PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Connectivity And Productivity Of Mainstem Alluvial Reaches

BPA project number: 20101
Contract renewal date (mm/yyyy): ☐ **Multiple actions?**

Business name of agency, institution or organization requesting funding
Pacific Northwest National Laboratory

Business acronym (if appropriate) PNNL

Proposal contact person or principal investigator:

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NPPC Program Measure Number(s) which this project addresses
2.2A, 5.2A.7, 5.3B.13, 5.4A.4, 5.4D.2, 6.1C, 7.1A.1, 7.1C.3, 7.1F, 7.3

FWS/NMFS Biological Opinion Number(s) which this project addresses
1998 Supplement to 1995 RPA Measure 10 (drawdown)

Other planning document references
• Snake River Recovery Plan (Section 1.4 and 2.11; Measure 4.1.d and 4.7)
• Wy Kan Ush Me Wa Kush Wi (Artificial Production Actions for the Snake River Maintstem Action 8)
• Return to the River (ISG 1996) emphasized the Hanford Reach of the Columbia River as a model of metapopulation dynamics and study area for "normative" river reaches. They also discussed the importance of alluvial mainstem reaches and the importance of core populations to system production, including the possibility of revitalizing drowned alluvial reaches.
• The ISRP FY99 review of the Fish and Wildlife Program also emphasized the Hanford Reach (Recommendation V-B.2.b.2) and also noted that "in the event that operations are modified or dams are removed…the greatest benefit may be expanded spawning and rearing habitat for stocks lower in the river" (p. 27)

Short description
Evaluate the relative importance of remaining mainstem alluvial habitats by linking physcial habitat variables, such as managed flow, to measurable biotic parameters and ecosystem processes.

Target species
Fall chinook salmon (Oncorhynchus tshawytscha)

Section 2. Sorting and evaluation

Subbasin
Mainstem

Evaluation Process Sort

CBFWA caucus	Special evaluation process	ISRP project type
Mark one or more caucus	If your project fits either of these processes, mark one or both	Mark one or more categories
☒ Anadromous fish ☐ Resident fish ☐ Wildlife	☒ Multi-year (milestone-based evaluation) ☐ Watershed project evaluation	☐ Watershed councils/model watersheds ☐ Information dissemination ☐ Operation & maintenance ☐ New construction ☒ Research & monitoring ☐ Implementation & management ☐ Wildlife habitat acquisitions

Section 3. Relationships to other Bonneville projects

Umbrella / sub-proposal relationships. List umbrella project first.

Project #	Project title/description

Other dependent or critically-related projects

Project #	Project title/description	Nature of relationship
9102900	Life history and survival of fall chinook salmon in Columbia River basin	share data on flow relationships and model development
9406900	A spawning habitat model to aid recovery plans for Snake River fall	share physical habitat data

	chinook	
9701400	Evaluation of juvenile fall chinook stranding on the Hanford Reach	share data on flow relationships and model development
99003	Evaluate spawning of salmon below the four lowermost Columbia River dams	
	Assessment of the impacts of development and operation of the Columbia Riv…	share data on flow management and riverine processes

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Describe physical habitat features influencing fall chinook salmon production	a	Conduct hydrographic analysis
		b	Assemble physical habitat features
		c	Describe hyporheic flow pathways
		d	Physcial modeling integration
2	Describe principle abiotic variables influencing primary and secondary production	a	Characterize primary production
		b	Characterize secondary production
3	Data analysis/integration		

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %

				Total	0.00%

Schedule constraints

Completion date

Section 5. Budget

FY99 project budget (BPA obligated):

FY2000 budget by line item

Item	**Note**	**% of total**	**FY2000**
Personnel		%46	76,792
Fringe benefits		%8	14,090
Supplies, materials, non-expendable property		%0	328
Operations & maintenance		%0	0
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		%0	0
NEPA costs		%0	0
Construction-related support		%0	0
PIT tags	# of tags:	%0	0
Travel		%5	8,728
Indirect costs		%15	25,389
Subcontractor	Associated Western Universities University of Idaho Streamside Programs Consultants	%25	41,578
Other		%0	0
TOTAL BPA FY2000 BUDGET REQUEST			$166,905

Cost sharing

Organization	**Item or service provided**	**% total project cost (incl. BPA)**	**Amount ($)**
		%0	
		%0	

