SULTAN RIVER HABITAT PRIORITIZATION – GUIDING PRINCIPLES

INTRODUCTION

The Washington Department of Fisheries Stream Catalog (Williams 1975) characterized the Sultan River well at the time:

> *Below Culmback Dam, for 13–14 miles, the Sultan has mostly steep gradients, confined channel, and numerous cascades and rapids separated by short pool-riffle stretches. The bottom is mainly large rock and boulders, some bedrock, and only a few patches of gravel areas. Widths in the canyon range 5–15 yards. Much of the bank is sheer rock face or large rock cuts.*
>
> *Over its lower 3 miles, the river is of moderate gradient with a number of channel split sections. Fall widths range from 8 to over 20 yards. A good pool-riffle balance prevails, with numerous long, broad riffles. The bottom is mostly rubble and gravel, with a few boulder-strewn areas. Banks are low earth cuts or broad gravel-rubble beaches.*

During project relicensing, Stillwater Sciences compiled a detailed assessment of the habitat conditions along the length of the river downstream of Culmback Dam (Stillwater Sciences 2010).

Study Area Description and River Reach Delineation

The Study Area defined by the District includes approximately 16.5 miles of the Sultan River from Culmback Dam to its confluence with the Skykomish River.

Within the Study Area, the river is divided into sub-reaches based on both Project operational structures (operational reaches) and physical and geomorphic characteristics (process reaches). Descriptions of designated operational reaches (herein referred to as OR) and process reaches (PR) are provided below. Process reaches will be defined in greater detail in the final report for RSP 22. Figure 1 illustrates the geographic location and overlap by river mile. Because the beginning and ending points for the process reaches (PR) are not precise, they are not easily identified in the field, and so we used the operational reaches to reference discrete boundaries during the field surveys.

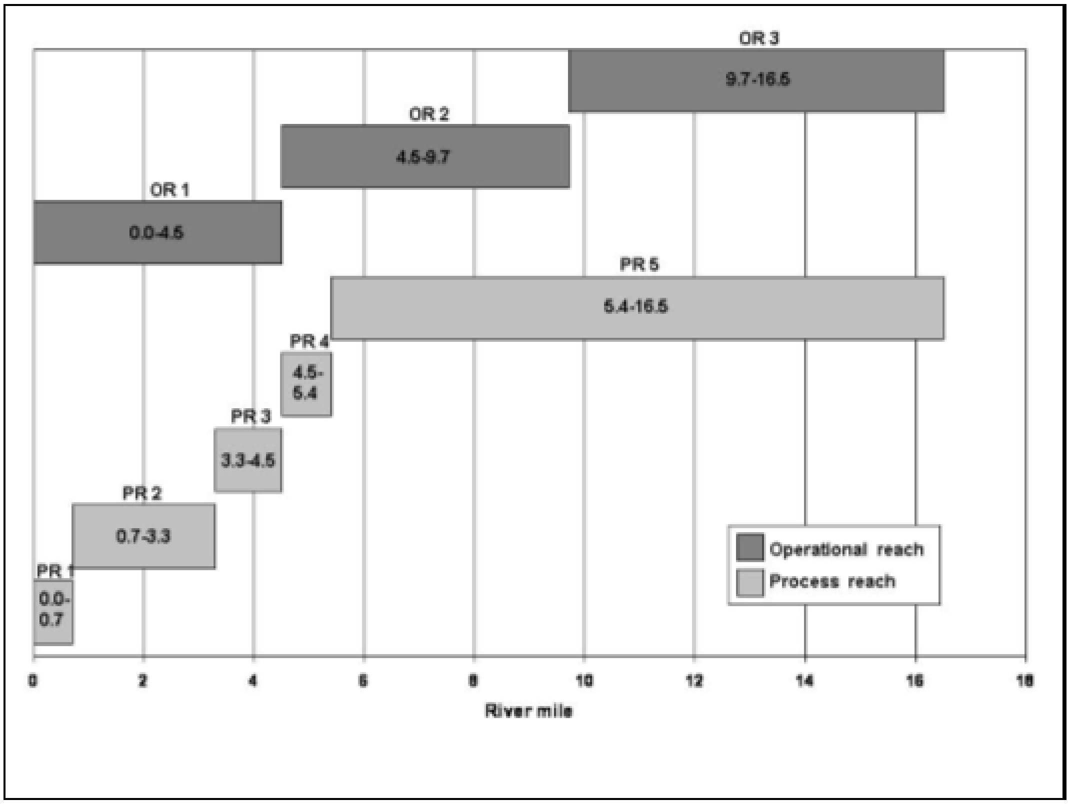

Figure 1. Operational and Process Reach Juxtaposition Downstream of Culmback Dam. (River miles are noted in the horizontal bars.)

