WASHINGTON SEA GRANT PROGRESS REPORT
for the period 2/1/2008 – 1/31/2009

WSG Project Number: **R/ES-65**
Project Title: Habitat modification due to sediment gravity flows - Elwha Dam removal baseline study

Principal Investigator(s) and Affiliation:
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1. ABSTRACT ELEMENTS

OBJECTIVES

This proposal describes a baseline study to provide monitoring information prior to the removal of two dams on the Elwha River. It will be used to leverage support for studies during the dam-removal period. We hypothesize that high concentrations of suspended sediment discharged from the Elwha River, following dam removal, will be transported dominantly as gravity flows (fluid muds, hyperpycnal plumes), which will come to rest beyond the deltaic platform (i.e., at the base of delta front or on the prodelta – in water depths >30 m). We anticipate that sediment transported in gravity flows will have relatively little interaction with the seawater, and will form thick (>10 cm) seabed deposits directly downslope and in water depths not regularly agitated by waves, and could produce erosive gullies on the delta front. The objectives for this phase of the overall project are to: 1) characterize the seabed and water column in the present river condition, 2) estimate the impacts of high-discharge events on the delta after dam removal, and 3) determine when and where instrumentation should be deployed during the dam-removal period to ensure the highest rate of return from our sampling.

METHODOLOGY (edited)

We propose to undertake a combination of water-column profiling, time-series instrument deployment, and seabed sampling as a baseline study prior to dam removal (FY 2007 and 2008). We will investigate three separate river-discharge and marine conditions: a) high river discharge/high wind and swell waves (predicted in the period Nov07-Feb08), b) high river discharge/low wind and swell (May07-Jun07), and c) low river discharge/high wind and swell (Mar08-Apr08). The double peak for Elwha River discharge (May-Jun, Nov-Feb) allows each of these conditions to be investigated individually in three short cruises.
Water-Column Profiling: A water-column profiler will collect salinity, temperature, and suspended-sediment concentration, and take pumped samples from the water surface to within 10 cm of the seabed.
Time-Series Instruments: A boundary-layer tripod will be deployed near the mouth of the Elwha River for a winter period 2007-08, at a location determined by coordinated planning with the USGS.
Seabed Sampling: The seabed will be cored at stations that coincide with a subset of those examined by the water-column profiling. During one of the cruises, we will map with a high-

resolution multibeam and seismic systems as a complement to USGS side-scan sonar mapping to identify detailed signatures in the seabed (e.g., erosional gullies).

RATIONALE (edited)
Gravity flows occur infrequently, but likely control the cross-margin transport of particulates and associated geochemical components for many coastal areas. The fate of sediment discharged in large floods and in anthropogenically induced flows (e.g., as the result of dam removal, construction, and logging) is likely controlled by gravity-driven processes. Therefore, investigating these elusive phenomena is critical for understanding the fate of many materials in the ocean. Dam removal on the Elwha River provides a special opportunity to address the operational mechanisms and sedimentary signatures of gravity flows, and the modifications to seabed habitat that they cause.

The only two dams on the Elwha River are located 8 and 22 km from the Straits of Juan de Fuca, so sediment released is guaranteed to reach the ocean. Not only would this be valuable for basic scientific purposes, but it would be extraordinary for applied purposes – to document the fate of sediment discharged by dam removal or other similar mechanisms for future coastal-zone management. Precedence will be set for dam-removal projects around the country, as the Elwha removals provide evidence of whether this kind of project is beneficial. The need for marine baseline studies that address bathymetry, sediment distribution, and turbidity is stated in the Technical Workshop on Nearshore Restoration report.

2. ACCOMPLISHMENTS AND OUTCOMES

Observations of modern sediment-transport processes were obtained under various river discharge conditions (April 2008, October 2008 and January 2009), and include nearshore currents, water-column structure and suspended-sediment concentrations. These data were used to evaluate circulation and sediment-transport capacity surrounding the river plume at different values of river flow, and are being compared to those in the previous funding increment at peak discharge. Two deployments of a bottom boundary layer tripod were undertaken and the span of time-series data encompasses a full 6 months over the winter. The time series of sediment resuspension and transport in ~ 20-m water depth explored relationships between sediment delivery by the Elwha River and oceanic processes (including winds, waves, tides, and currents) operating in the Strait of Juan de Fuca. Data collected in the bottom boundary layer were merged with river-discharge and wave-buoy data. Storm events associated with suspended-sediment resuspension were characterized based on buoy, river, and tripod data; the largest storm occurred in February 2008 with peak suspended-sediment concentration of 9 mg/L. Suspended-sediment concentrations did not vary significantly in response to river discharge, but rather, with storm intensity in the Strait.

