

# **Simulating Unsteady Flow and Sediment Transport in Vegetated Channel Network**

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# Introduction

- Vegetation in rivers increases flow resistance, increase bank stability, and improve water quality and habitat diversity,
- Vegetation also reduces channel conveyance. The existence of vegetation changes both flow field and sediment transport processes.
- The simulation of flow and sediment transport in vegetated alluvial channel needs to know the complex interaction between flow, vegetation, and mobile bed.

# Vegetation Near Bridges

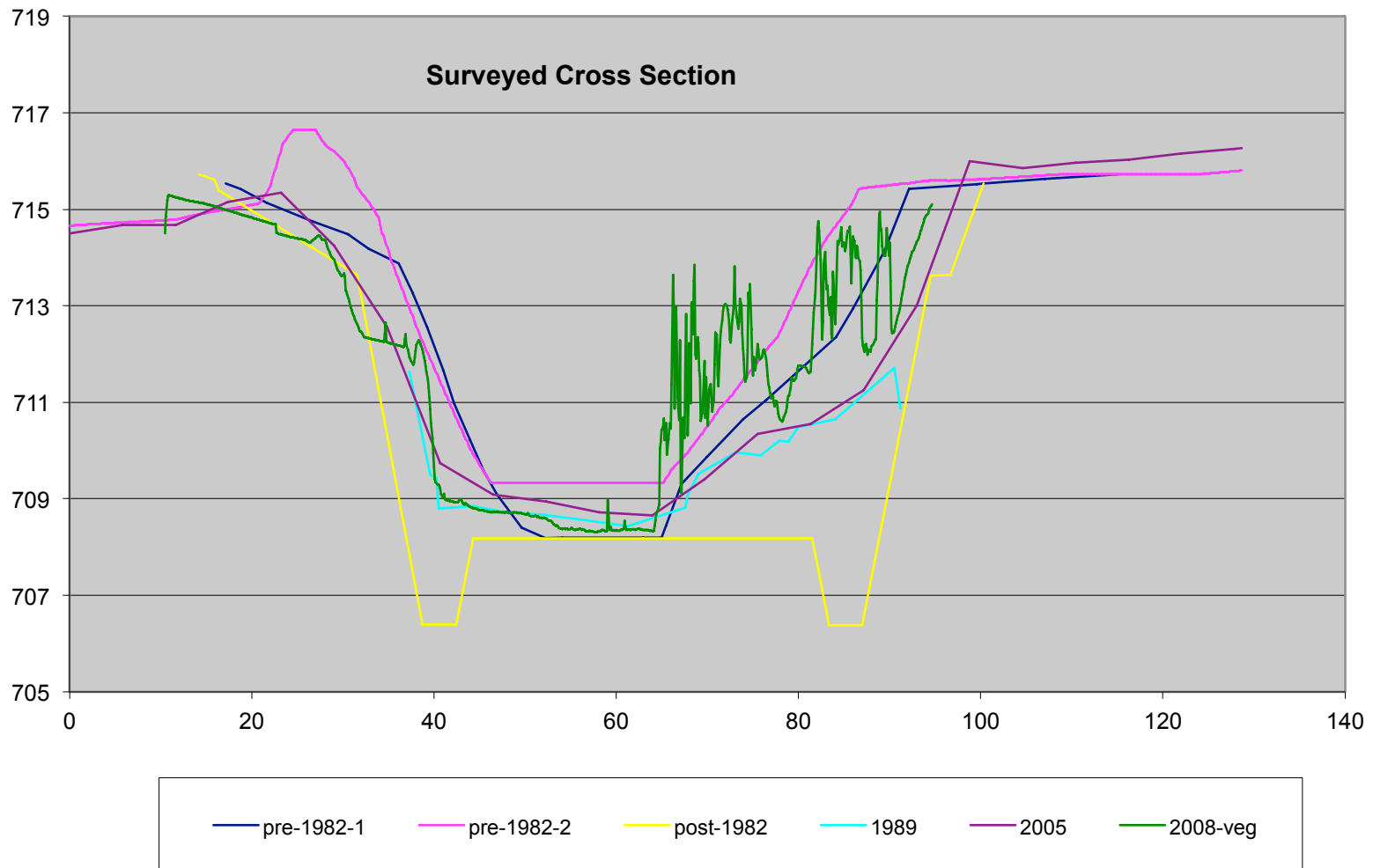


Congress Street Bridge on  
Santa Cruz River



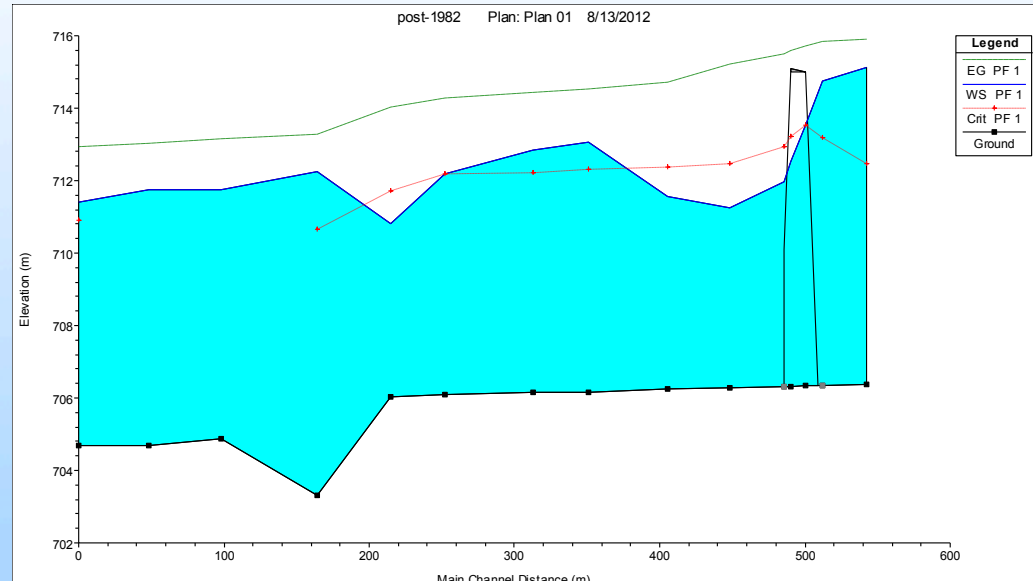
**Twin Peak Bridge on Santa  
Cruz River**

