Summary of Research and Education Activities

in the Elwha River Watershed and Adjacent Coastal Zone

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Executive Summary

In preparation for the planned removal of the two dams blocking the Elwha River, scientists and educators have conducted five workshops and a number of informal meetings to plan research, monitoring, and education activities. This report summarizes the published results of three technical workshops and unpublished notes from two education workshops held between 2001 and early 2005. Appendices list research and education initiatives now being conducted or proposed for the Elwha watershed and nearshore areas, and provide a compilation of previous investigations.

The workshops summarized in this report identified the following recurrent needs:

- conceptual models of socio-ecosystem dynamics and processes
- sufficient biological and physical baseline information to detect changes and identify their causes
- an adequate monitoring program guided by models and best available science
- an adaptive management system that informs and is informed by decision-makers.

In addition, a consolidated, comprehensive education agenda is necessary to help train future citizens, scientists and decision-makers how to work together in an uncertain and changing world.

Future planning efforts should focus on highest priority issues to go beyond generating ideas and offer concrete suggestions for implementation, scheduling, costs, collaboration and data sharing.

Once the data are collected and interpreted, there will be a need to synthesize and integrate available knowledge into a comprehensive picture of conditions in the watershed, and to communicate that picture to managers, the public, and the scientific community. Depending on the audience, scenarios of current conditions and possible future states, with visualization technology, may be useful. This knowledge will inform not only restoration and salmon recovery in the Elwha watershed, but will add to our broader understanding of river restoration and ecosystem processes.

Increasingly, researchers worldwide are recognizing the need to focus on science that helps solve pressing ecological or social problems as well as articulates linkages among both human and natural systems. These problems are seen as requiring new collaborations among disciplines and modes of thought. The spotlight focused on the Elwha River watershed presents a rare opportunity for integrated and interdisciplinary collaboration among researchers in the physical, biological and social sciences, and the humanities.

Research in the Elwha River watershed has the potential to inform river restoration activities throughout the nation, to improve our practical knowledge of dam removal and salmon recovery techniques, to advance our knowledge of ecosystem-scale processes, and to increase our understanding of linkages between social and ecological systems across multiple spatial and temporal scales. Such knowledge will have local as well as national and international benefits.

Introduction

The planned removal of the two Elwha River dams beginning in 2008 presents a rare opportunity to study the potentially profound physical, biological and sociocultural effects of removing a large perturbation on a major river system. At least a dozen agencies and institutions have – or are planning – a research or education presence in the Elwha watershed. In preparation for the dam removal project, three technical workshops have been convened over the past four years, numerous informal meetings have been held to discuss research, education and monitoring activities, and researchers are collecting data. However, no comprehensive strategy exists to coordinate scientific and sociocultural investigations in the basin or in the estuarine and nearshore areas to aid adaptive management, help train the next generation of scientists and decision-makers in watershed rehabilitation techniques, and advance our understanding of ecosystem-scale processes in the Pacific Northwest.

This report briefly summarizes the published results of three technical workshops focused on the biological and physical effects of the Elwha River dam removal project held between 2001 and 2004[1], and unpublished notes from education workshops held in 2003 and 2005[2]. A short discussion outlines some of the needs and opportunities to move toward a comprehensive research and education strategy for the watershed. Finally, appendices gather available information from previous sources to present a snapshot of past, current and planned research activities in the watershed.

Results of Technical Workshops

Elwha River Physical Processes Monitoring Workshop, August 13-17, 2001

During and after the removal of the Elwha and Glines Canyon dams, a significant fraction of the nearly18 million cubic yards of sediment (silt, clay, sand and gravel) estimated to be trapped in the reservoirs behind the two dams will erode downstream, with expected effects on water quality and potential effects on downstream flood stages and river channel migration (Randle et al. 2004), as well as expected biological consequences to the lower reaches, estuary and nearshore area (NPS 1995).

The Elwha River Physical Processes Monitoring Workshop convened in August, 2001 to identify critical parameters necessary to monitor and evaluate processes and characteristics related to sediment transport in the Elwha River during and after the dam removals, and to recommend monitoring strategies to assist project management in decision-making during the dam removal process. The "Elwha River Restoration Draft Sediment Monitoring and Management Plan" (Draft Monitoring and Management Plan – Randle et al. 2004) is a product of the workshop. The plan focuses on monitoring river hydrologic, hydraulic and

[1] Elwha River Physical Processes Monitoring Workshop, August 13-17, 2001; Elwha River Ecosystem Biological Monitoring/Research Workshop, March 18-19, 2003; Technical Workshop on Nearshore Restoration in the Central Strait of Juan de Fuca, March 31-April 1, 2004.
[2] November 3-4, 2003 and January 18, 2005.

morphologic characteristics, sedimentation processes, and relationships between flow and sediment transport, and suggests parameters to be monitored during the removal of the dams to aid real-time adaptive management. The plan also suggests monitoring activities over a longer time scale.

The Draft Monitoring and Management Plan divides its monitoring recommendations into two categories: those deemed necessary for adaptive management monitoring for the dam removal project (i.e., "critical to accomplishing dam removal in a safe, controlled manner" [Randle et al. 2004]), and those not critical but deemed useful for restoration monitoring and research. Activities not critical to managing the dam removal project are not expected to be supported by funds from the project; alternate funding sources for these "restoration monitoring" activities are not identified. However, some restoration monitoring measures are simply an increase in the duration or frequency of adaptive management monitoring already proposed, and the report suggests that these activities could be carried out by adaptive management monitoring personnel with additional funding. Table 1 summarizes monitoring categories outlined in the Draft Monitoring and Management Plan.

Table 1. Monitoring categories discussed in the Elwha River Restoration Draft Sediment Monitoring and Management Plan (used with permission from Randle et al. 2004).

Monitoring Category	Adaptive Management[1]	Long-Term Restoration
Reservoir Sediment Erosion and Redistribution		
➢ Delta erosion and downstream progression	X	X
➢ Release of coarse sediments from the reservoirs	X	X
➢ Re-establishment of reservoir flood plain and vegetation		X
Hillslope Stability	X	X
Water Quality (Suspended Sediment Transport)	X	X
Riverbed Aggradation and Flood Stage		
➢ Bed material size measurements	X	X
➢ River water surface elevations	X	X
➢ Channel geometry	X	X
Aquifer Characteristics		
➢ Water table elevations	X	X
➢ Well water yields, quality	X	X
River Channel Planform and Channel Geometry	X	X
Large Woody Debris Processes	X	X
Coastal Processes		
➢ Turbidity plume		X
➢ Beach bathymetry and shoreline position		X
➢ Beach profile surveys		X
➢ Beach berm survey		X
➢ Beach sediment size measurements		X
➢ River mouth cross section surveys		X
➢ Ediz hook geometry		X
Sediment Budgets		X

[1] It is expected that adaptive management monitoring will be funded through the Elwha Dam Removal project, though specific actions are being negotiated. Restoration monitoring has no identified source of funding.

The Draft Monitoring and Management Plan also includes summaries of previous surveys and investigations, and other data collected (e.g., survey data and LIDAR coverage from river miles 0 to 15) related to the Elwha dam removal project.

Adaptive Management Monitoring. The Draft Monitoring and Management Plan outlines key adaptive management monitoring tasks (i.e., necessary to achieve project goals) to be accomplished before and during dam removal. These tasks are summarized in Table 2. The reservoirs will be drawn down incrementally to redistribute sediment in a controlled manner, and will be halted during 'fish windows' and periods of high flow.

Table 2. Adaptive management monitoring tasks outlined in the Draft Sediment Monitoring and Management Plan (used with permission from Randle et al. 2004).

Timing	Monitoring Task
Before dam removal	➢ Bathymetric survey of Lake Mills (document initial conditions) ➢ Install new stream gages (river stage, discharge, temperature, turbidity, suspended sediment) ➢ Survey 22 river cross sections between river miles 0 and 15 o Bench marks and bank erosion pins o Staff gages (continuous stage recorders at 6 cross sections) o Compute and measure stage-discharge relationships (HEC-RAS hydraulic model, U.S. Army Corps of Engineers, 2002) o Initial bed-material size gradation (measured in 1994; Reclamation, 1996) o Document active bank erosion and log jams ➢ Inspect potential landslide areas ➢ Install water-level monitoring instruments in observation wells and measure yield of municipal wells ➢ Install web cameras overlooking Lake Mills, Glines Canyon Dam, Lake Aldwell, and Elwha Dam ➢ Hire and train adaptive management crews
During reservoir drawdown and dam removal (up to three years after removal)	➢ Monitor sediment erosion and redistribution in the two reservoirs during drawdown (advancing delta front and longitudinal slope of main river-erosion channel; estimate remaining sediment above river channel elevation) ➢ Inspect identified and potential landslide areas ➢ Bathymetric survey of reservoirs and topographic survey of exposed sediment when critical drawdown elevation reached for each reservoir (485 ft for Lake Mills and 140 ft for Lake Aldwell); determine from these surveys the amount of sediment eroded or remaining in stable condition ➢ Survey river erosion channels after each reservoir pool has filled with sediment (quarterly thereafter) ➢ After river delta has reached each dam: o Sample bed-material size gradation to monitor downstream progression of first bedload wave o Periodic (at least annual) river stage and channel geometry measurements, including longitudinal river profile o Continuous (real-time) monitoring of river stage 6 key cross sections ➢ Monitor large woody debris and bank erosion to detect threats to key infrastructure ➢ Monitor well water levels, and well yield at selected municipal wells

Restoration Monitoring. While not planned to be implemented as part of the project, the Draft Monitoring and Management Plan poses a number of questions of interest to this and to other dam removal or river restoration projects (Randle et al. 2004):

- What portion of the reservoir sediment erodes from the reservoir?
- What are the planform changes in the reservoir areas both during and after the dam removal?
- What are the concentrations of suspended sediment in the reservoir during dam removal?
- How well is fine suspended sediment mixed within the reservoir pool?
- What portion of the suspended sediment settles to the bottom of the reservoir and how does this change over time?
- What are the sediment erosion and transport rates from the reservoir during and after dam removal?
- Do anaerobic conditions exist that create odor problems?
- How do flood plains develop (width, geomorphic attributes, etc.) as a function of annual peak discharge and vegetation reestablishment?
- How long does it take for the remaining reservoir sediment to become stable?
- How many sediment terraces form and how many of these terraces remain stable?
- How much sheet, rill, and gully erosion of delta terraces occurs?
- As the bedload wave progresses downstream, are sediment particles sorted by size so that the finer particles move down ahead of coarser particles?
- Do sediment transport rates for sand and gravel increase as more of the cobbles and boulders of the existing river channel are covered with finer particles?
- What volume of sediment has aggraded within the channel bed and how does this volume change over time?
- Where, when, and over what timeframes do bed habitat features such as pools, riffles, bars, and backwaters form? What are the hydraulic characteristics associated with the formation of these features?

The plan goes on to outline measurements that "should work well to answer many of the restoration questions" (Randle et al. 2004):

- Measure repeat cross-section surveys of the reservoir delta and lakebed.
- Evaluate time-lapsed photography from web cameras.
- Measure suspended sediment concentrations throughout the reservoir area and at various depths.
- Measure bedload and suspended load in the reservoir erosion channel, especially after the eroding delta sediments have advanced to the dam.
- Periodically sample the sediment and measure the concentrations of contaminants and other water quality parameters.
- Measure the evolution of sheet, rill and gully erosion of the exposed reservoir sediments.
- Establish the causes of surface erosion of reservoir sediments (e.g., surface runoff generated by exceedance of infiltration capacities; subsurface seepage; upslope hillslope runoff).

- Identify the species of vegetation growing on the exposed reservoir sediments. Establish vegetation plots and measure plant density and growth rates.
- Correlate vegetation establishment with expected reductions in surface (sheet, rill and gully) erosion of reservoir sediments.
- Measure the change through time of armor and sub-armor layer development in the erosion channels to aid with the interpretation of longitudinal profile and channel planform evolution.
- Repeat selected river cross-sections at close distance and time intervals (10 cross sections at each selected reach, spaced less than ¼ channel-width, repeated at least 4X yearly) to measure dynamic channel response (would also document formation and erosion of river bars and channel response to large woody debris deposition).

Costs and priorities. The report estimates general costs for adaptive management monitoring conducted up to three years after completion of the dam removal to be between 2 million and 4 million dollars. Funds are currently being disbursed for present activities. Priorities for adaptive management monitoring are currently being developed to reconcile costs with available budget (J. Bountry, USBOR, pers. comm.). No priorities or budget was produced for the restoration monitoring recommendations, though the report states that restoration monitoring costs could match those of adaptive management monitoring.

Implementation plan and timeline. Timing, location, duration and frequency of adaptive management monitoring recommendations are outlined in the report (see Table 2, above). Monitoring would end three years after the completion of dam removal. Implementation and timing of restoration monitoring activities were not discussed in detail; however, the report states that some restoration monitoring activities could begin before dam removal, and dynamic equilibrium of river channel and flood plains could take decades (Randle et al. 2004).

Elwha River Ecosystem Biological Monitoring and Research Workshop, March 18-19, 2003

The Elwha River Ecosystem Biological Monitoring and Research Workshop met in March, 2003 to "capture essential biological questions, hypotheses, and monitoring issues" (Schreiner and Winter 2004) centered around the scheduled removal of the two Elwha River dams. Three working groups (vegetation and ecosystem processes, fisheries and aquatic science, and wildlife) convened to develop hypotheses and research / monitoring questions for the watershed. The groups were asked to prioritize the hypotheses, and develop a timeline and tentative budget, identify potential sources of funding, and suggest lead scientists to secure funding for the highest priority issues. A report documenting the workshop "Restoration of the Elwha River Ecosystem: Results of a Biological Monitoring/Research Workshop" (Draft Biological Monitoring Report – Schreiner and Winter 2004) has been drafted and is under review.

The report observes that different reaches of the river will be differentially affected by the removal project: the reach above the upper dam is expected be influenced by food web changes associated with anadromous salmonids returning upstream to spawn, die and (in

some species) compete for resources as juveniles in fresh water; the reach below the lower dam is predicted to experience profound changes in wood and sediment inputs (with biological as well as physical consequences); the middle reach, between the two dams, is likely to be subject to all of the changes besetting both upriver and downriver reaches; and the reservoir reaches will undergo unique successional and fluvial transformations as terrain is exposed and revegetated, and new floodplains are developed during the drawdown process.

In addition, Lake Sutherland will be open to anadromy for the first time in nearly a century; changes to the population of resident kokanee salmon (a non-anadromous life-history variation of sockeye salmon, *Oncorhynchus nerka)* may occur, though increasing human impacts along the lake shore may make the viability of new populations of sockeye in the lake problematic (NPS 1996). (Note: There are no plans to re-introduce sockeye salmon into the Elwha watershed [NPS 1996].)

