Response to ISRP Preliminary Review of ProjectID 29039: The effects of fine sediment on the hyporheic zone: monitoring and evaluating the influence of hyporheic exchange flows on stream temperature.

ISRP Review Comment: *"A response is needed to better describe the methods and relevance to management actions".*

1. Relevance to management actions:

The focus of this proposal is scientific research into the hyporheic zone, how it is influenced by stream sedimentation, and how hyporheic exchange flows may affect stream temperature. Links to management actions tend to be indirect, but are substantial, none the less.

1.1. What is the relative importance of the hyporheic zone in regulating stream water temperature and should the hyporheic zone be considered in restoration or other management actions intended to improve stream temperature regimes?

> Stream water temperature standards continue to be contentious, especially within the Interior Columbia basin, where some believe that current temperature standards are unrealistic goals for many streams. This view point includes an unstated assumption—that land-use impacts on stream temperature result from changes in the amount of shade and from changes in stream discharge. However, the potential role of changes to channel morphology (channel width, floodplain connectivity, pool-riffle sequences) and to streambed sediment composition (% fines, embeddedness, porosity, saturated hydraulic conductivity) on stream water temperature has mostly been ignored. Yet, because these factors control hyporheic exchange flows, there is a direct mechanism through which they can influence stream temperature regimes.
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> Previous research in small streams documents the mechanisms through which temperature regulation occurs. However, in large streams and rivers, it is not known if these effects are of sufficient magnitude to measurably influence stream temperature regimes or to create thermal refugia large enough to be usable by either juvenile or adult salmonids.
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> The first goal of this project is to answer the question: <u>Do hyporheic exchange flows measurably influence stream temperature regimes, or create usable thermal refugia, in the mainstems of mid-sized to large rivers</u>?

1.2. If the proposed research shows that hyporheic exchange flows can be important in regulating temperature regimes of large streams or rivers, how can this information be used to change or to develop new stream restoration projects and other management actions?

ISRP Review Comment: *One question that might have been addressed by the proposal (and should be addressed in a response) is what could be done to restore streams where fine sediments are so abundant that hyporheic flow is obstructed. Does this study end by simply documenting good and bad conditions or could it provide guides for stream rehabilitation?*

1.2.1. Improved understanding of the suite of physical processes that influence stream temperature provides a better basis for designing restoration projects.

This research examines the function of the hyporheic zone in stream ecosystems and will provide better understanding of this component, relative to other components that influence stream temperature. Stream or watershed restoration projects designed to control stream temperature tend to focus on the restoration and maintenance of riparian forests that provide shade. Habitat restoration projects tend to focus on the number and size of pools and on stream structure, especially the addition and future recruitment of large wood. Where fine sediment is perceived to be a problem, erosion from roads and other ground disturbing activities occurring within the watershed are often addressed. These factors, often viewed as disparate elements, are functionally related through their influence on channel morphology and both surface and subsurface hydrology.

Restoration projects need to fully recognize the physical relationships among the factors limiting habitat quality. To date, the potential influence of hyporheic exchange flows on stream temperature, their dependency on the texture and structure of streambed sediment, and their dependency on channel morphology has not been explicitly included in restoration planning.

1.2.2. How can improved knowledge of the hyporheic zone lead to improved guidelines for stream rehabilitation?

Improved knowledge of the role of the hyporheic zone in regulating stream temperatures can lead to improved guidelines for stream rehabilitation. The fundamental work of reshaping stream channels and removing fines from streambed sediment must rely on natural processes that scour, transport, and deposit sediment. However, passive restoration can be facilitated by smaller-scale, active restoration projects. For example, restoration of fluvial and geomorphic processes can be facilitated by removing dikes and road foundations that channelize streams through wide alluvial river valleys; or removal of riprap that hardens stream banks and prevents lateral channel migration. Restoration of these processes can encourage scour and redeposition of streambed sediment such that fines are winnowed from streambed gravels during periodic floods. Also, mobilization and redistribution of gravels in altered channels can reform pool-riffle sequences, especially if large wood is available. Similarly, better recognition of the importance of fine sediment in restricting hyporheic exchange flows could increase the relative priority placed on: 1) controlling accelerated erosion caused by ground disturbing activities in sediment source areas; 2) controlling erosion of fine sediment from roadbeds; and 3) controlling hydrologic linkages between road-runoff and streams.