The uppermost operational reach (OR 3) extends from Culmback Dam (RM 16.5) downstream to the Diversion Dam (RM 9.7) and is wholly contained in the uppermost process reach (PR 5 [RM 16.5 to 5.4]). Operational Reach 3 is best described as a high gradient, highly confined bedrock gorge characterized by higher rates of sediment transport as compared to downstream reaches. The middle operational reach (OR 2) extends from the Diversion Dam (RM 9.7) downstream to the powerhouse (RM 4.5) and contains portions of one process reach and all of a second process reach: (1) PR 5 (RM 16.5 to RM 5.4), best described as a bedrock gorge, and (2) PR 4 (approximately RM 5.4 to RM 4.5) above the powerhouse. Channel confinement and slope in PR 4 are moderate in comparison to PR 5, and gravel patches, large woody debris (LWD), and sediment deposition are more evident. The lowermost operational reach (OR 1) extends from the powerhouse (RM 4.5) to the Sultan River's confluence with the Skykomish River (RM 0.0). This reach contains three process reaches: PR 3 (RM 4.5 to 3.3), which is defined as the lowermost extent of a bedrock gorge; PR 2 (RM 3.3 to RM 0.7), which is predominately a low gradient, unconfined alluvial reach; and PR 1 (RM 0.7 to RM 0.0), which is also a low-gradient, unconfined alluvial reach, although it differs from PR 2 in that it is subject to backwater effects during Skykomish River flood events, which increases deposition and fines in the substrate.

Operational reach designations were used to stratify the survey field effort and data for quantifying in-river habitat and LWD. A summary of relative conditions and habitat can be found in Table 1. This approach was selected because of unambiguous field identification of river reach breaks. Channel gradient and confinement by canyon walls is relatively consistent through 13 miles of the river channel below Culmback Dam (PR 3), excluding the steep 0.7-mile section immediately downstream of the dam. The lower 3.3 miles (PR 2 and PR 1), extending to the confluence with the Skykomish River, differ substantially in gradient and confinement from the rest of the river. A plot of channel gradient (Figure 2) within the Study Area suggests that the channel has relatively consistent gradients of 1 to 2 percent through most of its length, with average gradients decreasing to less than 1 percent in the lower 3.3 miles (PR 2 and PR 1) to its confluence with the Skykomish River. The steepest parts of the river are in the 0.7-mile section just below Culmback Dam and the 1-mile section just below the Diversion Dam (RM 9.7 to RM 8.7). At the finer scale of local habitat units, slopes can average up to 3 to 5 percent over hundreds to thousands of feet, in OR 2 and OR 3 for example.

Reservoir operations (rule curves) have reduced both the frequency and magnitude of spill events. The reduction in frequency and magnitude of spill events has also reduced the frequency and magnitude of scour events. The reduction in scour also limits the flow induced habitat work that can be accomplished. The Process Flow program attempts to strike a balance, but the volumes associated with the high flow releases are effective at transport only in the upper operational reaches but insufficient for habitat creation in the lower operational reach. The timing of high flows (natural and regulated) can results in impacts to developing eggs.

Table 1. Summary of Reach Conditions and Utilization.																
	Physical Habitat Conditions (general description)						**Relative Fish Use (observed relative utilization)**									
							SPAWNING					**REARING**				
Reach	**Estimated Bankfull Width (feet)**	**Average Gradient (percent)**	**Relative Stream Power**	**Scour Potential**	**Gravel**	**LWD**	**Chinook**	**Coho**	**Chum**	**Pink**	**Steelhead**	**Chinook**	**Coho**	**Chum**	**Pink**	**Steelhead**
3	49.2	1.37	High	High	Wide expanses of good gravel	Some isolated large jams	High	High	Low	Low	Medium	Limited	Limited	N/A	N/A	Limited
2	69.5	1.36	Medium	Variable	Patchy (DDAM, Marsh Creek, PH Index)	Perched and patchy, some jams	High	Medium	Low	Medium	High	Fair to good	Fair to good	N/A	N/A	Fair to good
1	161	0.42	Low	Low	Wide expanses of good gravel	Low	High	High (most in SC 1 and 2)	High	High	High	Very good	Very good	N/A	N/A	Very good

