Evaluating sediment transport and gravel storage in the Lower Chetco River, Oregon

Prepared by:

Rose Wallick (rosewall@usgs.gov)

Jim E. O'Connor (*oconnor@usgs.gov*)

U.S. Geological Survey
Oregon Water Science Center
2130 SW 5th Avenue
Portland, Oregon, 97201

e-mail: info-or@usgs.gov

Prepared for:

U.S. Army Corps of Engineers
Portland District
Regulatory Branch (CENWP-OD-G)
P.O. Box 2946
Portland, OR 97208-2946

June 30, 2008

SUMMARY

Problem/Background

The Chetco River in southern Oregon drains a 352 mi^2 coastal watershed and provides spawning and rearing habitat for two species of Pacific Salmon: coho salmon (Oncorhyncus kisutch) and Chinook salmon (O. tshawytscha). Although the basin has historically supported a wide range of landuses, including logging and in-stream gravel mining, recent concerns regarding gravel extraction on fish habitat have highlighted the need for information regarding the impact of gravel extraction on channel processes along the Chetco River and other rivers throughout Oregon.

An interagency team, chaired by the U.S. Army Corps of Engineers, Portland District and the Oregon Department of State Lands, has been convened to address in-stream gravel mining issues across the state of Oregon. Evaluating sediment transport within the Chetco River system has been determined to be a critical piece of the overall study. The Technical Team recommended the use of two approaches, specifically the morphological approach and the Sediment Impact Analysis Model (SIAM). These methods were chosen because they have similarities and can be run concurrently, which is important given the short timeframe to complete the studies. This proposal presents a multi-pronged strategy for evaluating sediment transport through the development of sediment budgets and through the application of bedload transport equations. In the course of this work, the USGS will develop geospatial database of historic and current channel and floodplain conditions enabling evaluation of long-term trends pertaining to aquatic habitat conditions. The approach proposed herein is applicable not only to the Chetco River, but is also potentially transferable to other river basins in Oregon where there are similar issues of sediment storage and landuse planning.

Objectives

1. Develop a sediment budget for lower 11 miles of the Chetco River which will entail identifying and characterizing sources and sinks of bed-material sediment throughout the study area and determining bed-material fluxes entering and exiting the lower Chetco River via natural and anthropogenic processes. The sediment budget will be determined through two independent methods; (1) a morphology-based approach allowing estimation of decadal scale sediment fluxes and (2) a modeling based approach (the ACOE SIAM model) which will allow a reach-by-reach prediction of transport conditions for specified flow conditons.

2. Independently evaluate the sediment budgets determined in Objective 1 by applying bedload transport equations to evaluate sediment flux on the basis of flow records, channel hydraulics and sediment characteristics. The bedload equations will be applied at the USGS gage located at River Mile 10.7 on the Chetco River.

Approach

<u>Objective 1</u> will be achieved by determining sediment budgets using two separate methodologies, a morphology-based approach and the Sediment Impact Analysis Model (SIAM). In addition to producing a sediment budget (Objective 1), the morphology-based approach will also involve a series of sub-tasks, several of which will yield products that will also be useful for long-term monitoring as well as quantifying historical channel change and linking historical channel change with a variety of natural and anthropogenic controls on channel change.

Objective 2 will be achieved by applying bedload transport equations to verify the sediment budgets determined using the morphology-based approach and SIAM.

Relevance and Benefits

According to *Strategic Directions for the Water Resources Division, 1998-2008*, the WRD will make an effort to "design study products that will be more useful and relevant to solving problems that are faced by water managers and other decisionmakers." The results from this study will be directly relevant to the U.S. Army Corps of Engineers, the Oregon Department of State Lands, USFWS, NOAA Fisheries, ODFW and other agencies that will be reviewing and permitting in-stream gravel mining issues on the Chetco River.

FULL PROPOSAL

Evaluating sediment transport and gravel storage in the Lower Chetco River, Oregon

Problem/Background

The Chetco River is like many western U.S. rivers where issues of fish habitat, water quality, climate change and changing land use values have set in motion new efforts to manage rivers and floodplains for multiple resource values.

The Chetco River, drains a 342 mi^2 coastal watershed in southern Oregon and historically provided important spawning and rearing habitat for two species of Pacific Salmon: coho salmon (Oncorhyncus kisutch) and Chinook salmon (O. tshawytscha). Southern Oregon/Northern California (SONC) coho salmon are listed as threatened under the Endangered Species Act and SONC critical habitat includes one of the gravel mining sites presently operating on the lower Chetco River. Additionally, stream temperature in the lower Chetco River does not meet Oregon water quality standards. Like other southern Oregon coastal streams, the lower 20 miles of the Chetco River is an alluvial reach characterized by extensive gravel bars (Figure 1). Some of these bars, particularly in the lower 11 miles of the river, have been utilized for in-stream gravel extraction since the early 20th century. Until recently, gravel extraction on the Chetco River and other southern Oregon coastal streams was primarily regulated by the Oregon Department of State Lands and Curry County, but in 2006 the U.S. Army Corps of Engineers, Portland District determined that gravel mining may also fall under jurisdiction of the Corps, because mining activities may result in the discharge of dredged material (hence requiring a Corps issued 404 permit).

These factors have motivated an interagency team, chaired by the U.S. Army Corps of Engineers, Portland District and the Oregon Department of State Lands to address in-stream gravel mining across the State of Oregon. This larger team is further divided into an Executive Team, made up of management level representatives, and a Technical Team, made up of technical level staff. The first river system to be addressed is the Chetco River near Brookings, Curry County, Oregon. A determination must be made by June 2009 to develop the permitting conditions necessary for continued gravel extraction. Evaluating sediment transport within the Chetco River system has been determined to be a critical piece of the overall study and will provide a scientific basis from which the permitting agencies can evaluate gravel mining activities.

