Pajaro River Watershed Study

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Technical Memorandum No. 1.2.10

Task: Evaluation of Four Watershed Conditions - Sediment

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INTRODUCTION

Study Objectives

The overall project objectives are to address the following issues:

- What are the causes of flooding along the Pajaro River below Chittenden?
- Has streamflow increased downstream with increasing development upstream?
- Has stream channelization and maintenance affected flooding downstream of Chittenden?
- Has erosion or sedimentation in the streams affected flooding?
- Have upstream retention basins reduced or mitigated the degree of flooding?

Objectives of This Technical Memorandum

This Technical Memorandum (TM) summarizes use of the sediment transport model to analyze the impact of different upstream watershed conditions on sedimentation conditions within the channel of the Pajaro River, along the reach from the San Benito confluence to the ocean. Simulations were made for the 100-year event which is critical from the standpoint of flood control.

The PRO-SED sediment transport model was described in TM 1.2.9 along with boundary conditions, field conditions, calibration and other aspects of modeling. That description is not repeated here.

MODEL DESCRIPTION

The calibrated sediment transport model was used to simulate the impact of different upstream watershed conditions for the 100-year flood event. Discharge hydrographs for an Existing Condition and four different scenarios were developed using PRO-FLO. These models simulate the response of the watershed (hydrologic system) and the stream channels and storage areas (the hydraulic system) to different land use conditions. The four different conditions modeled by the HEC-RAS portion of PRO-FLO are summarized in Table 1.

Table 1: Summary of Scenarios Developed by HEC-RAS Modeling and Used as Input for Sediment Transport Modeling.

Scenario	Chittenden Peak Discharge (cfs)	Description
Existing	42,501	**Existing Condition:** Current condition in watershed and channel; baseline against which all other simulations will be compared.
1	43,151	**General Plan Build-out**: This scenario allows the model to predict the watershed flood potential using the urbanization and land use for each city based on the efforts of the individual planning departments.
2	47,103	**Back in Time to 1947**: The year 1947 is significant because it is just before the Army Corps of Engineers' levees were built in 1949 and has similar conditions to when the 1955 flood occurred. In addition, three of the four existing reservoirs and some additional levees were not yet in place.
3	43,675	**Ultimate Build-out in 2050**: This scenario represents a worst-case scenario, in terms of flooding, for urbanization. The model predicts how the watershed responds to unchecked growth in the cities beyond what the general plans currently allow. The year 2050 is the approximate end of the economic life of a project started at the time of this report.
4	42,921	**Changes in Agriculture**: Agriculture can play a large role in the amount of runoff and therefore flooding in an area. This scenario parallels the urbanization scenario and acts as a worst-case agricultural condition.

As can be seen from Table 1, there are very small differences in peak discharges between the different scenarios for the 100-year flood event. The largest difference occurs between the Existing Condition and Scenario #2 (1947 condition). Peak discharge is lower for the Existing Condition due to reservoir construction. The remaining three scenarios are virtually identical to the Existing Condition in terms of peak discharge as well as the hydrograph shape. For this reason, the sediment transport analysis was run comparing only the Existing Condition against the 1947 Condition hydrograph (Scenario #2), and for determining its sensitivity to changes in hydraulic roughness and incoming sediment load.

INPUT DATA

Hydrograph Scenarios

The HEC-RAS modeling generated hydrographs for the 100-year storm with a duration of 6½ days. Discharge values were computed by HEC-RAS at 15-minute intervals, and these data were input into the PRO-SED sediment transport model. Scenarios #1, #3 and #4 were not run as their discharge hydrographs were very similar to the Existing Condition. The Existing Condition model was compared to the 1947 Condition, because this represented the greatest difference between the scenario hydrographs (an 11% difference in peak discharge).

Channel Vegetation Scenario

An additional scenario was constructed by altering the Existing Condition model to examine the possible impact of additional shrubby vegetation growth in the channel. This was simulated by increasing the value for hydraulic roughness (Manning's n-value) in the model. For this scenario channel hydraulic roughness values were increased by 50% over the Existing Condition model; floodplain hydraulic roughness was unchanged.