Critical baseline data. The Draft Biological Monitoring Report discusses a critical general need for baseline studies of the genetic signatures of wild and hatchery fish, chemical and nutrient signatures/variation in tributaries, and the structure and distribution of vegetation communities and woody debris (Table 3). (Note: some baseline data are being collected by USGS, the National Park Service and NOAA Fisheries.)

Table 3. Recommended baseline information to be collected in the Elwha River watershed (adapted from Shreiner and Winter 2004).

Category	Data Need
Genetics	➢ Genetic profiles of wild and hatchery salmon ➢ Genetic profiles of hatchery salmon seeded into upper watershed ➢ Archive tissues for future genetic profiling
Physico-chemical	Physicochemical signatures of all tributaries (spatial scales need elaboration): ➢ Water temperature and thermal budgets ➢ Nutrient budgets ➢ Sediment budgets and suspended sediment concentrations ➢ Wood budgets ➢ Aquatic chemistry – N, P, dissolved organic carbon (DOC) ➢ Soil chemistry
Vegetation	➢ Vegetation structure ➢ Sediments ➢ Large woody debris (LWD) ➢ Topography, landform, and channel evolution ➢ Nutrients

In addition, if final salmon restoration plans include the introduction of hatchery fish into the upper watershed, knowing the genetic signatures of outplanted hatchery fish populations will permit monitoring the dispersal and colonization rates of outplanted fish (Schreiner and Winter 2004). This will allow comparison of the relative success of wild vs. hatchery outplant colonization in the watershed, a research question with far-reaching implications.

Without adequate and appropriate baseline data, unequivocal insight into key biological responses related to the dam removal and salmon restoration project will be impossible to obtain.

Research questions or hypotheses. In addition to recommending baseline studies, the Draft Biological Monitoring Report lists research and monitoring issues in the form of hypotheses, some of which were elaborated upon by the workshop participants (Table 4). While the workshop participants were segregated according to broad classifications (vegetation, aquatic, and wildlife), the hypotheses listed in the draft report are grouped according to their position in the watershed (upper reach, middle and lower reaches, and reservoir reaches).

Assumptions. Key assumptions for the upper reach were that a) returning anadromous fish will affect trophic dynamics in the ecosystem and b) the upper reaches of the river present baseline conditions for physical changes expected in the middle and lower reaches (Schreiner and Winter 2004).

Assumptions for the middle and lower reaches were a) sediment inputs will dominate fluvial processes in the middle and lower reaches until a new equilibrium is reached; b) the large quantity of sediment in the middle and lower reaches will initially inhibit the rate of fish use; c) ultimate numbers of anadromous fish in the middle and lower reaches may be greater than those in the upper reach because of migration barriers to pink and chum salmon; d) returning anadromous fish will affect trophic dynamics in the ecosystem; and e) anadromous fish in the middle and lower reaches will spawn mostly in the main channel because few tributaries exist there (Schreiner and Winter 2004).

Elaboration of hypotheses. The draft report offers brief discussions of and elaborations on selected hypotheses. These include suggested experimental approaches for nutrient studies, research and monitoring suggestions for specific hypotheses, potential direct and indirect trophic effects, and a discussion of river floodplain forest structure and patch dynamics (Schreiner and Winter 2004). Some additional study questions are listed without elaboration.

Costs and priorities. Although workshop participants were asked to suggest a tentative budget for each hypothesis, costs are not identified in the draft report. Hypotheses in Table 4 are numbered to reflect priorities. The report includes a three-page appendix that sketches out possible funding strategies for researchers: it recommends a diverse approach that explores the possibilities of cost-sharing, leveraging, and interdisciplinary partnerships that "emphasize and market dynamic interactions rather than a laundry list of projects." Potential sources of funding include foundations such as Canon and Bullitt, and federal agencies including the National Park Service, U.S. Geological Survey, NOAA Fisheries, USDA Forest Service, and the U.S. Army Corps of Engineers. The appendix suggests that the Elwha program could be an "ideal candidate" and complement to existing LTER research.

Table 4. Hypotheses identified in the Biological Monitoring Workshop (adapted from Schreiner and Winter 2004)

	Hypothesis
Upper Reach	1. C, N and P will accumulate in the floodplain and adjacent uplands as an indirect and direct result of inputs from returning anadromous fish 2. Trophic pathways will be restructured with a cascading effect throughout the ecosystem o Abundance of salmon predators and scavengers (e.g., bears, otter, mink, osprey, eagles, corvids, other piscivores, macroinvertebrates) will be affected, with cascading effects (e.g., increases of bear population could result in increased predation on neonatal elk) 3. Productivity of the aquatic ecosystem will increase following dam removal o Longitudinal differences in primary and secondary productivity will be apparent, with lower reaches exhibiting greater productivity 4. Resident fish already utilizing the upper river will compete with re-introduced anadromous fish 5. Fish species will recolonize the upper river at different rates (i.e., natural barriers will influence recolonization rates of different species throughout basin) o Radio telemetry, isotopic analysis and other methods could be used to track fish movement and habitat usage 6. Hatchery and wild populations of anadromous fish will interact by exchange of genetic material and possibly through competition
Middle and Lower Reaches[1]	1. Post-dam removal floodplain areas will move toward a dynamic equilibrium characteristic of the natural condition of the Elwha River ecosystem 2. As fluvial processes are restored to the lower reaches of the river (below Rica Canyon) physical and vegetative changes will affect wildlife communities 3. Nonnative brook trout will not pose a threat to native char 4. River-type sockeye salmon are more likely to recolonize through straying 5. Sediment additions from dam removal will temporarily destroy macroinvertebrate populations below the dams 6. A wild run of sockeye salmon will be re-established from the existing stock of Lake Sutherland kokanee 7. Stream productivity is highest in the lower portion of the watershed 8. Sediment discharge from the two reservoirs will alter the behavior and dynamics of existing fish populations below the dams
Reservoir Reaches	1. Plant life history characteristics will interact with environmental factors to influence successional pathways and rates of change 2. Stable floodplain surfaces will form where accumulations of large wood deflect flows and facilitate deposition of fine sediments 3. Herbivory by native ungulates will decrease the density and growth of woody vegetation colonizing floodplains 4. Townsend's vole and mountain beaver will increase due to a large quantity of herbaceous plants in recovering lakebeds – this will adversely affect restoration of woody plant species 5. Recovery of soil microbial diversity and function will vary with texture, aeration, and volume of litter inputs from the surrounding forest 6. Gradients in nutrient availability due to longitudinal patterns of hyporrheic transfer will only develop after channel and floodplain complexity develops in response to wood jams 7. Marine-derived nutrients will be transferred to riparian and upland vegetation

[1] It is understood that some hypotheses identified for the upper reach will also apply to middle and lower reaches.

	as soon as anadromous fish colonize former reservoir areas 8. Transfer of nutrients from upland slope soils to riparian and aquatic ecosystems will only occur after hydrologic connectivity has been restored 9. The topography of the de-watered reservoirs will change dramatically as dams are gradually removed and delta deposits are distributed throughout former pool areas. After dam removal is complete, most topographic change will occur within the river's meander zone 10. Prior to recruitment of sufficient large wood into channels to create jams, the river channel will change position primarily through incremental migration rather than through evulsion 11. By the time de-watering is complete, mixing of sediments from reservoir deltas and lake beds will be so complete that substrate texture will be homogeneous throughout 12. Where tributaries enter the former reservoir pools, considerable incision into sediments and erosion will occur 13. De-watering of sediments in the newly exposed upland areas will require two to three years, with the rate modified by sediment texture and insolation as determined by topography 14. Longitudinal gradients (primarily sediment texture) will be maintained by hydraulic and fluvial dynamics within the unconstrained reaches

Implementation plan and timeline. Implementation of recommendations is not discussed in the draft report, though the broad elements of a timeline are presented (Schreiner and Winter 2004):

Before dam removal:

- Determine factors responding to restoration that would influence plant growth (water, nutrients, soil carbon)
- Identify baseline/background isotopic signatures in Elwha and adjacent basins
- Identify "intersection of good salmon and terrestrial habitat" for marine derived nutrient sources and movement

After removal:

- Identify physical and chemical characteristics of soils in recovering areas (lateral and longitudinal)
- Initiate experiments to isolate nutrient source contributions (e.g., exclosures, fertilization)

Long term:

- Measure parameters that are integrative over time (e.g., isotopes or vegetation) and over space (e.g., stream chemistry of small basins).

Technical Workshop on Nearshore Restoration in the Central Strait of Juan de Fuca, March 31-April 1, 2004.

A workshop focusing on restoration and monitoring priorities in the nearshore area at the mouth of the Elwha River and nearby coast convened March 31 to April 1, 2004 in Port Angeles, Washington. Participants were asked to "identify management, restoration, research, monitoring, and educational opportunities" in the nearshore area posed by the dam removal project, and develop recommendations to submit to agencies and the public

(CCMRC 2004). A public meeting prior to the workshop provided input to the participants. A report, "Technical Workshop on Nearshore Restoration in the Central Strait of Juan de Fuca," has been published (CCMRC 2004).

Participants met in four separate, concurrent technical sessions – physical processes, habitat, biological communities, and fisheries – and were asked to report their findings using the following common template (CCMRC 2004):

- Issue
- Nature of the activity
- What this recommendation will accomplish and why it is important
- Discussion of the recommended action(s)
- Linkages to other nearshore restoration activities

A general consensus was reached in plenary session for the need to develop a sediment routing model for the nearshore area, collect adequate baseline data, create an adaptive management process, and perform long-term monitoring. Table 5 outlines the recommendations of the four nearshore working groups.

In addition, the report states the need to create integrated research and management strategies involving all major stakeholders to identify goals, communication mechanisms, and funding and education strategies. It observes the need to create a monitoring team with a clear leadership structure.

Table 5. Nearshore working group recommendations (adapted from CCMRC 2004).

	Recommendation	Comments
Physical Processes	1. Develop a nearshore processes conceptual model	How much sediment will be delivered, where will it go, when it will get there, and what are the forcing mechanisms?
	2. Develop comprehensive monitoring strategy	Collect key baseline parameters and continue collection throughout project (bathymetry, sediment distribution, turbidity plumes, beach topography, etc.)
	3. Consider nearshore restoration options	Explore restoration opportunities that can improve on those provided by dam removal project
	4. Follow-up workshop for managers and scientists	Decision makers and scientists need to improve communications
	5. Public education program	Communicate restoration goals, possible risks and levels of certainty, and management strategies
Habitat	1. Develop a nearshore/estuarine conceptual model	How will nearshore/estuarine habitat structure and conditions be affected by dam removal project? Need predictive capabilities
	2. Establish habitat and biological baseline conditions: ➢ Historic ➢ Current ➢ Literature review	Inventory habitat and aquatic organisms
	3. Develop an adaptive management and monitoring strategy that incorporates conceptual model	Need the capability to predict and evaluate changes to nearshore/estuary, assess accuracy of predictions, and plan for alternative actions
	4. Develop a management strategy	Other structures in estuary/nearshore affect sediment

	for other shoreline structures (e.g., pipelines, dikes, roads, armoring, landfill, and Ediz Hook)	distribution; other actions (e.g. sediment augmentation) may be needed for full restoration	
	5. Use existing resources to educate and be educated by the public	Create dialogue with the public regarding dam removal and ecosystem restoration to build understanding and support	
Biological			Timing
	1. Create a vision statement ("naturally functioning deltaic ecosystem along the Strait)	Identify desired future conditions	March 05
	2. Define historical baseline	Determine historical system function and processes	
	3. Define current baseline	Determine geographic extent of communities studied and prioritize biological communities to evaluate	asap
	4. Identify goal based on historical conditions	Identify, establish, and maintain target ecosystems and culturally significant and unique populations	March 05
	5. Develop a conceptual model (data gaps and research needs)	Needed to anticipate different species responses to sediment input	March 05
	6. Develop monitoring program to track changes	Observe ecosystem response to determine management response	
	7. Identify needs for active restoration	See above	
	8. Monitor active restoration	See above	1-2 years before dam removal
	9. Implement adaptive management feedback loop	See above	2005
	10. Disseminate information and expertise	Inform pubic, stakeholders, and similar projects	ongoing
Fisheries	1. Develop comprehensive baseline monitoring and research plan	Need baseline information on broad number of species/issues in order to design and implement harvest management plans prior to and after dam removal	
	2. Develop an education strategy targeting fishers and recreational users	Fishers and recreational users need information related to fisheries impacts, strategies, and dam removal objectives	
	3. Develop an education strategy targeting managers and decision-makers	See above; strategy for manages and decision-makers likely to be different than that for fishers and recreational users	
	4. Increase funding for harvest management activities (stock assessment, stock enhancement / protection, enforcement)	Additional activities resulting from dam removal project need funding – either from new or existing sources	
	5. Develop a comprehensive harvest management plan	Prioritize species and identify specific species-based management tools to achieve long-term net gain of harvest opportunity as result of dam removal	
	6. Research enhancement and restoration of sea urchins and cucumbers	Anticipate possible restoration needs of these species; little is known about aquaculture techniques	
	7. Research enhancement and restoration of other selected species	See above; little may be known of aquaculture techniques for restoration of certain species	

Costs and priorities. At the end of the nearshore workshop, the plenary session members were asked to identify the two most important issues from each working group category, as well as the most important issues or questions raised in the workshop in general. Table 6 and Table 7 reproduce their responses. Consensus was reported on the need for coordinated action across governments and agencies regarding goals, communication mechanisms, funding strategies, education strategies, and developing a monitoring team with clear leadership – however, a strategy for creating this coordination was not identified in the report.

Table 6. Recommended priorities for nearshore restoration and monitoring, with 27 respondents (adapted from CCMRC 2004).

	Recommendation	Number of responses
Physical Processes	Create a model (conceptual or numerical)	27
	Conduct monitoring	11
	Coordinate activities among project entities	6
Habitat	Study/model habitat change	18
	Conduct monitoring	11
	Collect baseline data	10
	Use adaptive management for restoration goals	4
	Enhance habitat that is not being restored naturally	3
Biological	Collect baseline data	14
	Conduct monitoring	13
	Create a comprehensive model	10
	Identify target biological communities / goals / indicator species	4
	Conduct restoration	3
Fisheries	Gather scientific information on current and historical status of fisheries	11
	Conduct monitoring	7
	Model future fisheries status	6
	Educate the public/fishers about expected impacts to fisheries and level of uncertainty well in advance of dam removal	5
	Develop a harvest management strategy	3
	Establish goals	3
	Restore species	3

Implementation plan and timeline. No general implementation plan or timeline was presented in the report. However, the Biological Communities technical session made general suggestions for the timing of their recommendations (Table 5, above).