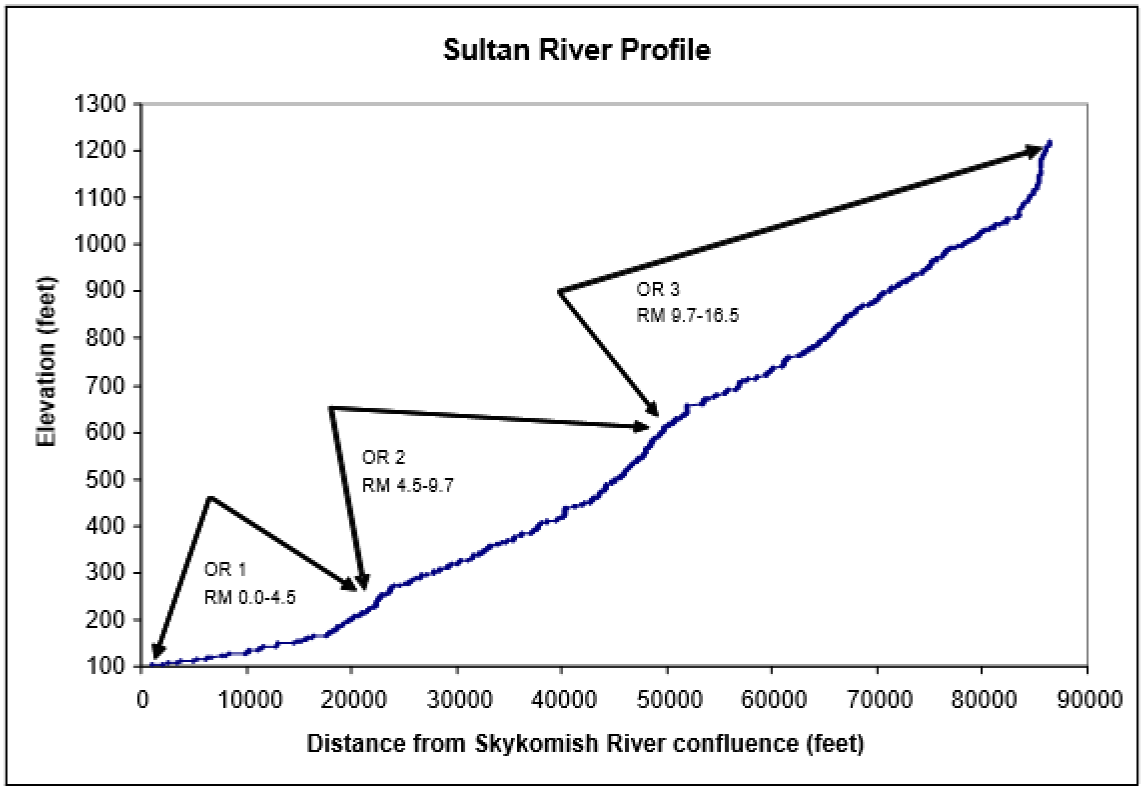

Figure 2. Profile of Sultan River Channel Gradient from the Confluence with the Skykomish River Upstream to Culmback Dam (RM 0–RM 16.5) (OR = "operational reach"; vertical exaggeration 50x).

Table 2. Channel Characteristics in Each Process Reach (after Stillwater Sciences 2010).

Process Reach	Estimated Bankfull Width (feet)	Total Main Channel Length (feet)	Channel Width per Pool	Standard Deviation	Comments
1	161	15,537	96.5	573	Only one pool
2	60	42,076	10.6	6.83	
3	49	26,317	11.2	22	

The First Phase of Work

The first phase of restoration work was motivated by a geomorphic assessment in the lower Sultan River (Stillwater Sciences 2010), which found that a combination of sediment and wood starvation and a lack of flood flows had simplified the channel network of the lower river. As a result, the first phase of work sought to reengage or extend existing side channels that were either lost or in the process of being lost. New side channels were also excavated. Log jams were placed along the main channel and near side-channel entrances to increase hydraulic complexity and encourage reengagement of the enhanced side channels. The project was primarily constructed in 2012.

What Worked

Off-channel rearing has significantly improved as a result of the first phase of restoration in the lower river. The best example of this is at the downstream end of the first phase project work. Side Channel 4 at Reese Park (and the associated entrance engineered log jam, ELJ 1) has been a complete success. The jam has nearly doubled in size and turned the newly created side channel into a viable, perennial side channel. Geomorphic activity around the side channel is within the bounds of behavior of an unmanaged river. The relative success of this project element is an indication that the reduced flows and sediment transport have essentially shrunk the active fan to the area immediately upstream from the US 2 Bridge.

The other seven engineered log jams that were constructed along the main stem river channel did not initiate as much geomorphic change around them as hoped, partly because zero-rise regulations forced them to remain at the fringes of the channel. As a result, they did not generate main channel pools. However, all of them remain in place and have deepened the river on their edges and deposited material in their lee. Several of the log jams have achieved their objective of redirecting flow, especially those located near the entrances to side channels, specifically Side Channel 2 and Side Channel 1.

The log jam across from the mouth of Side Channel 2 has triggered the delivery of more flow into the side channel. The successful increase in flow has been accompanied by a drop in chum salmon spawning in this previously very productive side channel (PUD Escapement Surveys). One explanation for the reduction in spawning could be that the additional flow has increased velocities and is also potentially diluting hyporheic input in this side channel (see next section), though other (external) factors including regional population trends may be at play.

Side Channel 1 has remained engaged and wetted throughout its extended length. The flow pathways have also remained stable over time. However, geomorphic activity has been less than desired but probably realistic given the low gradient. We interpret the lack of geomorphic activity to be partially a result of a plug of material that was left in the inlet to the side channel. The plug was left to ensure that Side Channel 1 did not induce an avulsion of the main channel to the newly enhanced side channel.

