PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

A Spawning Habitat Model To Aid Recovery Plans For Snake River Fall Chinook

BPA project number: 9406900
Contract renewal date (mm/yyyy): 10/1999 ☐ **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
7.5B.3, 7.5B.5

FWS/NMFS Biological Opinion Number(s) which this project addresses
None

Other planning document references
The Snake River Recovery Plan recommends an ecosystem approach to land management and habitat recovery (Sec. 1.4), provision of adequate instream flows (Sec. 1.5), and expansion of life history information (Sec. 2.11). The "Return to the River" (ISG 1996) emphasizes the Hanford Reach of the Columbia River as both a model of metapopulation dynamics and study area of "normative" river reaches (p. 519-520). The report finds that ground-water/surface-water interactions in salmon habitat are important components of a normative river and managers should strive to incorporate this information in salmon recovery options (p. 510). Hanford Reach fall chinook salmon are recommended as an index population in the Multi-Year Implementation Work Plan (CBFWA 1997; p. 17). In their FY99 review of the Fish and Wildlife Program, the ISRP specifically recommends additional research in the Hanford Reach (recommendation V-B.2.b.2). This research addresses each of the above recommendations.

Short description
Investigate ground-water/surface-water interactions influencing fall chinook salmon spawning site selection in the Hanford Reach, and predict spawning habitat of other mainstem spawning salmonids.

Target species
Fall chinook salmon, steelhead trout

Section 2. Sorting and evaluation

Subbasin
Middle Columbia River Mainstem (Bonneville to Priest Rapids Dam), Snake River Mainstem (mouth to Hells Canyon Dam)

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
	I assume this project would fall under an umbrella project that would
	collectively include fall chinook salmon research projects. However, I am
	not aware of an organization who has organized this umbrella project.
	Projects that could be included in this umbrella project may include:
9701400	Evaluation of Juvenile Fall Chinook Stranding on the Hanford Reach
9801003	Monitor and Evaluate the Spawning Distribution of Snake River Fall Chinook
9102900	Life History Requirements of Fall Chinook in the Columbia River Basin.
99003	Evaluate Spawning Just Below the Four Lowermost Columbia Dams

Other dependent or critically-related projects

Project #	Project title/description	Nature of relationship
9102900	Life history requirements of fall chinook in the Columbia River Basin.	The US Fish and Wildlife Service depends on our project for validation/verification of their Snake River fall chinook salmon spawning habitat model.
9701400	Evaluation of juvenile fall chinook stranding in Hanford Reach	The Wash. State Department of Fish and Wildlife depends on our project for sharing of staff and computer resources for conducting Hanford Reach stranding project.
	PATH	Data from this project will be used by PATH.

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?
1997	Completed conceptual spawning habitat model for fall chinook salmon (Geist and Dauble 1998).	Yes
1998	Completed comparison of geomorphic features between Snake and Columbia rivers (Dauble and Geist, manus. submitted).	Yes
1998	Provided empirical evidence that interstitial flow pathways and ground water/surface water interactions were important determinants of fall chinook salmon spawning (Geist, in press).	Yes
1998	Translated information and technology from Hanford Reach to on-going efforts in Snake River (Geist, in press).	Yes

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Define production potential of fall chinook salmon that spawn in the Hanford Reach.	a	Conduct limits analysis for depth, substrate, velocity, and lateral slope at representative habitat types/locations.

		b	Select and describe appropriate geomorphic features and hyporheic zone characteristics in areas where limits analysis suggest spawning should occur.
		c	Estimate potential redd densities at various seeding levels and compare to known values.
		d	Extrapolate range of density values to other areas deemed suitable based on geomorphic features.
		e	Prepare report/paper.
2	Demonstrate that steelhead spawn in the Hanford Reach and determine the characteristics of key physical features that define steelhead spawning habitat.	a	Identify historical and existing steelhead spawning locations.
		b	Conduct limits analysis for depth, substrate, velocity, and lateral slope at representative habitat types/locations.
		c	Select and describe appropriate geomorphic features and hyporheic zone characteristics in areas where limits analysis suggest spawning should occur.
		d	Prepare report/paper.
3	Evaluate whether an analysis of geomorphic features within the Hells Canyon Reach of the Snake River can be used to assist in defining existing or potential fall chinook salmon spawning habitat.	a	Select study sites and identify permitting and coordination issues.
		b	Place and monitor piezometers in study areas within Hells Canyon Reach.
		c	Conduct data analysis.
		d	Prepare final report.
4	Synthesize information from objectives 1 through 3 into a final completion report.	a	Information collected in each of the first three objectives will be synthesized into a project completion report.

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %
1	10/1998	6/2000		Task completion report	45.00%
2	1/1999	9/2001		Task completion report	20.00%
3	10/1999	9/2001		Task completion report	25.00%
4	10/2001	9/2002		Project completion report	10.00%
				Total	100.00%

Schedule constraints
Section 7 consultation may be required for Snake River fall chinook and Columbia River steelhead (Objectives 2 and 3). The installation of piezometers will require habitat protection permits from the states of Washington and Idaho (Objectives 1 - 3).

Completion date
FY 2002 (note that this is one year later than proposed in FY99. This is because we did not receive full funding for the project in FY99).

