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May 15, 2003

Mr. Michael Scuderi
U.S. Army Corps of Engineers
Seattle District Office
4735 East Marginal Way South
Seattle, WA 98134-2385

Re: Draft Scope of Work for the Phase II of the Geomorphology and Sediment Transport Study of Skagit River Flood Hazard Mitigation Project
Skagit County, Washington
Pentec #7683-03

Dear Mr. Scuderi:

As we developed the initial scope of work for the Geomorphology and Sediment Transport Study in February 2002, we proposed a scope of work including eight tasks that collectively would complete the analysis. After reviewing the draft scope of work, we decided to restructure the work plan by creating two phases in the analysis. The first phase includes the first four tasks focusing on characterizing existing conditions, evaluating historical change, and developing a conceptual model to describe the dominant geomorphic processes operating within the project area. The second phase builds on the first phase through the development of a sediment supply budget coupled with a sediment routing model to assess sediment movement (transport, deposition, and scour) within the project area.

The Phase I scope of work dated February 6, 2002, provided a detailed description of the first four tasks and brief descriptions of the last four tasks that compose Phase II of the study. We have completed the analysis and data collection for Phase I, and we submitted the Phase I Interim Report on December 20, 2002, presenting the findings of Phase I. We submitted a draft scope of work for Phase II on September 13, 2002. We received technical review comments on both the Phase I Interim Report and the draft Phase II scope of work from stakeholders and regulatory personnel during January and February 2003. The current Phase II scope of work has been revised in response to review comments and a series of discussions with you and other Corps staff.

Rather than reiterating all of the background information, I have included the Phase I scope of work as an attachment to this letter. Our proposed scope of work for Phase II as

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described below includes descriptions for Tasks 5 through 8 as referenced within the Phase I scope of work.

The work plan presented herein has been prepared to be consistent with the guidance provided by the following engineering manuals published by the U.S. Army Corps of Engineers:

- EM 1110-2-4000 Sedimentation Investigations of Rivers and Reservoirs, published December 15, 1989

- EM 1110-2-1418 Channel Stability Analysis for Flood Control Projects, published October 31, 1994

TASKS 1 THROUGH 4

Tasks 1 through 4 are described in detail within the Phase I scope of work dated February 6, 2002 (included as an attachment to this document).

TASK 5 – SEDIMENT SUPPLY AND TRANSPORT

Sediment movement through the river system continually modifies the form of the river. Lateral migration and plan form change are driven by the combined action of water flow, and sediment transport and deposition. The sediment budget and sediment transport analysis coupled with the results of the hydraulic modeling will provide a basis for quantitative assessment of the physical and morphological changes in the Skagit River. The critical questions addressed by this study are listed below:

- What is the total volume of sediment delivered by the river to the project area?

- How does sediment delivery vary with time (both short-term and long-term trends)?

- What is the nature of the sediment yield (i.e., size distribution, composition, etc.)?

- How is sediment routed through the project area (i.e., is the project area functioning as a depositional reach or a transport reach)?

- If the project reach is transitional from gravel-bed to sand-bed alluvial to deltaic, has the longitudinal position of the transitional zone shifted over time? Does this position continue to shift?

- How does the existing levee system affect channel evolutionary patterns and rates, including aggradation, scour, and meander migration?

- What is the estimated volume and distribution of stored sediment in the channel system within and immediately upstream of the project area?

- What is the timing of channel responses to changed sediment input?

- In what ways does each alternative modify sediment routing through the project area?

- What affect would the alternatives for levee setbacks have on channel migration, sediment deposition, and the possibility for habitat creation in and downstream of the proposed setback areas?

- How far would levees need to be set back to restore the natural geomorphic processes of meander migration and off-channel habitat formation?

- How do the proposed project alternatives affect channel evolutionary patterns and rates?

Task 5 will include two primary subtasks. Task 5.1 describes our proposed approach to developing a sediment budget to estimate sediment delivery to the project area. Task 5.2 describes our proposed approach to modeling sediment routing through the project area.