Table 7. Ten most important questions, issues, and recommendations from the Nearshore workshop plenary session, with 27 respondents (adapted from CCMRC 2004).

Recommendation	Number of responses
1. Create a model (conceptual or numerical)	25
2. Educate and involve the public	15
3. Conduct monitoring/research	14
4. Secure funding	12
5. Identify a project lead	11
6. Ensure communication/coordination among project entities	7
7. Use adaptive management	5
8. Address/plan for restoration	4
9. Ensure long-term management	3
10. Establish vision/goals for the project	3

Education and outreach workshops

An education workshop was convened for two days in November 2003 to generate ideas for education and outreach. Over forty participants from local school districts, agencies, non-profit organizations, colleges and universities attended. No report was prepared to document outcomes or recommendations, but meeting notes distributed after the meeting suggest that implementation strategies, costs, priorities, and timing were not discussed. Notes from the 2003 workshop are included in Appendix C.

Since the workshop, a number of education initiatives have been set in motion (B. Carlson, Olympic National Park, pers. comm.):

- Olympic Park Institute has received grants to create a field science program focused on the Elwha
- American Rivers is creating computer visualization models of the river valley before, during and after dam removal
- National Parks Conservation Association produced a driving tour brochure of the Elwha river valley and has received funding to create a volunteer project to remove invasive plants from around Lake Mills and near certain campgrounds
- Olympic National Park is writing an interpretive plan for the Elwha Restoration Project, and will be creating introductory and supporting materials for middle and high-school curriculum development.

Another workshop was convened January 18, 2005 to begin development of an Elwha River education plan to be implemented in 2005. While a formal report is unavailable at the time of this writing, informal reports state that the workshop focused on K-12 and community-based education, citizen outreach, and strategies for educating lawmakers and the press (T. O'Keefe, University of Washington, pers. comm.). An outreach and education plan targeting these groups will be developed as a joint effort between National Parks Conservation Association (NPCA), American Rivers, Olympic National Park, Trout Unlimited, Surfrider Foundation, and Olympic Park Associates, and may potentially involve other groups as they are identified (O'Keefe, pers. comm.). No details of priorities, costs, implementation plans or timing are available at this writing.

Grant Proposals

As a result of much of the efforts described above, an informal consortium has been established that has been working the past year on several NSF grant proposals. One proposal has been submitted to establish and fund an Elwha Research Consortium; three proposals have been submitted to establish an undergraduate research program at Peninsula College in which two- and four-year students will work on the Elwha ecosystems; and one has been submitted to create a science education program focusing on Tribal children (see Appendix A).

Discussion

The three technical workshops summarized in this report identify a number of recurrent needs: conceptual models of socio-ecosystem dynamics and processes, sufficient baseline information, an adequate monitoring program guided by models and best available science, and an adaptive management system that informs and is informed by decision-makers. These recurrent needs are accompanied by equally recurrent questions:

- Is adequate baseline information being collected? Where are the gaps?
- Is enough known about variability of parameters across spatial and temporal scales?
- Who will create the conceptual and quantitative models that integrate biophysical and sociocultural systems in ways that enrich our understanding and inform our decisions?
- Who will perform the system-level analysis to place research in the Elwha basin in a larger context, explore linkages, and tie together disparate elements?
- Who will investigate the management, policy and sociocultural questions that are begging to be answered?
- Who will establish and maintain the feedback system between scientists and managers necessary for successful adaptive management?
- Who will administer and coordinate the program?
- How will data be shared and managed among participants?
- How will an integrated program be funded?

It is notable that all the workshops generated vital research questions and most of the working groups prioritized their questions. The next step is to develop specific implementation strategies, costs, and schedules. Future planning efforts should focus only on the highest priority issues and offer concrete suggestions for implementing them.

Once the data are collected and interpreted, there will be a need to synthesize and integrate available knowledge into a comprehensive picture of conditions in the watershed, and to communicate that picture to managers, the public, and the scientific community. Depending on the audience, scenarios of current conditions and possible future states, with visualization technology, may be useful (Alcamo 2001). This knowledge will inform not

only restoration and salmon recovery in the Elwha watershed, but will add to our broader understanding of river restoration and ecosystem processes.

In addition, a consolidated, comprehensive education agenda is necessary to help train future citizens, scientists and decision-makers to work together in an uncertain and changing world. Not only must specialized knowledge and training be developed at all levels, there is an increasing need for individuals and institutions that can move across disciplinary boundaries, synthesize knowledge, and communicate effectively to those outside their specialties (Gunderson et al. 1995). Community-based and K-12 education groups appear to have established a dynamic collaborative effort and are moving forward. A clear implementation strategy at the post-secondary level is in the planning stages, with Peninsula College and others collaborating on funding proposals and other initiatives.

A large number of agencies and institutions have a research presence in the Elwha River watershed today. The U.S. Geological Survey, the Lower Elwha Klallam Tribe, the National Park Service and NOAA Fisheries have been prime participants in conducting baseline research, and Peninsula College has been at the forefront of education initiatives. Olympic National Park continues to play a central role in many of the activities underway, and has initiated efforts to coordinate research and education in the basin. Allaway (2004) sets forth a template for the foundation of a comprehensive monitoring, research and education program, with an ambitious implementation strategy and timeline. However, because no single entity has been identified and funded to administer and coordinate the program, progress has been slow to date.

Research in the Elwha River watershed has the potential to inform river restoration activities throughout the nation, to improve our practical knowledge of dam removal and salmon recovery techniques, to advance our knowledge of ecosystem-scale processes, and to increase our understanding of linkages between social and ecological systems across multiple spatial and temporal scales. Such knowledge will have local as well as national and international benefits.

Increasingly, researchers worldwide are recognizing the need to focus on science that helps solve pressing ecological or social problems and articulates linkages among both human and natural systems (e.g., Schnellnhuber and Wenzel 1998, NRC 1999, Kates et al. 2001, Alberti et al. 2003). These problems are seen as requiring new collaborations among disciplines and modes of thought. The spotlight focused on the Elwha River watershed presents a rare opportunity for integrated and interdisciplinary collaboration among researchers in the physical, biological and social sciences, and the humanities.

References

Alberti, M., J. M. Marzluff, E. Shulenberger, G. Bradley, C. Ryan, and C. Zumbrunnen. 2003. Integrating humans into ecology: opportunities and challenges for studying urban ecosystems. BioScience 53:1169-1179.

Alcamo, J. 2001. Scenarios as tools for international environmental assessments. Environmental Issue Report Number 24, Office for Official Publications of the European Communities, European Environment Agency, Luxembourg.

Allaway, J. 2004. Understanding the Elwha: a strategy for research and education programs on the Elwha River. Huxley College of the Environment, Western Washington University, Port Angeles, WA. Report prepared for Olympic National Park.

Clallam County Marine Resources Committee [CCMRC]. 2004. Technical workshop on nearshore restoration in the central Strait of Juan de Fuca. Prepared for CCMRC by Triangle Associates, Seattle, WA. [Accessed January 28, 2005] http://www.clallammrc.org/CCMRC/Workshop%20CSJ.pdf

Gunderson, L. H., C. S. Holling, and S. S. Light, editors. 1995. Barriers and bridges to the renewal of ecosystems and institutions. Columbia University Press, New York.

Kates, R. W., W. C. Clark, R. Corell, J. M. Hall, C. C. Jaeger, [and others]. 2001. Sustainability science. Science 292:641-642.

National Park Service [NPS]. 1995. Final environmental impact statement: Elwha river ecosystem restoration. Denver, CO.

National Park Service [NPS]. 1996. Final environmental impact statement: Elwha River ecosystem restoration implementation. Denver, CO.

National Research Council [NRC]. 1999. Our common journey: a transition toward sustainability. National Academy Press, Washington, DC.

Randle, T. J., J. Bountry, B. Jackson, and G. Smillie. 2004. Elwha river restoration draft sediment monitoring and management plan. U.S. Department of the Interior, Bureau of Reclamation and National Park Service, Port Angeles, WA. [September 10, 2004 draft].

Schnellnhuber, H.-J., and V. Wenzel, editors. 1998. Earth system analysis: integrating science for sustainability. Springer-Verlag, New York.

Schreiner, E. G., and B. D. Winter. 2004. Restoration of the Elwha River ecosystem, research and monitoring questions: March 18-19, 2003 (Draft). Port Angeles, WA. [January, 2005 draft].

Appendix A: Active and planned/proposed research in the Elwha River watershed and nearshore areas

The following section briefly presents current and planned research activities in the Elwha River watershed and nearshore area. Sources of information include electronic mail surveys and telephone calls directed at investigators from various agencies and institutions known to be involved in the Elwha River dam removal project (e.g., NOAA Fisheries, U.S. Geological Survey, U.S. Bureau of Reclamation, Olympic National Park, University of Washington, etc), reports from the three technical workshops focused on the Elwha River dam removal project, and queries to the Olympic National Park research coordinator.

Research is categorized as either physical processes and water quality, marine and nearshore, terrestrial and wildlife, freshwater and riparian, fish ecology and biology, sociocultural, education, or data sharing and management.

Consortium Organization

Proposed
Title: RCN: Elwha Research Consortium

Principal Investigator: Smith (WWU, Huxley College; PI), Eaton (Peninsula College; co-PI)

Description: This RCN grant supports a core research consortium studying effects of removing two dams on the Elwha River on Washington's Olympic Peninsula. This grant supports coordination of a growing number of scientists to examine the return of salmon species; the fate of large woody debris; hydrology, sediments and water quality; the role of marine derived nutrients in forest food webs; control of invasive species; and other potential topics. The core of the consortium will establish by-laws, coordinate work of teams in the field, and establish the experimental designs for the inter-connecting studies. The Elwha is a model system for dam removal demonstrating ecological processes under ideal conditions. Results from the Elwha will inform the world on the potentials and pitfalls of dam removal for river restoration.

Expected Products: This grant will allow local educational institutions, the Elwha Tribe, and government agencies to coordinate the wide range of research afforded by this unique opportunity. It will: provide administrative staff; support the development of conceptual models; coordinate the various interlocking research efforts; allow scientists to meet; and support data infrastructure. Core participants will write a charter ensuring a level playing field for all researchers, encouraging participation, and enhancing funding opportunities for all

Schedule: Project to begin Spring 2005 and last through September 2010

Link for additional information: bille@pcadmin.ctc.edu; Bradley.Smith@wwu.edu

Physical processes and water quality

Title: Channel morphodynamics and sediment management during the removal of the Glines Canyon Dam from the Elwha River, Washington State, USA: drawdown experiments and physical modeling

Principal investigators: Bromley, Grant, Thorne

Description: A scaled physical model of Lake Mills and Glines Canyon Dam was built and used to run a series of dam removal experiments. The aim of the modelling exercise was to test hypotheses regarding the behaviour of the Lake Mills delta sediments in response to different magnitudes of dam removal.

Expected products: PhD dissertation and substantial report to the US Bureau of Reclamation. These items will provide a detailed explanation of the morphodynamic response of a delta incising and prograding into a reservoir that still retains significant storage space. A conceptual model will be developed to summarise this behaviour, which will expand on the existing channel evolution models.

Schedule: Planned completion September 2005.

Link for additional information: http://www.fsl.orst.edu/wpg/

Title: Effects of suspended sediment on water quality and aquatic habitat in the Elwha River

Principal investigators: Konrad

Description: 1-dimensional, sediment transport model to assess the effects of dam removal on suspended sediment concentration and particle-size distribution of the riverbed

Expected products: Journal paper.

Schedule: 2004-2006

Link for additional information: http://wa.water.usgs.gov/projects/elwha/summary.htm

Title: Real-time analysis of suspended sediment in the Elwha River

Principal investigators: Konrad, Melis, Rubin

Description: Developing an instrument for monitoring suspended sediment concentration and particle-size distribution based on laser diffraction. The instrument will have an automatic dilution system so that it can analyze over a relatively unlimited range of sediment concentrations

Expected products: Sediment analyzer.

Schedule: 2004-2005

Link for additional information: cpkonrad@usgs.gov.

Marine and nearshore

Title: Juvenile Salmon in the Nearshore Ecosystems of the Strait of Juan de Fuca

Principal investigators: Fresh, Ward, Shaffer

Description: At present, this is a pilot scale study of juvenile salmon use of the nearshore ecosystems of the Strait of Juan de Fuca.

Expected products: T.B.D.

Schedule:

Link for additional information: kurt.fresh@noaa.gov

Title: Photographic monitoring of the central straits shoreline

Principal investigators: Ian Miller, Surfrider Foundation

Description: Aerial and ground-level digital photographic monitoring of shoreline before and after dam removal from Freshwater Bay to Ediz Hook.

Expected products:

Schedule: First overflight planned for January 2005

Link for additional information: imiller@surfrider.org

Title: Historical changes in the Strait estuaries and nearshore, Neah Bay to Discovery Bay

Principal investigators: Todd, Collins

Description: Use historical sources to reconstruct physical landscape and major habitat types from ~1850 to early 1900s.

Expected products:

Schedule: Expected completion July 2005.

Link for additional information: stodd@pnptc.org

Title: Effects of Elwha dam removal on nearshore habitats

Principal investigators: Warrick. Gelfenbaum

Description: Part of "Coastal Habitats in Puget Sound" project, USGS Coast and Marine Geology Program: 1) Nearshore and beach surveys at over 100 beach cross sections to be repeated twice yearly during dam removal; 2) shelf substrate and habitat mapping using swath sonar, video, and grain-size sampling; 3) deploy acoustic sensors (W 05) to measure water circulation and waves offshore of river delta; 4) numerical (hydrodynamic) modeling of Strait and river mouth.

Expected products:

Schedule: Funded through FY 04 and 05

Link for additional information: jwarrick@usgs.gov

Subject to funding renewal

Title: Beach profile monitoring of the Elwha River delta coast

Principal investigators: Beirne, Ward, Johannessen

Description: Contract with Coastal Geologic Services Inc to survey beach profiles at 7 locations on coastline.

Expected products: Tribe plans to increase number of profiles and area surveyed

Schedule:

Link for additional information: beirne@elwha.nsn.us

Proposed
Title: Elwha River dam removal and the Venus Cable: a unique experiment in marine sediment dispersal

Principal investigators: Nittrouer, Ogston

Description: The removal in 2007 of dams from the Elwha River (north coast of Olympic peninsula) will provide relatively predictable sediment discharges that are expected to reach concentrations >50 g/l (US Department of Interior, 1996). The possible presence of the VENUS cabled observatory in 2005 at the mouth of the Elwha River would provide a unique opportunity to observe and respond to gravity flows (fluid muds and hyperpycnal flows) and to investigate their dynamics and impacts. Not only would this be valuable for basic scientific purposes, but it would be an extraordinary opportunity for applied purposes – to document the fate in the marine environment of sediment discharged by dam removal, and to understand the processes responsible.