What Could Be Improved

Salmonid spawning, while not limiting at current population levels, could be improved by building in resiliency through diversification of substrate and habitat types. Rerouting of flow, where possible, could add to the diversity of habitat in the main channel. While conventional pool metrics indicate a lack of holding habitat in the lower river, more than adequate holding habitat is provided in the form of glides. The value and utilization of holding habitats could be improved through the addition of wood and/or boulders. Increasing cover could mitigate for depths greater than 6 feet since achieving significant changes in depth is probably not realistic under the regulated flow regime.

Beginning upstream in Side Channel 2, the log jam installation and increased flow to this side channel has potentially impacted chum spawning and has not triggered diversification of the habitat in the associated reach of the main channel. This jam was placed further into the channel because of its limited flooding impact and illustrates that these types of jams can be effective, if feasible from a flooding perspective. Therefore, actions could be taken to return the flow regime of this side channel closer to pre-project conditions and create the hydraulic and geomorphic complexity desired in this area. The island across from the side channel inlet makes an excellent target for this action.

More aggressive log jams could be planned that leverage the flood reductions of the first phase, those geomorphic changes that have occurred since the first phase was constructed (i.e., primarily the expansion of the side channels), and those planned in this next phase. However, flood impacts may still limit the possible size, and thus how productive these jams can be.

Removal of the plug at the Side Channel 1 inlet could increase flow into, and potentially geomorphic activity within, the side channel. Risk of avulsion to this channel appears to be minor. Very little geomorphic activity is present near the newly constructed inlet, which indicates that it could be widened without risk to avulsing the main channel to the side channel.

There also is an opportunity to extend the length of Side Channel 1. One of the former high flow outlets of Side Channel 1 was blocked in the first phase to ensure adequate flow to the newly extended side channel and because it lacked a defined outlet for fish to return to the river. With the successful construction of the first phase and the building of a relationship with downstream landowners, it may be possible to extend the side channel to this former alignment and beyond. It will likely be necessary to increase flow to the side-channel inlet, as mentioned in the previous paragraph, to support this side-channel extension without compromising flow in the existing side-channel network.

In all, it appears that the side channel creation has nearly reached a sort of saturation in terms of the flow and sediment available that could trigger natural habitat forming processes in those existing side channels—except for those areas at the downstream half of PR2, where sufficient sediment deposition and flow is achieved due to the influence of the Skykomish River. Main channel flow and geomorphic diversity is also still low and could be improved, particularly considering recent geomorphic change that might make more aggressive actions possible.

Operational Reaches 2 and 3

Operational Reaches 2 and 3 were not included in the original analysis by Stillwater Sciences (2010). Like areas farther downstream, these reaches are relatively sediment starved as compared to predevelopment conditions, although the process flows have reengaged sediment supply present from past and present slumping and deep-seated landslide along both banks in the canyon in OR 3 (DNR Landslide Hazard Zonation, Stillwater Sciences Study Plan 22, and PUD observations). Wood loading is also likely less than predevelopment conditions due to the presence of the dam upstream and reduced channel migration (which can result in recruiting wood via trees falling in the river) in the canyon due to a reduction in peak flows. The result is that the channel planform is not changing over time, despite relatively intact riparian conditions and a lack of other human modifications. Reintroduction of large wood in these areas could trigger local geomorphic change and more diversification and protection of Chinook spawning areas if the substrate is not mobile, or contribute to downstream geomorphic change if the wood migrates downstream.

CONCLUSION

The ARC is taking adaptive actions to meet a variety of objectives, tied to habitat as well as fish and aquatic resources. The general philosophy is to responsibly manage the regulated river, as infrastructure and regulatory conditions allow. This means that channel forming and deforming flows are likely not possible or reduced in both frequency and magnitude such that geomorphic variation must be forced, except in the most downstream areas (e.g., SC 4). In terms of high flows, guidance on ecosystem objectives is provided in Appendix B. The first 8 years of operation under the new license indicate that flow volumes may be insufficient to meet the full suite of ecosystem objectives. Physical interventions that allow us to meet the objectives listed under Channel Migration are desired and some of those actions have been presented above (Table 1).

These objectives, as they relate to channel morphology, riparian habitat, and fish habitat, respectively, include:

- Maintain channel planform, sediment transport, and bank erosion sufficient to cause periodic lateral migration, maintenance of spatially complex channel morphology.
- Create diversity and maximize extent of river bank habitat, patch dynamics, and vegetation community succession, and create backwater/off-stream habitat.
- Maintain shallow water, low-velocity channel edges and backwater/off-channel habitat to provide a complex mosaic of fish habitat suitable for all life stages.

The objectives lead to a prioritization of a series of projects that culminate in the work plan described in Table 3.

Table 3. Sultan River FHEP Work Plan.