Between the surface-plume and bottom-boundary-layer observations, we can deduce that sediment dispersal under present, restricted supply is broad and most of the fine-grained sediment likely leaves the delta topset. The little that does get temporarily deposited during floods is resuspended and moved away from the nearshore during storms. The active processes have winnowed the seabed leaving a coarse surface lag layer. Characterization of seabed

sediment shows this layer to be ubiquitous over much of the delta, although regions with some fine-grained sediment are found near the river mouth and trapped between the paleo-spits. Much of the research on this project has been incorporated into educational activities, including our regular teaching within the School of Oceanography and a newly developed research-based course at the Friday Harbor Laboratories, "Marine Sedimentary Processes – The Elwha Dam Removal Example".

This research provides a framework for future seismic, coring and process studies to understand sediment budgets offshore of small mountainous rivers, and has helped to increase the level of understanding of nearshore sedimentary processes so that better decisions can be made concerning restoration projects impacting the shorelines of Puget Sound.

3. IMPACTS (These have been edited/added to, but are similar to PR1)

Sea Grant encourages a systems approach to nearshore restoration: Dam removal projects are becoming an increasingly popular way to restore the habitats of depleted fisheries and river ecosystems. As the dams age over time, the negative impacts of the dam on the river and riparian communities may outweigh the benefits of the dam. But we do not understand the full range of effects our "restoration" will have. Sea Grant funded researchers have collected high-resolution bathymetry, seabed-characterization and sediment-transport data on the Elwha River delta to begin investigations on the dispersal of dam-impounded sediment in the nearshore environment. **Impact:** The baseline monitoring prior to the Elwha Dam removal has been focused on nearshore habitat and fish use, which depend on substrate characteristics. The scientists involved in the Elwha Nearshore Research Consortium will make use of the multibeam and seabed characterization data as detailed bathymetry and surficial-materials maps in their assessment of the existing habitats.

Sea Grant educates students and public on nearshore sedimentary processes: Many Washington coastal communities are experiencing coastal alteration through both natural and anthropogenically induced processes. The environmental forces that cause sediment to move, and cause erosion and deposition are not well understood by the public. Washington Sea Grant academic researchers are participating in outreach lectures to the public and are incorporating topics of marine sedimentary processes (using the Elwha River environment as a case study) into their courses at the University of Washington and have developed a new inquiry-based course at the Friday Harbor Laboratories that integrates science and management for the Elwha restoration. **Impact:** The public is better educated and has access to more information to make important decisions on restoration projects.

Sea Grant supports future scientific researchers and managers: Integration of basic scientific research and management is fundamental to healthy West Coast policy development. Sea Grant funds are being used by a graduate student to complete her graduate degree and to train her as a nearshore researcher. She plans to become an active research scientist with a solid understanding of marine geological processes, specifically dynamic nearshore processes. Additionally, this Sea Grant funded project provided research opportunities to undergraduates and graduate students that will enhance their education and environmental decision-making ability. **Impact:** Support and development of a young, female researcher and education of

undergraduate and graduate students interested in environmental issues creates a greater talent pool for understanding and managing Washington's shorelines.

4. PERFORMANCE MEASURES

Measure 1: Economic and societal benefits derived from the discovery and application of new sustainable coastal, ocean, and Great Lakes products from the sea.

n/a

Measure 2: Cumulative number of coastal, marine, and Great Lakes issue-based forecast capabilities developed and used for management.

n/a

Measure 3: Percentage/number of tools, technologies, and information services that are used by managers (NOAA and/or its partners and customers) to improve ecosystem-based management.

n/a

5. PUBLICATIONS

Please refer to instructions for hardcopy reprint requirements and citation formats.

A. Journal articles:

Lee KM, Ogston AS, Nittrouer CA (in prep) Using Modern Processes to Understand Postglacial Delta Evolution: Elwha River Delta. To be submitted to: Marine Geology.