Expected products:

Schedule: 2005-2010

Link for additional information: nittrouer@ess.washington.edu

Proposed
Title: Nearshore central Strait of Juan de Fuca: an ecosystem assessment of salmonid use and priority restoration actions

Principal investigators: Shaffer

Description: Project will define fish use of habitats within the central Strait of Juan de Fuca nearshore, including species, populations, and life history strategies of juvenile salmon and forage fish.

Expected products:

Schedule: Anticipated begin spring 2005 for up to 3 years.

Link for additional information: shaffjas@dfw.wa.gov

Proposed
Title: Nearshore restoration of the Elwha dam removals: sediment fate and beach restoration

Principal investigators: Shaffer, Beirne

Description: Modeling support for linking physical and biological functions of the nearshore

Expected products:

Schedule:

Link for additional information: shaffjas@dfw.wa.gov

Terrestrial and wildlife

Title: Surficial geology map for Elwha drainage

Principal investigators: J. Riedel, J.Probala and S. Dorsch

Description: Surficial geology is one of the 12 basic inventories targeted by the Natural Resource Challenge. A program developed at North Cascades National Park is designed to meet this need by mapping of 30 different surficial geology/landforms units, ranging from alluvial fans and floodplains to landslides and glacial moraines. Our approach is focused on depositional features that are mapped on 1;24,000 scale base maps using LIDAR, 1:12,000 scale stereo photos, and field verification. Work on the Elwha was initiated in 2003 and will continue through 2005, with the valley below Elkhorn nearing completion.

Expected products:

GIS data layer of surficial geology units (landforms).
Inventory of all landslides including several dozen characteristics of each feature.
Inventory report summarizing results, with brief discussion.

Schedule: Summer 2004 = field verify landforms in lower valley main stem Elwha; Winter 2004-05 = digitize landforms of lower Elwha below Elkhorn; Summer 2005 = field check landforms in upper Elwha valley and initiate mapping in other watersheds; mapping will continue through 2011 before Olympic Park is completed.

Link for additional information: jon_riedel@nps.gov

Title: Land cover/ land use classification using very high resolution (4m multispectral) satellite imagery of the lower Elwha watershed

Principal investigators: Steinmaus, Miller

Description:

Expected products: GIS dataset and map for Elwha tribe.

Schedule: Unknown.

Link for additional information: karen.steinmaus@pnl.gov

Title: The Sediments of the Elwha River: A Preliminary Study of the Affects of Dam Removal

Principal investigators: Mussman, Zabrowski (UW)

Description: Removal of the two Elwha River dams has been proposed as a method for restoring endangered anadromous salmon to the Elwha River. However, the removal of the dams affects not only aquatic biota, but also the riparian habitats associated with river margins and floodplains. If the sediment is not stabilized, excessive amounts could erode downstream causing turbid waters and health threats to salmon. When the dams are removed, it is estimated that half of the reservoir sediment will erode downstream and the remaining sediment remain in situ. Concerns regarding the remaining sediments include infestation with invasive plants, wind and water erosion, and cracking. This proposal would address these concerns by conducting experiments on the sediment to predict erosivity and prescribe mulches or amendments that could prevent erosion and reduce establishment of invasive species. In addition, soil ecosystem development on glacial lake sediments in the Elwha area will be examined to predict long-term soil development and ecosystem succession. This proposal will directly address two of the network's emphasis areas: 1) monitoring ecosystem health and establishing baseline data and reference points and 3) ecological restoration. There are three

main goals proposed to address these emphasis areas. The first goal is to establish a reference ecosystem by describing soils developed on old glacial lake terraces and the vegetation that has grown on them. The second goal is to perform experiments on sediments to study treatments for erosion prevention. The third goal is to sample areas around the two reservoirs to be used as N-15 baseline data.

Expected products:

Schedule: Start in 2005

Link for additional information: zabow@u.washington.edu

Title: Soil survey of lower Elwha drainage within Olympic NP

Principal investigators: coordinated by NPS national soil scientist Pete Biggam

Description:

Expected products:

Schedule: probable start in 2007

Link for additional information: pete_biggam@nps.gov

Title: Seed bank in the sediment of lakes to be drained

Principal investigators: Smith, Ewing (UW)

Description: Sediment samples will be taken from various areas of the lake. Seed banks will be germinated. Vegetation sampling will be done in the riparian or upslope zone that is currently unflooded. Seed bank representation and existing vegetation will be compared.

Expected products: Inventory of germinable seeds in lake sediment. Composition of existing vegetation communities. Suggestions for use of seed bank in restoration.

Schedule: Will start this spring and be finished in the fall of 2006

Link for additional information: joshuacs@u.washington.edu

Title: Monitoring of the rare plant, *Cimicifuga elata*

Principal investigators: Schreiner

Description:

Expected products:

Schedule:

Link for additional information: ed_schreiner@usgs.gov

Title: Baseline monitoring of black bear seasonal distribution in the Elwha Valley prior to dam removal

Principal investigators: Happe, Jenkins

Description:

Expected products:

Schedule:

Link for additional information: patti_happe@nps.gov

Proposed
Title: Responses of streamside wildlife communities to salmon restoration

Principal investigators: Jenkins, Happe, Adams, Perakis

Description:

Expected products:

Schedule:

Link for additional information: kurt_jenkins@usgs.gov

Freshwater and riparian

Title: Baseline monitoring of floodplain vegetation and geomorphology prior to dam removal, Elwha River, Olympic National Park

Principal investigators: Shafroth, Braatne, Hartt

Description: We have collected baseline data on vascular plant communities along 15 permanent cross-valley transects along the Elwha River. We located five transects above both dams on the Elwha (in Geyser Valley), five transects between the two dams, and five below both dams. Vegetation measurements included line intercept (woody vegetation), point intercept (herbaceous vegetation), nested quadrat sampling (tree, shrub, herbaceous, woody seedlings) within different vegetation patches, and stand age determination within patches. These measurements will yield data on species richness, abundance (cover, density, basal area), vegetation dynamics (age classes, woody seedlings), and tree growth. Physical environmental measurements included topographic surveying of transects/plots and surficial soil texture, which will be complemented by stage-discharge modeling done by the Bureau of Reclamation. These data will be initially interpreted in the context of effects of the dams on riparian vegetation. Following dam removal, transects will be resampled over time to enable evaluation of the effects of dam removal. Finally, our measurements of woody vegetation composition will be linked to broader scale vegetation classifications that are being undertaken by R. Hauer and J. Braatne.

Expected products: MS thesis; Project report to Olympic National Park; 1-2 peer reviewed publications

Schedule: Hartt's thesis will be completed for Spring or Summer 2005 graduation; final report to Olympic Natl. Park will be completed by Summer or Fall 2005; first peer-reviewed publication will be submitted by Summer or Fall 2005

Link for additional information: pat_shafroth@usgs.gov

Comments: We are seeking funding to resample herbaceous vegetation and woody seedling dynamics for as many years as possible prior to dam removal. At this point, we don't anticipate having funding to resample in summer 2005, however. We are open to collaboration with other investigators interested in using our permanent transects as sites for other measurements (e.g., nutrient dynamics to relate to tree growth or vegetation composition changes post-dam removal).

Title: Consequences of a natural dam-break flood for geomorphology and vegetation on the Elwha River, Washington, U.S.A.

Principal investigators: Acker, Beechie, Shafroth

Description: To use unmanipulated ecosystems as models for riparian restoration, it is important to identify the roles of various disturbance mechanisms in structuring riparian forests. As part of the preparation for dam removal and riparian restoration on the Elwha River in Washington state, we examined a 0.5 km long debris fan on a wilderness reach of the river to determine whether geomorphic and vegetation patterns could be attributed to a natural dam-break flood in 1967. We identified five major surfaces within the fan, three of which date to the dam-break flood based on tree ages. Two surfaces closer to the present channel of the river were created by more recent disturbances. The surfaces created by the 1967 flood vary in height from 4 m above the present channel to essentially level with the channel, and vary in surface texture from boulders to sand and silt. Consistent differences in tree species composition and stem density between the five surfaces generally do not correspond to differences in surface age. The heterogeneity of riparian forests in this one portion of a presumed "reference ecosystem" for riparian restoration is due to both the diversity of environments generated by the 1967 flood and repeated disturbances since then.

Expected products: Manuscript for submission to peer-reviewed journal; poster presented at Ecological Society of America annual meeting, 2004

Schedule: Expect to submit manuscript in spring 2005

Link for additional information: steve_acker@nps.gov

Title: Pre-dam removal monitoring on the Elwha River Basin: establishing baseline conditions for primary and secondary productivity

Principal investigators: Morley, Coe, Duda, McHenry, Kiffney, Pess, and Beechie

Description: In order to effectively evaluate the potential effects of dam removal on primary and secondary productivity in the Elwha River Basin, a coordinated data-collection effort is needed for establishing pre-dam removal conditions. Building on earlier monitoring work conducted by the Lower Elwha Tribe and the USGS in the mid-90's, we began collecting baseline data in the summer of 2004. In order to sample mainstem, tributary, and side channel habitats below, between, and above the dams, data collection was coordinated amongst NOAA, the USGS, and the Lower Elwha Klallam Tribe. The focus of this first year of data collection was on standardizing data collection protocols, collecting a representative number of samples from varied habitats, and on establishing long-term monitoring locations. Along with physical habitat characterization, at each of our monitoring sites we collected benthic invertebrates, periphyton, and water chemistry samples. Based on this collaborative research effort, we will determine adequate sample size, appropriate spatial distribution of samples sites (lateral and longitudinal), and refine sampling protocols as necessary for ongoing dam removal monitoring.

Expected products: Peer-reviewed papers

Schedule: Continue sampling for 3 to 5 five years after dam removal

Link for additional information: http://www.nwfsc.noaa.gov/research/divisions/ec/wpg/index.cfm

Title: Documenting current stream productivity and fish populations prior to dam removal in the Elwha River: Setting the stage for long-term monitoring of ecosystem responses. [also listed in "Fish Ecology and Biology," below]

Principal investigators: Reisenbichler, Petersen, Duda and Connolly

Description: Collection of baseline stable isotope levels for aquatic species including periphyton, macroinvertebrates, and fish from the upper, middle, and lower Elwha. Analyze and archive O. mykiss DNA throughout the watershed, including tributaries. Develop protocols for fish sampling to determine community composition and production.

Expected products: 1) Baseline values of marine derived nutrients in aquatic food webs. 2) Genetic characteristics of O. mykiss and archived tissue collection for future studies 3) Community composition of fish populations from index reaches in the middle and upper Elwha from electroshocking and snorkeling surveys.

Schedule: FY04 & FY05

Link for additional information: reg_reisenbichler@usgs.gov

Title: Collect remote sensing information on terrestrial and aquatic variables and compare to habitat data collected from traditional methods in same areas.

Principal investigators: Lorang, Hauer, McHenry, and Pess

Description: Utilize new technology (hyperspectral imagery and Acoustic Doppler Processing) to expand our current habitat inventory in the Elwha, as well as increase its overall accuracy and repeatability. We will compare differences in the accuracy, precision, repeatability, and cost between remote sensing and traditional habitat survey techniques and in order to help make such efforts more efficient.

Expected products: Peer-reviewed paper.

Schedule: Continue work 5 to 10 years after dam removal.

Link for additional information: mark.lorang@umontana.edu

Title: Develop reference site data for monitoring biological integrity and water quality of streams

Principal investigators: Freilich

Description:

Expected products:

Schedule:

Link for additional information: jerry_freilich@nps.gov

Title: Alteration of channel and ecosystem dynamics downstream of Elwha dams

Principal investigators: Beechie, Pollock, McHenry, Liermann, and Pess

Description: Reduced sediment supply to the lower Elwha River since construction of the first Elwha dam in 1912 has caused river entrenchment and decreased channel movement. To understand how these changes alter the spatial and temporal dynamics of the river-floodplain ecosystem, we combine data for erosion and formation of floodplain surfaces, successional patterns of floodplain vegetation, and responses of riverine fauna to the shifting suite of habitat types. We first develop a matrix of transition probabilities that describes the spatial and temporal dynamics of habitat patches in the river-floodplain system. Field surveys of morphological and biotic attributes of different patch types are then used to infer spatial and temporal variations in aquatic communities based on the

transition matrix, and to predict how the floodplain ecosystem will respond to dam removal. Monitoring will continue after dam removal to test our predictions.

Expected products: Peer-reviewed papers

Schedule: 2003 till ? Continue work 5 to 10 years after dam removal.

Link for additional information: http://www.nwfsc.noaa.gov/research/divisions/ec/wpg/index.cfm

Fish ecology and biology

Title: Biological monitoring of engineered logjams (ELJs) in the Lower Elwha River below the dams

Principal investigators: Pess, McHenry, Coe, Liermann, Kloehn, Bennett, and Peters

Description: Juvenile and adult salmonid and non-salmonid seasonal snorkel surveys began in 2000 in reaches with and without ELJs in the Lower Elwha River. We also conduct an annual fish census below the dams. We plan to continue seasonal surveys and the summer fish census through 2005. Primary and secondary productivity sampling began in 2002 in reaches with and without ELJs in the Lower Elwha. Within treatment reaches, sampling occurred both on the ELJ structures and in habitats directly influenced by the presence of ELJs.

Expected products: Peer-reviewed papers

Schedule: 2000 till 2005

Link for additional information: http://www.nwfsc.noaa.gov/research/divisions/ec/wpg/index.cfm

Title: Collecting and creating baseline genetics on salmonids in the Elwha River

Principal investigators: Winans and Meyers

Description: In 2004, we began sampling chinook, steelhead/rainbow trout, and chum salmon in the Elwha watershed in conjunction with the Lower Elwha-Klallam Tribe, USGS, WDFW, and NPS. Extensive sampling of resident rainbow trout was begun in the middle and upper portions of the river that included nonlethal collections for DNA analysis and, in some cases, photographs for morphometric evaluations. We are in the process of statistically analyzing preliminary DNA-based genetic data for a subset of the steelhead/rainbow trout samples and a chinook salmon collection, as well as morphological data for middle and lower river steelhead/rainbow trout collections. The power of these data rely on thorough geographic coverage as well as temporal representation of the variability. In 2005, then, we will continue to sample the above species as well as coho, pink, and sockeye salmon, and kokanee in conjunction with the above agencies. Emphasis will be on obtaining samples of late-spawning (wild) steelhead and early-returning chinook salmon; and collecting and analyzing genetic and morphological data (where possible) for all species in light of existing genetic and phenetic data sets.