Section 5. Budget

FY99 project budget (BPA obligated): $165,000

FY2000 budget by line item

Item	Note	% of total	FY2000
Personnel		%49	163,890
Fringe benefits		%9	30,139
Supplies, materials, non-expendable property		%14	45,511
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	15,510
Indirect costs		%17	56,072

Subcontractor	Associated Western Universities	%7	22,005
Other		%0	
	TOTAL BPA FY2000 BUDGET REQUEST		$333,127

Cost sharing

Organization	**Item or service provided**	**% total project cost (incl. BPA)**	**Amount ($)**
		%0	
		%0	
		%0	
		%0	
		Total project cost (including BPA portion)	$333,127

Outyear costs

	FY2001	**FY02**	**FY03**	**FY04**
Total budget	$340,000	$110,000		

Section 6. References

Watershed?	**Reference**
☐	Arnsberg, B.D., W.P. Connor, and E. Connor. 1992. Mainstem Clearwater River study: Assessment for salmonid spawning, incubating, and rearing. Bonneville Power Administration, Portland, OR.
☐	Becker, C.D. 1985. Anadromous salmonids of the Hanford Reach, Columbia River: 1984 status. PNL-5371, Battelle, Pacific Northwest Laboratory, Richland, WA.
☐	Brunke, M., and T. Gonser. 1997. The ecological significance of exchange processes between rivers and ground water. Freshwater Biology 37:1-33.
☐	Burner, C.J. 1951. Characteristics of spawning nests of Columbia River salmon. Fishery Bulletin 52:95-110.
☐	Chapman, D.W., D.E. Weitkamp, T.L. Welsh, and T.H. Schadt. 1983. Effects of minimum flow regimes on fall chinook spawning at Vernita Bar 1978 - 1982. Report to Grant County Public Utility District, Ephrata, Washington, By Don Chapman Consultants, McCal
☐	Columbia Basin Fish and Wildlife Authority (CBFWA). 1997. Draft FY 1998 annual implementation work plan. Portland, OR.
☐	Connor, W.P., A.P. Garcia, H.L. Burge, and R.H. Taylor. 1993. Fall chinook salmon spawning in free-flowing reaches of the Snake River. Pages 1-29 in D.W. Rondorf and W.H. Miller (eds.). Identification of the spawning, rearing, and migratory requiremen
☐	Connor, W.P., A.P. Garcia, A.H. Connor, R.H. Taylor, C. Eaton, D. Steele, R. Bowen, and R.D. Nelle. 1994. Fall chinook salmon spawning habitat

	availability in the free-flowing Snake River. Pages 22-40 in D.W. Rondorf and K. Tiffan (eds.). Identifica
☐	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. Manuscript in prep. Changes in watershed characteristics that affect production of fall chinook salmon. Submitted to Regulated Rivers.
☐	Department of Commerce. 1997. Final Rule on Endangered Species Listing for Evolutionary Significant Units (ESUs) of West Coast steelhead. August 18, 1997. Department of Commerce, Washington, D.C.
☐	Department of Energy (DOE). In preparation. Hanford Site steelhead management plan.
☐	Eldred, D.R. 1970. Steelhead spawning in the Columbia River, Ringold to Priest Rapids Dam, September 1970 progress report. Washington Department of Game, Ephrata, WA.
☐	Frissell, C.A., W.J. Liss, C.E. Warren, M.D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management 10:1099-214.
☐	Geist, D.R. 1995. Hanford Reach: What do we stand to lose? Illahee 11:130-141.
☐	Geist, D.R., D.D. Dauble, and R.H. Visser. 1997. The development of a spawning habitat model to aid in recovery plans for Snake River fall chinook salmon. Fiscal Year 1995 and 1996 Progress Report to the Bonneville Power Administration , Portland, OR.
☐	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. Environmental Management 22:655-669.
☐	Geist, D.R. In press. Redd site selection and spawning habitat use by fall chinook salmon. Ph.D. Dissertation. Oregon State University, Corvallis, Oregon.
☐	Geist, D.R., M.C. Joy, D.R. Lee, and T. Gonser. 1998. A method for installing piezometers in large cobble-bed rivers. Ground Water Monitoring and Remediation 18:78-82.
☐	Groves, P.A., and J.A. Chandler. In press. Spawning habitat used by fall chinook salmon in the Snake River. North American Journal of Fisheries Management.
☐	Hvorslev, M.J. 1951. Time lag and soil permeability in ground water observations. U.S. Army Corps of Engineers, Waterways Experiment Station, Bulletin 36.
☐	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.
☐	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.

☐	Independent Scientific Group (ISG). 1996. Return to the river, restoration of salmonid fishes in the Columbia River ecosystem. Pre-publication copy dated September 10, 1996. Northwest Power Planning Council, Portland, OR.
☐	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 Amendment to the NW Power Act. Northwest Power Planning Council, Portland, OR.
☐	Lee, D.R., and J.A. Cherry. 1978. A field exercise on groundwater flow using seepage meters and mini-piezometers. Journal of Geological Education 27(1):6-10.
☐	National Marine Fisheries Service (NMFS). 1995. Proposed Recovery Plan for Snake River salmon. U.S. Department of Commerce, NOAA.
☐	Northwest Power Planning Council (NPPC). 1994. 1994 Columbia River Basin Fish and Wildlife Program. Northwest Power Planning Council, Portland, Oregon.
☐	Palmer, C.D. 1993. Borehole dilution tests in the vicinity of an extraction well. Journal of Hydrology 146: 245-266.
☐	Rondorf, D.W., and W.H. Miller (eds.). 1993. Identification of the spawning, rearing, and migratory requirements of fall chinook salmon in the Columbia River basin. U.S. Department of Energy, Bonneville Power Administration, Portland, OR.
☐	Shirvell, C.S. 1989. Ability of PHABSIM to predict chinook salmon spawning habitat. Regulated Rivers: Research and Management 3:277-289.
☐	Spane, F.A., Jr. 1996. Applicability of slug interference tests for hydraulic characterization of unconfined aquifers: (1) analytical assessment. Ground Water 34(1): 66-74.
☐	Stanford, J.A., J.V. Ward, W.J. Liss, C.A. Frissell, R.N. Williams, J.A. Lichatowich, C.C. Coutant. 1996. A general protocol for restoration of regulated rivers. Regulated Rivers: Research & Management, 12:391-413.
☐	Swan, G.A. 1989. Chinook salmon spawning surveys in deep waters of a large, regulated river. Regulated Rivers: Research & Management 4:355-370.
☐	Watson, D.G. 1973. Estimate of steelhead trout spawning in the Hanford Reach of the Columbia River. Battelle, Pacific Northwest Laboratories, Richland, WA.
☐	White, D.S. 1993. Perspectives on defining and delineating hyporheic zones. Journal of the North American Benthological Society 12:61-69.
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PART II - NARRATIVE