# Surveyed Cross Sectional Changes

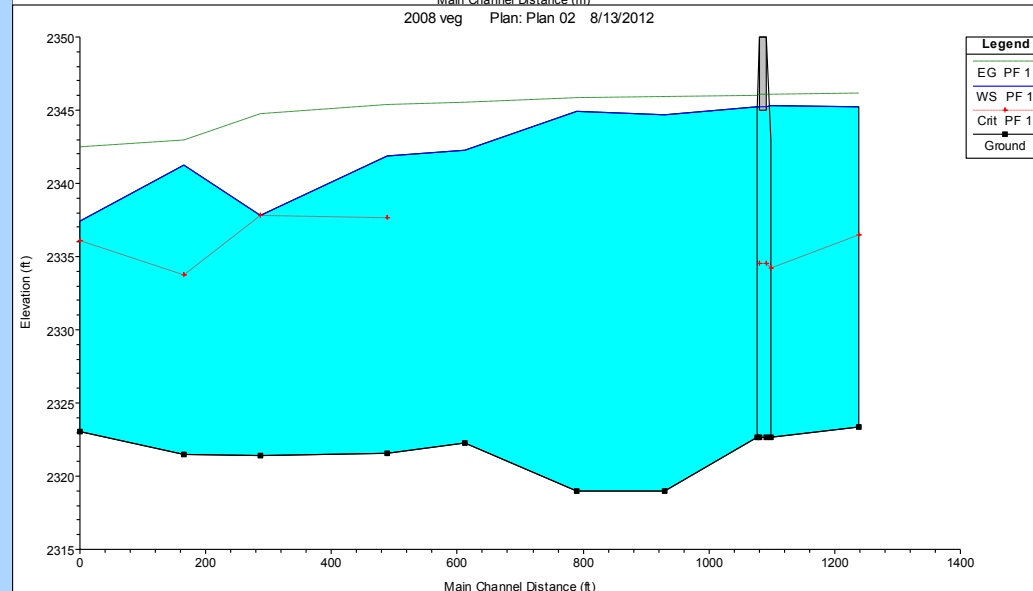


# HEC-RAS Simulated Flow Profile

**Post – 1982  
Construction  
Design  
 $Q = 60,000$   
cfs**



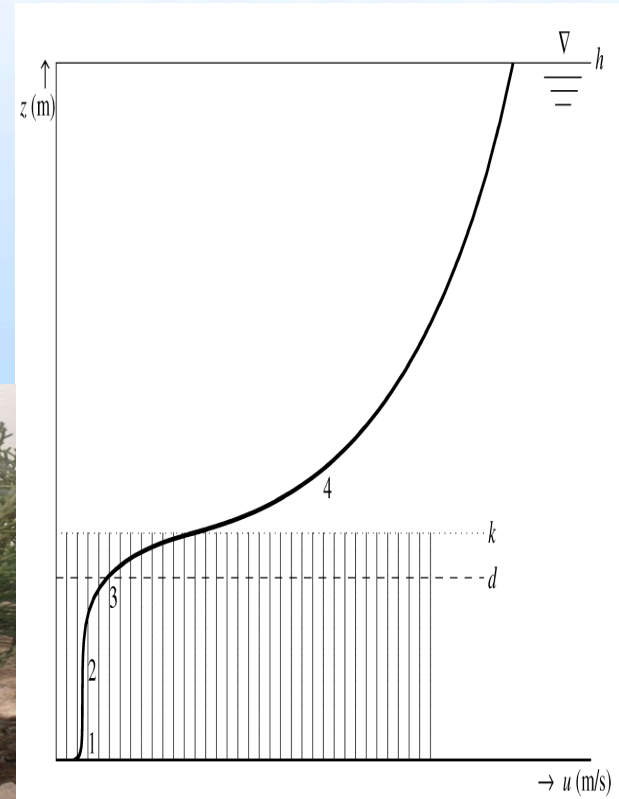
**2008  
Vegetated  
channel  
Capacity  
 $Q = 27,000$   
cfs**



# Sediment Transport in Vegetated Channel



# Velocity Distribution in Vegetated Channel



Vegetation alters velocity distribution by reducing velocity near the bed surface. The velocity in vegetation zone is nearly a constant. This distribution significantly reduces bed shear stress for transporting sediment. However, if vegetation is not significantly dense, local scour can occur around individual vegetation.

# Vegetation Model

For un-submerged vegetation, bed shear stress can be calculated as :

$$\tau_b = \rho c_p l u(z) \frac{\partial u(z)}{\partial z} \quad \frac{\partial u(z)}{\partial z} = \frac{a \exp(\frac{z}{L}) - b \exp(-\frac{z}{L})}{2L \sqrt{u_{s0}^2 + a \exp(\frac{z}{L}) + b \exp(-\frac{z}{L})}}$$

For submerged vegetation, flow velocity can be calculated as :

$$\bar{u} = C_r \sqrt{hi}$$

In which Chezy's coefficient is:

$$C_r = \sqrt{\frac{1}{1/C_b^2 + (C_d m D k)/2g}} + \frac{(h-k)^{3/2} (\sqrt{g}/\kappa) \ln((h-k)/ez_0)}{h^{3/2}}$$

# Grain - Scaled 1D Model

- A one dimensional (1D) finite-volume model is developed for simulating non-equilibrium sediment transport in unsteady flow. (Zhang and Duan, JHE, 2013).
- The governing equations are the 1D mass and momentum conservation equations for sediment-laden flow and the sediment continuity equation for both bed load and suspended-load transport.
- The Rouse profile is modified to consider the non-equilibrium transport of suspended sediment. The spatial lag between the instantaneous flow properties (e.g., velocity, bed shear stress) and the rate of bed load transport in unsteady flow is quantified by using an adaptation length, which is derived theoretically by applying the momentum principle in the bed load layer.
- This new method for calculating the adaptation length is verified using data from several experiments, and yields better results than other empirical formulas for a wide range of shear stress.