Changes in roughness values reflect only the impacts of vegetation on average flow velocities and water depths in the channel. However, vegetation will also mechanically trap coarse sediment and reduce flow velocities at the sediment-water interface on the channel bed. These mechanisms will increase sediment deposition in the channel and are not accounted for by increased hydraulic roughness values. Thus, hydraulic roughness provides only an approximate idea of the potential effect of increased vegetation coverage, and actual sediment deposition in the channel could be greater than simulated by roughness changes alone.

Changes in Inflowing Sediment Load

Changes in the inflowing sediment load can result from changes in upstream land use, instream gravel mining, incision and erosion of upstream channels, and reservoir construction. The state-of-the-art of sediment yield estimation does not allow exact estimation of the impact of watershed changes on sediment delivery to the river. It was therefore decided to determine the sensitivity of the model to changes in inflowing sediment load. A 20% change in incoming sediment load in rivers that are as large as the Pajaro River is considered significant, especially under the conditions that prevail in this watershed. Therefore, should the model indicate little sensitivity to a change of 20% in incoming sediment load, it would be an indication that the changes in sediment delivery from the upper river sub-watershed would probably have an insignificant effect on riverbed response during extreme flood events.

Sediment was input into the model using the sediment rating curve (sediment discharge as a function of water discharge) for total sediment load, previously presented as Figure 4 of TM 1.2.9 (and reproduced below as Equation #1). The equations used to represent changes in total sediment load, 20% higher and lower, are presented in Equations #2 and #3 respectively:

Existing condition (from Figure 4 of TM 1.2.9):

$$Load = 0.033*Qcfs^{1.56} \quad (1)$$

20% increase in total sediment load:

$$Load = 0.040*Qcfs^{1.56} \quad (2)$$

20% decrease in total sediment load:

$$Load = 0.026*Qcfs^{1.56} \quad (3)$$

Application of these equations incorporates the assumption that the increase in load is evenly distributed over all discharges, and there is no change in the inflowing grain size distribution.

Summary of Simulations

The conditions simulated by the PRO-SED sediment transport model are summarized in Table 2.

Table 2: Summary of Conditions Modeled.

Simulation Number	Hydrograph Scenario	Peak Discharge (cfs)	Hydraulic Roughness	Sediment Input Rating Curve
1	Existing Condition	**42,501**	Existing	Existing
2	1947 Condition	**47,103**	Existing	Existing
3	Existing Condition	42,501	**50% higher**	Existing
4	Existing Condition	42,501	Existing	**20% Increase**
5	Existing Condition	42,501	Existing	**20% Decrease**

SEDIMENT TRANSPORT MODELING RESULTS

Graphical Simulation Results

Sediment transport modeling results are summarized graphically by showing the changes in bed elevation along the length of the river, which reflects either net scour or deposition of coarse bed material sediment.

- Simulation #1: Results of the Existing Condition simulation are shown using the **Bed Profile Graph** presented in Figure 1. This graph compares the pre-flood bed profile against the post-flood profile along the length of the river, indicating the net scour or deposition of sediment along the streambed.

- Simulations #2-#5: Results for each simulation are illustrated in Figures 2 - 5 as the change in bed profile at the end of the flood event, as compared to the Existing Condition simulation. The **Change in Bed Profile Graph** shows the difference in the bed profile at the end of the flood for the simulation event, as compared to the Existing Condition bed profile. Zero values in this graph represent “no difference” between the Existing Condition and Simulated bed levels at the end of the flood event.

The Existing Condition initial condition riverbed composition and profile is used for all simulations.

Discussion of Modeling Results

Existing Condition Model: The bed profile for the Existing Condition model is presented in Figure 1, comparing the pre-flood and post-flood bed profile. Very little net change occurs in the bed profile over the duration of the flood event. Scour and refilling of scour holes may occur during the event, but is not shown here.