PORTFOLIO: Release 1								
Operational Reach	**Opportunity Name**	**Project ID**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
1 – lower	New Extension of SC 1[a]	A				?	?	?
1 – lower	Winter's Creek Riparian	B						
1 – lower	KB Island	C						
1 – lower	PUD Parcel at Rope Swing	D						
1 – lower	SC 2 Island Modification	E						
1 – lower	ReStart ELJ[b]	F			?	?		
1 – lower	Boulder Clusters	H						
1 – lower	Unc's Side Channel	I						
1 – lower	Gravel Supplementation SC 3	J					?	?
1 – lower	Ames Creek	K					?	?
1 – lower	Gravel Supplementation TFR	L		?	?	?	?	?
1 – upper	Gravel Supplementation Powerhouse	M		?	?	?	?	?
2 – lower	Side Channel Reactivation	N		?				
2 – lower	ELJ[b]	O						
3 – lower	Gravel Retention Structures[b]	P						

[a] Possibly eligible for partial DOE funding (Hirst).

[b] Possibly as license obligation outside FHE account and pending (future) acquisition of wood.

Acquisition
Feasibility
Implementation

APPENDICES

Appendix A: Sultan River Drainage, WDF Stream Catalog

Appendix B: PowerPoint Presentation – Prescribed High Flow Types in Relation to Ecosystem Objectives. Prepared by Stillwater Sciences and presented to CALFED Bay Delta Program

REFERENCES

Stillwater Sciences. 2010. Sultan River Geomorphic Assessment of Side Channel Enhancement Opportunities. Prepared for: Snohomish County Public Utility District No. 1. June 22.

Williams, R.W. et. al. 1975. Washington Department of Fisheries Stream Catalog. <http://jeffersonco-treis.info/PDF%20Files/3.07%20Threatend%20&%20Endangered%20References/Williams_RW.pdf>.

APPENDIX A

Sultan River Drainage, WDF Stream Catalog

SULTAN RIVER DRAINAGE

This section covers the 30 miles of the Sultan River plus 32 tributaries adding 91 linear stream miles. Location is 8 miles east of Monroe in central Snohomish County, with access via Highway 2. Much of the upper river is in Snoqualmie National Forest, with considerable state and private land below.

Stream Description

From the Vesper Peak vicinity the Sultan courses west more than 19 miles, then south-southwest 11 miles to the Skykomish River at Sultan. Principal tributaries are the South Fork Sultan, Elk, Williamson, Marsh, Chaplain and Winters creeks.

Over its upper 11 miles to Spada Lake (R.M. 19.5) the river cuts through a narrow steep-sloped, densely forested valley. The next 3 miles are through Spada Lake, a City of Everett reservoir impounded by the high, earth-fill Culmback Dam (R.M. 16.5). Below Culmback, the river cuts nearly 14 miles through a deep ravine. The steep side slopes above are densely forested with conifer and mixed deciduous growth. At R.M. 9.7 the Everett diversion dam directs water to Lake Chaplain, a second reservoir in the water supply system. Near mile 3 the Sultan emerges from the canyon onto a broad, relatively flat valley floor containing intermittent stands or strips of deciduous trees, underbrush and some mixed conifers. The drainage is managed primarily for water supply and timber harvest, with some mineral mining in the upper basin. The lower 3 miles contain numerous small farms, scattered residences, and the town of Sultan. Although access is limited, there is much recreational activity in the basin.

From Sultan River headwaters to Elk Creek (R.M. 22.8) the river has mostly steep gradient, its narrow channel containing small falls, many cascades and rapids, and a few short pool-riffle stretches. The bottom is rubble and boulder with some patch gravel. Fall stream widths range 3-7 yards. From Elk Creek to Spada Lake the gradient is moderate with only a few steeper areas and channel widths of 4-12 yards. It possesses a fairly good pool-riffle balance, with the bottom mainly rubble and gravel and a few boulders. Banks are natural earth or rock cuts, with mostly dense conifer forest. Much of Spada Lake shoreline cover has been removed, and periodic lake drawdowns reveal extensive barren shoreline.

Below Culmback Dam, for 13-14 miles, the Sultan has mostly steep gradients, confined channel, and numerous cascades and rapids separated by short pool-riffle stretches. The bottom is mainly large rock and boulders, some bedrock, and only a few patch gravel areas. Widths in the canyon range 5-15 yards. Much of the bank is sheer rock face or large rock cuts.

Over its lower 3 miles the river is of moderate gradient with a number of channel split sections. Fall widths range from 8 to over 20 yards. A good pool-riffle balance prevails, with numerous long, broad riffles. The bottom is mostly rubble and gravel, with a few boulder-strewn areas. Banks are low earth cuts or broad gravel-rubble beaches. Cover consists of stands of deciduous trees and underbrush separated by intermittent cleared areas.

Most tributaries exhibit typical mountain stream character over most of their lengths: steep gradients; narrow channels; numerous cascades and falls; and bottoms mainly of boulder and rubble. Only Winters and Ames creeks enter the lower river and have moderate gradient over their lower reaches, good pool-riffle conditions, and gravel bottoms. Most tributaries have dense cover.