# Turbulent Unsteady Flow

Two-dimensional depth-averaged finite volume model for unsteady turbulent flow

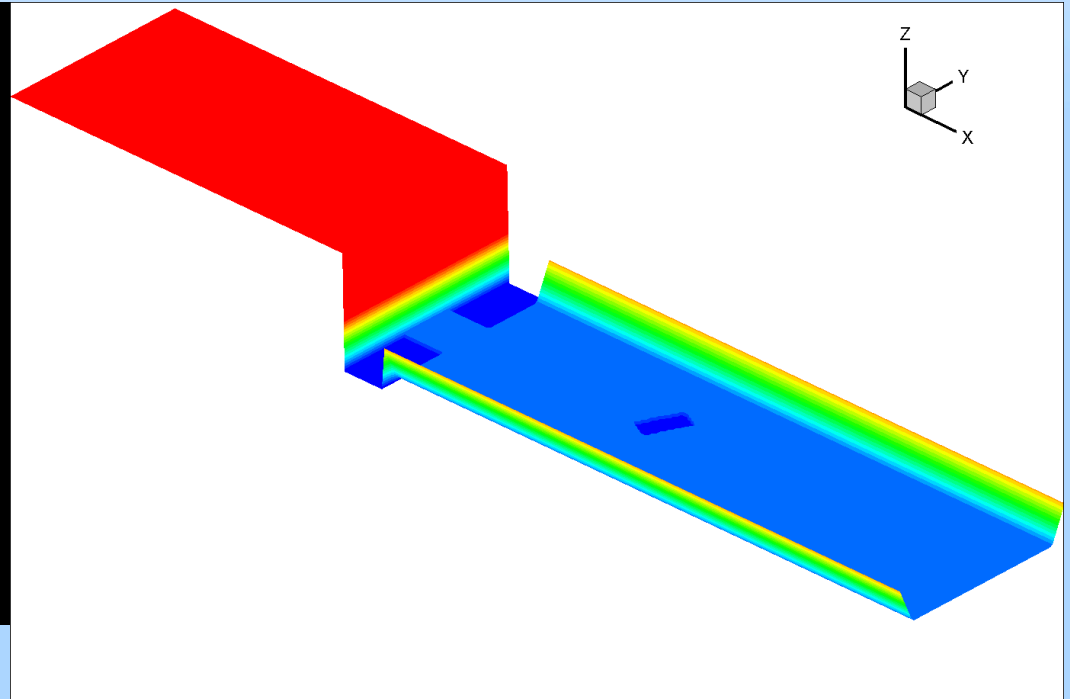