Changes of Hydrology: The greatest difference in hydrology occurs between the Existing Condition and the 1947 Condition, the latter having a greater peak discharge than the former. This is not a particularly large difference, and the hydrograph shapes are very similar.

The end-of-flood bed levels for the Existing Condition and the 1947 Condition are compared in Figure 2. The increase in peak discharge results in an increase in sediment input at the peak of the flood. This results in about 0.12 m (5 inches) of additional bed material deposition in the vicinity of the confluence of Pajaro and San Benito Rivers, but along the remainder of the river the changes in bed profile are essentially insignificant and no net change is evident.

These results indicate that the change in discharge between the 1947 Condition and the Existing Condition does not significantly impact sedimentation conditions along Pajaro River, as long as the sediment yield relationship remains unchanged.

Vegetation and Increase in Hydraulic Roughness: As shown in Figure 3, a 50% increase in hydraulic roughness (simulating increased in-channel vegetation) increases deposition in the upstream portions of the river; reduced velocities allowed more of the coarser material to deposit. Maximum increase in deposition depth is 0.15 m (about 6 inches). Scour to a depth of 0.25 m (about 10 inches) occurs at one cross section. For the most part, the model predicts deposition in the upstream area of the model, with virtually no change in bed material further downstream in the vicinity of Watsonville.

Part of the deposition pattern is attributed to the single-event nature of this simulation. Inflowing sediment experiences greater trapping in the upstream portion of the model due to increased roughness. Over a period of multiple events the area of deposition could advance further downstream.

The simulation indicates that sediment deposition would be increased by the growth of shrubby in-channel vegetation which significantly increases channel hydraulic roughness.

<u>Change in Inflowing Sediment Load</u>: The simulated response to a 20% increase in the inflowing sediment load is presented in Figure 4. Sediment deposition occurs at the upstream end of the model, with bed elevation increasing about 0.43 m (about 17 inches) over the duration of the event. Over time (multiple events) this bed material could be expected to be transported further downstream along the river.

The river's response to a 20% decrease in the inflowing sediment load is presented in Figure 5, showing scour of about 0.43 m (17 inches) at the upstream end of the model, in the vicinity of the confluence of San Benito and Pajaro Rivers. Scour in the area of Chittenden would be limited by geologic controls.

It should be noted that the deposition at the upstream end of the model could be the result of boundary conditions. As the change in bed elevation at this location is relatively minor (compared to the total increase in sediment load), the absence of change in riverbed elevation over the rest of the model indicates that the sediment transport capacity in the downstream river may be adequate to convey relatively large changes in sediment input to the model. Further long-term simulations are needed to better define this issue.

Summary

Sediment transport modeling indicates that changes in peak discharge alone, over the range predicted for the 100-year flood by HEC-RAS modeling, should not significantly alter sedimentation conditions within the Pajaro River channel.

If significant shrubby vegetation grows within the channel, this should be expected to cause an increase in sediment deposition.

A significant (e.g. 20%) change in coarse sediment load appears to have a relatively minor impact on sedimentation in the Pajaro River during extreme flood events such as the 100-year flood, except potentially at the confluence with the San Benito River. The simulated increase in deposition at the confluence could potentially result from boundary conditions within the computer model. Should this be the case, the model results indicate that the sediment transport capacity of the lower Pajaro River during 100-year flood conditions could be adequate to convey relatively large changes in sediment load without significant changes in deposition pattern. Long-term simulations are required to better define potential change in bed elevation subject to changes in sediment load.