		%0	
		%0	
Total project cost (including BPA portion)			$166,905

Outyear costs

	FY2001	FY02	FY03	FY04
Total budget	$278,764	$207,324		

Section 6. References

Watershed?	Reference
☐	Dauble DD, and DG Watson. 1997. Status of fall chinook salmon populations in the mid-Columbia River, 1948-1992. North American Journal of Fisheries Management 17:283-300.
☐	Fulton LA. 1968. Spawning areas and abundance of chinook salmon (Oncorhynchus tshawytscha) in the Columbia River basin--past and present. U.S. Fish and Wildlife Service Spec. Sci. Rep. Fish. No. 571.
☐	Geist DR, and DD Dauble. 1998. Redd site selection and spawning habitat use by fall chinook salmon: the importance of geomorphic features in large rivers. Environmental Management 22:655-669.
☐	Horner N, and TC Bjornn. 1979. Status of upper Columbia River fall chinook salmon (excluding Snake River populations). U.S. Fish and Wildlife Service, Moscow, Idaho.
☐	Hymer J. 1997. Results of Studies on Chinook Spawning in the Main Stem Columbia River below Bonneville Dam. WDFW Progress Report #97-9. Washington Department of Fish and Wildlife, Battle Ground, Washington.
☐	Huntington C, W Nehlsen, and J Bowers. 1996. A survey of healthy native stocks of anadromous salmonids in the Pacific Northwest and California. Fisheries 21(3):6-14.
☐	Independent Scientific Groups (ISG). 1996. Return to the river, restoration of salmonid fishes in the Columbia Riber ecosystem. Pre-publication copy dated September 10, 1996. Northwest Power Planning Council, Portland, Oregon.
☐	Independent Science Review Panel (ISRP). 1998. Review of the Columbia River Basin Fish and Wildlife Program for fiscal year 1999 as directed by the 1996 ammendment to the NW Power Act. Northwest Power Planning Council, Portland, Oregon.
☐	Van Hyning JM. 1969. Factors affecting the abundance of fall chinook salmon in the Columbia River. Fish. Bull. 4:1-83.
☐	Neitzel, D.A., T.L. Page, and R.W. Hanf, Jr. 1982. Mid-Columbia River zooplankton. Northwest Science. 57:112-118.
☐	Neitzel, D.A., T.L. Page, and R.W. Hanf, Jr. 1982. Mid-Columbia River microflora. Journal of Freshwater Ecology. 1:495-505.

☐	Neitzel, D.A., T.L. Page, and R.W. Hanf, Jr. 1981. Mid-Columbia River benthic macrofauna. Report to Northwest Energy Services. Kirkland, Washington.
☐	Becker, B.D. 1990. Aquatic bioenvironmental studies: the Hanford Experience 1944-1984. Elsevier Science Publishers. New York.
☐	Cushing, C.E. 1963. Plankton-water chemistry cycles in the Columbia River. HW-7600. Pacific Northwest National Laboratory. Richland, Washinton.
☐	Ebel WJ, CD Becker, JW Mullan, and HL Raymond. 1989. The Columbia River: toward a holistic understanding. Proceedings of the International Large River Symposium (LARS). DP Dodge. Special Publication of the Can. J. Fish. Aq. Sci. 106: 205-219.
☐	Gray, R.H. and T.L. Page. 1977-1979. Aquatic ecological studies conducted near WNP 1,2, and 4. WPPSS Columbia River Ecology Studies Vols. 3-6. Prepared by Battelle, Pacific Northwest Laboratories for Washington Public Power Supply System, Richland, Was
☐	Hynes, H.B. 1970. The ecology of running waters. University of Toronto Press. Canada.
☐	Imhof, J.G., J. Fitzgibbon, and W.K. Annable. 1996. A hierarchical evaluation system for characterizing watershed ecosystems for fish habitat. Canadian Journal of Fisheries and Aquatic Sciences 53(Suppl.1):312-326.
☐	Jacobi, G.G. 1971. A quantitative artificial substrate sampler for benthic macroinvertebrates. Transactions of the American Fisheries Society 100:136-138.
☐	Reeves GH, LE Benda, KM Burnett, PA Bisson, and JR Sedell. 1995. A disturbance-based ecosystem approach to maintaining and restoring freshwater habitats of evolutionary significant units of anadromous salmonids in the Pacific Northwest. AFS Symp. 17:334-
☐	Southwood, T.E. 1977. Habitat, the template for ecological strategies? Journal Animal Ecology 46:337-365.
☐	Stanford, J.A., and six coauthors. 1996. A general protocol for restoration of regulated rivers. Regulated Rivers Research and Management 12:391-413.
☐	Stanford, J.A. and J.V. Ward. 1993. An ecosystem perspective of alluvial rivers: connectivity and the hyporheic corridor. Journal North American Benthological Society 12:48-60.
☐	Poff, N.L. and seven coauthors. 1997. The natural flow regime. Bioscience 47:769-784.
☐	Vannote, R.L. G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.
☐	Karr, J.R. 1991. Biological integrity: a long-neglected aspect of water resource management. Ecological Applications 1:66-84.