Objectives

The overall goal of the project is to provide an understanding of sediment transport in the Chetco River, with a primary goal of developing a sediment budget for the lower Chetco River. Because the bed substrate of the lower Chetco River is dominated by gravel and cobble sized clasts, and because this bed material composes the predominant size range utilized by the gravel mining companies, this project will focus on understanding the bedload component of the sediment budget. This project will also provide information on how the Chetco River channel, floodplain and related water features interact, and how changes in these features relate to landuse practices such as channel stabilization and gravel extraction. This broad understanding will be accomplished through the following objectives:

1. Develop a sediment budget for lower 11 miles of the Chetco River. This will entail identifying and characterizing sources and sinks of sediment throughout the study area and determining sediment flux entering and exiting the lower Chetco River via natural and anthropogenic processes. The sediment budget will be determined through two different methods (a morphholology-based approach and the Sediment Impact Assessment Method) which will provide a more robust determination of sediment storage trends in the lower Chetco River.

2. Independently verify the sediment budgets determined in Objective 1 by applying empirical bedload transport equations to evaluate sediment flux on the basis of flow records, channel hydraulics and sediment characteristics. The bedload equations will be applied for flow conditions measured at the USGS gage located at River Mile 10.7 on the Chetco River.

Approach

This project will consist of a series related but specific tasks aimed at the understanding the sediment budget of the Chetco River and the relationships between sediment storage, channel morphology floodplain processes and landuse practices. In addition, several optional tasks are presented which will provide critical data to support the project objectives.

Objectives 1 will be achieved by determining sediment budgets using two separate methodologies as outlined in Tasks 1 and 2. In addition to producing a sediment budget (Objective 1), Task 1 will also involve a series of sub-tasks, which will support a more comprehensive understanding of channel and floodplain processes along the lower Chetco River.

Task 1: Develop sediment budget for the Lower Chetco River using a morphology-based approach

In this task, sediment budget will be developed for the lower 11 miles of the Chetco River using a morphology-based approach. This approach will not only provide a means of quantifying sediment fluxes throughout the lower Chetco River, but it will also provide a geomorphic framework for understanding temporal and spatial changes in channel morphology over the past 70 years and will thus offer insight into the role of gravel movement and removal on channel evolution and floodplain processes.

The morphology-based sediment budgets are estimated with repeat (historic) topographic surveys and areal photo analyses documenting volumetric changes of bed and bar sediment (e.g., Ham and Church, 2000). As such, this task will rely heavily upon historic datasets and will involve developing sediment budgets from historical data for several different time periods in order to track temporal changes in sediment storage. In order to calculate volumetric fluxes of sediment, we will develop a geospatial database composed of GIS maps of the channel and related features such as gravel bars, secondary channels and floodplain for several different time periods. Comparing GIS maps between two time periods will allow us to compute the area eroded or deposited within a particular reach. These planview (e.g., 2D) representations of channel and active floodplain will be paired with historic survey data and recent field measurements in order to estimate the depth of the mobile sediment layer for each time period, and hence provide a means of computing the volumetric sediment flux for each time period (Martin and Church, 1995; McLean and Church, 1999; Ham and Church, 2000; Gaueman et al., 2003).

We will aim to develop sediment budgets for a minimum of four key points in time utilizing historical and modern channel maps (see Table 1 for information on map sources).

- 1930's-1940's: The Army Corps of Engineers aerial photographs from 1939 represents the earliest known aerial photographs for the Chetco River. There was also bathymetric mapping conducted for the lower Chetco River as part of the 1939 mapping effort which will be used to compare long-term changes in sediment storage at the mouth of the Chetco River. Aerial photographs from 1940 flown by the BLM and South Coast Lumber Company will be reviewed and potentially utilized in order to obtain a sediment budget for this period. Although gravel extraction did occur prior to the 1930's, extraction practices during this period are not well documented and it is presumed that extraction during this period was less than occurred in subsequent decades.
- 1960's-1970's: This period captures the 1964 flood, which was the largest flood of record, triggering channel changes on the Chetco River and other rivers throughout the Pacific Northwest. The 1960's-1970's also represents a period of increased gravel extraction which was used to supply the construction of Highway 101. Aerial photographs are available from the BLM and South Coast Lumber Company for this period, from which we will select a pair of photos that bracket the 1964 flood while also providing representative coverage and resolution to support our mapping endeavors.
- Present (1990's-2000's): This most recent period provides multiple high-resolution aerial photo datasets and well documented gravel extraction practices. By developing several sediment budgets for shorter time intervals within this period, we aim to characterize the variability in sediment flux occurring on the modern Chetco River under the influence of modern landuse and recent climatic patterns. We plan to use the high resolution, digital orthophotographs from 1995, 2000, 2005 and 2008 (see Table 1 for data sources) which will provide three sets of data from which to compute changes in sediment storage along the lower Chetco River. The aerial photo mapping will be paired with survey data provided by the gravel operators, field measurements conducted during the summer of 2008 and LiDAR data (to be flown in 2008) to estimate the volumetric sediment flux and three-dimensional changes in channel geometry for each of the three time-periods 1995-2000, 2000-2005 and 2005-2008.