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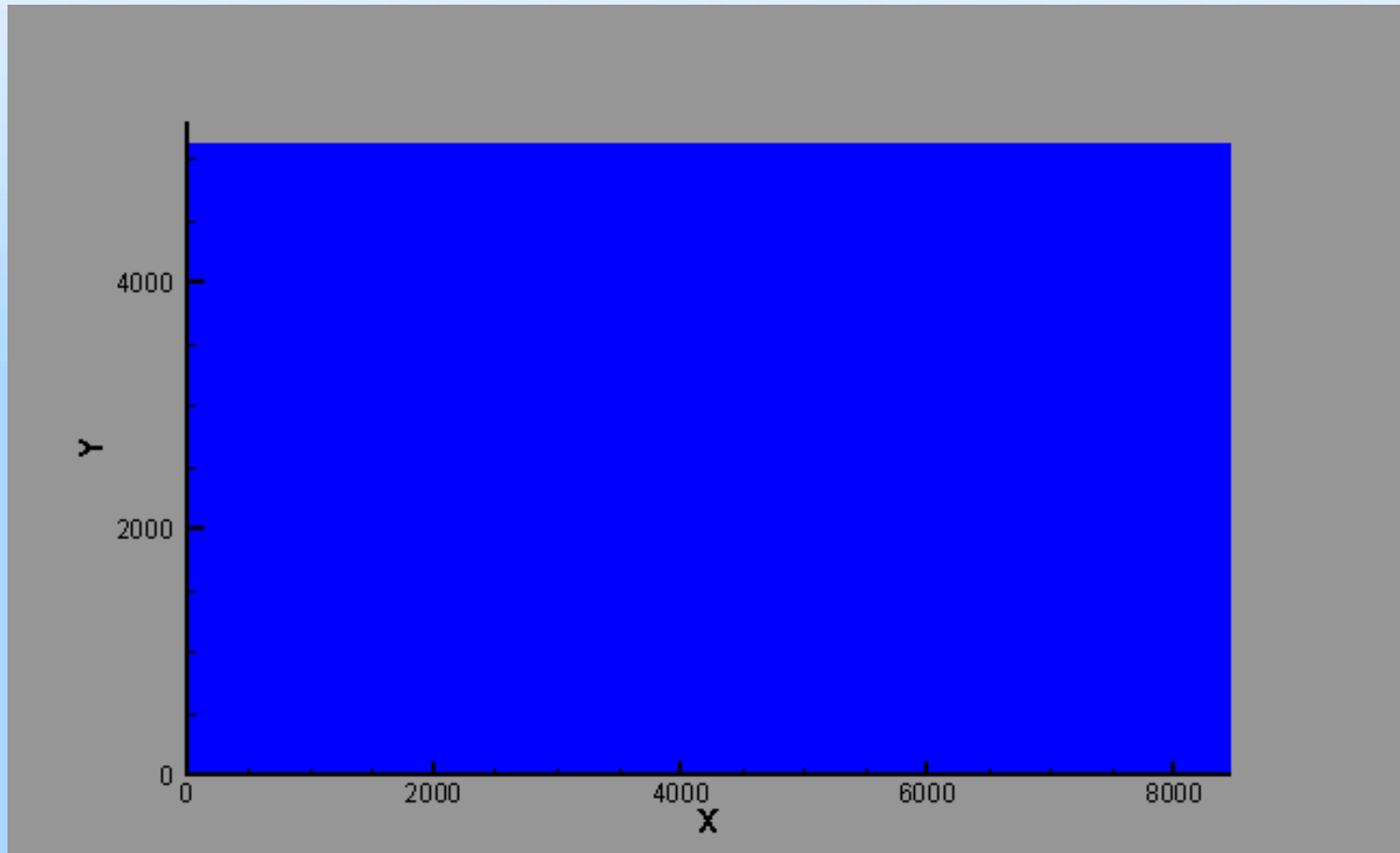
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JHR, 2012