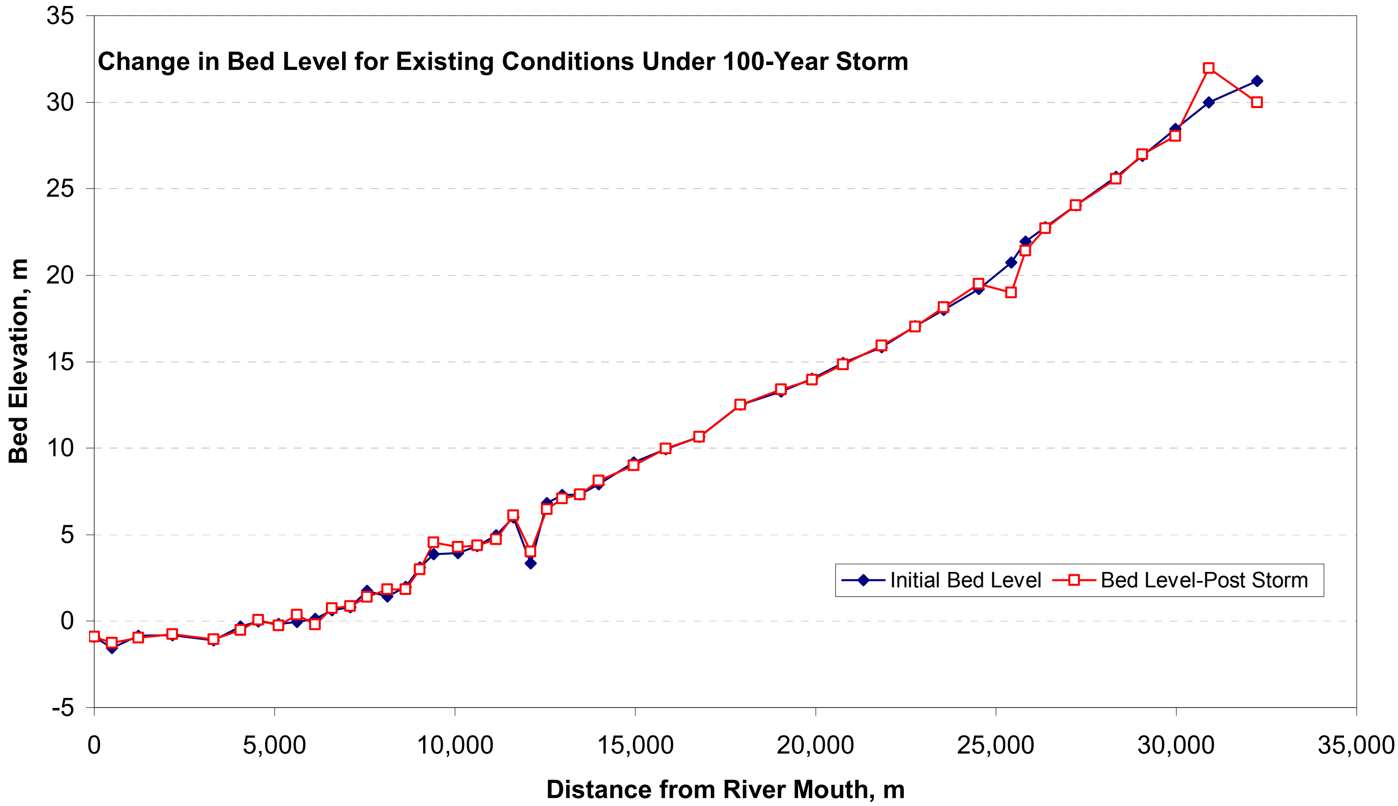

Figure 1: Results of Simulation #1. Comparison of initial and final riverbed profiles at the start and the end of the 100-year flood, Existing Condition model.