Better knowledge of the physical factors affecting habitat condition, and the relationships among these factors, will help managers prioritize the management actions necessary to address specific habitat problems. Improved understanding of the role of the hyporheic zone may not lead to dramatic changes in stream rehabilitation projects, but it could result in small changes that better focus rehabilitation efforts.

2. Relevance to Monitoring:

"*The ISRP emphasizes its support* [for the development of] *aquatic monitoring and evaluation procedures with common field procedures and probabilistic site selection…*" (from ISRP, Preliminary Review of Fiscal Year 2003 Proposals for the Upper and Middle Snake, Columbia Cascade, and Lower Columbia and Estuary Provinces, 2002).

This project is not designed as a Tier 1 (trend or routine) monitoring project. However, the methods developed, and the data collected, will provide an opportunity for future repeated measurements which will be useful for monitoring changes in stream habitat quality over time. Therefore, the collected data and the metadata describing the study location and sampling design must be archived so that the study can be reactivated in the future.

Equally importantly, the sampling design must provide a usable and statistically rigorous data set to examine changes through time. However, there is insufficient preliminary information on within site, between site, and between river variability to develop an efficient sample design. Thus, the project calls for a staggered implementation. The project will use a preliminary study design in Year 1, and that data will be used to explore sampling variation and to evaluate the preliminary study design. The Year 2 sampling design will be enhanced with additional sampling effort if the preliminary design proves to have insufficient statistical power to resolve real differences in fine sediment, siltation rates and fine-scale patterns of water temperature. The sampling design will be re-evaluated after Year 2. The development of the full sampling design over one or two years (more fully described under Methods, below), will ensure that the final data set is adequate to monitor changes through time.

The results of the first two years effort will be used to develop guidelines for sampling and monitoring fine-sediment and siltation rates in rivers of the interior Columbia basin.

This sampling protocol will be published as a General Technical Report through the Pacific Northwest Research Station to ensure that the results are readily available for use in designing monitoring projects within the region.

3. Relationship to other BPA-funded projects:

ISRP Review Comment: *"The proposal relates the work to Forest Service projects that monitor sediment and temperature, but not to BPA-funded ones"*.

3.1. ProjectID 29015: Thermal Imaging of the Okanogan and Wenatchee Watersheds.

This project (ID29039) is complimentary to the FLIR-based analyses of temperature planned for the Okanogan subbasin and mainstem Wenatchee River, as well as those already completed in the upper Wenatchee subbasin. The FLIR imagery is both fine-grained and extensive, covering many stream miles with square-meter resolution. However, the mechanisms accounting for longitudinal changes in temperature can only be inferred from observed spatial patterns. It is often assumed that cooling associated with individual channel units, pool-riffle sequences for example, results from hyporheic exchange flows. This project (ID29039) will examine the potential for hyporheic exchange flows to create cool-water refugia (in summer) at the channel unit scale, and examine the physical mechanisms accounting for those patterns.

ProjectID 29015 will use FLIR data and additional data to parameterize the Stream Segment Temperature Model (SSTEMP). To date, stream temperatures models (e.g., SSTEMP) have not fully incorporated hyporheic exchange flow and heat storage in hyporheic sediments. Data collected in this study (ID29039) could be used to modify stream temperature models to more fully account for the influence of hyporheic exchange flows on stream temperatures.

3.2. ProjectID 29018: Analyze ground-water and surface-water exchanges influencing anadromous salmonid habitat in the Methow River and its major tributaries.

One objective of ProjectID 29018 is to identify locations of ground-water and surface-water exchanges in the Methow, Twisp, and Chewuch Rivers. ProjectID 29018 differs substantially from this project (ID29039), especially in the scale at which exchange flows are to be examined. This project focuses on hyporheic exchange flows occurring at the channel-unit scale (10s of meters), rather than patterns of groundwater recharge and discharge occurring at the reach or larger scales (kilometers to 10s of km). However, because the two studies focus on mechanistic understanding of physical processes, they are complementary. Similar, large-scale patterns of groundwater recharge and discharge are present in the Wenatchee subbasin and smaller-scale hyporheic exchange flows are present in the Methow subbasin. Together, these two projects provide a much fuller investigation into the mechanisms controlling stream–subsurface exchange flows than is possible in either study alone.

3.3. ProjectID 29041: Evaluate distribution, abundance, genetic structure and habitat use of bull trout in the Wenatchee, Entiat, and Methow Rivers.