Development of sediment budgets using a morphology-based approach involves a number of sub-tasks, several of which will yield useful products helpful for understanding historical channel change relative to a variety of landuse practices that may have impacted the channel (e.g., gravel extraction, construction of revetments etc). Task 1 Sub-Tasks include:

Task 1.a: Development of historical channel maps

In order to create sediment budgets for several different time periods, we will create digital channel maps from a minimum of six different time periods spanning the interval 1939-2008. The set of six channel maps will be used to calculate sediment budgets from four different time intervals. We will aim to create a set of four digital maps from the period (1990-2008) in order to develop three sediment budgets representing recent landuse patterns and hydrology. We will also aim to create two additional channel maps from historical aerial photos for use in developing a fourth sediment budget from the early-mid 20th century. Although we will aim to create six digital channel maps, the exact number of channel maps created, and sediment budgets developed using the morphological approach, will be determined once all datasets have been reviewed for data quality and coverage.

The digital channel maps will be created by first scanning the historical aerial photos into a digital format (e.g., TIFF format), and then georectifying the images using standard techniques (e.g., ERDAS Imagine ® and ESRI ArcMap®). Once the images are georectified, we will digitize key fluvial features for the entire study area for each time period. Digitizing units will be explicitly defined and the digitizing line work will be proof-read by a second experienced team member. For this project, we will digitize the following kinds of units:

- Active channel boundary (left and right banks): This includes the wetted (low flow) channel plus dry but vegetated bars and other surfaces. It represents approximately the bankfull channel (Rapp and Abbe, 2003).
- Channel bars and islands: this includes all bars and islands, vegetated and bare that lay within the active channel.
- Other water features on the floodplain: this includes springs, ponds and secondary channels.
- In-stream structures: this includes revetments, bridges and other structures located within, or adjacent to, the active channel boundary.
- Land-use practices: Where we can reasonably identify gravel extraction and other in-stream landuse practices from the aerial photos, we will include such features in our digitization.

Task 1.b: Determine planimetric changes in channel and bar geometry over time

In this task, we will calculate planimetric (e.g., 2D) changes in channel morphology by overlaying the historical channel maps created in Task 1.a (e.g., O'Connor and others, 2003b; Rapp and Abbe, 2003, Wallick and others, 2007). For each time-period, we will calculate rates of bank erosion and deposition, as well as aerial changes in bar and island morphology. Our analysis will be completed using standard methodologies in ESRI ARCMap®.

Although quantification of planimetric changes in channel morphology is a key component to determining the sediment budget using the morphology-based approach, these analyses also provide a basis for quantitative analysis of channel migration and their spatial and temporal variation (e.g., O'Connor and others, 2003b). While a detailed analysis of channel migration is beyond the scope of this project, the channel maps and the quantification of planimetric change will allow us to identify key channel and floodplain formation processes and may also allow us to make generalized statements regarding historical changes to these processes. More importantly, the channel maps provide a platform for future studies that seek to establish linkages between spatial and temporal patterns of channel change and controlling factors such as flood discharge, landuse practices and valley geomorphology.

Task 1.c: Determine depth of the mobile bed layer

While planimetric changes in channel features can be measured from aerial photographs, the depth of sediment stored in these eroded (or deposited) features, must be measured in the field or determined from historical survey data. In this task, we will determine the reach-average depth of the mobile bed layer through a combination of field measurements, analysis of historical surveys and by reviewing previous reports documenting vertical changes in the bed profile of the lower Chetco River.

During the summer of 2008, we plan to measure the height of channel banks, gravel bars and islands in order to determine the difference in elevation between these surfaces and the bottom of the channel thalweg. By measuring multiple surfaces along the entire study area, we hope to characterize the spatial variability in bank and bar height in order to determine reach-average values for each of the key types of features present. Although the precise methodology for determining bank and bar heights will be determined during an initial reconnaissance visit and will depend upon flow conditions, site access and other variables, we anticipate that the measurements will be made by surveying cross-sections across key channel/bar features and the adjacent channel. The LiDAR survey (flown spring of 2008, expected to be available by fall 2008) will complement our field reconnaissance by providing a mechanism for rapidly and remotely measuring bank and bar heights above the water surface. Such measurements can be combined with field measurements characterizing the bank/bar height below the water surface, to provide a more comprehensive dataset of bank and bar heights.

Finally, we will augment our bank and bar height dataset by reviewing gage data and channel measurements as collected by the USGS for the stream flow gage at River Mile 10.7. Beginning in 1969, there have been repeat cross-section surveys at this location, which will provide an indication of the magnitude of vertical bed changes at the upstream end of our study reach.

Task 1.d: Describe sediment characteristics

As part of our summer 2008 field campaign, we will measure particle size by conducting pebble counts and will also describe other characteristics such as lithology, rounding and other characteristics that are relevant to the development of the sediment budgets. In particular, we will conduct particle size analysis for both armor and sub-armor layers on gravel bars and, where feasible, along the channel bed. We will develop a sampling scheme that will allow us to track longitudinal changes in grainsize, to determine the degree of downstream fining that occurs along the Chetco River. Although a formal analysis of sedimentologic characterics (e.g., particle density, ablation rates etc) is beyond the scope of this project, the reconnaissance level characterization proposed herein will provide data required for the sediment budgets and will also provide bed substrate data that will be useful to other disciplines examining habitat and biological processes along the lower Chetco River.

Task 1.e: Determine sediment budget for lower Chetco River

Here, we will quantify changes in sediment storage, identify sources and sinks of sediment and calculate the sediment budget for the lower Chetco River. We anticipate developing sediment budgets for a minimum of four different time periods, including three sediment budgets spanning the relatively short time intervals from the period 1990-2008 for which there are high resolution, digital orthophotos available (Table 1). We will also aim to develop at least one sediment budget from a historical time period utilizing historical aerial photographs and survey data. However, the actual number time periods we will evaluate will depend upon data quality and coverage. Our analysis will draw upon the systematic measurements of channel change completed in Tasks 1.a-1.c to compute reach-average trends in sediment flux over time (e.g., McLean and Church, 1999; Ham and Church, 2000). We will calculate volumetric changes in bed-material storage as the product of planimetric change (as computed in Task 1.b) and the average depth of the mobile bed layer (as determined in Task 1.c).