Salmon Utilization

The Sultan River provides transportation, spawning and rearing for chinook, coho, pink, and chum. Adult fish may ascend to the diversion dam; however, most utilize the main river below R.M. 3. The lower tributaries support mainly coho.

Limiting Factors

The diversion dam at mile 9.7 is a barrier to upstream migration. Flow fluctuation and/or prolonged low flows have presented severe limitations. Extensive clear-cut logging in some sections, mainly below the diversion, has at times created excessive siltation over the lower river. Also, some gravel removal has impacted lower river production habitat.

Beneficial Developments

At present a water control schedule with the City of Everett, under agreement authorized by the Federal Power Commission, provides at least minimum fish use water during critical periods. Some planting of hatchery juveniles takes place in the drainage.

Habitat Needs

A major requirement will be to continue close coordination of flow control for the lower river. Stream-side cover should be preserved, and stream and streambed conditions maintained in as near natural state as possible. Gravel removal operations should be carefully monitored to not disrupt spawning habitat.

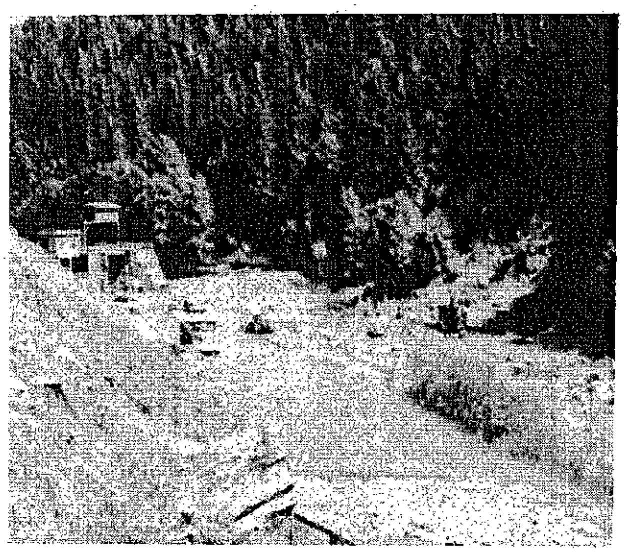

PHOTO 07-28. Diversion dam on the Sultan River.

APPENDIX B

PowerPoint Presentation – Prescribed High Flow Types in Relation to Ecosystem Objectives

Prepared by Stillwater Sciences and presented to CALFED Bay Delta Program

Environmental Water Program:
Restoring Ecosystem Processes Through
Geomorphic High Flow Prescriptions

FINAL DRAFT

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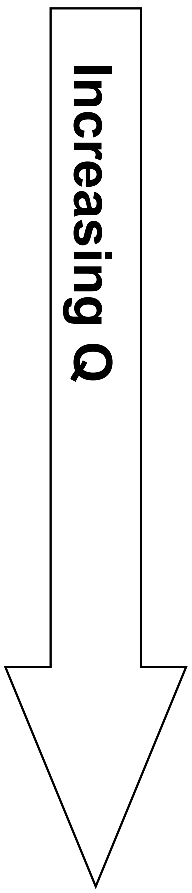
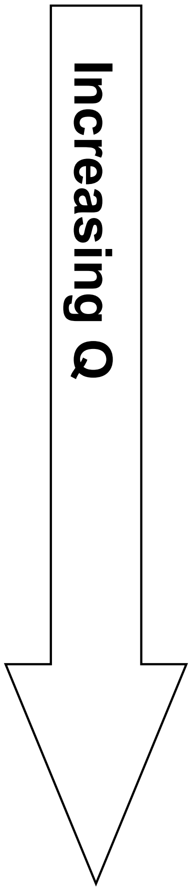
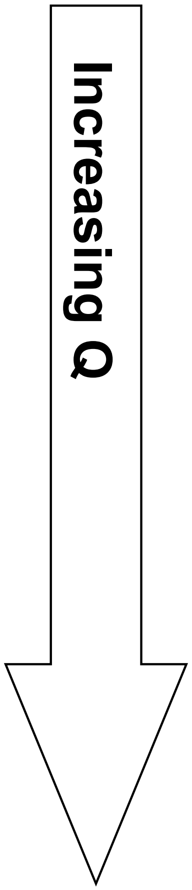


Table 3. Prescribed high flow types in relation to ecosystem objectives (objectives in italics are developed as scientific hypotheses in Chapter 5).

