 3b:

What is the relationship between stream flow and connection to existing off-channel areas and other important lateral rearing habitats?

Scope Elements

- From the results of ***Study Question 3a,*** identify important off-channel and other important lateral rearing habitats.

- Determine the river stage level and corresponding stream flow at which individual off-channel and important lateral rearing habitats become disconnected with the primary channel.

<u>Study Topic #4:</u> Behavioral response of adult chinook and sockeye salmon to changes in stream flow and the operation of sockeye broodstock collection facilities

Suggested Study Objectives:

- Investigate the effects of stream flow on adult chinook in-river migration behavior.

- Investigate the effects of stream flow on adult chinook spawning site location.

- Assess the confounding effects, if any, of the operation of the Cedar River sockeye broodstock collection facility on adult chinook migration behavior and spawning site location.

Study question 4a:

What is the effect of stream flow on the temporal and spatial distribution of chinook spawning activity in the Cedar River?

Study question 4b:

What, if any, are the confounding effects of the sockeye broodstock collection activities on the temporal and spatial distribution of chinook spawning activity in the Cedar River?

Scope elements

- Identify newly formed chinook salmon redds throughout in the Cedar River during the entire spawning season.
- Record the longitudinal and lateral location of each redd.
- Record daily stream flow.
- Using appropriate statistical tools, evaluate the relationship between stream flow, spawning time and temporal and longitudinal spawning location. Also evaluate the relationship between the operation of the sockeye broodstock collection facilities and the longitudinal spawning location.

Study question 4c:

What is the effect of stream flow in the Cedar River on the spatial and temporal distribution of Cedar River chinook migration and final maturation in the Lake Washington Basin?

Scope elements

- Radio tag an appropriate number of adult chinook salmon at the Ballard Locks.
- Monitor the movements and travel time of these fish as they hold and migrate through Lake Washington.
- Record daily mean stream flow in the Cedar River and other major tributaries to Lake Washington.
- Using appropriate statistical tools, evaluate the relationship between stream flow and the behavior and migration of adult chinook in Lake Washington.

<u>Study Topic #5:</u> Analysis of the potential impacts of stream flow at Landsburg on water temperature at the mouth of the river and in Lake Washington

Suggested Study Objectives:

- Investigate the effects of stream flow as measured at the USGS gage below Landsburg on water temperature in the river near the river mouth at Renton.

- Investigate the effects of stream flow as measured at Renton on water temperature in Lake Washington.

Study Question 5a:

To what degree is water temperature in the Cedar River at Renton correlated with stream flow as measured at Landsburg within the normal range of stream flows and water temperatures that occur during the late summer and early fall?

Scope elements

- Initiate continuos water temperature, air temperature and solar radiation monitoring at the USGS stream flow gage below Landsburg and at other locations in the river as deemed appropriate. (Note: water temperature is currently being recorded at the Renton stream gage).

- Using appropriate statistical tools assess the relative effect of stream flow, air temperature and solar radiation on water temperature in the Cedar River.

Study Question 5b:

To what degree is water temperature in Lake Washington, including any localized effects associated with the Cedar River plume, correlated with stream flow as measured at Renton within the normal range of stream flows and water temperatures that occur during the late summer and early fall?

Scope elements

- Initiate continuos monitoring of water temperature, air temperature, solar radiation, wind speed and wind direction at an appropriate array of locations in the surface waters of the south Lake Washington.

- Using appropriate statistical tools, assess the relative effect of stream flow, air temperature, solar radiation, wind speed and wind direction on water temperature in the surface waters of the south Lake Washington.

Study Topic #6: **Analysis of the potential effects of spring and early summer stream flows measured at Landsburg on water velocity vectors, water residence time, and the behavior and survival of emigrating juvenile salmonids in Lake Washington**

Suggested Study Objectives:

- Investigate the effects of stream flow (as measured at Landsburg), within the normal range of flows that might be expected in the spring and early summer, on velocity vectors and water residence time in Lake Washington.

- Investigate the effects of stream flow (as measured at Landsburg), within the normal range of flows that might be expected in the spring and early summer, on the behavior and survival of emigrating juvenile salmonids in Lake Washington.

Study Question 6a:

To what degree are velocity vectors and turnover rate in Lake Washington correlated with flow in the Cedar River as measured at Landsburg?.