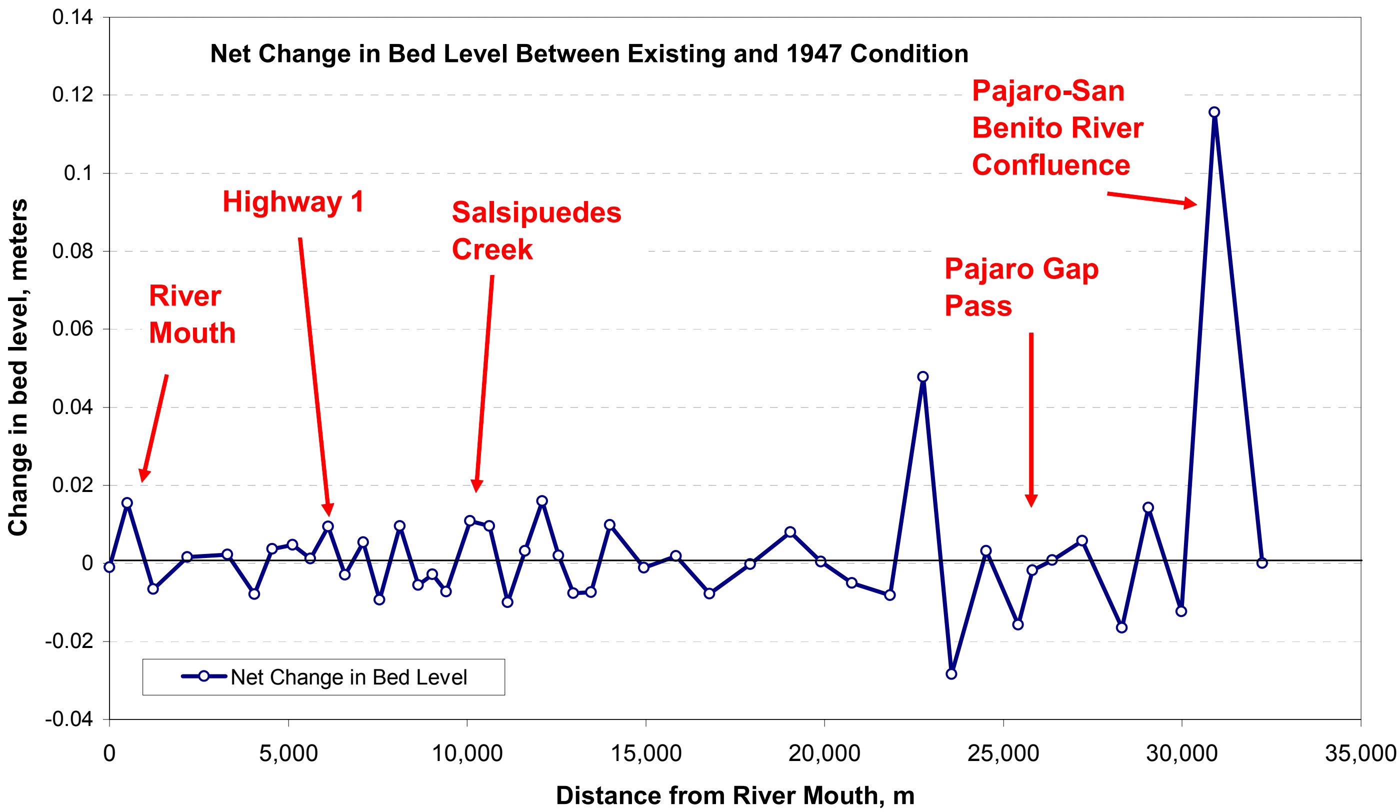

Figure 2: Results of Simulation #2. Difference in the end-of-flood bed profile along Pajaro River for the 1947 discharge hydrograph, as compared to the end-of-flood bed level for the Existing Condition model.