# Goodwin Creek Watershed



# Field Case: Santa Cruz River



# Simulation Period

- This study simulated an unprecedented flood event occurred in the Rillito River and the Santa Cruz River basin in July 2006.
- The storm duration is 96 hours from July 26, 2006 to August 4<sup>th</sup>.
- During this event, considerable amount of sediment are deposited in the river and many vegetation are removed.
- The maximum flow rate reached 37,900 cfs at the Dodge Blvd in the Rillito River exceeding the 100-year discharge.

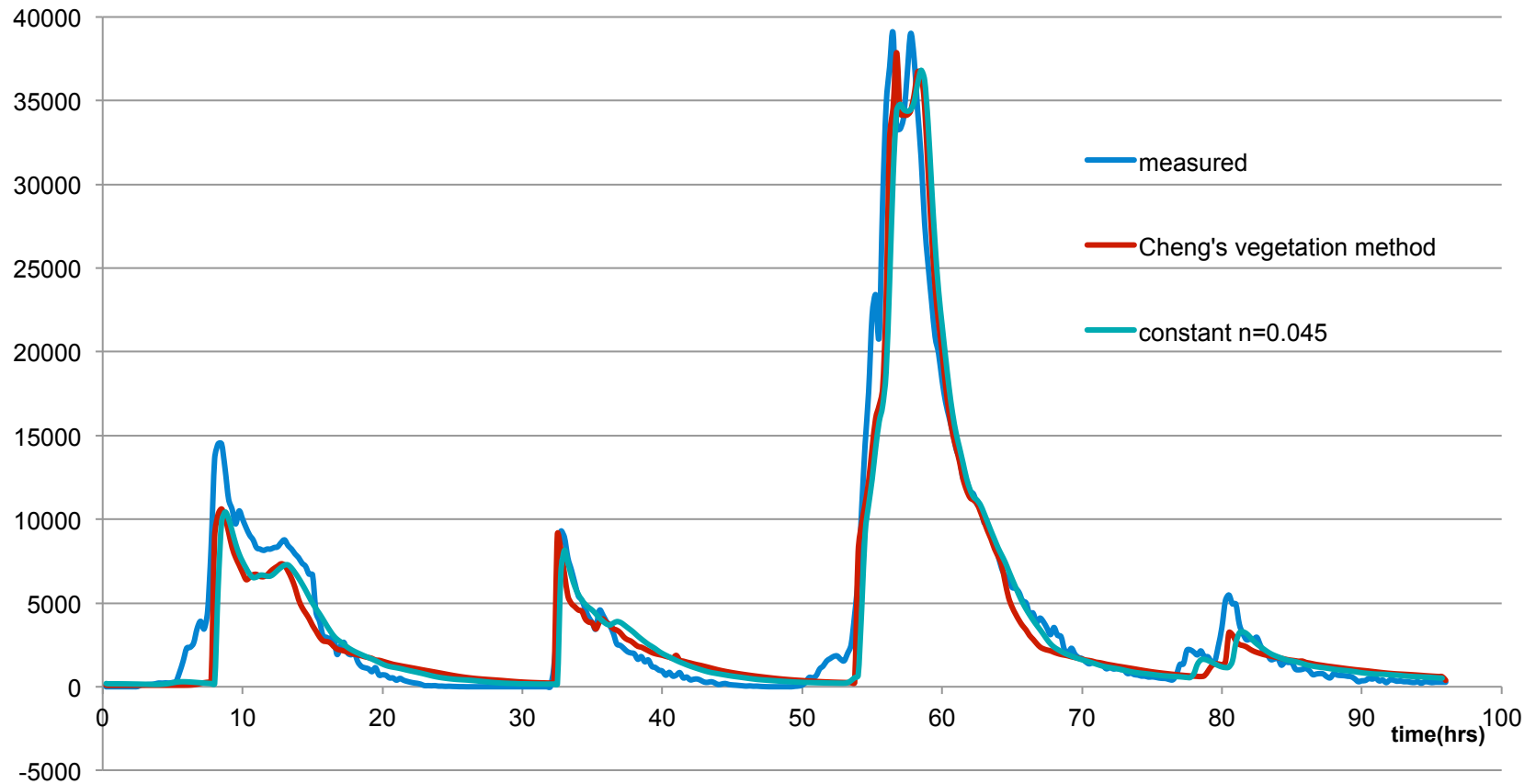
# Vegetation Parameters

- Vegetation in the floodplain of the Santa Cruz are mostly herbaceous (Stromberg 2009). The average height of these plants is 2-7 feet, and the coverage percentage is about 0.1.
- Since there has not been a large flood for several years, vegetations have been very well established in the main channel and floodplains.
- To evaluate whether vegetation impact is essential to sediment transport, three scenarios are selected: one assumes vegetation impacts is negligible, and the other accounts for the effect of vegetation using modified velocity profile.