In determining the sediment budget, we aim to examine a variety of natural and anthropogenic influences that may have impacted sediment storage in the lower Chetco River over the past 70 years. In particular, we will rely upon the aerial photos, survey data and previous reports to identify both discrete sources/sinks of sediment (e.g., tributary influences, instream gravel mining, dredging in the Chetco River Estuary), as well as diffuse sources/sinks of sediment (e.g., factors that influence longer reaches such as channel erosion). We also aim to determine the flux of sediment entering and exiting the lower Chetco River (e.g., net influx of sediment entering the lower Chetco River from the upper watershed, net efflux of sediment from lower reach into the estuary).

Task 2: Development of sediment budget using the Sediment Impact Assessment Model (SIAM)

In this task, we will develop a sediment budget for the lower Chetco River using the SIAM method. SIAM is a rapid assessment screening tool used to evaluate the impacts of sediment management activities and determine trends in sedimentation. The tool has been incorporated in the latest version of the U.S. Army Corps of Engineers HEC-RAS model (vsn. 4.0) as a design module. The SIAM model is similar to a simplified 1D hydraulic model whereby the channel is represented by a series of geomorphically similar reaches (e.g., the channel centerline is divided into several reaches on the basis of planform and physiography). We will then define local sediment sources/sinks (e.g., tributary inputs, landuse practices) as well as the upstream and downstream boundary conditions. The hydraulics and bed sediment characteristics of each reach will be characterized using a representative data determined from field surveys and hydraulic analyses. Although much of the information needed for the SIAM model (e.g., channel geometry, sediment inputs from tributaries) will be determined during Task 1, we will verify each of the SIAM inputs during Task 2.

We will develop three sediment budgets using the SIAM model to represent ‘wet’ years, ‘dry’ years and ‘average’ conditions. These scenarios will be developed by assembling flow and sediment data for a representative time period (typically several decades) and then defining the thresholds for ‘wet’ and ‘dry’ years and categorizing the data accordingly. We will then annualizing the data across the entire time period, (to create the boundary conditions for the ‘average year’). Data from each of the ‘wet’ and ‘dry’’ subsets will also be annualized to create boundary conditions representing those conditions. The product for Task 2 will be three sediment budgets for each of the SIAM reaches defined in the lower Chetco River.

An additional outcome of the SIAM model development will be hydraulic characteristics for various reaches of the lower Chetco, which can be formally presented in the Final Report and made publically available. For example, the SIAM model will require channel geometry which we will extract from the 2008 LiDAR data and from surveys conducted in the summer of 2008. Such data can be provided to the U.S. Army Corps of Engineers, so that biologists may develop width-to-depth ratios or other metrics that are useful for evaluation of habitat characteristics

<u>Objective 2</u> will be achieved by applying bedload transport equations to verify the sediment budgets determined in Tasks 1 and 2. The methodology for applying the equations is described in Task 3.

<u>Task 3 Independent bedload transport equations to verify sediment budgets</u>

In this task, we will apply empirical to semi-empirical bedload transport formulae to estimate bedload transport. Bedload transport equations are widely applied due to their relative ease of use in comparison with other methodologies (e.g., direct measurement) for estimating sediment transport (e.g., Gomez and Church, 1989; Wilcock, 2001) The formulae are typically based upon the assumption that upstream supply is unlimited, hence the bedload transport is limited solely by flow conditions. However, several recent applications have been developed which partly account for the supply limitation by considering the bed-material particles size distributions. We will draw upon recent applications of this approach including work by Ned Andrews (USGS) for several coastal California streams (Andrews, 2007; Andrews, 2008 in prep) and work by J. Barry for several Idaho gravel-bed streams (Barry et al., 2004). Because this approach requires streamflow information, we will apply the bedload transport equations at the site of the USGS gage at mile 10.7 of the Chetco River. This approach requires field measurements to characterize particle size distribution and local flow conditions which will be conducted during the summer of 2008, and will also draw upon the GIS analyses and channel metrics completed in Task 1.

We will evaluate several different bedload transport formulas and will select a minimum of two equations for use on the lower Chetco River. Our selection will be made by evaluating several equations and selecting equations that are suitable for the Chetco River (in terms of its hydraulic, sedimentologic and geomorphic characteristics) and have data requirements that can be satisfied through existing datasets, proposed surveys and the fieldwork proposed for the summer of 2008.

By applying the bedload transport equations, we aim to independently verify the sediment fluxes determined through the morphology-based approach and the SIAM model (e.g., Martin and Ham, 2005). Bedload transport equations typically provide an indication of sediment flux for a particular discharge, whereas sediment budgets estimated from the morphology-based approach and SIAM provide average annual sediment fluxes.

We will use instantaneous measurements of discharge as collected at the USGS gaging station at 15-minute intervals in order to estimate sediment fluxes over the course of actual hydrographs. Because the Chetco River typically experiences very rapid rise and fall of peak flows, the 15-minute data will allow for greater resolution of the hydrograph than might be gained by using daily average values which would tend to reduce the peak discharges that are likely responsible for transporting a majority of the bed material. The 15-minute data is available from 1988 to present, which corresponds with our goal of creating three sediment budgets using the morphology-based approach for the period 1990-2008. By using the bedload formulas to calculate sediment flux over the same periods for which we are developing the sediment budgets, we aim to develop directly comparable estimates of volumetric sediment flux for the lower Chetco River.

Objectives 1 and 2 will be supported through the following tasks, which will provide important data to substantiate our findings from Tasks 1-3.