PART II - NARRATIVE

Section 7. Abstract

We propose to investigate the current status of the Hanford Reach as a functional ecosystem to asses the relative importance of remaining mainstem alluvial habitats to fall chinook salmon. This proposal links the effects of physical habitat variables, such as managed flows, to measurable biotic parameters and ecosystem processes. We will describe the principle abiotic variables that influence primary and secondary production in the Hanford Reach. This information will be used to quantify relationships between regulated flows and ecological processes. The results of this project will provide benefits for other research projects that focus on restoration and enhancement of fall chinook salmon in the Columbia River basin and is to future recovery planning that involves manipulation of mainstem habitats and anadromous fish populations.

Section 8. Project description

### a.	Technical and/or scientific background

Knowledge of the current status of the Hanford Reach as a functional ecosystem is critical to future recovery planning that involves manipulation of mainstem habitats and anadromous fish populations. This information need is consistent with Reeves et al. (1995) notion that recovery programs need to consider ecosystem processes <u>that create and maintain habitats through time</u> (in addition to identifying causal factors that result in loss of habitat). It is also consistent with the recommendations of independent scienctists that increased attention be placed on healthy populations like those found in the Hanford Reach (ISRP 1998). The Hanford Reach may be considered as having the only “core population” of fall chinook salmon within the Columbia River system (ISG, 1996). Hanford Reach populations have increased during the past 25 years because suitable spawning and rearing habitat remained intact, runs were supplemented by hatcheries, and because the mainstem core population remained viable (Dauble and Watson, 1997). In contrast, populations in other parts of the Columbia and Snake rivers have declined because spawning areas were inundated, former core populations were effectively “closed-off” from important upriver production areas, and/or habitat quantity or quality of remaining riverine areas is poor.   These changes provide strong evidence that production potential of remaining mainstem fall chinook salmon is influenced by both abiotic and biotic conditions and that these conditions limit successful completion of life history requirements. Further, the Hanford Reach core population will likely be important in recovering satellite populations of fall chinook salmon. Understanding the important processes affecting Hanford Reach fall chinook salmon will insure this population is protected.

It is well established that stream flow quantity and timing are critical components of water supply, water quality, and the ecological integrity of river systems (Poff et al. 1997).   Flow regimes, geology of surrounding landscapes, and longitudinal slope are important controlling variables in salmon habitats and operate at both the watershed and reach scale (Imhof *et al.*, 1996). In the Columbia River, flow regimes are highly regulated by the hydroelectric complex and seasonal discharge is influenced by water storage and water use practices (Ebel *et al.*, 1989). Flow regulation also affects connections among groundwater, floodplains, and surface water (Stanford et al. 1996), or convergence zones (hyporheic habitats) where biodiversity and bioproduction are frequently high (Stanford and Ward 1993). Hydrologic variables such as discharge become a controlling factor at the reach and site scale in regulated rivers. The relative magnitude and frequency of high flow events also acts to modify channel form, but only within constraints of existing geological features. For example, major floods are less frequent because of upstream flood-control projects constructed since the 1940s. This change is significant because rivers that flood frequently maintain different species and food webs from systems that are more ecologically benign (Stanford et al 1996).

The River Continuum Concept (Vannote et al 1990) describes streams as longitudinally-linked systems in which ecosystem-level processes in downstream areas are linked to those in upstream areas. Over extended river reaches, the biological community also becomes established in response to the dynamic physical conditions of its environment. Thus, the physical structure, coupled with the hydrologic cycle, form a template for biological responses (Southwood 1977). If the Hanford Reach functions as an alluvial stretch of river it should exhibit attributes typical of coarse-bedded alluvial rivers (i.e., spatially complex channel morphology, natural variability in flows and water quality, periodic channel bed scour and fill, functional floodplain, etc.). These alluvial attributes result in greater environmental heterogeneity or habitat complexity in the river continuum (Stanford et al. 1996).