B. Theses and dissertations:

C. Book chapters:

D. Book or Monograph:

E. Paper in Proceedings

F. Proceedings or Symposia:

Lee KM, Ogston AS, Nittrouer CA Holmes M (2008) Using Modern Processes to Understand Postglacial Delta Evolution: Elwha River Delta, EOS Trans. AGU, 89(53), Fall Meet. Suppl., Abstract OS53F-07.

Lee KM, Ogston AS, Nittrouer CA (2009) Using Modern Processes to Understand Postglacial Delta Evolution: Elwha River Delta. Northwest Scientific Assoc. 81st annual meeting. Seattle, WA.

G. Technical reports:

H. Advisory publications (e.g. handbooks, manuals, guides):

I. Magazine articles:

J. Media Placements:

K. Other publications (e.g., videos, DVDs, software, websites):

6. PRESENTATIONS - inc. Conference (Poster or Oral), Seminar & Public

Bogardus B, Ogston A, Lee K, Nittrouer C (2009) The Potential for Hyperpycnal Flows During Removal of the Elwha River Dams. University Research Day, University of North Carolina at Chapel Hill, Chapel Hill, NC.

Lee KM, Ogston AS, Nittrouer CA, Allison MA (2008) Effect Of Abrupt Change In Sediment Supply On Small Mountainous River Deltas: Elwha River, Washington, USA. EOS Trans. AGU, 2008 Ocean Sciences Meeting: From the Watershed to the Global Ocean, Orlando, FL (USA), 2-7 Mar 2008.

Lee KM, Ogston AS, Nittrouer CA, Holmes M (2008) Using Modern Processes to Understand Postglacial Delta Evolution: Elwha River Delta. EOS Trans. AGU, 89(53), Fall Meet. Suppl., Abstract OS53F-07.

Lee KM, Ogston AS, Nittrouer CA (2009) Using Modern Processes to Understand Postglacial Delta Evolution: Elwha River Delta. Northwest Scientific Assoc. 81st annual meeting. Seattle, WA.

Mansfield M, Ogston A (2009) Sediment Transport in the Marine Environment: The Study of Sediment Resuspension and Transport on the Elwha Delta. 12th Annual UW Undergraduate Research Symposium, University of Washington, Seattle, WA.

Ogston AS, Nittrouer CA, Lee KM (2009) Habitat modification due to sediment dispersal processes. Presentation to the Elwha Nearshore Research Consortium, Port Angeles, WA.

Ogston AS, Nittrouer CA, Lee KM, Gelfenbaum, G (2009) Habitat modification due to marine sediment dispersal processes. Public Lecture to the City of Port Angeles, WA.

Ogston AS, Lee KM, Nittrouer CA (2009) Habitat modification due to marine sedimentary processes during the Elwha Dam removal -- Incorporating undergraduate research experience into baseline studies. Puget Sound Georgia Basin Ecosystem Conference, Seattle, WA.

Ogston AS, Nittrouer CA, Lee KM (2009) Habitat modification due to marine sediment dispersal processes. Marine Geology and Geophysics Seminar Series. School of Oceanography, University of Washington, Seattle, WA.

7. PATENTS AND COPYRIGHTS

n/a

8. NEW BUSINESSES OR JOBS CREATED

n/a

9. LIST ALL STUDENTS SUPPORTED BY OR AFFILIATED WITH THIS PROJECT

Student Name: Kristen M. Lee
Department: School of Oceanography
Major/Degree field: Oceanography
Major Professor: Ogston/Nittrouer
Student Type (Ph.D., M.S., M.A., B.S., B.A. J.D., etc): Ph.D.
Dissertation/Thesis title: "Formation of small mountainous river deltas"
Date of graduation (actual or anticipated): 6/2011
Total support or affiliation period (e.g., Jan – June 2005): 6/2007 – 1/2009
Type of support (RA, research costs, conferences – list all that apply): RA
Current employment if applicable: n/a

10. INTERACTIONS

Elwha Nearshore Research Consortium

We coordinated our studies with the members of the Elwha Nearshore Research Consortium (Elwha NRC; a group of state, federal and academic researchers). We have been involved in consortium meetings, and communicate our efforts and results with the group.

Other University Interactions

As part of our final tripod retrieval cruise in January 2009, we provided time and space for a UC Santa Cruz student, Ian Miller, to deploy a wave recorder in the shallow nearshore. He is co-advised by researchers at the US Geological Survey. We continue to provide equipment and guidance when needed.