<u>Task 4 Reconnaissance level description of sediment sources in Chetco River Basin</u>

In this task, we will conduct a reconnaissance level examination of sediment sources in the upper Chetco River Basin. In particular, we will examine aerial photographs and conduct a site visit to determine the primary sources of sediment to the Chetco River and will identify key storage sites (such as fans or debris flows) that may be releasing sediment to the lower Chetco. We will also conduct a literature review to assess the primary processes and rates of sediment generation and delivery in other coastal basins in Oregon and Northern California. The goal of this task is to provide a brief, qualitative assessment of sediment sources in the Chetco Basin and provide the rates of sediment yield that have been published for other coastal basins.

Task 5 Conduct Bedload Measurements to Determine Initiation of Bedload Transport

In this Task, we will take direct measurements of bedload transport from the bridge located at River Mile 10.7 on the lower Chetco River near the USGS streamflow gage. The goal of the bedload sampling is to determine the discharge at which bedload transport is initiated, as this information will help us refine our estimates of sediment flux as calculated from the bedload transport equations (e.g., Task 3), as well the sediment budgets determined in Tasks 1 and 2. Furthermore, when combined with the other analyses and data collection proposed for this project, the bedload measurements provide critical information that helps us to better characterize and quantify sediment transport on the lower Chetco River.

For example, we may determine that a discharge of 5,000 cfs is necessary to get substantial bedload transport. By comparing this critical discharge against flow records, we can gain a better understanding a) the total number of days that bedload transport likely occurred during a particular year; and b) the magnitude of sediment transport and the degree of re-working of the channel bed that may have occurred in a particular year. For example, if the threshold discharge for initiating bedload transport is determined to be 5,000 cfs, and if a particular time-period from our aerial photo analysis has multiple flow events exceeding 20,000 cfs, we will be able to combine our sediment budgets for that period (as determined through the morphology-based approach) with calculated rates of sediment flux (as determined from the bedload transport equations) to make inferences regarding the degree of re-working and re-mobilization of channel and bar deposits that occurred during that time-period. Such an analysis will allow us to ultimately refine and enhance our understanding of sediment fluxes throughout the lower Chetco River and will substantiate the sediment budgets determined through both the morphological approach and SIAM.

To determine the initiation of bedload transport in a timely and economic manner, we propose making two site visits during the winter of 2008-2009 for the purpose of making a minimum of one, and possibly two measurements of bedload transport per visit. The site visits will be strategically timed on the basis of flow and weather conditions so as to capture the initiation of motion. However, measuring the initiation of bedload transport can be extremely difficult, particularly on a flashy system such as the Chetco River which can experience rapid rise and fall of the hydrograph, so there is some chance that we may not obtain meaningful measurements with this effort. To measure bedload transport, USGS staff will draw upon both standard techniques (e.g., Edwards and Glysson, 1999) that can help define when the bed is mobile. The USGS field crews in the Medford and Portland offices have ample experience collecting and analyzing bedload transport data, and have recently been directly involved with extensive bedload sampling efforts on the both the Sandy and Deschutes rivers.

Objectives 1 and 2 will also be supported through the following optional tasks, which while not required, will provide information to better understand the channel processes and habitat characteristics along the lower Chetco River.

Optional Task 6 Mapping of temporal trends in riparian vegetation from historical aerial photos

In this Task, we will develop GIS layers of streamside vegetation in the historical channel migration zone. From the temporal sequence of aerial photos used to map and channel and gravel bar conditons, we will map major vegetation classes (such as non-woody vegetation, shrubs, open trees, closed canopy trees) for each of the six different time periods mapped in Task 1. The vegetation mapping will be done by 1) determining the appropriate spatial resolution for the mapping effort 2) determining the categories of vegetation to be mapped 3) field verification vegetation types to ensure good correlation between air photos and ground-based surveys and, 4) digitizing riparian vegetation from air photos. We will consult with U.S. Army Corps of Engineers and USGS biologists in determining the final mapped vegetation classes.

The vegetation maps will be developed in coordination with our geomorphic mapping of the channel and floodplain features, with an overall goal of providing a comprehensive geospatial database that can be used to relate fluvial and biological processes. Each of the vegetation GIS layers will undergo an internal QAQC process and will be publically available at the conclusion of the project. The main product for this task will be GIS datasets depicting major types of vegetation for different time periods for the lower 11 miles of the Chetco River. We will provide a description of the vegetation mapping methods and a brief overview of the findings from the mapping efforts as part of the Final Report. We will also provide basic metrics describing the spatial and temporal trends in vegetation over time. However, a formal quantitative analysis of vegetation changes and discussion of the underlying biological/geomorphic processes is beyond the scope of this project.

Optional Task 7 Mapping of bank materials through field surveys and aerial photo analysis

In this task, we will develop GIS layers depicting the distribution of resistant bank materials along the lower 11 miles of the Chetco River. We will develop these datasets by utilizing field surveys and existing datasets (e.g., soils and geology maps) to determine the primary types of bank materials bordering the active channel. These bank materials will be defined during the field survey, and will likely consist of four major categories: erodible alluvium (e.g., loose sands and gravels), resistant alluvium (e.g., cohesive clays or indurated gravels), highly resistant bedrock and highly resistant anthropogenic materials (e.g., revetments).

In addition to creating GIS files showing the distribution of resistant bank materials, we will use the bank lines of the active channel (as mapped in Task 1)and separate these bank lines into discrete sections according to the bank material bordering the channel in that location. We will also separate the channel centerline into bend-sized reaches and classify each section according to the bank material that each bend is actively eroding into. The spatial unit for our discretization scheme will probably be on the order of one bend, because the goal of this task is characterize the dominant bank materials that are determining channel change.