One objective of ProjectID 29041 is to evaluate habitat use by bull trout in the Wenatchee River subbasin. This project (ID29039) will collect detailed stream temperature and fine-sediment data from spawning gravels in 4 major tributaries of the Wenatchee River, 3 of which (Nason, Little Wenatchee and White) are known to be current or historically important spawning locations for bull trout, as are two tributaries of the Chiwawa River (page 22, Wenatchee Subbasin Summary, 2001). Fish and Wildlife Service (USFWS) led bull trout studies have been collecting stream temperature data in the Chiwawa River using thermographs spaced every 2 km, both in tributaries and in the mainstem. However, this project (ID29039) will collect finer-scale temperature data to identify potential thermal refugia, and relate those patterns to the physical processes driving (or limiting) hyporheic exchange flows. This information on hyporheic exchange flows, fine sediment, and water temperature will provide detailed information that can be related to habitat used for spawning, rearing, and adult holding by bulltrout (and other salmonids) in the Wenatchee River subbasin.

3.4. ProjectID 29045: Protect and Restore Salmon and Steelhead Habitat at the Similkameen/Okanogan River Confluence.

The goal of ProjectID 29045 is to “design and implement measures to protect and restore flood plain processes…”. Hyporheic exchange flows are an important component of stream-floodplain connectivity and restoration of fluvial and geomorphic processes will help maintain hyporheic processes. Especially important is the restoration of channelized rivers to allow lateral channel migration and rejuvenation of sediment scour, transport, and depositional processes that form pool-riffle sequences. Restoration actions from ProjectID 29045 will likely contribute to increased hydrologic connectivity via the hyporheic exchange flows, benefiting critical spawning and rearing habitat in ways other than those already recognized in the proposal. Explicit recognition of the hyporheic connectivity would provide additional reasons to support habitat restoration; and better understanding of the physical factors driving hyporheic exchange flow may provide information so that active restoration projects maximize stream-floodplain connectivity.

3.5. Relevance to BPA projects in other provinces:

The projects highlighted above were selected from the FY2003 list of proposals submitted for the Columbia Cascade province. However, similar projects are underway, or planned, for other provinces, and many of these project could benefit from a more thorough understanding of the role of the hyporheic zone in stream ecosystem processes. For example, the John Day subbasin has a long history of stream temperature and habitat studies utilizing FLIR and radio tagged salmonids. This study (ID29039) would be relevant to these studies in the Columbia Plateau province, in the same ways as already described above for projects 29015 and 29041. Other examples would include the existing ProjectID 199703400 "*Monitoring Fine Sediment in the Grande Ronde and John Day Rivers*". Results from that project provide an opportunity to compare fine-sediment abundance and annual siltation rates across broad geographic scales, and in watersheds with substantial differences in underlying geology, climate, and landuse. Similarly, monitoring conducted in the existing ProjectID 199901000 "*Mitigate Effects Of Runoff & Erosion On Salmonid Habitat In Pine Hollow and Jackknife*" would provide data useful in a regional examination of the influence of habitat restoration on fine-sediment in streambed gravels.

4. Methods:

ISRP Review Comment: "*The objectives, tasks, and methods section is too brief to allow scientific review. Sample sizes and sampling methods are not adequately described or referenced in the published literature. The specific sample areas, methods, and sampling frequency and intensity (i.e., how many samples of what type where and when) need to be specified. Appropriate statistical analysis procedures should be given. This information should be provided in a response.*"

The primary objective of this study is to determine the degree to which intrusion of fine sediment into riffles limits hyporheic exchange flow, and how the volume of hyporheic exchange flow influences water temperature. The sampling design will focus on a series of riffles located in the mainstems of the Chiwawa River, White River, Little Wenatchee River and Nason Creek. However, there is insufficient preliminary information on sampling variability to develop an efficient sample design at this time. The lack of preliminary information requires a staggered development of the project design. Year 1 data will be used to analyze sample variability and evaluate the study design. The Year 2 sampling design will be enhanced with additional sampling effort if the preliminary design proves to have insufficient statistical power to resolve real differences in fine sediment, siltation rates and fine-scale patterns of water temperature. The sampling design will be re-evaluated after Year 2 and then finalized. The development of the full sampling design over one or two years will ensure that the final data set is sufficient to meet the objectives described in this proposal.