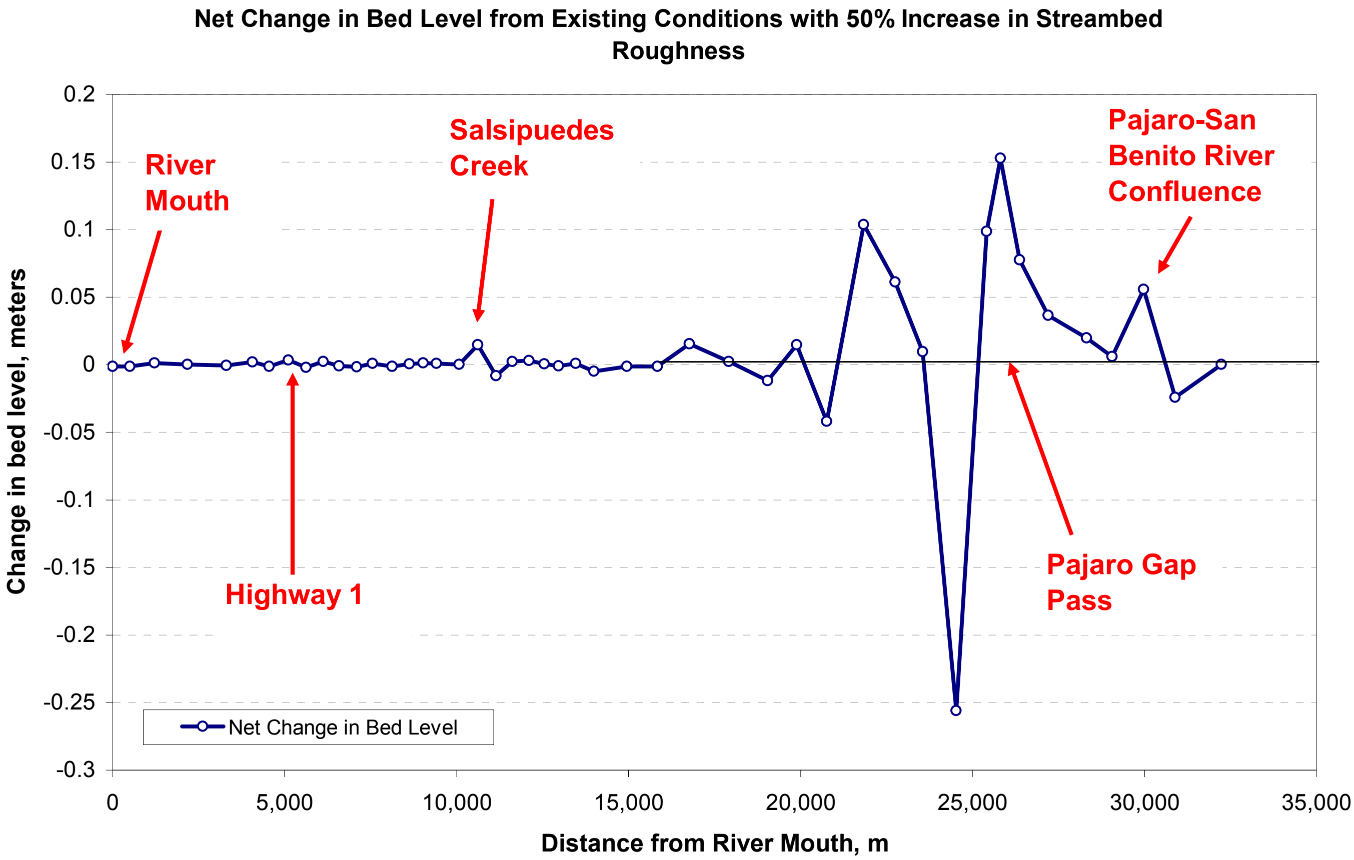

Figure 3: Results of Simulation #3. Difference in the end-of-flood bed profile along Pajaro River for a 50% increase in channel hydraulic roughness, as compared to the end-of-flood bed level for the Existing Condition model.