Task 5.1 – Sediment Budget

We will develop a sediment budget to approximate the volume of sediment delivered to the project area from upstream. This will provide context for the sediment transport modeling effort and provide a basis for evaluating long-term trends in channel aggradation.

To develop the sediment budget, we will review and compile existing information from previous studies of portions of the Skagit Basin. We will combine the available sediment budgets for sub-basins to estimate the sediment yield delivered to the project area.

Previous studies address the sediment budget for selected sub-basins in the Skagit Basin, but a synthesis of these local budgets has not yet been performed to assess the sediment yield. Typically, sediment yield can be determined by considering both the supply of sediment from the landscape and the capacity of the drainage network to transport the sediment. In

situations where sediment supply is less than the transport capacity, the sediment yield is determined by the rate at which sediment is supplied to the stream network. In situations where sediment supply exceeds the transport capacity of the drainage network, the sediment yield is determined by the transport capacity.

Initial estimates of sediment transport capacity indicate that the reach above Sedro-Woolley is either at relative equilibrium or is transport-limited. This means that there may be more sediment coming into the system than it is capable of carrying. Significant channel shifts within this reach during the last 50 years support this idea.

The following steps outline our approach to developing the sediment budget:

1. **Conduct aerial photograph analysis of middle reach of Skagit River**. We propose to conduct a detailed aerial photograph interpretation of a reach of the Skagit upstream of the project area (between about RM 26 and RM 32) to estimate channel migration rates and the degree of channel change during historic times. Our findings will determine whether or not the river is in an aggrading mode within this reach. We will use multiple sets of photographs as available. We assume aerial photographs covering the period from approximately 1950 to present will be available from the Corps of Engineers, the Forest Service, and the Washington Department of Natural Resources. This analysis will focus on identifying local sediment sources and storage areas within and adjacent to the river channel through this reach. Our intent is to provide quantitative estimates of sediment storage and channel migration rates within this reach of the river. We recommend including an optional task for additional fieldwork to validate the estimates made by aerial photo analysis if necessary.

2. **Synthesize previous sediment budget analyses.** Previous work (Paulson 1997) has established the sediment load from 10 sub-basins within the Skagit River Basin. Sediment load was classified by land use, landform, and rock type. We understand that the Skagit System Cooperative (SSC) has employed a consistent analysis method to extrapolate this analysis to other portions of the basin. We understand that SSC will make their work available to us in performing this scope of work. We will coordinate with Paulson and with SSC to synthesize their work and estimate total sediment yield. Because reservoirs trap nearly all sediment that would contribute to channel changes downstream, those portions of the basin behind reservoirs will be excluded from the analysis.

3. **Compare the estimated sediment yield to sediment transport data collected during Phase I of this study.** The sediment transport data collected as part of the first phase of

the current study provide a basis for estimating sediment yield by developing a sediment rating curve and integrating sediment load and discharge over time. This method of estimating sediment yield will be calibrated against the sediment source evaluation. Existing available data on water turbidity will be compared with sediment transport rates and turbidity measurements taken during Phase I. Available turbidity data will be used in the evaluation of sediment yield.

4. **Compare the estimated sediment yield to calculated sediment transport rates for selected locations in the middle Skagit River.** We will utilize measured particle size distribution data for the middle Skagit River along with surveyed channel dimensions and stage discharge relationships to compute the average annual gravel discharge. This calculation will provide a check against estimated sediment yield, and it will provide additional support to the evaluation of long-term trends in channel aggradation resulting from sediment delivery to the project area. We will also complete a specific gage analysis for the USGS gages on the Skagit using archival 9-207 forms to plot average cross section changes over time. The gages to be included in the analysis will be USGS gages No. 12199000, 12200500, and 12196150.

The sediment budget will be used to bound long-term sediment delivery rates and potential riverbed and floodplain aggradation rates. The sediment budget will not provide a direct means of calibrating the sediment transport model, but it will provide useful context. Model calibration will be accomplished primarily by using measured sediment transport data obtained during Phase I.