Section 7. Abstract

We will investigate the role of interstitial flow pathways and ground-water/surface-water interactions in spawning site selection by salmonids in the mainstem Columbia and Snake rivers. The information is needed to refine our definition of spawning habitat and develop recovery goals for Columbia River salmonids that are listed under the Endangered Species Act (ESA), including Snake River fall chinook salmon (*Oncorhynchus tshawytscha*) and Upper Columbia River steelhead (*O. mykiss*). The benefits of this information include an estimate of the production potential for Hanford Reach fall chinook salmon, a population that is critical for the recovery of Columbia River salmon; an evaluation of Hanford Reach spawning habitat used by ESA-listed steelhead; and an evaluation of the ground-water/surface-water interactions and spawning site selection by Snake River fall chinook salmon. We expect the project results from each of the objectives to be published in peer reviewed journals. We will synthesize this information into a project completion report to be used by fishery managers to improve production estimates for Snake River fall chinook salmon, and to provide information to critically evaluate recovery options for Columbia River salmonids.

Section 8. Project description

a. Technical and/or scientific background

Current mainstem production areas for salmonids are now largely restricted to habitats that remain non-inundated, i.e., the Hanford Reach of the Columbia River and the Hells Canyon Reach of the Snake River (Connor et al. 1993, 1994; Dauble and Watson 1997). Although the Hanford Reach stock of fall chinook salmon is relatively healthy (Huntington et al. 1996; Dauble and Watson 1997), the Snake River fall chinook salmon were listed under the Endangered Species Act (ESA) in 1994. Upper Columbia steelhead, including those suspected to spawn in the Hanford Reach (Eldred 1970; Watson 1973; Becker 1985), were listed under ESA in 1997 (Dept. of Commerce 1997). Recovery planning is underway for stocks listed under ESA and will rely on a combination of spawning habitat protection and restoration (NPPC 1994; NMFS 1995; Dept. of Commerce 1997), among other actions. If habitat in other portions of the basin can be protected, then the core population of fall chinook salmon in the Hanford Reach may be able to seed depressed stocks (ISG 1996; ISRP 1998). With limited recovery funding, it is important to find the specific habitats that should be protected and enhanced (Rondorf and Miller 1993). Traditional methods to characterize spawning habitat involve measurements of depth, substrate, and velocity at the spatial scale of a redd (e.g., Burner 1951; Swan 1989; Groves and Chandler, in press). While these methods provide useful information regarding the limits of suitable spawning habitat, the range of micro-habitat characteristics within the areas that salmonids spawn is quite broad (Geist et al. 1997; Groves and Chandler, in press), and actual use does not always relate to predicted use (Geist and Dauble 1998; Geist, in press).

Recent reviews suggest that salmonid spawning habitat in river systems is linked to the geomorphic characteristics of river channels that occur at various spatial scales (Frissell et al. 1986; Stanford et al. 1996; Imhof et al. 1996; Geist and Dauble 1998). Rivers are highly interactive with the surrounding landscape within the floodplains of most rivers (Stanford et al. 1996; ISG 1996), and these interactions create connections between the ground water and surface water. The area where surface water and ground water come together has been termed the hyporheic zone (White 1993; Brunke and Gonser 1997). Through funding provided by the Fish and Wildlife Program since 1994, we have been investigating the relationship between hyporheic flow and fall chinook salmon spawning in the Hanford Reach (Geist et al. 1997; Geist et al. 1998; Geist and Dauble 1998; Geist, in press). Based on our results to date, the hydrologic exchange that occurs within the hyporheic zone is an important geomorphic process within large river systems that affects where fall chinook salmon spawn (Geist and Dauble 1998; Geist, in press). Our research in the Hanford Reach suggests that in spawning areas with equal amounts of depth, substrate, and velocity (i.e., micro-habitat characteristics), fall chinook salmon spawning is more prevalent in areas of hyporheic upwelling (Geist, in press).

We have developed models that apply information on the spatial extent of hyporheic upwelling to better predict where fall chinook salmon spawning occurs in the Hanford Reach (Geist et al. 1997; Geist and Dauble 1998; Geist, in press). We believe that these conceptual models can be used to (1) *predict the production potential of Hanford Reach fall chinook salmon*. This information can be used to estimate the level of escapement needed to provide excess production for seeding satellite populations. (2) *identify critical habitat of other mainstem salmonids such as ESA listed Hanford Reach steelhead*. This information can be used to assist fishery managers in recovery efforts for Upper Columbia steelhead. (3) *identify the critical spawning habitat that is available for fall chinook salmon in the Hells Canyon Reach of the Snake River*. This information can be used by fishery managers to improve production estimates for Snake River fall chinook salmon and to critically evaluate recovery strategy options.