Expected products: Peer-reviewed papers.

Schedule: Continue work 5 to 10 years after dam removal.

Link for additional information: http://www.nwfsc.noaa.gov/research/divisions/ec/wpg/index.cfm

Title: Predicting salmonid response to the removal of the Elwha River dams

Principal investigators: Pess, McHenry, and Beechie

Description: The Elwha River dams have disconnected the upper and lower Elwha watershed for over 90 years. This has resulted in a disruption to upstream salmonid migration and a "loss" of 90% of the salmonid habitat. The dams have also interrupted the downstream movement of both sediment and wood, leading to such inputs being dominated by local sources (e.g., bank erosion and avulsions). The current salmon habitat, as well as salmonid abundance and distribution, reflects these changes. Current salmonid populations (several of which are hatchery-dominated) are either dramatically smaller than estimated historical population or extirpated. Nevertheless, salmonid populations do persist below the dams in part because channel incision has not been significant, and floodplain habitats remain an important component of the Elwha River ecosystem. Dam removal will (1) reconnect upstream habitats increasing salmonid carrying capacity, and (2) allow the downstream movement of sediment and wood leading to long-term aquatic habitat improvements. Both large-scale changes will allow salmonid populations to rebuild on a watershed-scale. We hypothesize that the salmonid recolonization will be concentrated in several large alluvial valleys in the Middle and Upper Elwha.

Expected products: Peer-reviewed paper to be submitted Feb 2005.

Schedule: 2001 till ? Continue work 5 to 10 years after dam removal.

Link for additional information: http://www.nwfsc.noaa.gov/research/divisions/ec/wpg/index.cfm

Title: Documenting current stream productivity and fish populations prior to dam removal in the Elwha River: Setting the stage for long-term monitoring of ecosystem responses. [also listed in "Freshwater and Riparian," above]

Principal investigators: Reisenbichler, Petersen, Duda and Connolly

Description: Collection of baseline stable isotope levels for aquatic species including periphyton, macroinvertebrates, and fish from the upper, middle, and lower Elwha. Analyze and archive O. mykiss DNA throughout the watershed, including tributaries. Develop protocols for fish sampling to determine community composition and production.

Expected products: 1) Baseline values of marine derived nutrients in aquatic food webs. 2) Genetic characteristics of O. mykiss and archived tissue collection for future studies 3) Community composition of fish populations from index reaches in the middle and upper Elwha from electroshocking and snorkeling surveys.

Schedule: FY04 & FY05

Link for additional information: reg_reisenbichler@usgs.gov

Title: Monitoring coho, chinook and steelhead smolts captured in smolt trap on Lower Elwha

Principal investigators: Mumford and House

Description: General fish health monitoring of outgoing smolts captured in a trap on lower end of Elwha River will take place annually in an effort to collect baseline information on pathogenic bacteria, parasites and viruses in the fish populations. The sampling will be approached in a manner consistent with the National Wild Fish Health survey, with routine screening of 60 fish per species for specific viral, parasitic and bacterial pathogens.

Sampling will take place in collaboration with Dr. Walt Dickhoff (NOAA, Montlake), who is studying several aspects of the reproductive physiology. Additionally, toxicology could potentially be done on the same fish.

Expected products: Determine if there is a change in the pathogens detected in surveys of outmigrating smolts before and after dam removal.

Schedule: The trap will be in place from mid-March through mid-June. Sample will start in 2005.

Link for additional information: http://wildfishsurvey.fws.gov/

Title: Monitoring Lake Sutherland kokanee for IHNV and *Parvicapsula minibicornus* prior to and following dam removal and the natural colonization of sockeye

Principal investigators: House and Mumford

Description: There have been historical accounts of kokanee in Lake Sutherland prior to the construction of the Elwha dam in 1911, as well as records of hatchery kokanee released into the lake from various sources from 1933 to 1964. There is no health history from fish in Lake Sutherland available. Currently the kokanee in Lake Sutherland have been isolated from anadromous fish, and therefore marine pathogens since 1911. With the removal of the dams in 2008 and renewed access for anadromous fish, it is anticipated that a sockeye run will return to Lake Sutherland. We will sample spawning kokanee adults prior to and following dam removal (as well as returning sockeye) and monitor the populations for pathogens, including Infectious Hematopoetic Necrosis Virus (IHNV) and *Parvicapsula minibicornus*, to which these species are known to be especially susceptible.

Gary Winans (NOAA, Montlake) is conducting a genetic evaluation of Lake Sutherland kokanee and sockeye with a comparison to other regional stocks, and we will coordinate sampling as much as possible, with the assistance of the Lower Elwha Tribe.

Expected products: To provide fish health data on Kokanee in Lake Sutherland prior to and after dam removal; these fish may be at higher risk of infection with the re-introduction of anadromous fish. The fish health sampling will be done with an emphasis on detection of IHNV and *Parvicapsula minibicornus*.

Schedule: Expect to begin sampling November 2005 as fish are spawning, and sample annually.

Link for additional information: mhouse@nwifc.org

Proposed
Title: Coho Salmon Spawning Distribution in the Lower Elwha River prior to Dam Removal: Implications for Recolonization after Dam Removal

Principal investigators: Burke, Frick, McHenry, and Pess

Description: Prior to the construction of the Elwha and Glines Canyon Dams, the Elwha River supported large populations of all major native west coast species of Pacific salmonids (Oncorhynchus spp.). Currently, these populations are depressed, supported primarily by hatcheries, or extinct. Removal of these two dams, scheduled for 2008 to 2010, will provide salmon and other species access to 79 km of pristine spawning habitat (Gregory et al. 2002). Current spawning habitat use by coho salmon (O. kisutch) below Elwha Dam is unknown, yet coho, heavily supplemented by hatchery outplants, are the most abundant salmonid species below the dams (McHenry et al. 2000). Coho have also been documented as being one of the initial salmonid colonizers in newly opened habitats, regardless of whether the barriers are natural or artificial (Milner et al. 2001, Pess et al. 2003). Thus, understanding how coho salmon use existing spawning habitat will be critical to predicting and evaluating the effects of dam removal on species distribution and abundance. Our objectives include: 1) establishment of optimal placement of radiotelemetry receivers for adult salmon monitoring in the lower Elwha River, 2) quantification of movement patterns of adult coho salmon prior to spawning, and 3) determination of the number and

spatial extent of coho salmon spawning areas in the Elwha River and estimation of selectivity by comparing characteristics of spawning habitat with those of available habitat.

Expected products: Peer-review papers.

Schedule: 2005 till ?

Link for additional information: Brian.Burke@noaa.gov

Proposed
Title: Smolt Outmigration Monitoring in the Elwha River

Principal investigators: McHenry and M. Elofson

Description: Natural production of all salmonid species in the Elwha River is poorly understood. Most stocks are either supported by hatchery production, dramatically depressed or extirpated. Our objectives include: 1) quantify numbers and species of salmonids produced in the Elwha River before during and after dam removal, and 2) monitor changes in the proportion of naturally produced and hatchery produced Chinook and coho salmon, as well as steelhead.

We propose a multi-year project that will likely run the length of the Elwha restoration project through recovery (2005-2030). Pre-dam removal smolt production will be measured using two rotary screw traps fished at different locations in the Elwha River below Elwha Dam. This method, because of relatively low capture rates in large rivers, requires an estimation of trap efficiency, typically through the use of mark-recapture studies. To accomplish these objectives we propose to use two rotary screw traps to collect and estimate population size on the Elwha River. An 8' rotary screw trap will be fished at river mile 1.0 in the downstream end of the Hunt Road Channel (largest west side channel). A 5' rotary screw trap will be simultaneously fished at river mile 2.5 (outlet of Spruce hole). The smaller trap will be used to collect fish for marking to be used in a continuous mark-recapture study to evaluate the trap efficiency of the 8' screw trap. All coho, steelhead, and Chinook salmon smolts larger than 55 mm captured at the upstream site will be anaesthetized in (MS-222) weighed and measured, and given a unique mark. While there are numerous marking techniques available, many have limitations in that they are expensive, slow, and difficult to read or may cause unacceptably high rates of mortality. We anticipate the need to experiment between marking techniques in order to find the best method for the Elwha. Traps will be fished annually during the period from March 1 to July 31.

Expected products:

Schedule: 2005 till ?

Link for additional information: mchenry@elwha.nsn.us

Sociocultural

Title: Cultural resource inventories related to Elwha project

Principal investigators: Contact Paul Gleeson, Olympic National Park

Description: Requirement in EIS.

Expected products: 1) cultural landscape inventory; 2) historic structures inventory; 3) HABS/HAER studies of two dams; 4) historic context statements; 5) historical archeology research design; 6) pre-historical archeology research design; 7) archeological resources inventory; 8)

ethnographic study; 9) inventory of archival resources; 10) historical assessment of Elwha River fisheries; 11) genealogical studies of Lower Elwha Klallam Tribe; 12) ethno-historic study of non-native settlements; 13) interpretive plan – Elwha and Glines Canyon dams

Schedule:

Link for additional information: Paul_Gleeson@nps.gov

Education

Title: An integrated approach to restoration of anadromous salmonids and their habitat in the Elwha River following dam removal

Principal investigators: Contact Nancy Wright, University of Idaho

Description: Train Tribe staff to acquire and evaluate physical, ecological, and socioeconomic datasets for lower Elwha River, estuary, and nearshore area; develop GIS tools; develop and apply characterization of parameters for long-term resource management by Tribe.

Expected products:

Schedule: March 2005 through March 2007.

Link for additional information: nwright@uidaho.edu

Title: Extreme Makeover: The Elwha River Edition

Principal investigators: O'Keefe

Description: Course to be taught at Olympic Park Institute on river ecology and restoration of the Elwha River. The course will include field tours and lectures. This project will be placed in the context of other dam removal projects.

Expected products: 3 day course for a general audience.

Schedule: To be presented Oct 7-9, 2005**.**

Link for additional information: okeefe@u.washington.edu

Title: Field science program focused on Elwha watershed

Principal investigators: Olympic Park Institute

Description: Pilot project involving local schools in data collection.

Expected products:

Schedule:

Link for additional information: sschaffer@yni.org

Proposed
Title: Summer science education: Elwha restoration

Principal investigators: Young

Description: NSF proposal for science education program focusing on tribal kids

Expected products:

Schedule:

Link for additional information: ryoung@wcu.edu

Proposed
Title: REU Site—An Undergraduate Research Program on the Elwha Dam Removal and Restoration Project in Washington State

Principal Investigator: Eaton (Peninsula College; PI), Allaway (WWU, Huxley College; co-PI)

Description: NSF proposal for both PC and Huxley College program at PC students will be involved with scientists from PC, Huxley College, Olympic National Park, USGS Biological Resources Division, NOAA Fisheries, and Lower Elwha Klallam Tribe in a year-long research course (Fall through Summer Quarter) that includes over 100 hours of course activities and 400 hours of research on the Elwha system, working as full participating members of the consortium. The research projects will focus on analysis of a variety of parameters in the Elwha ecosystems throughout the year, identifying mechanisms and indicators of changes in population distribution and abundance; predicting changes in these populations due to dam removal; and providing information on the effects of dam removal and restoration projects for use worldwide. The 16 students per year will include four students from the tribal communities in PC's district enrolled in either a two or 4-year science program at PC; four PC students in the sciences; four students in the Huxley College program at PC; and four students from other rural college districts.

Expected Products: In addition to being trained in a variety of areas of study in natural resources management and ecology, students will present their results to the regional scientific and public communities at an annual REU Public Workshop, and at national undergraduate research conferences (i.e., CUR and NCUR conferences); scientist mentors and students will produce scientific publications, and protocols for long-term ecosystem monitoring that will be documented and made available in technical report format and on the National Parks in the North Coast and Cascades Network (NCCN), and PC Center for Excellence websites.

Schedule: Project to begin Fall 2005 and last through September 2009

Link for additional information: bille@pcadmin.ctc.edu

Proposed
Title: ATE—A Technical Experiences Program on the Elwha Dam Removal and Restoration Project in Washington State

Principal Investigator: Eaton (Peninsula College; PI), Allaway (WWU, Huxley College; co-PI), Dwight Barry (Peninsula College; co-PI), Brian Hauge (Peninsula College; co-PI)

Description: The purpose of this ATE Project is to develop a new regional community college student technical experiences program at PC for students in the Natural Resource-related fields, using the Elwha ecosystems as focal points for the project. This program would provide advanced skills training and job preparation for students to help them enter into the workforce or transfer to baccalaureate programs for the last two years of technician training, and provide a significant regional recruitment tool to attract and retain students to help address a developing workforce gap. The grant would sponsor nine students from the tribal communities in PC's district, twelve PC students in the sciences, and nine students from other rural districts in the state in the two-course sequence involving 60 hours of classroom activities and 180 hours of research on the Elwha ecosystems. There will also be sponsorships for five students in the Huxley College BA and BS

programs at PC to conduct research during the year, and for 5 high school faculty and 5 college students for a 10 week summer projects program.

Expected Products: Students will be trained in a variety of areas of study in natural resources management and ecology, and prepared for entry into jobs or upper division programs at universities. In addition, students will present their results to the regional scientific and public communities, and at national undergraduate research conferences (i.e., CUR and NCUR conferences). Scientist mentors and students will produce scientific publications, as well as technical reports and protocols that will be made available in technical report format and on the National Parks in the North Coast and Cascades Network (NCCN), and PC AETCE websites.

Schedule: Project to begin Fall 2005 and last through September 2008

Link for additional information: bille@pcadmin.ctc.edu

Proposed
Title: ATE—A Technical Experiences Program on the Elwha Dam Removal and Restoration Project in Washington State

Principal Investigator: Eaton (Peninsula College; PI), Allaway (WWU, Huxley College; co-PI), Dwight Barry (Peninsula College; co-PI), Brian Hauge (Peninsula College; co-PI), Freilich (Olympic National Park)

Description: This is a four year grant project that will provide advanced training for undergraduate science students by development of an undergraduate student research and data collection program at PC to study the Elwha River system ; and in so doing, provide baseline data on the ecosystem's biotic community and chemical conditions and trends prior to before and after dam removal in order to help address several specific hypotheses and questions associated with the impacts of dam removal; The research students will be involved in writing all reports, final protocols, website material, developing any presentations, and any other products resulting from this work. The Scientific Team members will serve as mentors and editors for all student writing and presentation preparation efforts.