Based on annual escapements that have remained relatively stable over the past 10 years at about 80,000 adults (Dauble and Watson, 1997), it appears that the geological template and hydrologic conditions in the Hanford Reach are compatible with life history requirements of fall chinook salmon. However, it is unknown whether hydropower development and flow management practices have altered species assemblages that form key trophic relationships with fall chinook salmon. In other words, it appears that Handford Reach fall chinook are currently healthy but because of our limited understanding of the relationships between these fish and their ecosystem, we don't know if the population will continue to be healthy in the future. Given the overall importance of the Handford Reach population, this is a relatively high risk. This project will examine changes occurring in the river hydrograph during the last 60 years and assess whether these changes have modified the biological integrity (after Karr 1991) of aquatic communities in the Hanford Reach.

b. Rationale and significance to Regional Programs

Return to the River (ISG 1996) emphasized the Hanford Reach of the Columbia River as a model of metapopulation dynamics and study area for "normative" river reaches. They also discussed the importance of alluvial mainstem reaches and the importance of core populations to system production, including the possibility of revitalizing drowned alluvial reaches. The Hanford Reach core population will likely be important in recovering satellite populations of fall chinook salmon. Understanding the processes affecting fall chinook in the Reach will insure this population is protected.

The Fish and Wildlife program addresses the need for understanding the maintstem habitat ecosystem (both biotic and abiotic factors) as well as the necessary flow regimes specifically in 5.4D.2. Flows and power peaking operations must take into account many factors, including but not limited to the juvenile migration (5.4A.4) and for naturally spawning fall chinook populations (6.1C). Information is still needed improve the management and conservation of naturally spawning populations in mainstem reaches, for instance limiting factors to production, habitat, and risk exposure (7.1C.3).

The ISRP FY99 review of the Fish and Wildlife Program also emphasized the Hanford Reach (Recommendation V-B.2.b.2) and noted that "in the event that operations are modified or dams are removed…the greatest benefit may be expanded spawning and rearing habitat for stocks lower in the river" (p. 27). The full costs or benefits of drawdown and dam modification scenarios cannot be realized without improved understanding of mainstem alluvial reaches.

c. Relationships to other projects

The results of this project will provide benefits for other research projects that focus on restoration and enhancement of fall chinook salmon in the Columbia River basin. In particular, it provides a means for evaluating the relative importance of remaining mainstem alluvial habitats. Flow regulation practices at storage projects influence the relative production of all mainstem populations including those being studied in the Hells Canyon Reach of the Snake River (e.g. 9102900), Hanford Reach (e.g. 9406900, 9701400), as well as those populations that spawn and rear downstream of Bonneville Dam (e.g. 9900301). Our proposal provides a means for linking the effects of physical habitat variables, such as managed flows, to measurable biotic parameters and ecosystem processes.

d. **Project history** (for ongoing projects)

New project, not applicable.

e. Proposal objectives

The overall study objective of this project is to identify key connections among biotic and abiotic variables that influence salmon production in remaining main stem alluvial habitats in the Columbia River system and to determine if these connections have changed over time.

Within this general framework, there are three specific objectives:
- Describe the abiotic environment that influences fall chinook salmon production in the Hanford Reach.
- Describe principal biotic variables influencing fall chinook salmon production
- Describe key linkages among ecosystem processes

There are two hypotheses for this project:

• The biotic production of the Hanford Reach is attributable to the fact that it functions as an alluvial stretch of river
• Regulated flow regimes have affected the abiotic and biotic characteristics of the Hanford Reach.
• The primary characteristics that historically made the Reach an important production area have not changed through time.

f. Methods

Our approach to answering project objectives involves three technical tasks to be conducted over 3 years. The basic approach involves data integration, field verification, and analysis of physical habitat conditions and biological attributes known to influence salmon production. Much of the physical habitat data (i.e., discharge and temperature) are readily available and include the entire hydroelectric development period (pre-1930 to present). An important aspect of our study is the ability to "mine" the extensive historical data sets available on the aquatic community (reviewed in Becker 1990). This analysis will establish past conditions in the Hanford Reach and be used for comparison with field data to be collected in the second and third years of the study.