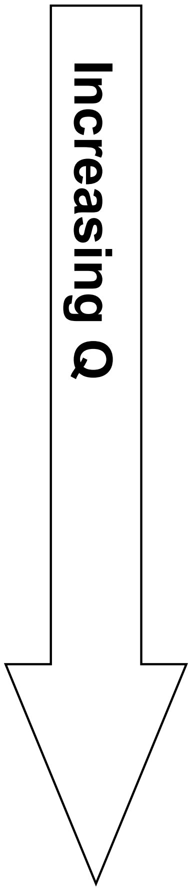
Primary Physical Threshold	Ecosystem Concern	Specific Ecosystem Objectives	Flow Type Required
Maintaining flow depth	Morphology	- none	'In-channel'
	Riparian habitat	- Discourage germination of riparian plants on lower bar surfaces - Cause woody riparian mortality on lower bar surfaces, promote woody riparian regeneration of upper bar surfaces previously unwetted	
	Fish habitat	- Provide suitable combinations of velocity, depth and temperature at particular times - Spatial separation of warm-water predators and salmon smolts: suppress non-native fish habitat preferences - Stimulate emigration - Attraction flows - Provide summer base flows	
	Invertebrates	- Provide suitable conditions of velocity, depth and temperature for particular life history stages to provide prey for secondary consumers	
	Morphology	- Inherently none, but if the flows are carrying suspended sediment then floodplain deposition will result (see "Floodplain Deposition Flows")	'Over-bank'
	Riparian habitat	- Maintain water table for off-channel wetlands and side channels - Promote woody riparian regeneration on floodplain	
	Fish habitat	- Rejuvenate backwater habitats for native fish - ***Floodplain food availability*** – for growth of juveniles - ***Floodplain water temperatures*** - suitable for fish use - ***Provide floodplain habitats for utilization by rearing salmon*** - ***Increased juvenile salmon growth rates*** - ***Reduce piscine predation*** - ***Moderate stage change to reduce stranding***	
	Invertebrates	- ***Chironomid life history*** – provision of suitable frequency and duration of floodplain inundation	



Primary Physical Threshold	Ecosystem Concern	Specific Ecosystem Objectives	Flow Type Required
Maintaining channel bed functions	Morphology	- Export fine sediment from pools where excess fine sediment has accumulated; essentially to create a net loss of fine sediment accumulation in the reach	**'Pool scouring'**
	Riparian habitat	- none	
	Fish habitat	- Maintain well-developed pools for rearing and holding	
	Invertebrates	- unknown	
	Morphology	- Remove surficial fine sediment without extensive mobilization of riffle gravel - ***Fine sediment removal from gravels*** - winnowing of interstitial fine sediment to maintain interstitial void space - Transport sand out of reach at volume greater than input from tributaries to reduce instream storage (where elevated fines)	**'Riffle cleaning'**
	Riparian habitat	- none	
	Fish habitat	- Turn riffle substrates periodically to achieve high permeability spawning habitat - Conserve stocks of limited bed material of suitable spawning size - Cause slightly elevated turbidity to reduce predation on migrating juveniles	
	Invertebrates	- Provide interstitial spaces for cover and protection of various species	



	Morphology	- ***Bed mobilization*** - riffle gravel mobilization, scouring channel bed greater than 1-2 multiples of D84 depth; redeposition of gravels on face of alternate bar - Frequent gravel mobilization to maintain interstitial void space e.g. mobilization of matrix particles (D84) on alternate bar surfaces	**'Riffle mobilization'**
	Riparian habitat	- none	
	Fish habitat	- Mobilize riffles to ensure high permeability spawning habitat when gravel supply is ensured / augmented - ***Maintain framework size gravel distribution***	
	Invertebrates	- Provide new surfaces for colonization by less armored and more available prey for benthic feeders	
Maintaining channel morphology functions	Morphology	- Facilitate periodic deposition of fine sediment onto bars - Transport of bed material load at a rate equivalent to upstream import, facilitating alluvial deposits	**'Margin accretion'**
	Riparian habitat	- Promote woody riparian regeneration on upper bar surfaces - Maintain diversity of aquatic-terrestrial transitional zone	
	Fish habitat	- Provision and maintenance of shallow water, low-velocity channel edges for juvenile rearing	
	Invertebrates	- Changes in species composition caused by reduction in sand volume in substrate	
	Morphology	- Mobilization of bed material load across full extent of unimpaired, or other pre-determined, channel width. - Elimination of tributary deposits in mainstem channel	**'Channel width'**
	Riparian habitat	- Cause woody vegetation mortality on lower bar surfaces and thus prevent vegetation encroachment - Re-set woody vegetation community status in marginal zones	
	Fish habitat	- Provision and maintenance of shallow water, low-velocity channel edges for juvenile rearing	
	Invertebrates	- unknown	
	Morphology	- ***Maintain channel planform*** - sediment transport and bank erosion sufficient to cause periodic lateral migration - Maintenance of spatially complex channel morphology	**'Channel migration'**
	Riparian habitat	- Create diversity and extent of river bank habitat, patch dynamics, vegetation community successions - Create backwater / off-stream habitat	
	Fish habitat	- Provision and maintenance of shallow water, low-velocity channel edges, a existence of backwater / off-channel habitat to provide a complex mosaic of fish habitat suitable for all life stages	
	Invertebrates	- unknown	