11. OUTREACH AND INFORMATION/TECHNOLOGY TRANSFER

Educational Benefits.

The project has been incorporated into a popular sophomore-level course, "Rivers to Beaches" offered by PI Nittrouer focusing on the concept of a continuum of processes within a dispersal system from mountain tops to ocean floor. A field trip as part of this course was held to explore the Elwha River drainage system and nearshore marine environment. The course is filled each year with 80 students who learn about earth surface environments, the processes that shape them, how humans affect them and are affected by them – which will aid in creating a population educated about marine geological processes. Undergraduate research assistants were hired as part of this program. The students typically find careers in environmental agencies or engineering firms and their research education is a valuable skill. Additionally, two UW-funded student cruises were conducted as part of the required sophomore-level Oceanography course, "Field Methods in Oceanography". PI Nittrouer is responsible for the Marine Geology group

within the course and made the focus on the Elwha delta. Another student cruise was conducted for a senior capstone project.

The Elwha dam removal baseline studies were incorporated into a 10-week intensive Research Apprenticeship held at the UW Friday Harbor Laboratories. The program attracted undergraduates from a wide range of universities and backgrounds to design and implement research that helps better understand the impacts of damming on coastal sedimentary processes, and to evaluate critically the predictions of impacts following dam removal. Undergraduate research projects focused on characterizing seasonal variations in sediment-transport dynamics and on sediment sampling of the seabed and seismic reflection profiling paired with multibeam and acoustic backscatter data collected in 2007 under this grant. These results provide insight into the Elwha sediment dispersal system under conditions of limited supply, evolution of the delta in response to sea-level rise, and provide a framework to evaluate the changes to the nearshore sedimentary environment when the dams are removed. One year later, several students have given talks on their individual research at their home institutions and presented two posters at undergraduate research symposia. All seven of the students are choosing careers or graduate education in environmental sciences. Through the combined scientific and educational efforts, we expect to increase the understanding of how marine sedimentary processes operate near the mouths of rivers and to educate the next generation of scientists and managers who will be in charge of decision-making and evaluation of future restoration projects.

Outreach

The PIs have participated in multiple meetings designed to discuss the impacts of dam removal on the environment, and results from baseline studies. These meetings have had a public component to them where the public is invited to join the discussion. PI Ogston has given an evening lecture in both 2008 and 2009 to the citizens of Port Angeles, WA concerning pre-dam removal studies in the marine environment. The public is very engaged in this project and eager to understand more about the impacts of sediment that reaches the ecological habitats in the shallow marine environment.

We participated in leading a field trip by the American Water Resources Association, UW Student Chapter. PI Ogston presented the nearshore dynamics and potential sediment dispersal mechanisms to a group of approximately 15 students. The presentation was coordinated with fisheries habitat concerns discussed by Washington Department of Fish and Wildlife and glacial history discussed by the Washington Department of Natural Resources.

During the Research Apprenticeship at Friday Harbor Labs, the Elwha dam removal studies were highlighted in an Open House series of hands-on activities designed to appeal to grades K-12 and adult audiences. The graduate student on this project, Kristen Lee, gave presentations to K-12 classrooms on the Elwha restoration project and the scientific studies being undertaken. Additionally, the baseline studies were used as a focus of a presentation to the Friday Harbor Labs Development Board. An experiential learning presentation was made at a Puget Sound management conference (PSGB09) highlighting the value of the hands-on Research Apprenticeship approach to educate future environmental scientists and decision-makers.

Elwha Nearshore Update. A newsletter of the Elwha Nearshore Research Consortium, October 2008. PIs Ogston and Nittrouer contributed to the newsletter, which summarizes current activities of federal, state, and academic researchers focusing on the Elwha nearshore. It is sponsored by the Elwha Nearshore Research Consortium.

12. FUTURE ACTIVITIES

This period defines the end of the grant duration, with only a small amount of funding that will be applied through a no-cost extension for the graduate student support to continue her work on this project. The PIs and graduate student will continue to process data collected as part of the Elwha dam removal baseline studies into the future, and will continue to provide input into the Nearshore Consortium's predictions for the dam removal process. We are pursuing re-obtaining funding for the dam-removal period from NSF.