Task 1. Describe physical habitat features (abiotic environment) influencing fall chinook salmon production.

Approach**:**
The expected results from this task are a description of how riverine processes function under a range of flow conditions (especially recent and contemporary conditions). With this knowledge we can establish predictive flows required to maintain ecosystem processes and determine if flow conditions should be changed in the Hanford Reach to maintain biological attributes required by fall chinook salmon for spawning and rearing. That is, we can prescribe different flow conditions that would accommodate key ecosystem processes.

Subtask 1a. Conduct hydrographic analysis
We will analyze hydrograph records to evaluate changes by development period, e.g., pre-1938 (before Grand Coulee Dam), 1938-1970, and post -1970 (relates to Canadian storage projects). This will require an analysis of flow characteristics (i.e., variability, magnitude, timing, duration, frequency) to determine if hydrological characteristics have changed over time, with emphasis on the period following hydroelectric development. We will develop water year classification and quantify seasonal hydrograph components (e.g., extreme winter events, snowmelt runoff, seasonal baseflows).

Subtask 1b. Assemble physical habitat features
Data sets to be described include channel cross-sections, water surface elevations, discharge profiles, substrate composition, depth of alluvium, etc. Much of this information is present in GIS format from past and ongoing projects. We will use GIS analysis to compare channel cross-section and plan form features from pre-dam hydrographic surveys (i.e., ~1880-1930) to present-day (post-1970). This analysis will allow us to quantify changes over time.

Subtask 1c. Describe hyporheic flow pathways.
We will use existing data (both empirical and modelled) on major groundwater flow pathways, in addition to site-specific data (based on near-shore piezometers) to identify and describe relationships between groundwater flow and nearshore processes, e.g. nutrient cycling. The focus of this subtask will be to assimilate information currently available from Hanford Site monitoring (Hanf and Dirkes 1997) and from ongoing studies by D.R. Geist (BPA Project 9406900).

Subtask 1d. Physical modeling intregration.
Channel bed surface mobility will be monitored and modelled for coarse bedload movement over a range of discharges. This effort will involve the use of pebble counts for size class development, and tracer rock monitoring for mobilization and routing. We will also monitor and model channel bed scour over a range of discharges using scour chains and scour cores. Aerial photo interpretation will be used to assess changes in channel features, i.e., evidence of bar accretion/depostion, slumpage, etc.

Critical assumptions:
• Hydrologic data for the Hanford Reach is readily available
• Physical habitat features can be digitized and analyzed
• Data on Hanford Site groundwater processes can be linked to near shore monitoring (i.e., differences in measurement scale can be resolved using existing models)

Task 2. Describe principle abiotic variables influencing primary and secondary production

The expected product from this task is a test of how hydrologic processes influence primary and secondary production in the Hanford Reach. These studies will be initiated in the second year of the proposed project.

Approach:
Up to 8 reference sites will be randomly selected from river cross-sections where hydraulic features have been previously characterized. At each cross-section, six samplers will be deployed at 50 ft intervals perpendicular to the shore at water surface elevations deeper than the low water level (~ 50,000 cfs discharge). All sample locations will be recorded using a GPS. The following subtasks describe indices to be used as estimates of primary and secondary production.

Subtask 2a. Characterize primary production relative to physical habitat variables and time.

Benthic microflora (principally diatoms) will be collected from glass slides in diatometers (APHA 1975) anchored to the bottom by rock baskets. We will quantify biomass and rate of production (mg/cm^2) relative to location (i.e. distance from shore, average depth) and time of year. We will also collect seasonal (i.e., quarterly) phytoplankton samples for taxonomic identification and density estimates via a Van Dorne water sampler. We will also assemble historic information on these variables from studies conducted in the 1960s (Cushing 1963) and in the 1980s (Gray and Page, 1977-1979; Neitzel et al. 1982). We will compare historic measures of algal density and species composition to present-day values to determine if causal linkages exist between these measures and impoundments or reservoir operation.

Critical assumptions:
• Samplers can be effectively deployed and retrieved under variable flows
• Quarterly samples for 1 year are sufficient to characterize the algal community

Subtask 2b. Characterize secondary production relative to physical habitat variables and time.