Primary Physical Threshold	Ecosystem Concern	Specific Ecosystem Objectives	Flow Type Required
Maintaining floodplain functions	Geomorphology	- Floodplain aggradation through import of fine sediment	**'Floodplain deposition'**
	Riparian habitat	- Provide sediment and nutrient supply to floodplain - Promote microtopographic variability through variable sediment deposition	
	Fish habitat	- Inundation to provide flood pulse advantage - Rejuvenate backwater habitats for native fish	
	Invertebrates	- unknown	
	Morphology	- Floodplain scour and fill - Transport of sediment onto and from floodplain - Channel avulsion and migration	**'Floodplain mobilization'**
	Riparian habitat	- Invoke extreme end of intermediate disturbance hypothesis: re-set floodplain ecological community status	
	Fish habitat	- Inundation to provide flood pulse advantage - Rejuvenate backwater habitats for native fish	
	Invertebrates	- unknown	

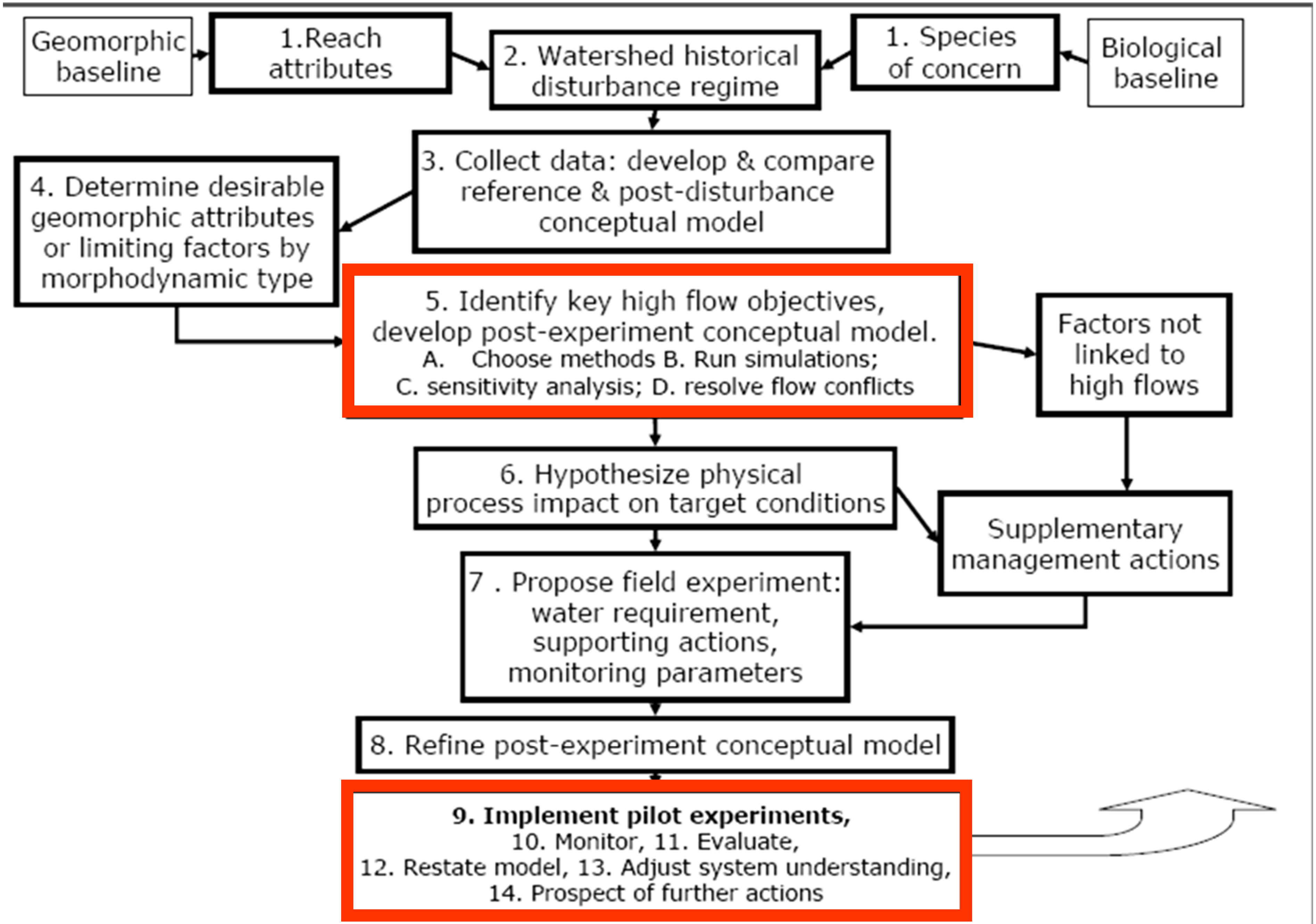


Figure 13: Adaptive management framework for high flow prescription. Developed from USFWS and Hoopa Valley Tribe (1999).