From these layers we will calculate the percentage of the right and left bank that are bordered by different types of bank materials (e.g., highly erosive alluvium, resistant alluvium, bedrock, highly resistant man-made feature). We will also calculate the length of channel (in terms of centerline distance) that is bordered by resistant bank materials. We will provide a description of the mapping methods in the Final Report, along with a brief overview of the findings. In addition, all GIS layers and related datasets will become publically available at the conclusion of the project.

Optional Task 8 Bathymetric survey of lower Chetco River

In this task, USGS staff will prepare a bathymetric map of the lower 3.5 miles of the Chetco River, from the approximate head of tide to the mouth of the Chetco. The bathymetric survey is performed by mounting an Acoustic Doppler current profiler (ADCP) to a moving boat and making multiple closely-spaced transects across the survey area. The ADCP can simultaneously measure water velocity and depth, providing multiple datasets that will be of use in evaluating fluvial and biological processes along the lower Chetco River. Depending on river levels at the time of the survey, the upper 1.5 miles of the survey area may be too shallow for an ADCP boat-based survey and may require an alternative survey methodology (e.g., cross-sections using total station). If an alternative approach is necessary for this 1.5 miles, USGS staff will communicate the survey options with the U.S. Army Corps of Engineers to ensure that the survey methodology employed will meet the project needs.

The survey data will be processed by USGS staff to prepare a bathymetric map that utilizes the same horizontal and vertical datum as the 2008 LiDAR survey, and has a spatial extent that blends seamlessly with the 2008 LiDAR coverage. This will allow us to create a single map of the lower Chetco that combines the terrestrial survey data (from LiDAR) with the channel bottom (from bathymetric survey). This data will become publically available in multiple formats (e.g., paper maps, DEM raster format and xyz point data). USGS staff will use the bathymetric data to compute volume changes in the lower Chetco River by comparing the recent survey data against the 1939 bathymetric survey completed by the Corps of Engineers. The bathymetric survey will also useful for a variety of biological studies. For example, the bathymetry can be combined with knowledge of tide elevations and turbidity to identify areas where aquatic vegetation is likely to be present or to determine habitat conditions in the estuary.

Laboratory Quality Assurance and Error Estimation

We aim to bolster our analyses, and ultimately minimize the uncertainty of our results, by applying multi-pronged strategy whereby the results from each individual analysis will serve to verify the results from the other components of the study. In this project, the primary sources of uncertainty will arise from our usage of historical datasets that have different levels of resolution. For example, we will utilize aerial photographs from several different time periods which will each have varying degrees of resolution and may also have shadows obscuring portions of the channel. Potential sources of error will primarily arise from our data processing procedures which include georectification of aerial photographs and digitization of channel features. To address such issues, we will employ standardized methodologies so that a repeatable procedure is employed at each step of our analyses, and the digitization and georectification is verified by a reviewer. To the extent feasible, we will document potential sources of uncertainty and error and will seek to quantify their impacts of on our results. At the conclusion of our analyses, we will present a formal error analysis as part of the final report.

Study Relevance and Benefits

According to *Strategic Directions for the Water Resources Division, 1998-2008*, the WRD will make an effort to “design study products that will be more useful and relevant to solving problems that are faced by water managers and other decisionmakers." The results from this study will be directly relevant to the U.S. Army Corps of Engineers, the Oregon Department of State Lands, USFWS, NOAA Fisheries, ODFW and other agencies that will be reviewing in-stream gravel mining issues on the Chetco River.

Currently, there is uncertainty regarding the role of gravel extraction and other landuses on altering channel morphology and floodplain processes on the Chetco River. However, in order to quantify impacts to the channel and its sediment budget from specific anthropogenic influences, we must first have a basic understanding of the channel and bar morphology along the Chetco River, as well as quantitative and qualitative characterization of the processes and rates of channel evolution. Inherent to this basic understanding of channel processes is knowledge of how variations in sediment supply and sediment transport capacity influences channel processes. Once we have developed baseline datasets (e.g., historical channel maps, surveys, flow records) from which to characterize historical channel processes along the Chetco River, we can begin identifying natural and anthropogenic controls on channel change, and systematically assessing the role of these impacts in influencing sediment storage throughout the lower Chetco River. Moreover, findings from the Chetco River will likely have relevance to nearby coastal watersheds and will provide a platform for developing specialized research strategies to tackle similar issues of sediment storage and landuse planning on adjacent basins.

Finally, this study will result in the creation of numerous datasets which can be utilized for a wide range of future studies. The digital historical maps which form a basis for the morphology-based approach will be useful to a variety of future studies such as those evaluating historical changes in riparian habitat and water quality. Similarly, the SIAM model developed for this study can be used a planning tool to not only evaluate alternative gravel extraction scenarios, but it can also be used to determine the potential impacts to the sediment budget resulting from changes to the discharge regime, channel geometry or sediment supply.

Reports and Products

Study results will be published in a USGS Scientific Investigation Report (SIR) which will be digitally published in Fiscal Year 2009. The SIR for the Chetco River will include historical channel maps (based on GIS layers developed in this study) of historical channel position, geomorphic map units and aerial photograph coverages. The report will include all basic data, in tables or appendices of quantitative channel measurements (including both measurements which document adjustments to both horizontal and vertical channel position). The report will include analyses of these data, including temporal and spatial trends in channel and floodplain characteristics and controlling variables such as gravel extraction volumes and flood volumes peak discharge. The report will describe the sediment budget as determined from the morphology-based approach and will present the spatial and temporal trends within the sediment budgets developed for different time-periods. The SIAM model will also be discussed, along with a description of the model development and model results. In describing each of these approaches, we will provide detailed explanations of the assumptions applied in each methodology and descriptions of all supporting datasets used for each model. Finally, the bedload transport equations will be described, along with descriptions of the underlying data and results gained from application of the equations. Within the report, these results from each of our analyses will be used to develop hypotheses describing the interaction of sediment load, channel processes and floodplain evolution along the lower Chetco River. By digitally publishing the report, the full report, including all plates and tables, will be publically available from the USGS website.