b. Rationale and significance to Regional Programs

The protection and restoration of fall chinook salmon spawning habitat within the Hells Canyon Reach of the Snake River is included in the 1994 Fish and Wildlife Program (Section 7.5B.3 and 7.5B.5; NPPC 1994). Realistic predictions of available spawning habitat are needed to define salmon and steelhead recovery goals (ISG 1996). However, our knowledge of what constitutes suitable spawning habitat for salmonids in large mainstem rivers is limited to current understanding of physical constraints imposed by depth, substrate, velocity, and slope on site selection, redd construction, and embryo survival (Chapman et al. 1983; Swan 1989; Groves and Chandler, in press). Consequently, traditional spawning habitat models based on these measures may over-predict suitable spawning habitat (Shirvell 1989; Arnsberg et al. 1992), leading to unrealistic recovery goals for Snake River fall chinook salmon and upper Columbia steelhead. Although these approaches have their place in identifying "limits" of suitable habitat, other models which are based on a geomorphic approach are needed to accurately predict production potential and determine recovery goals (Stanford et al. 1996; Imhoff et al. 1996; ISG 1996; Geist and Dauble 1998).

In "Return to the River", the Independent Science Group (ISG) recommended an alternative conceptual foundation for restoring Columbia River salmonids based on a "complex and dynamic continuum of habitats in the Columbia River" (ISG 1996; p. 21). The linkage of surface water and ground water within the hyporheic zone of alluvial rivers was suggested as a key process that establishes this continuum of habitats. The ISG reiterated that hyporheic flows and ground water upwelling was "an especially important habitat forming process that may be overlooked with respect to salmonid ecology" (ISG 1996; p. 21). Because the Hanford Reach retains many of the geomorphic features of an alluvial mainstem reach and resembles a "normative river", the scientists recommended that it be set aside as a salmon reserve and used as a model upon which to base recovery of fall chinook salmon in the entire basin. Further, they suggested that the Hanford Reach could serve as a core population in a metapopulation structure with potential recruits from the Hanford Reach available for seeding other production areas (ISG 1996; p. 31). The importance of the Hanford Reach fall chinook was not overlooked by the fishery management agencies and tribes (CBFWA 1997; p. 17) as well as by the NPPC (see Recommendations of the NPPC on FY98 Annual Implementation Work Plan, dated September 1997). The type of research conducted in this project provides empirical data on the role of hyporheic flow pathways and salmon spawning habitat. It will provide critical information needed to protect important core populations in the Hanford Reach and can be applied to developing habitat requirements of other salmonids. Thus, it is directly related to the ISG recommendations and is consistent with the NPPC program measures.

Below is a specific discussion of each project objective and linkage to objectives of the Fish and Wildlife Program and recommendations by several independent science groups (i.e., ISG/ISAB, ISRP).

Objective 1. Define production potential of fall chinook salmon that spawn in the Hanford Reach.

Protecting fall chinook salmon that spawn in the Hanford Reach has been suggested as one of the most prudent action items that could be taken to restore Columbia River salmon (Geist 1995; ISG 1996). The Multi-Year Work Plan calls for additional data on basic life history and habitat characteristics of Hanford Reach fall chinook salmon (CBFWA 1997; p. 17). This objective would result in a better definition of potential production that could be achieved in the Hanford Reach. This knowledge will allow managers to (1) identify and protect critical spawning habitat, (2) establish escapement adequate to ensure “seeding” of satellite populations (e.g., Yakima River, Hells Canyon Reach, upper Columbia) and to increase potential for seeding to former production areas if alternative hydropower management scenarios (e.g., drawdown) are implemented, and, (3) establish habitat protection criteria if a salmon reserve is established in the Hanford Reach.

Objective 2. Demonstrate that steelhead spawn in the Hanford Reach and determine the characteristics of key physical features that define steelhead spawning habitat.

ESA-listed steelhead pass through the Hanford Reach on their way upstream to spawn (Watson 1973; Becker 1985) and are also thought to spawn in the Hanford Reach (Eldred 1970). It is likely that identification and protection of critical habitat for fall chinook salmon will indirectly benefit steelhead because of similarities in life history requirements. However, it is also likely that sufficient differences exist and steelhead may require additional protection strategies. This objective would accomplish two things. First it would test the conceptual spawning model (Geist and Dauble 1998) using another species within the same geographic range. Second, it would provide critical information on the life history requirements and habitat utilization of a newly listed species. This objective is consistent with the information needs expressed in the Final Rule on west coast steelhead (Dept. of Commerce 1997).

Objective 3. Evaluate whether an analysis of geomorphic features within the Hells Canyon Reach of the Snake River can be used to assist in defining existing or potential fall chinook salmon spawning habitat.

This study is designed to provide new information for use by fishery managers that make decisions on the management and protection of Snake River fall chinook salmon. Careful consideration of actual habitat use relative to the amount actually available is needed to help narrow the range of criteria used in defining critical habitat. Specially, we propose that knowledge of the interstitial flow pathways and ground-water/surface-water interactions within fall chinook salmon spawning areas can be used to more accurately define production potential.

Objective 4. Synthesize information from objectives 1 through 3 into a final completion report.