Scope elements

- Use historic Cedar River stream flow data and in-lake stratification and circulation information to model the effects of stream flow on potential velocity vectors along the shores of Lake Washington and the Ship Canal.

- Use historic Cedar River stream flow data and in-lake stratification and circulation information to model the effects of stream flow on lake turnover rate.

Study Question 6b:

What are the effects of stream flow in the Cedar River as measured at Landsburg, dishcharge at the locks, and lake level management on the behavior and survival of emigrating juvenile salmonids in Lake Washington, including the ship canal?

Scope elements

- Use data from Study Question 2, *Approach B* to characterize the movement, distribution and survival of migrating juvenile Cedar River chinook in Lake Washington.

- Use appropriate statistical tools to asses the relative effect of stream flow in the Cedar River, stream flow in other tributaries to the lake, discharge at the

Study Topic #7: Vulnerability of chinook salmon and sockeye salmon to redd scour

Suggested Study Objectives:

- Assess the relative overall effects of peak flows on chinook and sockeye redd scour.

- Investigate the degree to which redd location in the channel effects redd scour vulnerability.

Study Question 7:

To what degree is scour of chinook and sockeye redds correlated with the magnitude and duration of peak flow events in the Cedar River? To what degree is scour correlated with redd position in the stream channel?

Scope elements

- Replicate previous work conducted by Michael Barclay of Cascades Environmental Services and Roger Peters of USFWS using buried radio transmitters to asses the effect of stream flow and redd location on redd scour.

Study Topic #8: The potential effects of redd superimposition on the survival of sockeye and chinook eggs and alevins

Suggested Study Objectives:

- Investigate the effects of sockeye spawning activity on previously established chinook and sockeye redds.

- Assess the relative impact of varying spawning population size on the tendency for sockeye spawning activity to affect previously established chinook and sockeye redds.

- Investigate the effects of chinook spawning activity on previously established chinook redds.

- Assess the relative impact of varying spawning population size on the tendency for chinook spawning activity to affect previously established chinook

- Investigate the relationship between stream flow and the incidence of redd superimposition.

- Investigate how flow management might potentially help reduce the incidence of redd superimposition.

Study Question 8:

Does superimposition of sockeye spawning activity on or near previously established chinook redds result in significant mortality of incubating chinook salmon?

Scope elements

- As part of Study Question # 4, document the incidence of sockeye salmon spawning on or near previously established chinook redds

- Examine past data to asses correlation between abundance of spawning sockeye and chinook egg to emigrant survival.

- Trap and enumerate chinook fry emerging from redds exposed to sockeye superimposition and from those that were not that were not.

- Investigate potential non-invasive approaches to determining the relative depth of sockeye and chinook egg deposition.

Study Topic #9: Further investigations of the relationship between hydrologic features and the structure and function of instream and riparian habitats in altered stream channels

Suggested Study Objectives:

- Investigate the degree to which present instream flow and flood management practices on the Cedar River may result in variations from unregulated stream flow patterns
- Investigate the degree to which past and present physical alterations of the Cedar River channel morphology may alter the hydraulic characteristics, meso- and microhabitat characteristics of the river under conditions of unregulated stream flow
- Explore approaches for understanding the integrated effects of stream channel and stream flow alteration on habitat conditions in the Cedar River

Study Question 9a:

In what ecologically significant ways do present regulated stream flows differ from historic unregulated flows in the Cedar River?

Study Question 9b:

In what ecologically significant ways have physical alterations to the channel and riparian corridor altered hydraulic characteristics, fish habitat characteristics and sediment dynamics from conditions that were present in the system prior to development?

Study Question 9c:

How do the integrated effects of stream flow regulation and alteration of the stream channel and riparian corridor affect habitat conditions in the Cedar River?

Scope elements

- Adapt the Richter et al. (1996) approach for assessing hydrologic alteration to the Cedar River and perform a subsequent analysis of the potential effects of hydrologic alteration on important ecological parameters with particular reference to key aspects of salmonid ecology and habitat preferences.

- Develop and implement a methodology for assessing the degree to which the channel of the Cedar River has been altered.

- Develop and implement a methodology for integrating the results of the assessment of hydrologic alteration with the results of the assessment of stream channel alteration.

- Delineate the location and relative abundance of potential off-channel salmonid rearing habitats (Note: This approach would link directly with Study Topic #3). Determine the degree to which they remain connected to the main channel at various levels of stream flow.