Benthic fauna will be collected at quarterly intervals from cobble-filled baskets (Jacobi 1971) placed next to the periphyton sampler. Biomass and principal taxonomic groups of all macroinvertebrates will be determined in the laboratory. Physical habitat data to be collected from baskets will include depth, velocity, substrate, and location. Depth and velocity volumes will include mean, minimum, and maximum, over the colonization period. The historical data base will include a comparison with studies conducted in the 1960s (summarized in Becker 1990) and the 1970s-1980 (Gray and Page, 1977-1979; Neitzel et al. 1981).

Critical assumptions
• Samplers can be effectively deployed and retrieved under variable flows
• Quarterly samples for 1 year are sufficient to characterize the benthic community

Task 3. Data Analysis/ Integration

The expected product is a measure of the strength of relationships between physical processes of the river and the ecological characteristics identified in Task 2.

Approach:
We will use regression techniques to examine the effects of physical variables on primary productivity, and the effects of physical variables and primary producivity on secondary productivity. We will utilize the biological and physical data sets obtained from the field studies to develop a predictive model describing the effects of the suite of physical habitat variables on the suite of primary productivity variables using a multivariate multiple regression analysis (Canonical Analysis). A small set of variables (primary production, flow, and depth variables) will be used in a similar canonical analysis of effects on secondary production variables. The resultant predictive models will be evaluated for efficacy using the historic data on primary and secondary production, and the historic physical data and physical model estimates from subtask 1d. This will provide a means to evaluate the generality of the predictive model.
Additional data on the effects of water level fluctuations on the biomass of macroinvertebrate fauna is expected to be available from Project 9701400 in FY2000. The amount of data collected under this sampling design (i.e., 8 stations with 6 samples each with quarterly samples) is expected to provide adequate statistical power.

Critical assumptions:
• Sample size of historic data sets is sufficient to make reasonable comparisons
• Variability of production indices is similar to data previously reported for the Hanford Reach.

g. Facilities and equipment

All research activities would be conducted at the Pacific Northwest National Laboratory, located in Richland, Washington. The facility has sufficient office and laboratory space to meet research objectives.

The following equipment is planned for use on this project with no cost to BPA:

- Global Positioning System (GPS)
- 17 ft Monark boat w/ twin outboard engines
- 16 ft Hewescraft boat w/outboard engine
- Notebook computer for field mapping
- GIS platform for data analysis and reporting

We intend to purchase the following equipment for use on this project: benthos samplers, periphyton samplers, dry suit for retrieving samplers, shoreline anchors, rope, and station markers. We will rent a 4-wd vehicle to tow the boat and collect data from shoreline stations in FY2001.

h. Budget

The total cost to complete this work in FY2000 is estimated to be $166,905. Approximately 54% is for personnel and fringe benefits. About 5% of the budget is for travel costs and approximately 15% of the budget allocated to indirect costs. Indirect costs include primarily organization overheads, which include costs for management, supervision, and administration of technical departments as well as costs for buildings and utilities, maintenance and operation of research equipment. Estimated costs for FY2001 and FY2002 are $279,000 and $207,000, respectively.

Section 9. Key personnel

DENNIS D. DAUBLE, Staff Scientist 0.10 FTE

Education

B.S.	Fisheries	Oregon State University	1972
M.S.	Biology	Washington State University	1978
Ph.D.	Fisheries	Oregon State University	1988

Related Experience

Dr. Dauble manages a team of scientists involved in research for private companies and federal agencies, including the U.S. Department of Energy, U.S. Forest Service, BPA, and the U.S. Army Corps of Engineers. Dr. Dauble has extensive experience in activities related to assessing impacts from hydropower generation and flow regulation to aquatic ecosystems. He has been invovled in regional planning for fisheries issues and conducted research on Columbia River fish populations for BPA and other clients for over 20 years. Specific experience relevant to this project includes:

• Characterizing Habitat Requirements for Salmonids - Dr. Dauble has expertise in the use of aerial photography, underwater video systems, stream mapping, Global Positioning System (GPS), and Geographic Information System (GIS) techniques to characterize spawning habitat of fall chinook salmon and other salmonids..

• Ecological Monitoring Studies - Dr. Dauble has directed field studies dealing with the design of sampling procedures and collection techniques for environmental impact studies of the Columbia River aquatic community. Emphasis has been on ecological relationships of Columbia River fish, including life history aspects, population assessment, and migrational characteristics of both resident and anadramous fish species.

• System Evaluations - Dr. Dauble was project manager for studies involving the biological impacts of drawdown on anadromous fish survival and Snake River ecosystems. He provided assistance to the Snake River Recovery team on the passage and survival of Endangered Species Act salmon stocks. He served as a member of the Technical Advisory Group for the Snake River drawdown.