A copy of the Draft SIR will be submitted to the U.S. Army Corps of Engineers at the same time that the report goes out for colleague review. Once the SIR is published, supporting datasets including the geospatial database containing GIS layers developed during the project, will also be publically available and will be distributed to U.S. Army Corps of Engineers

Presentation of Results

Monthly project updates will be presented to the Technical Team for the duration of the project (e.g., August 2008-April, 2009). During these monthly updates, USGS staff will provide a brief summary of activities and progress. The Final Results from the study will be presented at a meeting to the U.S. Army Corps of Engineers near the completion of the project. This final presentation will be scheduled well in advance of the meeting date (e.g., minimum of one month notice for planning purposes). The presentation will include key staff members from the USGS study team and will allow ample time for discussion of the study methods and results.

Photo Date	Source	Extent	Digital format	GeoRectified	Notes
1939	U.S. Army Corps of Engineers	unknown	unknown	unknown	
1940	BLM	unknown	unknown	unknown	
1955	BLM	unknown	unknown	unknown	
1976	BLM	unknown	unknown	unknown	
1986	BLM	unknown	unknown	unknown	
1992	BLM	unknown	unknown	unknown	
1997	BLM	unknown	unknown	unknown	
2002	BLM	unknown	unknown	unknown	
1940	South Coast Lumber Co.	unknown	unknown	unknown	
1962	South Coast Lumber Co.	unknown	unknown	unknown	
1972	South Coast Lumber Co.	unknown	unknown	unknown	
1976	South Coast Lumber Co.	unknown	unknown	unknown	
1981	South Coast Lumber Co.	unknown	unknown	unknown	
1985	South Coast Lumber Co.	unknown	unknown	unknown	
1990	South Coast Lumber Co.	unknown	unknown	unknown	
1994	South Coast Lumber Co.	unknown	unknown	unknown	
1998	South Coast Lumber Co.	unknown	unknown	unknown	
2000	South Coast Lumber Co.	unknown	unknown	unknown	
2002	South Coast Lumber Co.	unknown	unknown	unknown	
2004	South Coast Lumber Co.	unknown	unknown	unknown	
2006	South Coast Lumber Co.	unknown	unknown	unknown	
1995	USGS/USFS	full study area	yes	yes	Flown 8/5/1994 & 5/27/1997
2000	USGS/USFS	full study area	yes	yes	Flown July/August 2000
2005	NAIP	full study area	yes	yes	Flown July 15-20, 2005
2008	Watershed Sciences	full study area	yes	yes	Expected 8/2008

Table 1. Summary of aerial photos available for lower Chetco River. Data for COE, BLM and South Coast Lumber Company photos provided by Janine Castro, USFWS.