CEDAR RIVER HABITAT CONSERVATION PLAN
Instream Flow Management

Supplemental Study Topic #9: Toward a Comprehensive Approach to Understanding the Role of Stream Flow in the Conservation and Recovery of Salmonid Fishes in the Cedar River

Background

The management of rivers in western North America to provide instream and out-of-stream benefits is a complex topic with a long history marked by substantial debate and frequent conflicts (Gillilan and Brown 1997). The management of stream flow in regulated rivers is recognized as an important factor that has a substantial effect on the quantity and quality of fish habitat in fluvial systems (Gauvin 1997). With the recent listings of salmon, steelhead and bull trout under the federal Endangered Species Act in the northwestern United States, instream flow management is likely to be topic of even greater interest in this region for the foreseeable future.

During the past 30 or 40 years, researchers have developed a number of approaches to determine the effects of stream flow on habitat conditions for fish and other aquatic organisms (Lamb 1989, Poff et al. 1997, Stalnaker et al. 1995, Stanford et al. 1996). Despite considerable scientific work and a substantial literature base, a widely accepted, comprehensive methodology for assessing the effects of stream flow on aquatic ecosystems does not presently exist. Nevertheless, relatively diverse and often very sophisticated tools are presently used to assess the effects of stream flow on aquatic habitat. These tool, or approaches, can be placed into two broad categories: 1) those which tend to focus on the effect of stream flow on macro-, meso- and microhabitat characteristics in the stream channel ("habitat-based") and; 2) those which focus on characteristics of existing hydrologic regimes and how these differ from conditions that are unaltered by human perturbation ("hydrologic-based"). Because of the many challenges associated with measuring the direct effects of stream ***flow on fish*** production, both categories use measures of various environmental factors as surrogates for measures of fish production.

Most habitat-based approaches have been in use for a relatively long time, and have undergone considerable evolution. They are perhaps best exemplified by applications of the Physical Habitat Simulation System (PHABSIM), a component of the Instream Flow Incremental Methodology (IFIM) (Bovee et al. 1998). Hydrologic-based approaches have been developed primarily during the last 5 to 10 years and take advantage of a rapidly improving information base in the fields of ecology, and conservation biology.

These approaches can be linked with geomorphic assessments to explore the relationships between hydrology, and fluvial geomorphology (Ligon, et al. 1995). Examples of hydrologic-based approaches include methodologies such as the Range of Variability approach (RVA) and the Indications of Hydrologic Alteration approach (IHA) described by Richter et al. 1996 and Richter et al. 1997. In at least one example, a hydrologic-based approach has been linked to analyses of geomorphic processes and sediment dynamics in an effort to address the role of natural disturbances associated with peak flow events in shaping and maintaining instream and riparian habitat (U.S. Fish and Wildlife Service et al. 1999).

Habitat-based approaches can involve extensive field work and data analysis and often provide valuable insights about the effects of stream flow on particular species or groups of species. These approaches generally contribute less to our understanding of ecological processes, the way in which these processes are effected by stream flow and how they in-turn might effect instream habitat for various organisms. In contrast to habitat-based approaches, hydrologic-based approaches, when coupled with geomorphic information, can help analysts better understand the relationships between stream flow and natural ecological processes. However, these approaches usually provide less specific information on the effects of stream flow on particular species or groups of species. The challenges associated with using hydrologic-based approaches are further complicated when they are applied to river channels and floodplains that have been altered by human perturbation.

The Cedar River in the Lake Washington watershed near Seattle, Washington provides a potential opportunity to examine the application of both habitat-based and hydrologic-based approaches. Such an examination might help us understand how these two approaches can be integrated to help guide the management of regulated stream flows.

The City of Seattle (Seattle) diverts approximately 20% of the annual flow from the Cedar River to provide water for municipal and industrial use in the Seattle Metropolitan Area. Secondarily, water management facilities on the Cedar are used to provide flood protection and generate small amounts of electricity. Because of these activities and the water storage capabilities in Chester Morse Reservoir, stream flows in the lower 34 miles of the river downstream of Seattle’s facilities are partially regulated.