Expected Products: 20 students will be enrolled in PC and Huxley College at PC specific research courses. These will included 15 funded students (5 from PC, 5 from Huxley, and 5 from the Lower Elwha Tribe). Students will participate in the research projects associated with the Elwha Research Consortium. The research students will be involved in writing all reports, final protocols, website material, developing any presentations, and any other products resulting from this work. Students will also make presentations at local, regional and national.

Schedule: Project to begin Fall 2005 and last through September 2009

Link for additional information: bille@pcadmin.ctc.edu

Data sharing and management

Title: Point No-Point Treaty Council Salmon and Steelhead Habitat Inventory and Assessment Project (SSHAIP)

Principal investigators: Todd, Fitzpatrick

Description: Develop and maintain GIS datasets ; coordinate with Skagit River System Cooperative.

Expected products:

Schedule: Ongoing with progress expected in next 6 months.

Link for additional information: stodd@pnptc.org

Appendix B: Previous research and data collected in the Elwha River watershed and nearshore areas

The following section presents a compilation of past research activities in the Elwha River watershed and nearshore area. The list is adapted primarily from the Elwha River Restoration Draft Sediment Monitoring and Management Plan (Randle et al. 2004), Restoration of the Elwha River Ecosystem: Results of a Biological Monitoring/Research Workshop (Schreiner and Winter 2004), Technical Workshop on Nearshore Restoration in the Central Strait of Juan de Fuca (CMRC 2004), the Elwha River Ecosystem Restoration Implementation Environmental Impact Statement (Olympic National Park 1996), and Understanding the Elwha: A Strategy for Research and Education Programs on the Elwha River (Allaway 2004). Refer to those documents for additional lists of data collected where full citations were unknown or unavailable.

Atwater, B.F. 1987. Evidence for great Holocene earthquakes along the outer coast of Washington State. Science 236: 942-944.

Bachtold, L.M. 1982. Destruction of Indian Fisheries and Impact to Indian Peoples. In *The Historic and Economic Value of Salmon and Steelhead to Treaty Fisheries in River Systems in Washington, Oregon and Idaho.* A report to the Bureau of Indian Affairs. Meyer-Zangri Associates.

Bonnell, M. L., C. E. Bowlby, G. A. Green, and J. J. Brueggeman. 1992. Pinniped Distribution and Abundance Off Oregon and Washington, 1989-1990. In *Oregon and Washington Marine Mammal and Seabird Surveys*, edited by J. J. Brueggeman and Ecological Consulting, Inc. Final Report prepared for Pacific OCS Region, Minerals Management Service, U.S. Department of the Interior, Los Angeles, by Ebasco Environmental and Ecological Consulting, Inc., Bellevue, WA.

Bottom, D. L., J. A. Lichatowich, and C.A. Frissell. 1998. Variability of Pacific Northwest Marine Ecosystems and Relation to Salmon Production. In *Change in Pacific Northwest Coastal Ecosystems*, G.R. McMurray and R.J. Bailey (eds). NOAA Coastal Ocean Program Decision Analysis Series No. 11. NOAA Coastal Ocean Office, Silver Spring, Maryland.

Bowser, S., Didricksen, K., Haider, T.R., Jurenka, B., and Randle, T., March 1997. Water Quality Analysis and Mitigation Measures, Elwha Project, Washington (Elwha Technical Series PN-95-8), Pacific Northwest Region, Boise, ID, 67 pages.

Brannon, E.M. 1930. Elwha River and Hatchery Prospect. Department of Fisheries and Game. 3 pp.

Brannon, E.L., and WK. Herschberger. 1984. Elwha River Fall Chinook Salmon. In *Proceedings of the Olympic Wild Fish Conference*, edited by J.M. Walton and D.B. Houston, 169-181. Peninsula College, Port Angeles, Washington.

Brodeur, R. D. 1990. A synthesis of the food habits and feeding ecology of salmonids in marine waters of the North Pacific. (INPFC Doc.) FRI-UW-9016. Fisheries Research Institute, School of Fisheries, University of Washington, Seattle, Washington.

Bromley, C., Grant, G.G., Thorne, C.R., 2003, "A laboratory investigation of the variables that control the rate and volume of sediment movement through and out of impoundments during dam removal," research being undertaken at St. Anthony Falls Laboratory, University of Minnesota.

Brown, G.M. and H. Hodges. 1994. Economic Impacts on Port Angeles Due to the Closure of the Salmon Fishery. A Report to the City of Port Angeles. University of Washington and University of Puget Sound.

Burt, R., April 2003, Geologic Report on Lake Aldwell and Lake Mills Landslide Mapping and Elwha Dam Left Spillway Coffer Dam Foundation Explorations, Pacific Northwest Region, Boise, ID, 32 pages.

Calambokidis, J., and R.W. Baird. 1994. Status of Marine Mammals in the Strait of Georgia, Puget Sound and the Juan de Fuca Strait and Potential Human Impacts. In *Review of the Marine Environment and Biota of Strait of Georgia, Puget Sound and Juan de Fuca Strait*, edited by R.C.H. Wilson, R.J. Beamish, F. Aitkens, and J. Bell, 282-303. Proceedings of the BC/Washington Symposium on the Marine Environment January 13 & 14, 1994. Canadian Technical Report of Fisheries and Aquatic Sciences 1948.

Canning, D. J. and H. Shipman. 1995. The cumulative effects of shoreline erosion control and associated land clearing practices, Puget Sound, Washington. Coastal Erosion Management Studies, Volume 10. Shorelands and Water Resources Program, Washington Department of Ecology, Olympia, Washington.

Carter, S. K. 1999. Ecosystem effects of sea otter predation and commercial sea urchin harvest on nearshore benthic habitats in Northern Washington. Master's Thesis, University of Washington School of Fisheries. Seattle, Washington. 286 pp.

Carter, S. K. and G. R. VanBlaircom. 1998. A survey of nearshore benthic habitats of the Strait of Juan de Fuca from Kydaka Point to Port Angeles. Final report to the WDFW. University of Washington, School of Fisheries, Seattle, Washington.

Childers, D., Kresch, D.L., Gustafson, A.S., Randle, T.J., Melena, J.T., and Cluer, B., September 2000, Hydrologic Data Collected During the 1994 Lake Mills Drawdown Experiment, Elwha River, Washington, Water-Resources Investigations Report 99-4215, U.S. Geological Survey, Tacoma, Washington, 115 pages.

Cohen, A., C. Mills, H. Berry, M. Wonham, B. Bingham, B. Bookheim, J. Carlton, J. Chapman, J. Cordell, L. Harris, T. Klinger, A. Kohn, C. Lambert, G. Lambert, K. Li, D. Secord, and J. Toft. 1998. Puget Sound expedition: A rapid assessment

survey of non-indigenous species in the shallow waters of Puget Sound. Washington Department of Natural Resources, Olympia, Washington.

Collins, D.C. 1983. A Report on Rainbow Trout Populations From the Elwha River, Lake Aldwell and Lake Mills. Washington Department of Game.

Curtis, E.S. 1913. The North American Indian. Vol. 9. New York: Johnson Reprint Corporation. 1976.

Dethier, M. N. 1990. A marine and estuarine habitat classification system for Washington State. Washington Natural Heritage Program, Department of Natural Resources, Olympia, Washington. 56 pp.

Department of the Interior, Department of Commerce, and Lower Elwha S'Klallam Tribe, 1994. The Elwha report: Restoration of the Elwha River Ecosystem & Native Anadromous Fisheries. Olympic National Park, Washington. 174 pp.

Department of the Interior, 1995. Final environmental impact statement: Elwha River ecosystem restoration. Olympic National Park, Washington. 674 pp.

Department of the Interior, 1996. Elwha River ecosystem restoration: Final environmental impact statement. Olympic National Park, Washington. 281 pp.

Downing, J. 1983. *The Coast of Puget Sound: Its Processes and Development*. Washington Sea Grant Program. University of Washington Press, Seattle, Washington. 126 pp.

Ebbesmeyer, C. C., C. A. Coomes, J. M. Cox, J. M. Helseth, G. A. Cannon, and C. A. Barnes. 1984. Synthesis of current measurements in Puget Sound, Washington - Volume 3. Circulation in Puget Sound: An interpretation based on historical records of currents. NOAA Technical Memorandum NOS OMS 5. National Oceanic and Atmospheric Administration, Rockville, Maryland.

Elwha Project Human Effects Team. 1995. Elwha River restoration project: economic analysis. Report to U.S. Bureau of Reclamation, National Park Service, and Lower Elwha S'Klallam Tribe. Davis, California. http://www.nps.gov/olym/elwha/docs/econanaly.htm

Foster Wheeler. 2000. Environmental assessment for the interim management plan, Elwha River ecosystem restoration. Report to the National Park Service, Port Angeles. Foster Wheeler Environmental Corp., Bellevue, WA.

Gunther, E.

1925 "Klallam Folk Tales." University of Washington Publications in Anthropology 1(4):113-170 (August 1925).

1927 "Klallam Ethnography." University of Washington Publications in Anthropology 1(5):171-314 (January 1927).

Harrison, P. J. et al. 1994. An assessment of nutrients, plankton, and some pollutants in the water column of Juan de Fuca Strait, Strait of Georgia and Puget Sound, and their transboundary transport. In: Wilson, R. C. H., et al. *eds*. 1994. Review of the marine environment and biota of Strait of Georgia, Puget Sound and Juan de Fuca Strait: Proceedings of the B.C./Washington Symposium on the Marine Environment,

Hathorn, A.W., C. Byrnes, J. Cole, T. DaSilva, and B.B. Moorhead. 1995. "Marbled Murrelet Surveys in the Lower Elwha River Valley, Olympic National Park and Vicinity. Unpublished NPS report, Olympic National Park, Port Angeles, Washington.

Hawkins Hoffman, C. 1992. The Elwha Issue: A Fish Problem That Just Won't Die. The George Wright Forum 9(2):45-52.

Hepler, T., and Scott, G., May 1996, Removal of Elwha and Glines Canyon Dams (Elwha Technical Series PN-95-7), Pacific Northwest Region, Boise, ID, 86 pages.

Hepler, T., and Randle, T. September 1996 Dam Removals for Restoration of the Elwha River, American Society of Dam Safety Officials, 10 pages.

Hoffman C.H., and B.D. Winter, 1996. Restoring aquatic environments: A case study of the Elwha River. Pp. 303-323 in Wright RG, ed. National parks and protected areas: Their role in environmental protection. Cambridge, MA: Blackwell Scientific Publications.

Hosey and Associates, 1988, Appendix 5: Sediment Transport, Channel and Beach Morphology, prepared for Perkins Coie, 32 pages.

Houston, D., B.B. Moorhead, and R.W. Olson. 1987. Roosevelt Elk Density in Old-Growth Forests of Olympic National Park. Northwest Science 61(4):220-225.

Houston, D., E. Schreiner, B. Moorhead, and K. Krueger. 1990. Elk in Olympic National Park: Will They Persist Over Time? Natural Areas journal 10(1):6-11.

James, K.M. 1993. S'Klallam Use of Shellfish and Known Shellfishing Locations Within Previously Determined Usual and Accustomed Fishing Grounds. Unpublished report, tribal files.

James River II, Inc.
1987 Application for License, Archaeology, and Historical Resources Report. by James River II, Inc. December 1987. Unpublished report.

1988 Responses to May 28, 1987 Request for Additional Information. Prepared by Hosey & Associates. May 27, and December 2, 1988.

1989 Response to August 15, 1989 Request for Additional Information. Schedule B, Items I and 2: Rubble and Sediment Disposal. December 1, 1989.

1990 Responses to Requests for Additional Information. Prepared by Hosey & Associates. February 15, April 16, May 1, and September 27, 1990.

Jordan, M. 1995. Trumpeter and Tundra Swans Wintering on the Olympic Peninsula in Relation to the Elwha River Restoration Project. Lower Elwha Klallam Tribe, unpublished report.

Jones, E.E., 1927, Power Resources of the Elwha River, Washington (unpublished report to the U.S. Geological Survey). April 1927. Available from the Bureau of Land Management State Office, Portland, OR.

Klein, P.O. 1995. Elwha River Wetland Inventory for the Lower Elwha Restoration Project. Sheldon & Associates. Unpublished report, tribal files.

Lavelle, J. W., H. O. Mofjeld, E. Lempriere-Doggett, G. A. Cannon, D. J. Pashinski, E. D. Cokelet, L. Lytle, and S. Gill. 1988. A multiply-connected channel model of tides and tidal currents in Puget Sound, Washington, and a comparison with updated observations. NOAA Technical Memorandum ERL PMEL-84. Pacific Environmental Marine Laboratory, National Oceanic and Atmospheric Administration, Seattle, Washington.

Lane, B.S. 1975. Identity, Treaty Status and Fisheries of the Lower Elwha Tribal Community. Prepared for the U.S. Department of the Interior and the Lower Elwha Tribal Community. July 25, 1975.

Lane & Lane Associates. 1981. The Elwha River and Indian Fisheries. Prepared for The Bureau of Indian Affairs, U.S. Department of the Interior, Portland, Oregon. December 1981.

Leighton, C.C. 1884. Life at Puget Sound with Sketches of Travel in Washington, British Columbia, Oregon, and California, 1865-1881. Boston: Lee and Shepard.

Lencioni, J.L., 1995, Elwha River Restoration Project, Flooding Impacts Associated With Removal of the Elwha and Glines Canyon Dams, U.S. Army Corps of Engineers, Seattle District, 17 pages.

Loafman, P., A. Farris, R.B. Bury, and B.B. Moorhead. 1995. Elwha River Valley Amphibian Surveys, Olympic National Park and Vicinity. Olympic National Park, Port Angeles, Washington. Unpublished report.

Long, E. R. *ed.* 1982. A synthesis of biological data from the Strait of Juan de Fuca and Northern Puget Sound. EPA 600/7-82-004. Office of Engineering and Technology,

Loomis, J. 1995. Measuring the economic benefits of removing dams and restoring the Elwha River: results of a contingent valuation survey. Colorado State University, Fort Collins, CO.

Loomis, J. B. 1996. Measuring the Economic Benefits of Removing Dams and Restoring the Elwha River: Results of a Contingent Valuation Survey. Water Resources Research, 32 (2), 441-447.

Lower Elwha S'Klallam Tribe. 1994. Lower Elwha S'Klallam Tribe: Preliminary Land Use Plan for Elwha Project Lands. Lower Elwha S'Klallam Tribe, River Restoration Department.

Macdonald, K. B. and B. Witek. 1994. Management options for unstable bluffs in Puget Sound, Washington. Coastal Erosion Management Studies, Volume 8. Shorelands and Coastal Zone Management Program, Washington Department of Ecology, Olympia, Washington.