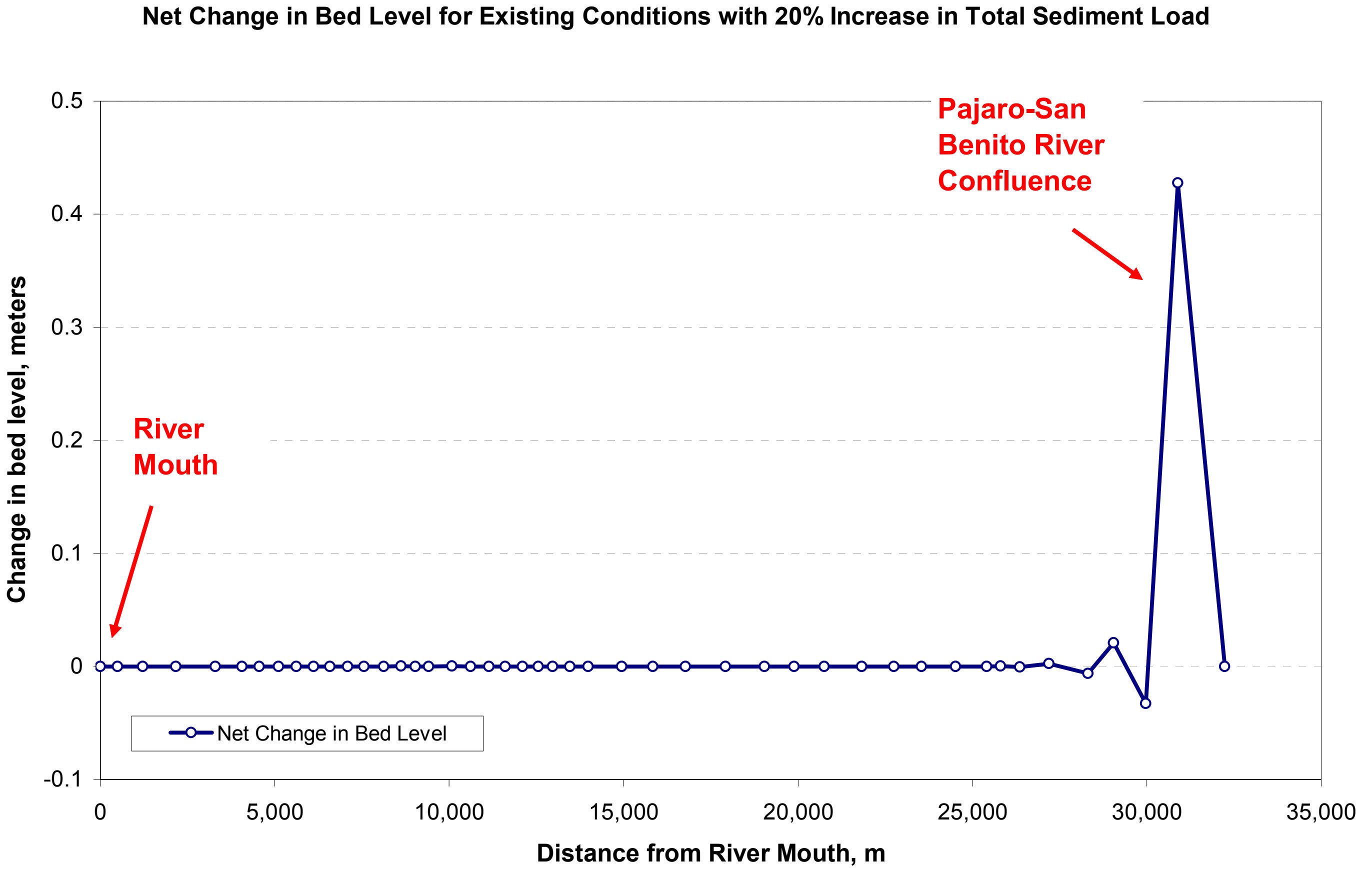

Figure 4: Results of Simulation #4. Difference in the end-of-flood bed profile along Pajaro River for a 20% increase in total sediment load, as compared to end-of-flood bed level for the Existing Condition model.