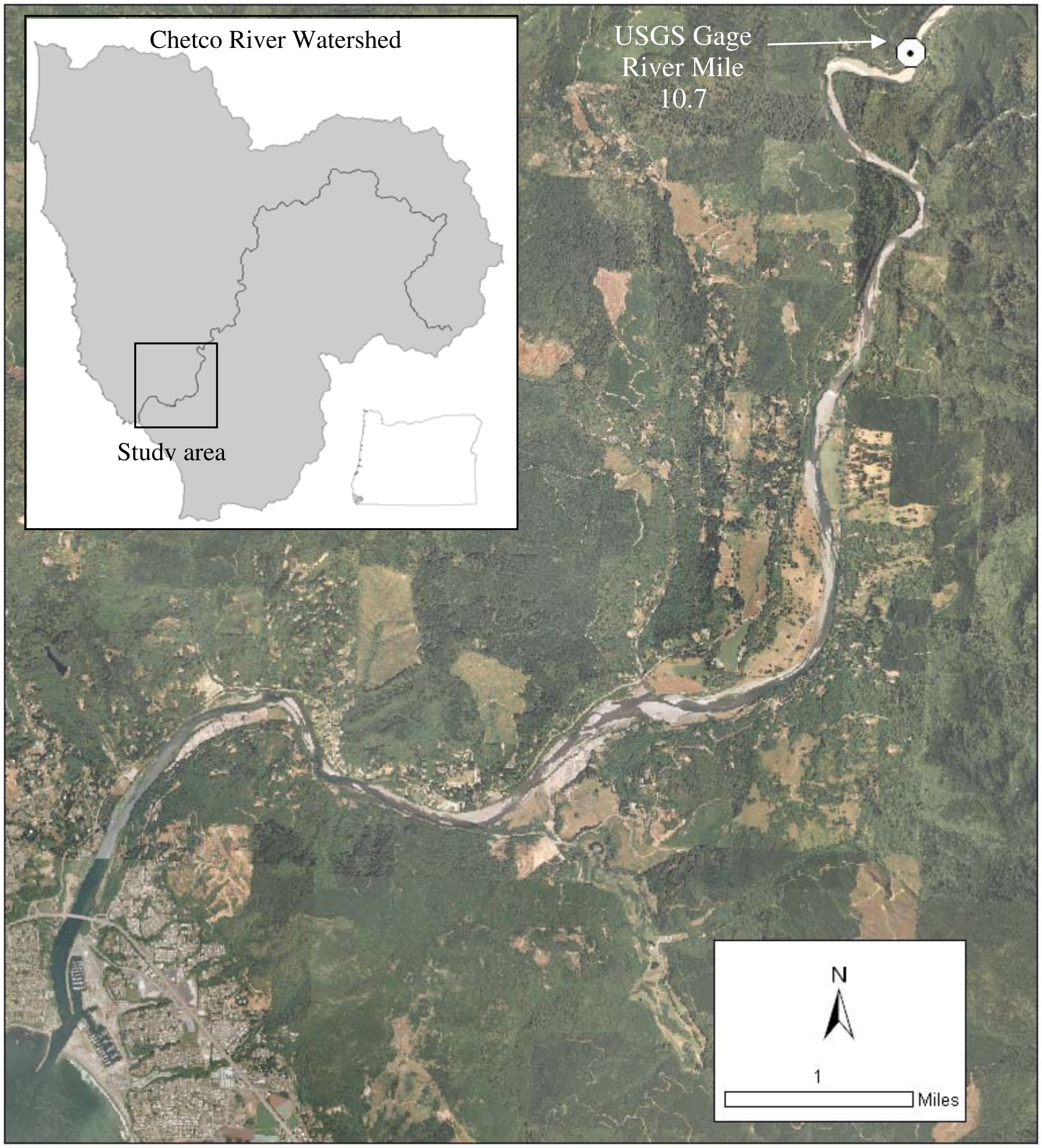

Figure 1. Chetco River study area in southern Oregon. Study area encompasses the lower, alluvial reaches of the Chetco River below the USGS gage located at River Mile 10.7. Aerial photography is from the 2005 NAIP digital orthophotos.

Expenses/Funding

The budget for this project assumes that project will be funded entirely by the U.S. Army Corps of Engineers. The budget assumes that the project will commence in the summer of 2008 (Fiscal Year 2008) and will continue through the spring of 2009 (Fiscal Year 2009).

EXPENSES FOR SEDIMENT TRANSPORT STUDIES	FY2008	FY2009
Sediment transport studies & development of sediment budgets (Tasks 1-4)		
Salaries, benefits and indirect costs	$45,144	$153,016
Supplies and equipment	1,700	500
Travel expenses	3,800	1,000
Publication expenses	0	10,000
Total cost for sediment transport studies	**$50,644**	**$164,516**
Expenses for measurement of bedload transport (Task 5)		
Salaries, benefits and indirect costs	$0	$19,400
Supplies, equipment & travel	-	3,140
Goods and services, other cost centers	-	3,600
Total cost for measurement of bedload transport	**$0**	**$26,140**
Total Project Cost for Sediment Studies & Measurements (Tasks 1-5)	**$50,644**	**$190,656**
Total two-year cost for Sediment Studies & Measurements (Tasks 1-5)	**$241,300**	

EXPENSES FOR OPTIONAL MAPPING TASKS	FY2008	FY2009
Mapping streamside vegetation from aerial photos (Task 6)		
Salaries, travel expenses, equipment, benefits and indirect costs	$6,030	$19,125
Mapping bank materials from field mapping & existing datasets (Task 7)		
Salaries, travel expenses, equipment, benefits and indirect costs	$5,280	$14,420
Total Optional Mapping Tasks (Tasks 6 & 7)	**$11,310**	**$33,545**
Total two-year cost for Optional Mapping Tasks (Tasks 6 & 7)	**$44,855**	

EXPENSES FOR BATHYMETRIC SURVEY OF ESTUARY	FY2008	FY2009
Bathymetric Survey of the lower 3.5 miles of Chetco River (Task 8)		
Salaries, benefits and indirect costs	$22,380	$10,000
Supplies, equipment & travel	3000	**-**
Goods and services, other cost centers	1000	**-**
Total cost for bathymetric survey (Task 8)	**$26,380**	**$10,000**
Total two-year cost for bathymetric survey (Task 8)	**$36,380**	

Personnel/Schedule

The schedule for this project assumes that the project will be initated in the late summer (e.g., July or August) of 2008, with field work, data collection and aerial photo processing occurring within Fiscal Year 2008. The remaining tasks, including data analysis and report preparation will be completed in Fiscal Year 2009. This schedule is based upon the assumption that key datasets (such as the Chetco River LiDAR) will be available to the project team by September 1, 2008. In order to meet the timelines requested by the U.S. Army Corps of Engineers, fieldwork must be completed during the low-water season (e.g., August-September, 2008), so that data analysis can begin by October of 2008. The personnel presented below represent the staff needed to develop the sediment budgets (e.g., Tasks 1-4). Additional staff from the USGS Central Point Field Office will conduct the bedload transport measurements during two site visits in the winter of 2008-2009. If the Optional Tasks are implemented, then additional staff from the USGS Portland Field Office and Oregon Water Science Center will be utilized to meet the project deadlines specified below.

PERSONNEL FOR SEDIMENT TRANSPORT STUDIES (OREGON WATER SCIENCE CENTER)	FY2008	FY2009
GS-15 Hydrologist	10 days	32 days
GS-11 Hydrologist	29 days	127 days
GS- 5 Hydrologist	25 days	45 days

WORKPLAN SCHEDULE	FY2008	FY2009
Sediment transport studies		
Data acquisition& field work; begin processing aerial photos	August-September	
Develop sediment budgets using morphology-based approach & SIAM; Apply equations for bedload transport		October-February
Conduct measurements of bedload transport		October-January
Prepare Scientific Investigation Report (SIR)		
Review literature, prepare background material, write up methods and approach, prepare base maps of study area.	August-September	October-January
Table data and prepare draft graphics		October-January
Interpret data and write up results and conclusions		December-January
Submit draft for colleague review		February
Submit final draft to USGS publishing center		April

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