The synthesis of information into a final project completion report will provide managers with needed information in order to refine production potential of mainstem spawning populations of salmonids.

c. Relationships to other projects

The completion of this work will assist the USFWS/BRD in interpreting their data and developing recovery goals for fall chinook salmon in the Snake River (Project 9102900). WDFW stranding project (Project 9701400) and this project have been able to share resources including staff and computer equipment.

d. Project history (for ongoing projects)

This project was initiated in FY1994 and is presently on-going. Total funding for FY98 and prior years equals $584,770. The four objectives described in this proposal were first proposed and approved in FY1999. Results from previous as well as current objectives are being used in an adaptive framework as described below:

- the transfer of technology for sampling hyporheic habitats of a large cobble bed river. These new methods allow investigators to evaluate hyporheic processes in spawning areas of large river salmonids, including fall chinook salmon in the Snake River.
- the development of a conceptual spawning habitat model for fall chinook salmon. This model is being proposed as a framework upon which to develop production estimates and future research/monitoring efforts.
- a comparison of watershed characteristics between the Snake and Columbia rivers and how these characteristics improve spawning habitat at other measurement scales. This comparison suggests that the Snake River and Hanford Reach have different production potentials. This information will allow managers to better interpret data from other sub-basins in the Columbia and Snake River system.

A total of 6 peer-reviewed papers and 5 technical reports have been submitted for publication and/or published on information generated from this project (examples listed below). An additional 7 platform presentations have been made at scientific meetings around the world and 4 papers are presently in preparation (due to space limitations these are not listed here):

<u>Peer Reviewed Journals</u>

- 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." <u>Environmental Management</u> 22:655-669.
- Geist, D.R., M.C. Joy, D.R. Lee, and T. Gonser. 1998. "A method for installing piezometers in large cobble bed rivers." <u>Ground Water Monitoring and Remediation</u> 18:78-82.
- Dauble, D.D., and D.R. Geist. In prep. "Changes in watershed characteristics that affect production of fall chinook salmon." Submitted to <u>Regulated Rivers</u>.
- Geist, D.R., J. Jones, C.J. Murray, and D.D. Dauble. In prep. "Physical factors associated with fall chinook salmon redd clusters at two sites in the Hanford Reach, Columbia River." Submitted to <u>Canadian Journal of Fisheries and Aquatic Sciences</u>.

<u>Technical Reports</u>

- Geist, D.R., R.H. Visser, and D.D. Dauble. 1997. Spatial and temporal distribution of fall chinook salmon redds within the Hanford Reach of the Columbia River. FY 1995 and 1996 progress report. Bonneville Power Administration, Portland, Oregon.
- Lee, D.R., D.R. Geist, K. Saldi, D. Hartwig, and A.T. Cooper. 1997. Locating groundwater discharge in the Hanford Reach of the Columbia River. RC-M-22 and PNNL-11516. Atomic Energy of Canada, Ltd., Chalk River Laboratories, Chalk River, Canada, and Pacific Northwest National Laboratory, Richland, Washington.
- Geist, D.R. In press. Redd site selection and spawning habitat use by fall chinook salmon. Ph.D. Disertation. Oregon State University, Corvallis, Oregon.

e. Proposal objectives

As previously noted, these four objectives were first proposed and approved in FY99. However, full funding was not received for all objectives. Consequently, work is on-going toward addressing objective 1 and portions of 2 and 3. We are requesting full funding to implement the study objectives as originally approved for FY99. Based on results to date, slight modifications were made to the original FY99 objectives.

Objective 1. Define production potential of fall chinook salmon that spawn in the Hanford Reach.

Hypothesis: Geomorphic features, including hyporheic flows, are related to fall chinook salmon spawning habitat availability (i.e., production potential) in the Hanford Reach.

Assumptions:
1. Physical habitat features available for spawning ultimately “set” salmon production potential of the Hanford Reach.
2. Depth, substrate, velocity, and slope determine the limits of where salmon can spawn but alone do not set production potential.
3. Sufficient information from over 50 years of monitoring Hanford Reach spawning can be used to define a range of seeding levels.
4. Geographic Information System (GIS) techniques, based on measured redd densities, can be applied to the production model.

Objective 2. Demonstrate that steelhead spawn in the Hanford Reach and determine characteristics of key physical features that define steelhead spawning habitat.

Hypothesis: Steelhead spawn in the Hanford Reach and geomorphic features, including hyporheic flows, are related to steelhead spawning habitat availability.

Assumptions:
1. Physical habitat features available for spawning ultimately “set” steelhead production potential of the Hanford Reach.

2. Depth, substrate, velocity, and slope determine the limits of where steelhead can spawn but alone do not set production potential.
3. Steelhead spawning can be identified using aerial surveys and/or underwater videography.

Objective 3. Evaluate whether an analysis of geomorphic features within the Hells Canyon Reach of the Snake River can be used to assist in defining existing or potential fall chinook salmon spawning habitat.

Hypothesis: Geomorphic features, including hyporheic flows, are related to fall chinook salmon spawning habitat availability (i.e., production potential) in the Hells Canyon Reach.

Assumptions:
1. Physical habitat features available for spawning ultimately "set" fall chinook salmon production potential of the Hells Canyon Reach.
2. Depth, substrate, velocity, and slope determine the limits of where fall chinook salmon can spawn but alone do not set production potential.
3. Fall chinook spawning can be observed using aerial surveys and/or aerial photography, or redd locations can be mapped with underwater video and Global Positioning System.
4. Sites can be identified that are similar in habitat quality, yet different in spawner density and frequency of use.

Objective 4. Synthesize information from objectives 1 through 3 into a final completion report.

Hypothesis: Information generated during the completion of objectives 1 through 3 can be compiled into a project completion report that describes spawning habitat requirements and protection criteria for mainstem populations of salmonids.

Assumptions:
1. The products for objectives 1 through 3 will consist of a series of peer reviewed publications testing the hypotheses stated.
2. These publications/data can be compiled into a project completion report that managers will use to critically review assumptions in recovery options for mainstem spawning populations of salmonids.

f. Methods

Objective 1. Define production potential of fall chinook salmon that spawn in the Hanford Reach.