Mackas, D. L. and P. J. Harrison. 1997. Nitrogenous nutrient sources and sinks in the Juan de Fuca/Strait of Georgia/Puget Sound Estuarine System: Assessing Potential for Eutrophication. Estuarine, Coastal, and Shelf Science 44. 1-21.

Mausolf, R.G., and D.B. Sundvick. 1976. A Report on the Limnology and Biota of the Reservoir Created by the Glines Canyon Dam. Report submitted to Crown Zellerbach Corporation.

McHenry, M., 2001, Physical/Biological Monitoring: Elwha River Engineered Log jams Study Plan 2001-2006.

Meyer, PA., R. Lichtkoppler, RB. Hamilton, CL. Borda, D.A. Harpman, and P.M. Engle. 1995. Elwha River Restoration Project: Economic Analysis. A Report to the U.S. Bureau of Reclamation, the National Park Service, and Lower Elwha Klallam Tribe. Davis, California.

Miller, B. S., C. A. Simenstad, J. N. Cross, K. L. Fresh, and S. N. Steinfort. 1980. Nearshore fish and macroinvertebrate assemblages along the Strait of Juan de Fuca including food habits of the common nearshore fish. Final report of three years sampling 1976-1979.EPA No. D6-E693-EN. Office of Environmental Engineering and technology office of Research and Development US EPA Washington DC.

Morrill, D.C. and M.L. McHenry. 1995. 1994 Elwha River Fish Community Study. Lower Elwha Klallam Tribe Draft Technical Report. Port Angeles, Washington.

Munn MD, RW Black, AL Haggland, MA Hummling, RL Huffman. 1999. An assessment of stream habitat and nutrients in the Elwha River Basin: Implications for restoration. USGS, Water-Resources Investigations Report 98-4223

Olympic National Park. 1994. Survey of Selected Elwha River Riparian Vegetation Communities in Olympic National Park. Prepared by Doss D.S. and R.W. Olson, Natural Resources Management Division, Olympic National Park.

Port Angeles Evening News. 1945. "Thousands of Big Salmon That Got Away are Crowding Spawning Beds of Elwha River." October 3, Page 1.

PSAMP (Puget Sound Ambient Monitoring Program). 2000. A conceptual model for environmental monitoring of a marine system.

Schmitt, C., J. Schweigert, and T. P. Quinn. 1994. Anthropogenic influences on fish populations of the Georgia Basin: I. Salmonids II. Marine fishes. In: Wilson, R. C. H., R. J. Beamish, F. Aitkens, and J. Bell. *eds.* Review of the marine environment and biota of the Strait of Georgia, Puget Sound, and Juan de Fuca Strait. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1948. pp. 218-255.

Schroer, G.L. 1986. Seasonal Movements and Distribution of Migratory Roosevelt Elk in the Olympic Mountains, Washington. M.S. Thesis, Oregon State University.

Schwartz, M.L. 1994. Beach Geomorphology at the Elwha River Delta in Connection with Removal of the Elwha and Glines Canyon Dams.

Sharpe, EA. 1990. Elwha River Basin Preliminary Bird Checklist. May 16,1990. Unpublished report.

Swindell, E.G. 1942. Report on Source, Nature, and Extent of the Fishing, Hunting, and Miscellaneous Related Rights of Certain Indian Tribes in Washington and Oregon together with Affidavits Showing Location of a Number of Usual and Accustomed Fishing Grounds and Stations, Vols. I and II. United States Department of Interior, Office of Indian Affairs, Division of Forestry and Grazing, Los Angeles, California, July 1942.

Randle, T.J., 2002, Memorandum to Brian Winter, Olympic Elwha Project Team Leader, Elwha River Restoration Project, Olympic National Park, National Park Service. Application of the report entitled: "Sediment Analysis and Modeling of the River Erosion Alternative", Elwha Technical Series PN-95-9, Randle, Young, Melena, and Ouellette, U.S. Bureau of Reclamation, October 1996.

Randle, T.J.; Young, C.A.; Melena, J.T.; Ouellette, E.M., October 1996, Sediment Analysis and Modeling of the River Erosion Alternative, Elwha Technical Series PN-95-9, U.S. Department of the Interior, Bureau of Reclamation, Boise, Idaho, 138 pages.

Schwartz, M., 1994, Beach geomorphology at the Elwha River Delta in connection with removal of the Elwha and Glines Canyon Dams, prepared for Lower Elwha Tribal Council, 32 pages.

Shaffer, J.A. 2000. Seasonal variation in understory kelp bed habitats of the Strait of Juan de Fuca. Journal of Coastal Research 16 (3), 768-778.

Shaffer, J.A. 2001. Nearshore marine habitats of Clallam County. In: Proceedings, Clallam County Marine Resource Committee workshop series, Clallam County, Washington.

Schaffer, J.A. 2002. Macroalgae blooms and nearshore resources of the Strait of Juan de Fuca. In Proceedings, Puget Sound Research Conference 2001. Puget Sound Action Team, Olympia, Washington.

Shaffer, J.A. 2004. Nearshore mapping of the Strait of Juan de Fuca: II. Preferential use of nearshore kelp habitats by juvenile salmon and forage fish. In Proceedings, Puget Sound Research Conference 2003, Puget Sound Water Quality Action Team, Olympia, Washington.

Shaffer, J. A., R. Moriarty, J. Sike and D. Penttila. 2003. Nearshore habitat mapping of the Strait of Juan de Fuca: Phase 2. Final report to the Northwest Straits Commission, Clallam Marine Resources Committee, and Washington Department of Fish and Wildlife. WDFW, Olympia, Washington.

Shreffler, D. K., R. M. Thom, and K. B. Macdonald. 1995. *Shoreline Armoring Effects on Coastal Ecology and Biological Resources in Puget Sound.* Final report prepared for the Washington Department of Ecology Shorelands and Coastal Zone Management Program by Battelle/Marine Sciences Laboratory, Sequim, Washington; Battelle, Pacific Northwest Laboratories, Richland, Washington, and CH2M Hill, Seattle, Washington.

Simenstad, C. A., B. S. Miller, C. F. Nyblade, K. Thornburgh, and L. J. Bledsoe. 1979. Food web relationships of Northern Puget Sound and the Strait of Juan de Fuca. EPA 600/7-79-259. Office of Engineering and Technology, Office of Research and Development,

Simenstad, C. A., K. L. Fresh, and E. O. Salo. 1982. The Role of Puget Sound and Washington Coastal Estuaries in the Life History of Pacific Salmon: An Unappreciated Function. In V.S. Kennedy (ed). *Estuarine Comparisons*. Pp. 315-341. Academic Press, New York, New York.

Simenstad, C. A., and J.R. Cordell. 2000. Ecological Assessment Criteria for Restoring Anadromous Salmonid Habitat in Pacific Northwest Estuaries. *Ecological Engineering* 15:283-302.

Simenstad, C. A., R. M. Thom, K. A. Kuzis, J. R. Cordell, and D. K. Shreffler. 1988 Nearshore Community Studies of Neah Bay, Washington. University of Washington Fisheries Research Institute. FRI-UW-8811, Seattle, Washington.

Simenstad, C. A., W.G. Hood, R. M. Thom, D. A. Levy, and D. L. Bottom. 2001. Landscape structure and scale constraints on restoring estuarine wetlands for Pacific Coast juvenile fishes. In M/P. Weinstein and D.A. Kreeger, editors, *Concepts and Controversies in Tidal Marsh Ecology*, Kluwer Academic Publishing, Dordrecht, The Netherlands.

Sizemore, B., and M. Ulrich. 2000. 2000 geoduck atlas: atlas of major geoduck tracts of Puget Sound. Washington Department of Fish and Wildlife, Fish Program, Point Whitney Shellfish Lab, Brinnon, Washington.

Taber, R.D., and K.J. Raedeke. 1980. Roosevelt Elk of the Olympic National Forest. Seattle: University of Washington.

Thom, R. M. 1987. The Biological Importance of Pacific Northwest Estuaries. *The Northwest Environmental Journal* 3(1): 21-42.

Thom, R. M. 2000. Adaptive Management of Coastal Ecosystem Restoration Projects. *Ecological Engineering* 15:365-372.

Thom, R. and L. Hallum. 1990. Long term changes in the areal extent of tidal marshes, eelgrass meadows, and kelp forests of Puget Sound. Fisheries Research Institute, University of Washington. FRI-UW-9008. Seattle, Washington.

Thom, R. M. and K.F. Wellman. 1996. *Planning Aquatic Ecosystem Restoration Monitoring Programs*. IWR Report 96-R-23. U.S. Army Corps of Engineers, Institute for Water Resources, Alexandria, Virginia.

U.S. Army Corps of Engineers

1971 Report on survey, Ediz Hook Erosion Control, Port Angeles, Washington. Part 2 of Main Report. U.S. Army Corps of Engineers, Seattle District, Seattle, Washington.

1987 Elwha River, Washington Flood Damage Reduction Study - Final Section 205 Definite Project Report, Finding of No Significant Impact and Final Environmental Assessment.

1995a Elwha River Restoration Project -- Flooding Impacts Associated with Removal of the Elwha and Glines Canyon Dams, by James L. Lencioni.

1995b Elwha River Restoration Project, Development of Flood Hydrographs. January 1995.

U.S. Bureau of Reclamation

1995a Overview of Ground-Water Conditions. Elwha Technical Series PN-95-3. Pacific Northwest Region, Boise, ID.

1995b Report of Water Quality Task Group, Elwha River, Washington. Elwha Technical Series PN-95-8. Pacific Northwest Region, Boise, ID. [this will incorporate Ground

Water (PN-95-3), Surface Water (PN-95-9), Industrial Water Treatment Measures (PN-95-10), and Infiltration Gallery (PN-95-11) reports.]

1995c Plan for Removal of Elwha and Glines Canyon Dams, Elwha River, Washington. Elwha Technical Series PN-95-7. Pacific Northwest Region, Boise, ID.

1995d Alluvium Distribution in Lake Mills, Glines Canyon Project, and Lake Aldwell, Elwha Project, Washington. Elwha Technical Series PN-95-4. Pacific Northwest Region, Boise, ID. 60 p.

1995e Development of Flood Hydrographs. Elwha Technical Series PN-95-1. Pacific Northwest Region, Boise, ID. 8 p.

1995f Report of Sediment Management Task Group, Elwha River, Washington. Elwha Technical Series PN-95-5. Pacific Northwest Region, Boise, ID.

1995g May 2 letter to Regional Director, Northwest Region, National Park Service; Literature Review of and Visit to Elwha Dam -- Safety Evaluation of Existing Dams (SEED) Program - National Park Service, Olympic National Park, WA.

1995h Regional Economic and Tax Revenue Impact Analyses. Elwha Technical Series PN-95-2. Pacific Northwest Region, Boise, ID.

1995i Geologic Design Data Report for Removal of Elwha Dam. Elwha Technical Series PN-95-6. Pacific Northwest Region, Boise, ID.

1995j Overview of Surface Water Conditions, Elwha River, Washington. Elwha Technical Series PN-95-9. Pacific Northwest Region, Boise, ID.

1995k Proposed Industrial Water Treatment Measures, Elwha River, Washington. Elwha Technical Series PN-95-l0. Pacific Northwest Region, Boise, ID.

19951 Proposed Infiltration Gallery for Water Collection and Treatment, Elwha River, Washington. Elwha Technical Series PN-95-11. Pacific Northwest Region, Boise, ID.

1996a Alluvium Distribution in the Elwha River Channel Between Glines Canyon Dam and the Strait of Juan de Fuca, Washington (Elwha Technical Series PN-95-5), Pacific Northwest Region, Boise, ID, 12 pages.

1996b Sediment analysis and modeling of the river erosion alternative. Elwha Technical Series PN-95-9.

1996c Elwha River Ecosystem Restoration Implementation, Final Environmental Impact Statement, Olympic National Park, Washington, 281 pages.

U.S. Department of the Interior, 1994, The Elwha Report, restoration of the Elwha River ecosystem & native anadromous fisheries: published jointly by the U.S. Department of Interior, National Park Service, U.S. Fish and Wildlife Service, Bureau of Reclamation, and Bureau of Indian Affairs; U.S. Department of Commerce, National Maritime Fisheries Service,; and the Lower Elwha S'Klallam Tribe, 174 pages.

U.S. Fish and Wildlife Service
1994 Elwha Dam and Glines Canyon Dam Hazardous Waste Status.

1995a Letter to Assistant Regional Director - Ecological Services U.S. Fish and Wildlife Service, Portland, Oregon, Level I Preacquisition Contaminants Survey for the Elwha Restoration Project, Clallam County, Washington. November 22, 1993, Olympia, Washington.

1995b Letter to Assistant Regional Director - Ecological Services U.S. Fish and Wildlife Service, Portland, Oregon, Revised Level 2 Preacquisition survey of the Elwha Restoration Project-Glines Canyon Switchyard. March 20, 1995, Olympia, Washington.

1995c Marine Resources of the Elwha River Estuary, Clallam County, Washington. Western Washington Office, Olympia, Washington.

1995d Elwha River Chum Salmon (Oncorhynchus keta): Spawner Survey and Escapement Estimate 1994-1995. Technical Report.

VanBlaricom, G. R. and M. D. Chambers 2003. Testing a charismatic paradigm: Consequences of a growing sea otter population for nearshore benthic communities along the south shore of the Strait of Juan de Fuca. Washington Cooperative Fish and Wildlife Research Unit Biological Resources Division, U.S. Geological Survey, School of Aquatic and Fishery Sciences, University of Washington, Seattle, Washington.

VanWagenen, R.F. 1996. Washington Coastal Kelp Resources: Port Townsend to the Columbia River. Final report for the Washington Department of Natural Resources, Olympia, Washington.

VanWagenen, R. F. 1998. Washington coastal kelp resources: Port Townsend to the Columbia River. A report to the Washington Department of Natural Resources, Olympia, Washington.

Washington State Department of Ecology. 1994. Shoreline photo layer, electronic database. Internet address: http:apps/ecy/wa.gov/website/coastal.atlas/1994 photo layer.

WDF (Washington State Department of Fisheries). 1971. Elwha River Fisheries Studies. Management and Research Division.

WDFW (Washington State Department of Fish and Wildlife). 1993. "Sport Fish Stocked into the Elwha River; 1981-1992, Outplanting Database." Olympia, Washington.

Washington State Department of Natural Resources. 1999. Shorezone inventory (1999). Olympia, Washington.

Wilson, R. C. H., R. J. Beamish, Fran Aitkens and J. Bell (eds.). 1994. Review of the marine environment and biota of Strait of Georgia, Puget Sound and Juan de Fuca Strait: Proceedings of the BC/Washington Symposium on the Marine Environment, Jan. 13 & 14, 1994. Can. Tech. Rep. Fish

Winter, B. D., R, Reisenbichler, and E. Schreiner. 2000. The importance of marine-derived nutrients for ecosystem health and productive fisheries.