A new instream flow management regime was recently adopted as part of the Cedar River Watershed Habitat Conservation Plan (HCP) (City of Seattle 2000). The HCP instream flow management regime was developed during more than 6 years of analysis and discussion with state, Tribal and federal resource managers using an extensive collaborative information base gathered over a period of more than ten years. It provides a broad array of protection measures for instream resources including a guaranteed flow regime designed to ensure that stream flows in the lower Cedar River will not drop below levels deemed beneficial to anadromous salmonids. This new management regime also ensures a relatively high level of flexibility for future water managers in several ways. First, it provides supplemental flows that are delivered according to hydrologic conditions and biological need as determined by the newly established interagency Cedar

River Instream Flow Commission (Commission). Second, Seattle has dedicated approximately 1/3 of its water claim on the Cedar River, or an additional 100 million gallons per day on an annual basis, to stream flows. In addition, Seattle has agreed to manage its water supply facilities in a manner that maintains diversions from the Cedar River at levels that will be not exceed present diversion rates for the next ten years. Finally, due to relatively limited reservoir storage capabilities, water managers often release large volumes of water during much of the year to maintain flood storage capacity. The combination of these elements means that, in most years, streams flows in the Cedar River will be well above guaranteed levels for much of the year.

As a result of these commitments, the Commission will have significant flexibility in managing stream flows that are frequently greater than the required minimum flows stipulated as part of the guaranteed flow regime. The volume of water that the Commission will be dealing with ranges from relatively small but important amounts, such as the 55 cubic feet per second difference between high and low normal flows during the early fall salmon spawning season, to scouring flows of several thousand cubic feet per second during the rainy season. While a relatively large body of information is presently available to support decision making, the HCP instream flow management regime also establishes an extensive monitoring and research program. This program is designed to fill recently identified information gaps and to help further improve instream flow management as our understanding of the ecology of fluvial systems evolves and improves.

SUGGESTED SCOPE OF WORK

While many of the elements of the HCP instream flow monitoring and research program will investigate specific technical issues and questions, this study is more general in nature. The objective of this study is to provide water managers with information regarding the present status of the applied science of instream flow management in regulated rivers and to make recommendations that will help guide the continued development of the information base used to manage stream flow in the Cedar River.

Task 1

Provide a comprehensive summary describing the development of analytical approaches to the study of instream flow management during the last 30 to 40 years. A number of previously completed reviews on the topic are available in the literature and can provide a basis for an updated summary. Describe the most widely applied methodologies and emerging approaches that appear to hold promise for the future. Summarize the reported strengths and weaknesses of various methodologies and approaches.

Task 2

Convene a symposium that provides a forum for prominent practitioners and researchers to describe and discuss the most recent developments in methodologies and approaches used to guide management regulated stream flows for the protection of fluvial ecosystems in regulated rivers.   Task them with a review of Task 1 and the establishment of a recommended framework for completing Tasks 3 through 5.

Task 3

Describe emerging opportunities to enhance habitat-based approaches when investigating the effect of flow on fluvial habitat. Suggest new approaches to enhancing habitat-based approaches. For example: Expand and enhance the parameters used to monitor the effects of stream flow on spawning fish, incubating fish, migrating fish, and rearing fish; explore opportunities to incorporate the effects of predation on the habitat preferences of juvenile fish; assess how habitat preferences vary with flow, with season, and with relatively small changes in juvenile fish size?

Task 4

Describe emerging opportunities to enhance hydrologic-based approaches when investigating the effect of flow on fluvial habitat. Identify geomorphic tools that may be used to help describe "ecologically important hydrologic factors." Incorporate the most current information on the biology and fluvial ecology of salmonids and other important aquatic organisms into the development and description of relevant hydrologic factors. For example, develop and describe ways to assess the effects of stream flow on channel structure, sediment transport, hyporheic features and riparian communities. Recommend ways to adapt hydrologic approaches to present and anticipated future conditions in the channel of Cedar River.

Task 5

Develop recommendations for integrating hydrologic-based approaches and habitat-based approaches to assess the effects of stream flow on aquatic organisms in stream channels that have been altered by human perturbation. Such integration should incorporate relevant fluvial geomorphic considerations and include important aspects of system connectivity such as nutrient inputs and cycling. Suggest methods to test integrated approaches.

Deliverables

A report containing the results of the comprehensive summary described in Task 1.

Proceedings from the Symposium described in Task 2.

A report providing a recommended framework for integrating habitat-based and hydrologic-based approaches to assessing the effect of stream flow on stream communities and suggestions for how such a framework could be applied to the management of stream flows in the Cedar River.

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