Task a. Conduct limits analysis for depth, substrate, velocity, and lateral slope at representative habitat types/locations.

The purpose of this task is to identify areas within the Hanford Reach that would not be spawning habitat-limited due to constraints imposed by depth, substrate, lateral slope, and/or velocity (i.e., standard spawning habitat characteristics). The Reach will be stratified into zones according to channel type, bar morphology and typology, and longitudinal gradient. Areas within each zone will then be randomly selected for analysis of standard spawning habitat characteristics. The size of each area will be consistent with the size of an average fall chinook salmon redd cluster. Standard spawning habitat characteristics will be analyzed by utilizing existing data (e.g., provided by the US Fish and Wildlife Service sturgeon research program) or collecting new data. Once the data are summarized, a logistic regression model will be used to determine the importance of standard spawning habitat characteristics in determining spawning habitat utilization (Geist, in press). Spawning habitat utilization will be based aerial photographs taken of most major spawning areas in 1994 and 1995, new aerial photographs (if necessary), and over 50 years of salmon spawning surveys done by Hanford biologists (Dauble and Watson 1997; PNNL unpublished data). Areas that are deemed to be unsuitable from the limits analysis will be noted and excluded from further consideration.

Task b. Select and describe appropriate geomorphic features and hyporheic zone characteristics in areas where limits analysis suggest spawning should occur.

The purpose of this task is to determine which geomorphic features are correlated with spawning. In areas where the limits analysis suggests spawning should occur (including previously studied areas), geomorphic features at various spatial scales will be measured. These features may include, but not be limited to, longitudinal slope, channel width/depth, bed form morphology and/or typology, and hyporheic zone characteristics. Geomorphic features will be measured from aerial photographs and GIS maps.

Characteristics of the hyporheic zone that will be measured within piezometers (Geist et al. 1998; Lee and Cherry 1978) may include water surface elevation, electrical conductivity, dissolved oxygen, and temperature (Geist, in press). A corresponding measurement will also be made in the river adjacent to the piezometer. Substrate permeability will be measured using bore-hole dilution techniques (Palmer 1993) and slug tests using the Hvorslev method (Hvorslev 1951) and/or the interference method (Spane 1996). Alluvium depth will be measured using a sub-bottom acoustic profiler and/or ground-penetrating radar.

Task c. Estimate potential redd densities at various seeding levels and compare to known values.

The purpose of this task is to compare the number of redds and redd densities from previous years' data sets to the percentage of available habitat used. Redd densities will be based on historical spawner surveys and aerial photographs of the salmon redds. These data are described in Dauble and Watson (1997), Geist (in press), and in Geist et al. (1997). We will determine whether new aerial photographs are needed following the 1998 spawning season. Information from aerial surveys will be acquired from a program funded by the U.S. Department of Energy. Percent utilization will be based on statistical analysis of redd patterns and densities (e.g., point pattern analysis, geostatistics, e.g., Geist, in press) and using GIS techniques.

Task d. Extrapolate range of density values to other areas deemed suitable based on geomorphic features.

The purpose of this task is to estimate the potential production that could be possible if the densities observed in high escapement years were applied over areas where geomorphic features were suggestive of suitable salmon spawning habitat. The amount of useable habitat, based on limits analysis and geomorphic features, will be quantified. Redd densities (task c) will be used to calculate the total number of spawners that could utilize the Hanford Reach at various seeding densities.

Task e. Prepare report/paper.

The report/paper will include an introduction, methods, results (including statistical representations of the data analysis), and discussion. GIS maps of redds, available spawning habitat using standard characteristics, and geomorphic features will also be included.

Objective 2. Demonstrate that steelhead spawn in the Hanford Reach and determine the characteristics of key physical features that define steelhead spawning habitat.

Task a. Identify historical and existing steelhead spawning locations.

The purpose of this task is to determine if steelhead spawning occurs in the Hanford Reach and to document these locations. We are currently compiling information on steelhead spawning and run size in the Hanford Reach for the U.S. Department of Energy's Steelhead Site Management Plan (DOE, in prep.). This information and aerial survey methods will be used to identify spawning sites. GIS data layers will be developed to document both historic and present day use sites.

Task b. Conduct limits analysis for depth, substrate, velocity, and lateral slope at representative habitat types/locations.

The purpose of this task is to identify areas within the Hanford Reach where spawning would not be expected to occur. Randomly selected locations within historic or present-day spawning locations will be selected for analysis of these physical habitat characteristics. Limits analysis will consist of comparing the ranges of these variables to those documented in the literature. Areas deemed unsuitable from the limits analysis will be noted and excluded from further consideration.

Task c. Select and describe appropriate geomorphic features and hyporheic zone characteristics in areas where limits analysis suggest spawning should occur.

The purpose of this task is to test whether the conceptual spawning habitat model developed for fall chinook salmon (Geist and Dauble 1998) can be used to predict steelhead spawning in the Hanford Reach. Geomorphic features, including hyporheic flows, will be compared to steelhead spawning areas. The amount of potential or usable habitat, based on limits analysis and other geomorphic features present, will be quantified using GIS techniques. Comparisons between fall chinook salmon and steelhead spawning areas will also be documented.

Task d. Prepare report/paper.

The report/paper will include an introduction, methods, results, and discussion. GIS maps will be included as will statistical representations of the data analysis.

Objective 3. Evaluate whether an analysis of geomorphic features within the Hells Canyon Reach of the Snake River can be used to assist in defining existing or potential fall chinook salmon spawning habitat.

Task a. Select study sites and identify permitting and coordination issues.