Wunderlich, R.C. 1983. A Preliminary Assessment of Juvenile Salmon Mortality Through the Elwha River Dams. U.S. Fish and Wildlife Service, Olympia, Washington. December 1983.

Wunderlich, R.C., B.D. Winter, and J.H. Meyer, 1994. Restoration of the Elwha River ecosystem. Fisheries 19(8): 11-19.

Young, S., In Progress, Assessment of the Slope Instabilities along the Perimeters of Lake Aldwell and Lake Mills, U.S. Department of the Interior, Bureau of Reclamation.

Appendix C: Notes from 2003 education workshop

November 3-4, 2003. Coordinator: Betsy Carlson, Olympic National Park.

University Students

General ideas/comments

- Interns working with education and research groups
- How can a permanent University presence enhance the project and economic development?
- Work with school districts as peers and mentors
- Invite Peninsula College to participate

Student research

- Case studies for the undergraduate classes
- Research topics for graduate student theses
- University - think-ongoing sustainable development. Long term involvement in research monitoring, summer institutes, grad projects, courses field trips.
- Opportunities for applied research drawing from prioritized list/plan
- UW or Pen. College research - student research integrated into environmental studies curriculum
- Ecological restoration studies at PC [Peninsula College] International (?)
- Elwha research conferences
- College students plan and conduct community lecture series (a for credit class) informing community about removal

Cultural Resource Archaeologist internship

- How was the Elwha Valley perceived by the first homesteaders?
- How did the Elwha Klallam feel when the dams were built?

Curriculum Development ideas

- Student inquiry into research design => develop into case study course Adaptive Management
- By the process of designing and conducting controlled (or even uncontrolled) experiments, we openly acknowledge uncertainty. Useful experiments require society to assess and accept a certain amount of risk.
- Remember the concept of Multiple Working Hypotheses!
- We scientists and managers (also your teachers) have not figured it all out yet! There is still plenty left to do and learn.
- Monitoring as methods class – trains on classrooms in Port Angeles
- Develop Environmental Economics curriculum based on Elwha Story

Physical/Biological Monitoring ideas

- Air traps to monitor aerial deposition of organic material onto “new landscape”
- Bird Transects to monitor changes in bird populations before, during and after
- Fisheries students at Peninsula College – genetics studies on returning populations pre-dam removal populations

Technology-based

Real-time

- Consider using “new” monitoring technologies that work and provide possibilities for telemetry for real-time access via web.
- Links to real-time stream flow information. Can you do underwater video cam of spawning fish through dam?

Dam cam

- Web-cam or just web-posted photos from permanent photo points for dam, reservoir and estuary changes.
- Camcorder in situ monitor of in-stream conditions

Video conferencing

- More satellite communication that would link classrooms to list to experts out of the area
- All K-20 is wired for video conferencing – let's share info, data, culture, etc amongst K-20 students.

Tie-in with **Naturemapping** UW and WA Dept pf Fish and Wildlife, include protocols and on-line databases

Web-based Information

- Dedicated web designer who can redesign web-site and make current general information, images research easily accessible to the public for at least 6 years (2005 – 2011)
- Challenge: usually project funded
- Partners: Other research projects, ed projects, etc – take % off each ONP project to fund term employee programmer for 5-6 years.
- Web site should feature a living, breathing section updated at least every couple of weeks during removal.
- Technology reaches a world-wide audience 24/7 IF well done, accurate, updated and useful
- Open access data sharing (monitoring and research findings)
- [can be used by] General public, Formal education, teacher training
- Model: teacher education College of Exploration. (www.collegeofexploration.org)

Other technologies

- Acoustics "High-Res" fish-passage camera (UW)
- LISST and "sediment" Acoustic Back.
- Special events
- Uplinks – satellite
- Live broadcast
- Local students as experts
- Expensive

Funding

- IMAX "Salmon Running" – could be funded by NSF
- NPS and USGS "QW" [funds for water quality?]
- USGS "coastal and marine geology"
- EPA + NPS + USGS "TMDL Test Bed"
- NSF "SAHRA" University of Arizona
- National Geographic
- USGS
- NSF

K-12 Non-formal

1) *What:* Monitoring program with web-based data distribution
   1) water quality
   2) birds
   3) cultural response
   4) fish
   5) etc

Why do this: Contribution to Research
- build ownership
- teach science – change over time
- deeper understanding
- applied skills for students
- reach diverse audiences

Challenges:
- Transportation
- Quality control – data
- Funding, facilities, staff, equipment
- Time for students (volunteers)
- Opportunity costs

Partners:
- Schools
- Park
- Researchers
- Tribes
- Non-profits (OPI, Dungeness River Center)
- Stream Keepers
- Universities and community colleges

Models:
- Chehalis Basin Monitoring
- NPS Bioblitzes
- Naturemapping
- Streamkeepers
- OPI biomonitoring

Funding:
- Program fees
- Grants: Department of Education, P.I.E.
- NPS, NSF, (UN?)
- Scholarships
- Restoration – Coastal America
- Tribe joint grants

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2) *What:* Develop a series of images – depicting the appearance of the watershed through time, including early formation valley, glaciation, dams, etc. Student generated, allow participants to develop – examine different visual depictions over time.

Challenges: Funding, data, accurate information, <= partnership to ensure

Partners/Models: GIS, Park, OPI, Local Artist, UW – visualization department/GIS

Funding:
- Foundations
- Arts and Education grants
- Parks
- Children's museums
- Clallam Co. Historical Society
- Volunteers – student images and other artists
- Student contests

Additional post-its
- Opportunities for students to link with other schools a la virtual classroom
- Establish bio-monitoring study sites at different points in the watershed, including some accessible by school bus, others deeper.
- Integrate on-site research mapping/monitoring / analysis with volunteer and non-formal students to connect kids to place and develop understanding of science.
- Visual representation (model) of the Elwha watershed with components to interpret the mass of fish / nutrients brought in and out of the watershed by anadromous fish and their cohorts (predators, parasites)

K-12 Non-formal (cont.)

- Creation of the Elwha watershed community alternative school
- Student decision making program on dam construction/removal
- Theme-based subject-integrated outdoor programming
- Summer camp for middle school students to learn about salmon habitat/dam removal, etc.
- Have existing groups take the lead on this area - provide support and counsel but get out of the way.
- Pre-removal, pre-set dam tours for students
- Field trips to sites
- Start a festival
- Learning Center site specific at re-veg site Aldwell reservoir
- Journaling and art over the recovery period to document changing perceptions of the Elwha
- Work with Girl Scout Council's science coordinator (Girl Scout Totem Council) to develop multi-aged level curriculum for scouts - could include field trips, service projects, etc. Could apply to campfire, 4-H, and BSA too
- "Activity Book" Featuring games, puzzles, maps/mazes, web links, pictures to color - could be distributed in newspaper or could be a "nicer" publication
- Discussion of cultural clash in history of dams > rare case of starting the healing process

K-12 Formal

What: Monitoring, restoration, outreach, tools
Why: Help students, teachers, and parents understand issues of their watershed and the Elwha
Challenges:

- Teacher training
- Transportation
- Time vs. EALRs and WASLs (time to teach it) desire or p? to see importance of doing this
- Teachers not yet seeing EE as a means to WASL success for their students
- Science-phobic teachers

Partners/models

- Washington Virtual Classroom Program
- Chehalis Basin Student Monitoring
- Dungeness Student Monitoring

Funding

- Partnerships - public / private and tribes
- PUDs

Curriculum Tools

- Have students create web pages on the Elwha/ Olympic Project
- Theme based curriculum, subject integrated
- Curriculum units developed to address science EALRs - Stanford Univ.?, UW?, local experts?
- Integrated projects for K-12 curriculum - Esp. at risk student population. All stages of the project
- Integrate research monitoring/ some analysis with inquiry-based science - over multiple years so that students grow with the project.
- Student art projects commemorating a "restored" Elwha and historic (memory) pictures
- Elwha trunk (or suitcase, even) based on NPS traveling trunk idea)

Outreach

- Hold summits to highlight students work on monitoring and outreach (webpages) etc.
- Satellite classroom settings to allow students to interact with resources out of the area
- Have high school students teach K-6 kids

K-12 Formal (cont.)

Monitoring Restoration
- Students water quality monitoring on sites before, during and after dam removal and sharing of the data.
- Permanent transects from older forest down through "new" landscape to new river channel
- Service learning restoration projects or senior projects
- Citizen monitoring water quality and bird populations in Elwha - other rivers
- Pitfall traps to monitor insect and small mammal re-colonization of "new" landscape
- Camera traps
- Herbivore exclusion fencing (small and large mesh)
- Watershed-wide student monitoring to understand river systems (many local partnerships together support this.)

Miscellaneous
- Establish plant nurseries (with in ONP protocol for services etc.)
- Train students in real-world civic engagement
- School based celebration river festival
- Letters to the future
- Journals of field trips art, writing
- Work with college students
- Have high school kids present findings to city councils or county commissioners meetings
- Use Stella or Powersim to develop dynamic simulation model to demonstrate salmon population dynamics with and without dams
- Consider priorities - 1st - local Port Angeles schools, 2nd - Olympic peninsula schools, 3rd - Western Washington etc.
- Fish require a spectrum of physical habitats and other elements for varied life-history success

Community Groups

Service Opportunities
- Begin marketing the idea of citizen involvement in monitoring restoration soon – Christmas Bird Count, etc
- Bird counts on the Elwha
- Watershed stewards volunteers – help community members prevent pollution from household practices
- Stream Team Restoration volunteers
- Stream keepers or EMMT take messages to other groups
- Citizen science programs – unite scientists with community members
- Opportunities for planting? Etc. by volunteer groups, garden clubs…
- Community/student involvement in exotic plant removal and planting native plants
- Repeating, regularly-scheduled, citizen-science monitoring programs, like Streamkeepers, bird counts, plant surveys etc.

Learning
- Work with Clallam County Historic Society for focus on Elwha 2006?
- Local focus groups to promote understanding of economic impact of dam de-construction.
- Canned (up-datable) program for Kiwanis, Rotary, Soroptomist clubs etc
- Forums
- Volunteer activities
- Celebrations i.e. Coastal Restoration Festival
- Provide opportunity for free outdoor education for all students/citizens
- Build community with land owners at river mouth

Community Groups (cont.)

Community Groups Providing Advocacy

- Presentations to Chamber of Commerce
- Presentations to business groups
- Develop key messages talking points and share with wide range of people to use in talking with community groups.
- Community groups such as Chamber of Commerce, business groups, travel, fishing, tourist businesses must know economics of restoration
- Consider community in concentric circles – local, regional, national, international (Canada is close!) and what this means to these groups.
- Interpretive center above Aldwell Reservoir on Hwy 101
- Visitors, community outreach, volunteers for re-veg
- Connect to values – Involve people in creating a vision for their community (community forum)
- Community groups sponsor free talks/ presentations from involved researchers and managers.
- Bio-blitzes on species with expert guidance – ie. birds, amphibians, etc.

General Public

Tourism

- Van tours
- Programs to sides as deconstruction, revegetation progress
- Park (all) visitors must leave the park excited about the project and clear on what is going on.
- (Special) opportunity to visit dam removal sites during process
- Highway turnouts/rest stops with interpretive signs explaining restoration/research/dam removal
- Economic benefit. What does that look like for Port Angeles, Crescent, Forks?
- More public tours of the dams and Elwha river before removal – "get the story out"
- Learning/ Visitor center at Aldwell reservoir on hwy 101

Media

- Develop and maintain relationships with key regional and national writers to cover progress and write general interest/ overview articles
- Fact sheets to help tell the story to the media (local, regional, national etc.)
- Documentary (Nat. Geo / PBS, History Channel, Discovery Channel)
- Articles in travel magazines / outdoor magazines/ etc.
- Clearly articulate who the key audiences are (by geo area, interests, age, etc) and develop key messages and a plan for delivering messages over time.
- Develop "Elwha story" presentation (video, PowerPoint, website, brochure) for outreach to community groups.
- Have students create web pages with Elwha Background
- Weekly / monthly column on project status to be sold to papers
- Press releases on all established programs results… citizen science stuff, funding progress
- Seattle Times/ PI articles, KUOW, radio, newspaper - information/background/ interviews
- Think about implications with the media - this is how the general public will learn about this issue the most
- Celebrate the act as a demonstration of the human commitment to stewardship and cross-cultural harmony, and the resiliency of nature. (Make a "sacred place" to visit for this, a reflective monument)

General Public (cont.)

Artsy
- Local artist work telling the story of the river and dam removal. Mary Peck - ask about.
- Elwha in Art - artistic context of Elwha Paintings, photographs, etc
- Nude calendar of scientists of the Elwha
- Book - anthology of local writers writing about the river, what dam removal means
- Writing contest - How was Elwha Valley perceived by first homesteaders? How did Elwha Klallam feel when dams were built?

Public Outreach / Ed
- Booth or table-top display for visibility at festivals, fairs, community events
- River festival celebration now.
- Still photo series to show on web as "flip book" showing sped-up account of changes over time.
- Web cams viewable on ONP website => archives of photos of change
- Handout/ pamphlet/ brochure available for distribution at visitor centers, for schools, for mailing, would provide messages addressing major themes
- Web-based information series. Kiosks on site to deliver historical, current and future scientific and cultural information.
- Panel discussions, forums, talks in the community
- ONP public briefings on project status -> every six months 2003 - 2010
- E-mail action list to mobilize community members (+ people across the state) to write elected officials to get more funding

Other

1) To local and regional media
- Schedules newspaper series for release to local, regional and national publication
- Seattle TV shorts (travel shows)
- Press release on this conference to PDN showing local involvement happening right now. (could happen tomorrow)
- National Public (needs web info) Parks are national (quick link on website)

2) Community groups/leaders
- Workshops with both research and education community to share hopes, lessons learned, new directions
- Senior citizen based groups
- Local decision makers (city council, county commissioners, land use planners, chamber of commerce, etc)
- Decision makers need to know what's happening, why it's happening, and how they should get involved. Stay regularly updated with quarterly Elwha updates.
- (How can Friends group be involved here?)

Packet of information
- Media Audience Press packets with updates, photos, research abstracts
- Media need to know the timing and story opportunities (*good spokespeople, *good images, *clean facts)
- Archive all education, knowledge transfer and science information. Photos too.

Structural / Waysides (Basis for interpretive center)
- Information kiosks a long an Elwha interpretive trail and road to serve all visitors
- A park interpretive center focused on the Elwha to serve all audiences

How was Elwha Valley perceived by first homesteaders? How did Elwha Klallam feel when dams were built?