MEMORANDUM

DATE: December 12, 2006

TO: Sheila Fleming

FROM: Colin Wagoner

SUBJECT: **Hydraulic Evaluation for Island Complex Site, Revision 1**

Background

Ridolfi is under contract to the Washington State Department of Ecology (Ecology) to develop remedial designs for the Island Complex site on the Spokane River The data that are necessary for the development of the remedial designs include the predicted velocities, shear stresses, and water surface elevations at various flow regimes, for example, a 20-year flood event. A summary of the data review and evaluation that was conducted for design development is presented below.

Data Sources and Assumptions

- HEC-RAS model files were obtained from the U.S. Army Corps of Engineers (USACE), Seattle District. The USACE assembled a hydraulic model to evaluate restoration design issues on the Starr Road site, which is located just downstream of Island Complex. The hydraulic model was assembled to build upon previous efforts conducted for a Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) prepared for unincorporated areas of Spokane County (FEMA, 1992).

- Data for the Liberty River gage on the Spokane River were obtained from the U.S. Geological Service (USGS). These data are used by the USGS to calculate discharge, measured in cubic feet per second (cfs), as a function of stage, measured in feet, in the river.

- Estimates of discharge for events with various flood recurrence intervals were tabulated by the USACE in the Engineering Analysis section of the Starr Road Restoration project The first return interval is listed as n/a or not applicable because it is a relatively low value that is frequently exceeded in winter. Table 1 summarizes these values.

- Vertical datum conversion. The FIS study and USGS records are tabulated in the National Geodetic Vertical Datum of 1929 (NGVD29). Topographic surveying at the Island Complex and Starr Road sites was performed using the North American Vertical Datum of 1988 (NAVD88). There is a 3 81-foot offset between these datums such that one adds 3.81 feet to a value reported in NGVD29 to convert it to a NAVD88 basis.

- USGS 1:24,000 topographic map Liberty Lake Quadrangle (1973) shows river miles for the Spokane River and the location of the Liberty Bridge gage. Note that the river miles shown on the map are not spaced one mile apart. So, these river miles cannot be used to establish the location of the HEC-RAS model cross-sections.

- Input and output files for the original WSP-2 model completed for the FIS were obtained from FEMA in PDF format. Review of this information along with review of the WSP-2 User's manual, provided primary evidence for locating the model cross-sections. The first WSP-2 file lists each cross-section and bridge within the model domain and lists the distance in feet between each cross-section. These values were used to post the cross-sections on a map, working from upstream to downstream, as shown on Figures 1 and 2. Table 3 summarizes the spatial information. It should be noted that the cross-section labels shown as "River Miles" are apparently inaccurate because they are inconsistent with the distances used in the WSP-2 and HEC-RAS models.

Analytical Approach

The HEC-RAS model files obtained from the USACE were opened in HEC-RAS and the model was executed to verify that the results reported by the USACE could be duplicated. Based on a visual comparison between a longitudinal profile presented in a memorandum prepared by the USACE and a similar output from the model, it appeared that the results were duplicated. An evaluation of the model indicated that it was set up with the parameters shown in Table 2 The measured cross-sections are those that were used in the original FIS. The USACE interpolated between the measured cross sections, generally at 100-foot intervals, although sometimes at other intervals. Note that there is a discrepancy between the extent of the model shown in Table 2 if the river miles are converted to feet: 3.1 miles x 5,280 feet/mile = 16,369 feet, which is over 10 percent different than the model length shown in Table 2 (18,650 feet) This problem is exacerbated because the maps in the FIS do not indicate the locations of the cross-sections. Furthermore, the river mile markers shown on the USGS topographic quadrangles for the area are not spaced at one mile intervals These discrepancies make it difficult to line up specific model cross-sections with features on the ground

The rating curve was used to adjust boundary conditions for the model. The rating curve provides an elevation for the discharges corresponding to events with a specified return interval. For example, the 20-year event has a discharge of 41,900 cfs for a gage height of 2,029.9 feet. The preliminary model obtained from the USACE indicated that the predicted water surface elevation for the 20-year event was 9.5 feet lower at RM 93.8 relative to RM 94.9 (the gage). Therefore, a boundary condition of 2,020.9ft – 9.5ft = 2,011.4ft, was used for the 20-year event