Selected Publications

Dauble, D.D., R.L. Johnson, A. Garcia. Fall chinook salmon spawning in the tailraces of lower Snake River hydroelectric projects. Transactions of the American Fisheries Society. In Press.

Geist, D.R. and D.D. Dauble. 1998. Redd Site Selection and Spawning Habitat Use by Fall Chinook Salmon: the Importance of Geomorphic Features in Large Rivers. Environ. Mgmt. 22:655-669.

Dauble, D.D., and D.G. Watson. 1997. “Status of Fall Chinook Salmon Populations in the Mid-Columbia River, 1948-1992. North American Journal of Fisheries Management 17:283-300.

Dauble, D.D. and D.R. Geist. 1992. Impacts of the Snake River Drawdown Experiment on Fisheries Resources in Little Goose and Lower Granite Reservoirs, 1992. PNL-8297. Prepared for the U.S. Army Corps of Engineers-Walla Walla District.

Dauble, D. D., T. L. Page, and R. W. Hanf, Jr. 1989. Spatial Distribution of Juvenile Salmonids in the Hanford Reach, Columbia River. Fish. Bull. 87(4):775-790.

TIMOTHY P. HANRAHAN, Research Scientist   0.01 FTE

Education

B.S.	General Sciences	University of Wisconsin	1989
M.S.	Natural Resource Science	Washington State University	1993

Related Experience

Mr. Hanrahan's professional interests and research focus on large river processes, including biotic and abiotic interactions. He is a technical contributor to public- and private-sector projects, including ecological characterization and monitoring, ecological risk assessment, ecological resource compliance, and regulatory analysis (e.g., NEPA, ESA, CWA).   Mr. Hanrahan's current work focuses on assessing aquatic ecosystem effects resulting from fluctuating large river flow regimes. Through this research, other projects, and training he has developed a strong background in methods for assessing flow/geomorphology relationships, assessment and modeling of aquatic habitats, and stream temperature modeling.

Recent fish community evaluation activities include the following:

- Assessment of Drawdown from a Geomorphic Perspective (lower Snake River). Mr. Hanrahan is co-principal investigator of a study assessing the geomorphological changes resulting from natural river drawdown and the subsequent effects on anadromous salmonids.

- Snake River Hyporheic Study (Hells Canyon). Mr. Hanrahan is co-principal investigator of a study investigating the interactions between groundwater and surface water and the associated relationship with fall chinook salmon spawning habitat.

- Assessment of Columbia River Hydroelectric System on Mainstem Riverine Processes and Salmon Habitats. Mr. Hanrahan is co-principal investigator of a systematic assessment of the extent and types of habitat modifications that have occurred to the mainstem Columbia and Snake rivers.

Mr. Hanrahan is a member of the American Fisheries Society and a participating scientist in the Citizen Ambassador Program of People to People International.

Selected Publications

Blatner, K. A., T. P. Hanrahan, and M. S. Carroll. 1994. *Evaluating Alternative Development Strategies*. USDA Forest Service, PNW Technical Bulletin, Blue Mountain Natural Resources Institute. 10 pp.

Frazier, B. E., B. C. Moore, and T. P. Hanrahan. 1992. *Remote Sensing of* Lythrum salicaria, *Purple Loosestrife, in Wetland Environments of Washington*. State of Washington Water Research Center, Washington State University, Pullman, Washington.

Hanrahan, T. P., D. A. Neitzel, M. C. Richmond, and K. A. Hoover. 1998. *Assessment of Drawdown from a Geomorphic Perspective Using Geographic Information Systems: Lower Snake River*, *Washington*. Final report submitted to U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

COLBERT E. CUSHING, Consultant 0.1 FTE

Education

Ph.D.	Biology (Limnology)	University of Saskatchewan	1961
M.S.	Zoology (Limnology)	Colorado State University	1954
B.S.	Fisheries Management	Colorado State University	1952

Related Experience

Dr. Cushing's major research interests are in the fields of stream ecology, mineral cycling, and radio ecology. His major research interests have been focused on theoretical ecological studies of lotic ecosystems. The emphasis of his research in the Hanford area includes Rattlesnake Springs, McNary Reservoir, and Gable Mountain Pond. These studies have included a detailed examination of the dynamics of stream ecosystems in several biomes in the U.S., with particular emphasis on the Salmon River, Idaho and its tributaries (co-Pl, NSF River Continuum Project); the impact of the Mt. St. Helens eruption on stream ecosystems at varying distances from the volcano and various aspects of the ecology of cold desert spring-streams, including primary and secondary production, organic carbon budgets, allochthonous organic matter input, insect food habits, recolonization following flash-floods, and carbon sources for insects.