The purpose of this task is to work with Snake River management and research agencies to identify a range of study areas within the Hells Canyon Reach. Selection criteria will be based on geomorphic characteristics, relative location within the basin, and historical/current fall chinook salmon spawning distribution (Connor et al. 1993, 1994). Study sites will include at least one area where fall chinook salmon spawning occurs and one area where micro-habitat characteristics suggest that spawning should occur, but does not. Activities related to the experimental design and sampling protocol, including permitting, will be coordinated with regional biologists (i.e., WDFW, USFWS, Idaho Power, Nez Perce Tribe, etc.) and others, as necessary.

Task b. Place and monitor piezometers in study areas in the Hells Canyon Reach.

The purpose of this task is to determine if measurable hyporheic zones exist within the Hells Canyon Reach. We plan to use piezometers to monitor hyporheic zones. Piezometers may consist of a perforated steel pipe (dia. ~4 cm) that is driven into the ground using a portable jack hammer (additional detail found in Geist et al. 1998), or of a drive-point consisting of polyethylene tubing installed by hand or jack hammer (Lee and Cherry 1978). The specific piezometer types used will be based on site access, permit issues, and specific site limitations. Up to 15 piezometers will be installed at each site in clusters of three; piezometers within the cluster will be installed to different depths. They will be positioned to account for differences in spawning distribution and geomorphologic features of the river channel. A surveyor will measure piezometer location and elevation, and channel topography. Once the piezometers are in place, we will measure vertical hydraulic gradient, temperature, electrical conductivity, and dissolved oxygen of the hyporheic zone and adjacent river channel. These measurements will be taken at least once during the spawning period, likely at the time of piezometer placement. In most cases, piezometers will be installed within the spawning areas, allowed to equilibrate, measurements made, and then the piezometers would be removed. Recording the locations of the piezometers will allow us to return to the site and re-install piezometers for additional measurements if needed. At key locations and key spawning/non-spawning areas, one cluster of piezometers may be left and a pair of pressure transducers deployed within a piezometer and adjacent river station in order to continuously monitor changes in elevation of the hyporheic zone over varying discharges.

Task c. Conduct data analysis.

The purpose of this task is to determine if a relationship exists between spawning use and hyporheic zone characteristics. Analysis of variance (ANOVA) will be used to compare piezometer data from the spawning areas to the non-spawning areas. Using ANOVA, continuous information on elevation from two data loggers (one river and one hyporheic) will be compared across ranges of discharge. Information collected from the piezometers installed within spawning areas will be compared to known fall chinook salmon redd locations using quadrat methods and/or regression analysis.

Task d. Prepare report.

A final report will be prepared that summarizes information related to hyporheic zone and salmonid spawning, study objectives, methods, results, and a discussion of results. The discussion will include an assessment of the influence of hyporheic flows to fall chinook salmon spawning in the Hells Canyon Reach.

Objective 4. Synthesize information from objectives 1 through 3 into a final completion report.

Task a. Information collected in each of the first three objectives will be synthesized into a project completion report.

The purpose of this task is to compile information collected during the course of this project into a project completion report. The project completion report will contain a summary of the findings from each of the objectives described above. A key component of the project completion report will be an evaluation of the results in the context of the project objectives.

g. Facilities and equipment

Practically all of the field equipment necessary to complete this project is available at Pacific Northwest National Laboratory. This includes boats, vehicles, piezometer installation and monitoring equipment, and computers/GIS work stations for data analysis and report preparation. Much of this equipment is available for use at no cost to the project. We plan on leasing a jet boat from an outside company to conduct field efforts in the Snake River. Various equipment and supplies that will be needed include piezometers, pressure transducers, thermisters, permits, video tapes, and other miscellaneous field/laboratory materials.

h. Budget

The total cost to complete this work in FY2000 is estimated to be approximately $333,000. Approximately 60% of this amount is for personnel and fringe benefits. Contained within these two categories are direct labor and direct overheads including program development and management (business development, planning and monitoring), PNNL procurement and subcontract support, general and administrative expenses (e.g., accounting, legal, contracting, and personnel departments), and service assessment fees (costs paid to the Department of Energy for plant-wide support services such as patrol, fire, library, mail and roads). Fourteen percent of the total is for supplies and materials. These includes piezometers and piezometers supplies, sensors and data loggers, equipment rental including vehicle, boats, and specialty items (e.g., alluvium depth instruments), and other miscellaneous expenses. Approximately 5% of the budget is for travel to and from the work sites in the Snake River as well as travel to various locations to present research findings at regional and national meetings. The percentage of the budget allocated to indirect costs is approximately 17%. Indirect costs include primarily organizational 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. Finally, approximately 7% of the budget is for subcontractors, specifically the Associated Western Universities.

The amount proposed for FY2000 is similar to the amount proposed for FY1999 and FY2000 in the FY1999 proposal. However, it should be noted that in the FY1999 proposal a mistake was made in allocating the total costs into the various categories. Thus, the category amounts appear different from last year's values. The project was not fully funded in FY1999, thus a comparison to last year's actual budget is not applicable.