Task 5.2 – Sediment Transport Analysis and Modeling

We will model sediment transport within the project area by building on the hydraulic modeling currently being performed by the Corps. Hydraulics engineers at the Corps are currently performing a hydraulic analysis to support the development of the Skagit River Flood Hazard Mitigation Project. The analysis utilizes a UNET model configured to represent the channel and floodplain within the project area. The UNET model will later be converted by the Corps to a Flow 2-D model to upgrade the analysis from a one-dimensional (1-D) to a two-dimensional (2-D) representation of floodplain flow coupled with a 1-D representation of flow within the channel.

We will model bank erosion, riverbed scour, sediment transport, and deposition within the project area to quantify anticipated changes in channel morphology.

For the sediment transport modeling effort, we will configure and run a HEC-6 model basing the model input on the boundary conditions and output of the Corps UNET model. HEC-6 is a 1-D, steady-state sediment transport model used to identify locations of deposition and scour within the project area. The 1-D sediment transport analysis will allow us to identify river reaches within the project area where sediment transport rates change rapidly or where transport rate under any of the alternatives is markedly different from transport rate under existing conditions. Changes in transport rate indicate the potential for adjustments in channel morphology through sediment deposition, erosion, or scour. River reaches identified using this screening approach will be targeted for a higher degree of analysis and evaluation. It is possible that additional field surveys will be required to provide higher-resolution data on channel bathymetry in these areas. Where existing channel cross section data are available in reaches selected for focused study, we will propose new cross section surveys to coincide with previously surveyed sections to allow for comparison and evaluation of past channel change. Such comparisons will be valuable in providing context for the modeling effort.

In accordance with review comments and discussions with Corps design engineers, we have elected to eliminate the 2-D sediment transport modeling effort from the current scope. The data needs and level of effort to prepare a viable 2-D model would be disproportionately large in comparison to the resolution, certainty, and applicability of the results of such a model.

Using the results of the HEC-6 model, we will focus additional attention on river reaches identified as having a high potential for physical change in response to implementation of any of the alternatives. Additional analysis will include hand calculations, if appropriate, to assess river scour, channel migration, and sediment bar accretion. Geomorphic comparisons will be used to assess and bound potential channel configurations that may result from reconfiguration of the channel through implementation of any of the alternatives.

Phase I included sampling of suspended load and bedload sediment transport as well as grab sampling of riverbed materials throughout the project reach. The transport and sediment characterization data collected during Phase I will be used to calibrate the sediment transport model. In locations where sediment transport data collection was not feasible, we will use local channel characteristics to estimate sediment transport values. Because the sediment transport model is sensitive to calibration techniques, we will include in the modeling effort a sensitivity analysis to establish error margins and quantify the uncertainty associated with the modeling results.

The sediment transport evaluation combined with the hydraulic modeling will provide the foundation for the geomorphic analysis and the analysis of potential changes in physical habitat. The sediment transport evaluation will also provide critical information to inform the design of the selected flood control alternative.

The proposed sediment transport analysis will include an assessment of flow, sediment transport, large woody debris (LWD), and channel/floodplain conditions in the reach where dikes are proposed for setback, in the bypass reach, and in the reach downstream of the proposed bypass. The analysis will consider the potential for LWD or sediment accumulations to affect the bypass inlet or conditions within the bypass. The alternatives analysis will include an assessment of the nature and volume of sediment delivered by the proposed bypass to the Swinomish Channel. For each project alternative, the floodplain and channel conditions and changes to these conditions will be evaluated within the main river channel as well as within the proposed bypass channel.

Deliverables for this task will be included as part of the report prepared under Task 8. This task will produce a data set (sediment samples, sediment yield), along with the sediment transport model with tabular and graphical output.