Dr. Cushing retired from PNNL after 35 years (1961 - 1996) of employment with much of his work centered on the Hanford Reach. He is currently with Streamside Programs Consultants

Selected Publications

Cushing, C.E. 1993a. Impact of experimental dewatering of Lower Granite and Little Goose reservoirs on benthic invertebrates and macrophytes. Completion Report. PNNL-8807. Pacific Northwest Laboratory, Richland, Washington.

Cushing, C.E. 1993b. Aquatic studies at the 100-HR-3 and 100-NR-1 Operable Units. Pacific Northwest Laboratories, Richland, Washington.

Watson, D.G., C.E. Cushing, and C.C. Coutant. 1967. Environmental effects of extended reactor shutdown - fish. IN: The environmental effects of an extended Hanford Plant shutdown. BNWL-CC-1056 (Classified). Battelle Memorial Institute, Pacific Northwest Laboratory, pp 71-75. (Unclassified biological data appears in Publication No. 17).

Cushing, C.E., D.G. Watson, J.L. Gurtisen, and A.J. Scott. 1981. Decrease of radio nuclides in Columbia River biota following closure of Hanford reactors. Health Physics 41:59-67.

Cushing, C.E., Jr. 1979. Trace elements in Columbia River food web. Northwest Sci. 53:118-125.

MARSHALL C. RICHMOND, Senior Research Engineer 0.1 FTE

Education

Ph.D. Civil and Environmental Engineering University of Iowa 1987
M.S. Civil and Environmental Engineering Washington State University 1983
B.S. Civil and Environmental Engineering Washington State University 1982

Related Experience

Marshall Richmond is a senior research engineer with PNNL and is a technical expert in the area of flow dynamics and river system modeling. He was the technical lead in the development of the unsteady flow model used for modeling total dissolve gas movement on the Snake River (under COE contract) and the unsteady flow model describing Columbia River flow dynamics for the Hanford Reach used in the Hanford Stranding Evaluation (Project # 9701400). His professional experience includes basic and applied research, university teaching, and project management. His principal areas of expertise are in the development and application of computational models of contaminant transport and fate in environmental systems, physical modeling of hydraulic structures, fisheries engineering, sediment transport modeling, and turbulence modeling in computational fluid dynamics.

Selected Publications

Walters, W.H., M.C. Richmond, and B.A. Gilmore. 1996. Restruction of Radioactive Contamination in the Columbia River. Health Physics, bol. 71, No. 4,
pp. 556-567.

Paluszkiewicz, T., L.F. Hibler, M.C. Richmond, D.J. Bradley, and S.A. Thomas. 1996. Modeling the Potential Radionuclide Transport by the Ob and Yenisey
Rivers to the Kara Sea. Accepted for publication in Marine Pollution Bulletin.

Richmond, M.C. 1995. Strategies for Modeling Dissolved Gas Transport in the
Columbia and Snake Rivers. U.S. Army Corps of Engineers Gas Abatement Study
Modeling Workshop, Newport, OR, February 1-2, 1995.

Richmond, M.C., M.S. Wigmosta, and W.A. Perkins. 1998. Lower Snake River
Hydraulics and Sediment Transport, Pacific Northwest National Laboratory, Richland, Washington.

Walters, W.H., M.C. Richmond, and B.G. Gilmore. 1993. Reconstruction of Radionuclide Concentrations in the Columbia River from Hanford, Washington to
Portland, Oregon for January 1950-January 1971. Hanford Environmental Dose Reconstruction Project. PNWD-2225 HEDR. Battelle Pacific Northwest Laboratories, Richland, Washington.

Section 10. Information/technology transfer

Products will consist of scientific reports thtat will be made available through BPA's report distribution system. In addition, where possible we anticipate papers (rather than or in addition to reports) will be published in peer reviewed journals. Further, PNNL staff annually attend professional society meetings (i.e. American Fisheries Society, North American Benthological Society) where we would anticipate presenting these results.

Congratulations!