Section 9. Key personnel

KEY STAFF

David R. Geist
Senior Research Scientist

EDUCATION

B.S., Biology, Eastern Washington University, 1984
M.S., Biology, Eastern Washington University, 1987
Ph.D., Fisheries Science, Oregon State University, 1998

EMPLOYER AND EXPERIENCE

Dr. Geist is a Senior Research Scientist in the Ecology Group at Battelle, Pacific Northwest National Laboratory. He has been with Battelle since 1991 and has extensive experience and expertise in the ecology of Pacific Northwest fishes, especially fall chinook salmon in the Hanford Reach. Dr. Geist is developing and testing a conceptual spawning habitat model that describes the importance of landscape processes in determining utilization of spawning areas by fall chinook salmon. Dr. Geist has served on several technical panels related to future management of the Hanford Reach, including invited expert testimony at Congressional hearings. He is a member of the American Fisheries Society and American Institute of Fishery Research Biologists. Recent research activities include:

- Lead scientist and project manager for several projects addressing environmental monitoring and technology applications, including investigating habitat utilization, bioenergetics, and migration behavior of fall chinook salmon in the Columbia River.
- Studying ground-water/surface-water interactions and contaminant movement in salmon spawning areas in the Hanford Reach.
- Modeling impacts of hydropower system operations on resident fish in the Upper Columbia River, including Lake Roosevelt; and participating in planning and evaluation activities of salmon supplementation in the Yakima and Klickitat rivers.

SELECTED PUBLICATIONS

Geist, D.R. 1995. "The Hanford Reach: What Do We Stand to Lose?" Illahee 11:130-141.

Geist, D.R., M.C. Joy, D.R. Lee, and T. Gonser. 1998. "A Method for Installing Piezometers in Large Cobble Bed Rivers". Ground Water Monitoring and Remediation 18:78-82.

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." Environmental Management 22:655-669.

Geist, D.R., D.D. Dauble, and R.H. Visser. 1997. The development of a spawning habitat model to aid in recovery plans for Snake River fall chinook salmon." Fiscal Year 1995 and 1996 Progress Report to the Bonneville Power Administration, Portland, Oregon.

Geist, D.R., L.W. Vail, and D.J. Epstein. 1996. "Analysis of Potential Impacts to Resident Fish from Columbia River System Operation Alternatives". Environmental Management 20:275-288.

PROJECT RESPONSIBILITIES

Dr. Geist will serve as Project Manager and Lead Investigator (0.75 FTE/1200 hours). His primary responsibilities will be to ensure project milestones are met on time and within budget; develop experimental study plan for each objective; coordinate all activities with regional agencies and tribes; and supervise staff in field work and data analysis. Dr. Geist has served in this capacity since the project's inception in 1994.

Dennis D. Dauble
Technical Group Manager

EDUCATION

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

EMPLOYER AND EXPERIENCE

Dr. Dauble has been a staff member at Battelle, Pacific Northwest National Laboratory since 1973. He is currently a Staff Scientist and Technical Group Leader for the Ecology Group. Dr. Dauble regularly interacts with state and federal regulatory and management agencies in issues relating to regional impacts of power plants, hydroelectric facilities, and other energy-development activities on anadromous and resident fishes.

Dr. Dauble has considerable expertise in activities related to impacts from hydropower generation and flow regulation on anadromous salmonids. For example, he served on regional committees and directed studies to evaluate potential impacts of drawdown and other operational scenarios on anadromous fish survival. He also provided assistance to the Snake River Recovery team on the passage and survival of Endangered Species Act salmon stocks. Dr. Dauble was involved in salmonid enhancement efforts in the Yakima River Basin, including coordination of environmental review activities among the science and policy teams for the project. On-going studies focus on characterizing habitat requirements of fall chinook salmon in the mid-Columbia and lower Snake rivers which involve the use of aerial photography, stream mapping, and geographic information system (GIS) techniques. He recently synthesized 45 yrs of data on factors influencing the abundance of fall chinook salmon populations in the Hanford Reach.

Dr. Dauble is a member of the American Fisheries Society, the Ecological Society of America, the Northwest Scientific Association, the Pacific Fishery Biologists, and is a Fellow in the American Institute of Fishery Research Biologists. He is also an adjunct professor at Washington State, Oregon State, and Central Washington State universities.

SELECTED PUBLICATIONS

Dauble, D.D. and D.G. Watson. 1997. “Status of fall chinook salmon populations in the mid-Columbia River, 1948-1992.” <u>North American Journal of Fisheries Management</u> 17:283-300.

Dauble, D.D., R.L. Johnson, R.P. Mueller, C.S. Abernethy, B.J. Evans, and D.R. Geist. 1994. Identification of fall chinook salmon spawning sites near lower Snake River hydroelectric projects. Prepared for the U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Dauble, D.D., J.R. Skalski, A.E. Giorgi, and A. Hoffman. 1993. Evaluation and application of statistical methods for estimating smolt survival. DOD/BP-62611-1. Prepared for Bonneville Power Administration, Portland, Oregon.

Dauble, D.D. and R.P. Mueller. 1993. Factors affecting the survival of upstream migrant adult salmonids in the Columbia River basin. Recovery issues for threatened and endangered Snake River Salmon. Technical Report 9 of 11. Prepared for Bonneville Power Administration, Portland, Oregon.

Dauble, D. D., T. L. Page, and R. W. Hanf, Jr. 1989. "Spatial distribution of juvenile salmonids in the Hanford Reach, Columbia River". Fishery Bulletin 87(4):775-790.

PROJECT RESPONSIBILITIES

Dr. Dauble will serve as Co-Lead Investigator (0.20 FTE/360 hours). His primary responsibilities will be to advise and participate with other staff on experimental design, implementation of field work, and data analysis and reporting. Dr. Dauble has served in this capacity since the project's inception in 1994.

Section 10. Information/technology transfer

Products will consist of scientific reports that 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. A specific objective will be to summarize the findings into a project completion report during FY 2002. Further, PNNL staff annually attend professional society meetings (i.e., American Fisheries Society, North American Benthological Society) where we would anticipate presenting these results. This is consistent with the approach we have used on this project, with a total of 18 papers, technical reports, and/or presentations having been published already in the project's four years.

Congratulations!