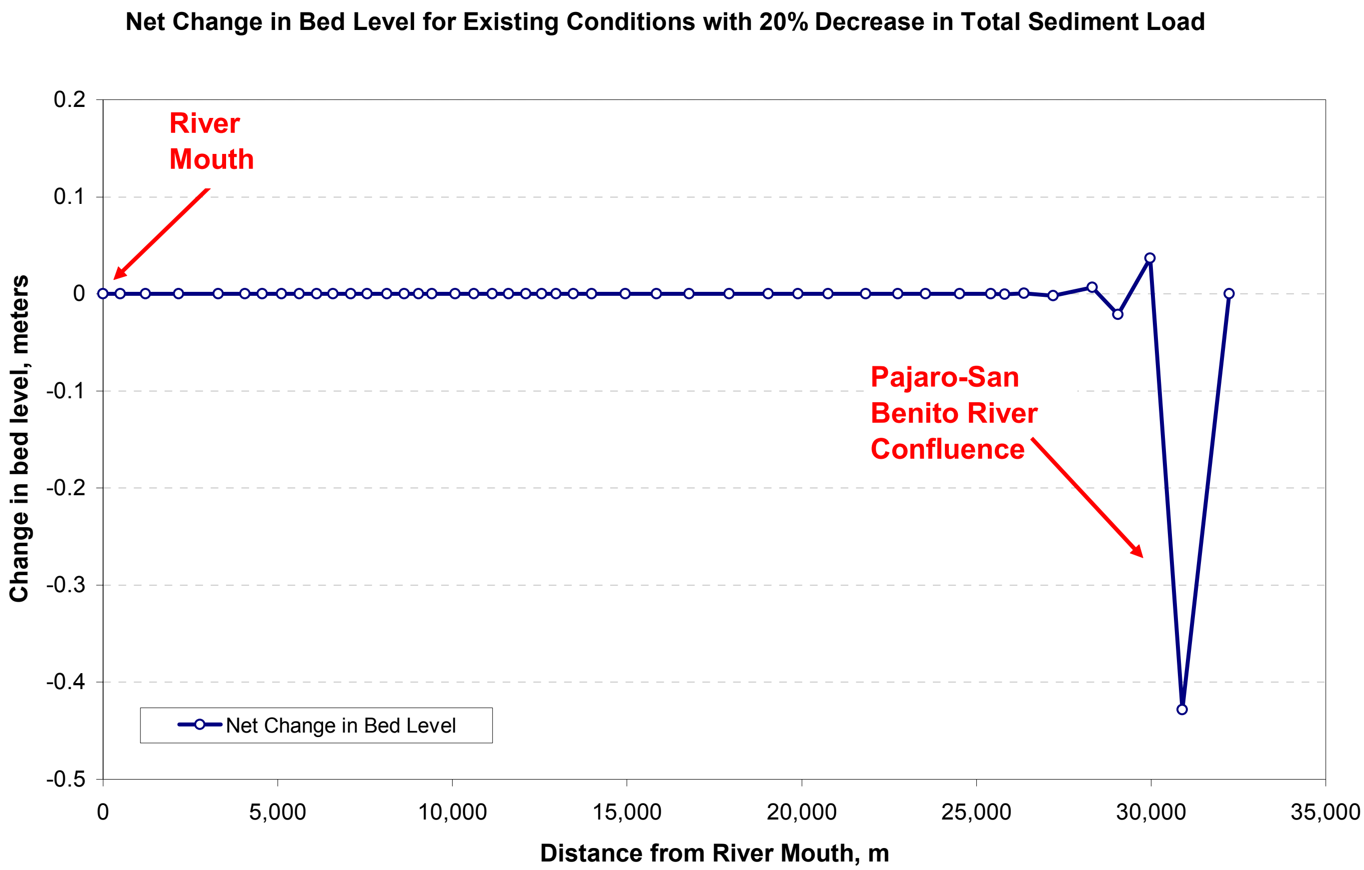

Figure 5: Results of Simulation #5. Difference in the end-of-flood bed profile along Pajaro River for a 20% decrease in total sediment load, as compared to end-of-flood bed level for the Existing Condition model.