<u>It is important to emphasize that changes in sampling design between years will be limited to adding sampling units. The overall nested sampling design (described below) will remain constant among years</u>. With one important caveat. I believe that it is important that the data collected be sufficient to test the influence of fine sediment on hyporheic exchange flows and on stream temperature; and that the data be sufficient to measure real changes in fine sediment through time. Therefore, if substantial additional sampling effort is required, the numbers of streams sampled will be reduced rather than maintaining extensive sampling design that examines all 4 major tributary rivers but does not provide sufficient statistical power to meet the stated objectives.

Only 2 rivers will be sampled in Year 1 because of the staggered development of the sampling design. The 4 rivers to be sampled will be prioritized in discussions with local fisheries managers so as to best meet local monitoring needs and to fill gaps in needed information. Again, I emphasize that this is not intended to be a Tier 1 monitoring project, but the data collected should be useful to local managers and for long term monitoring. So long as the scientific integrity of the project will not be compromised, every effort will be made to ensure that the project will contribute to local management and monitoring needs.

The basic sample locations will be riffles located in the lower mainstems of each river. The length of the lower mainstem used for spawning and rearing by anadromous salmonids will be divided into 15 equal length reaches. In Year 1, between 5 and 10 reaches will be sampled in each river. Riffles will be chosen, at random from the initial pool of 15, equal length reaches. Reaches not sampled in Year 1 will provide a pool of additional study sites should the analysis of variance show that additional samples will be needed to provide statistical power. A single riffle will be randomly selected within each study reach by generating a random "distance" from the bottom of the reach and located on the ground using GPS coordinates. The nearest "suitable" channel spanning riffle will be selected as the study site. Selection criteria for "suitability" will be determined in advance. For example, riffles immediately adjacent to camp grounds will not be accepted as possible sample units because of the high potential that wells and silt traps will be disturbed by campground visitors. Similarly, riffles that are bedrock controlled, or those that have large accumulations of large wood that create radically different patterns of scour and deposition across the width of the channel (or create dangerous working conditions) will not be selected.

I expect high, cross-channel variability in fine-sediment amounts and siltation rates within each riffle, such that within-riffle variability might equal, or even exceed, between riffle variability. Thus, samples will be nested, with two sampling transects located at each riffle. One transect will be located on the upstream third of each riffle in the area of hyporheic downwelling. The second transect will be located on the downstream third of each riffle in the region of hyporheic upwelling. Each transect will consist of 4 samples, spaced systematically across the width of the channel (Fig. 1).

Each sample will consist of a sediment sample, a piezometer, and a thermometer array (Fig. 2). Additionally, cross-sections will be surveyed at each sampling transect and a longitudinal profile will be surveyed down the thalweg of the channel, from the upstream pool, through the riffle, and into the downstream pool. Sampling protocols for fine sediment will follow the methods outlined by Lisle and Eads (1991)[1]. Bulk core samples (e.g., McNeil core samples) will be used to measure the abundance of fine-sediment in the streambed gravels. The coarse sediment fraction removed with the bulk-core sample will be placed in a silt trap located in the hole originally excavated for the bulk-core sample. A scour chain will also be installed adjacent to the silt trap to measure the depth of annual scour. A piezometer, screened over the lower 5 cm, will be driven 50 cm into

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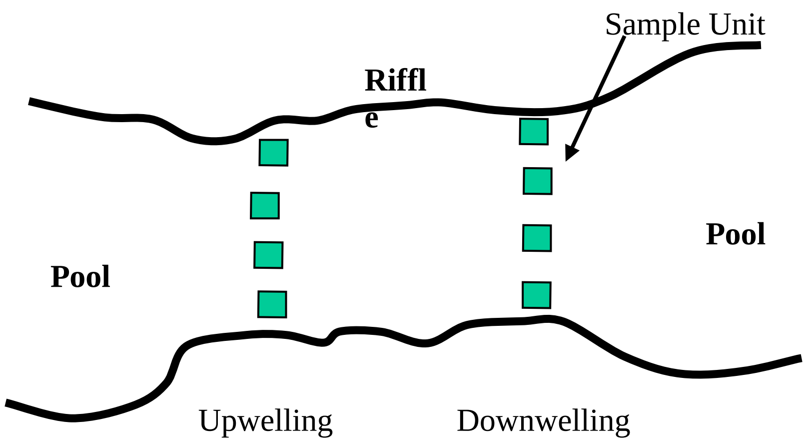
[1] Lisle, T. E. and R. E. Eads. 1991. Methods to Measure Sedimentation of Spawning Gravels. USDA Forest Service, Pacific Southwest Research Station, Research Note PSW-411.