TASK 6 – ALTERNATIVES EVALUATION

We will evaluate the potential geomorphic effects of three alternatives. In consultation with the Corps, we will develop up to nine modeling scenarios to represent distinct variations of these alternatives. We will assess (1) the potential increases or decreases to flooding and sedimentation hazards within and downstream of the project area, (2) general changes in the delivery and routing of sediment within project area, (3) changes in floodplain processes (i.e., overbank flooding), and (4) changes in channel dynamics. The delivery and routing of sediment within the project area will be assessed using the sediment transport model developed under Task 5.1. Channel dynamics may include lateral migration, avulsion, channel incision, channel aggradation, channel armoring, alteration of channel structure, streambank stability, and connectivity of the channel to the floodplain. The conclusions resulting from this assessment will be at a level appropriate for supporting the Environmental Impact Statement.

There are no deliverables associated with this task. The work completed under Task 6 will contribute to portions of the technical report produced under Task 8.

TASK 7 – CONSULTATION WITH AGENCIES AND TRIBES

We will assist the Corps staff in communicating with the representatives from participating stakeholders, including municipal governments, state agencies, federal agencies, and tribes. This effort will involve participation in meetings as well as presentation of the study results to the agencies and stakeholders. There are no written deliverables associated with this task. The task includes participation in up to three meetings.

TASK 8– REPORT

We will prepare and submit draft and final reports summarizing the results and conclusions of Tasks 1 through 6 and incorporating the content of the interim reports prepared under those tasks. We will submit one draft report and will meet with the Corps for comments and concerns to be integrated into the final document. The draft document will include the following sections:

- Characterization of historical physical processes of the Skagit River at and upstream of the project area;
- Characterization of current physical processes of the project area and its drainage area;
- Qualitative assessment of the geomorphic impacts of each alternative, as well as their effects downstream of the project area;
- Quantitative assessment of the effects of each alternative on sediment transport, scour, and channel migration; and
- Assessment of error margins associated with elements of the study combined with a discussion of the limitations of the study and an evaluation of our confidence in data and assumptions used to configure the model.

Following the submission of the draft report, we will prepare formal written responses to the Corps comments and incorporate changes into the final report as necessary. Upon completion of the final report, we will provide five copies of the final report to the Corps. One copy will remain unbound, and four copies will be spiral-bound.

SCHEDULE OF PERFORMANCE

The work as proposed in this document can be completed by October 15, 2003, provided we receive a notice to proceed by June 1, 2003, and provided the conceptual design and hydraulic modeling associated with each project alternative is made available to us no later than August 15, 2003. Completion of our tasks will require iteration between our analysis and the alternatives development performed by Corps staff. The following specific items should receive particular attention in developing a more detailed project schedule:

- Our ability to initiate the sediment transport modeling effort will depend on the availability of the conceptual alternatives currently in preparation at the Corps. The development of modeling scenarios to represent the alternatives cannot proceed without an adequate description of the alternatives.

- Additional modeling scenarios may be required if the alternatives are modified/optimized in response to sediment transport modeling results.

- Fieldwork may be required to complete portions of the sediment budget. Fieldwork will be weather dependent.

- Additional channel survey data will be required in selected areas identified by comparing the alternative modeling scenarios to the existing conditions modeling scenario. Feasibility of performing channel surveys will depend upon weather and flow conditions. Summer season provides optimal conditions for completing these surveys.

After any additional survey data are collected, the project performance schedule will depend primarily upon the number of iterations necessary to optimize the alternatives based on the intermediate modeling results.

CONCLUDING REMARKS

We appreciate the opportunity to continue our work with you on this project. I look forward to completing this work plan and moving forward with the next phase of the study. Thank you.

Sincerely,

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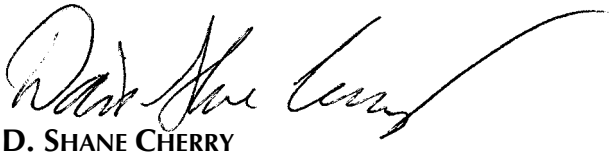

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Attachments: Phase I Scope of Work

REFERENCES

Paulson, K.M., 1997. Estimating Changes in Sediment Supply Due to Forest Practices: A Sediment Budget Approach Applied to the Skagit River Basin in Northwestern Washington. Master's Thesis. University of Washington, Seattle, Washington.