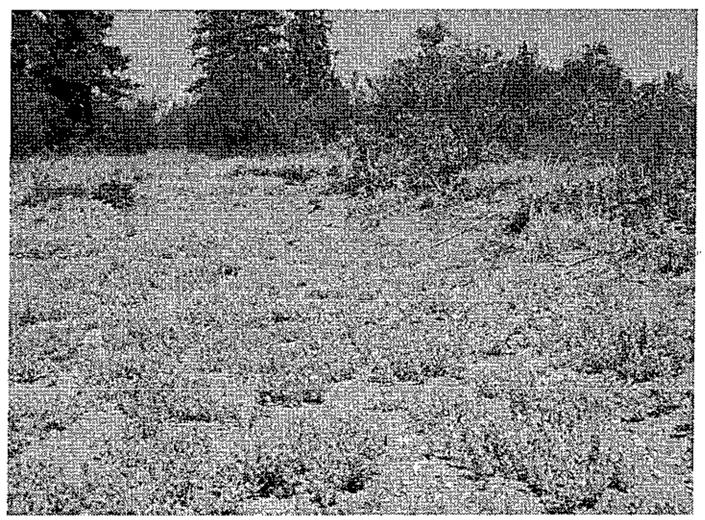
Figures 1 and 2 show representative cross-sections, above and below the Island Complex site as output from HEC-RAS. The cross sections are both oriented looking downstream so that the south, southeast side of the river is on the left. The cross-sections show predicted water levels for 0.5-year, 20-year and 100-year events. The color shading is an indication of the predicted velocities in strips across the river for the 20-year event. The values reach a maximum of almost 10 feet per second. Figure 3 compares the geometry obtained from the topographic survey of the Island Complex with the geometry in the HEC-RAS model. The comparison is approximate because of the difficulty in aligning the two data sets.

Because of the uncertainty in the model geometry, the modeling alone was deemed to be insufficient to be used as a basis for design purposes such as selecting the size of rock to withstand a particular design event such as a 20-year recurrence interval flood. While the model gives reasonable estimates of the predicted maximum velocities under different flow regimes, it isn't as useful in predicting where the maximal velocities will occur in a cross-section through the Island Complex. Specifically, we interpret that the model underestimates the velocity in the back-channel. Consequently, the model predictions will be supplemented with the USGS acoustic Doppler velocity measurements recorded during a high flow (reportedly a one-year recurrence interval) event. Those measurements are described in more detail below.

Chevron Stabilization Design Considerations

One of the areas identified for erosion control through bank stabilization is located at the downstream edge of the Island Complex. It is informally called the "chevron" because of its shape. The chevron is characterized by an exposed embankment of sand with gravel (Photograph 1).

The central portion of the chevron is unvegetated but there is low-lying vegetation on either side. The steepest portion of the slope is approximately 3:1 horizontal to vertical; the top of the slope is at approximately 2,030 ft. NAVD88; and the base of the slope is at 2,024 ft. Fine-grained recent deposits (silt-clay fraction) were noted on the base of the chevron suggesting deposition in quiescent conditions.



Photograph 1. The Chevron looking northeast.

The USGS conducted an acoustic Doppler velocity survey of the east-west channel in the vicinity of the chevron on May 25, 2006. In that survey they measured relatively low velocities, on the order of 1 ft/s and noted a complex flow pattern of eddies. A sketch of the survey area indicated "ponded water" in the vicinity of the chevron. The USGS observations were made when discharge at the Liberty Bridge gage was 16,700 cfs, approximately a one-year return interval event. Although it is possible that during a larger event, the Island will overtop, it is difficult to predict the velocities across the chevron under those conditions because the flow patterns are likely to be three-dimensional (i.e., significant cross-channel and vertical components).

Taken together, these observations suggest that the energy at the chevron is generally low and granular materials of the same approximate size as the native materials should be sufficiently stable for restoration purposes. The proposed design consists of a foundation consisting of a toe structure constructed of angular quarry spalls. On the lower section of the structure, rounded gravels will be used to blanket the quarry spalls and blend into the sand and gravel that are present in the flat area at the base of the chevron Willow bundles will be placed on the quarry spalls followed by Coir-wrapped organic rich soil building up toward the upper edge of the chevron. Native plants will be installed into the soil to provide root structure and stability. The plants will be irrigated for at least the first two years after installation to increase the probability of successful root establishment.