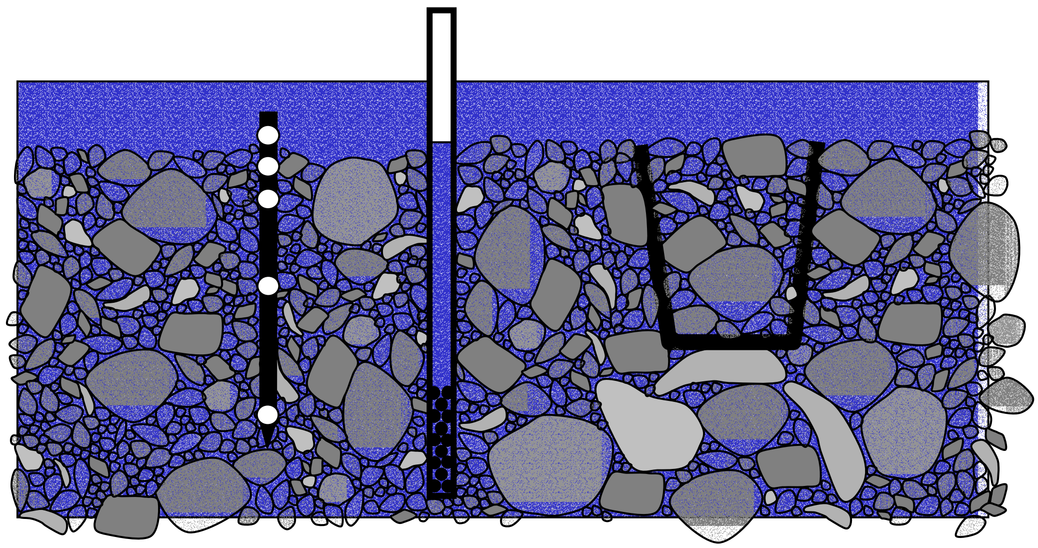
the streambed adjacent to the sediment sampler. Falling head slug tests will be used to measure saturated hydraulic conductivity of the streambed sediment, and the head difference between the stream water and the water level in the piezometer will be used to calculate the vertical hydraulic gradient driving hyporheic exchange flow. Finally, an array of mini-thermographs will be inserted into the streambed, with thermographs located at the streambed surface, and at 5, 10, and 20 cm depths, and where possible, at 50 cm depth. The mini-thermographs (iButtons: www.iButton.com) are approximately the size of a lithium watch battery, are waterproof to 10 m, and have sufficient memory to store 85 days of hourly temperature data. Thermographs will be installed in mid-summer, and remain in place throughout late summer and early fall, to sample the period of annual maximum stream water temperatures.

Figure 1. Schematic diagram of sampling transects located in upwelling and downwelling zones of a riffle.



The analysis of variance needed to refine the sampling design will be conducted using a nested analysis of variance model. The nested sampling design can also be used to apportion variance to examine changes in fine sediment and siltation rates through time. A means comparison test will be used to compare fine sediment, annual siltation rate, depth of scour, and temperature patterns between upwelling and downwelling zones where the sample size will be the number of riffles sampled within a given river. Temperature variables examined will include maximum daily temperature, 7-day running average maximum temperature, and range of diel variation over the 7-day period with the highest average maximum temperature. Regression analysis will be used to examine the influence of fine sediment on hyporheic exchange flows, comparing the abundance of fine sediment and siltation rates to vertical hydraulic gradients (VHG) and saturated hydraulic conductivities, and also to examine the relationship between VHG and the temperature variable described above.

Figure 2. Schematic diagram of each sample shown in Figure 1.



A tertiary objective of this project is to explore land-use affects on streambed sediment. However, each of the watersheds selected for study differ in type, degree, and recent history of both natural disturbance and land use. Lacking replicated watersheds, it will be impossible to draw statistical inference on the influence of land use on streambed sediment. A statistically rigorous study of land use effects is beyond the scope of this proposal. However, GIS coverages are available, from which the recent history of land use practices and their magnitude and extent can be quantified. We will examine correlations between fine sediment and siltation rates with measures of land use practices.