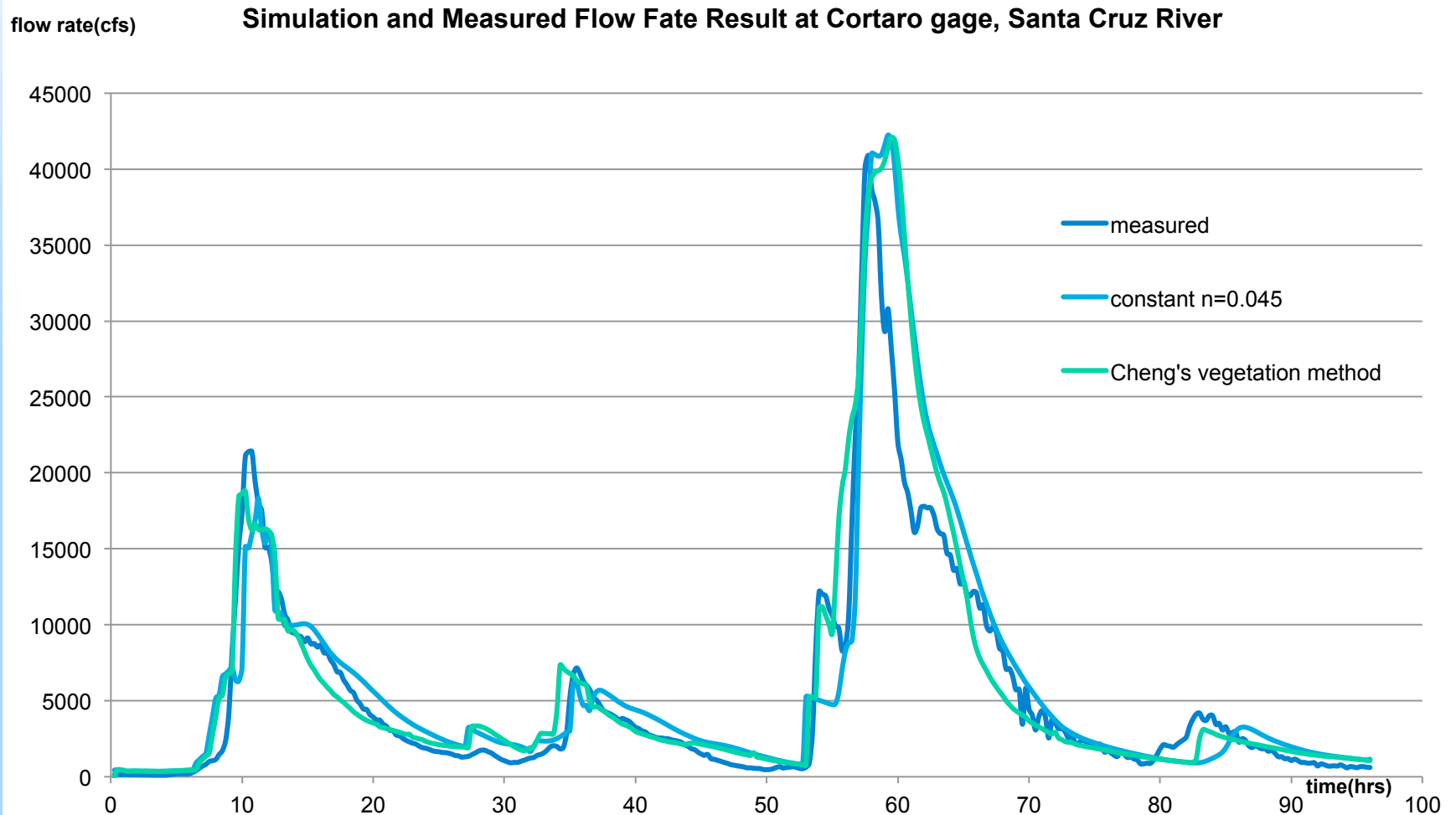
# Flow Hydrograph

flow rate(cfs)

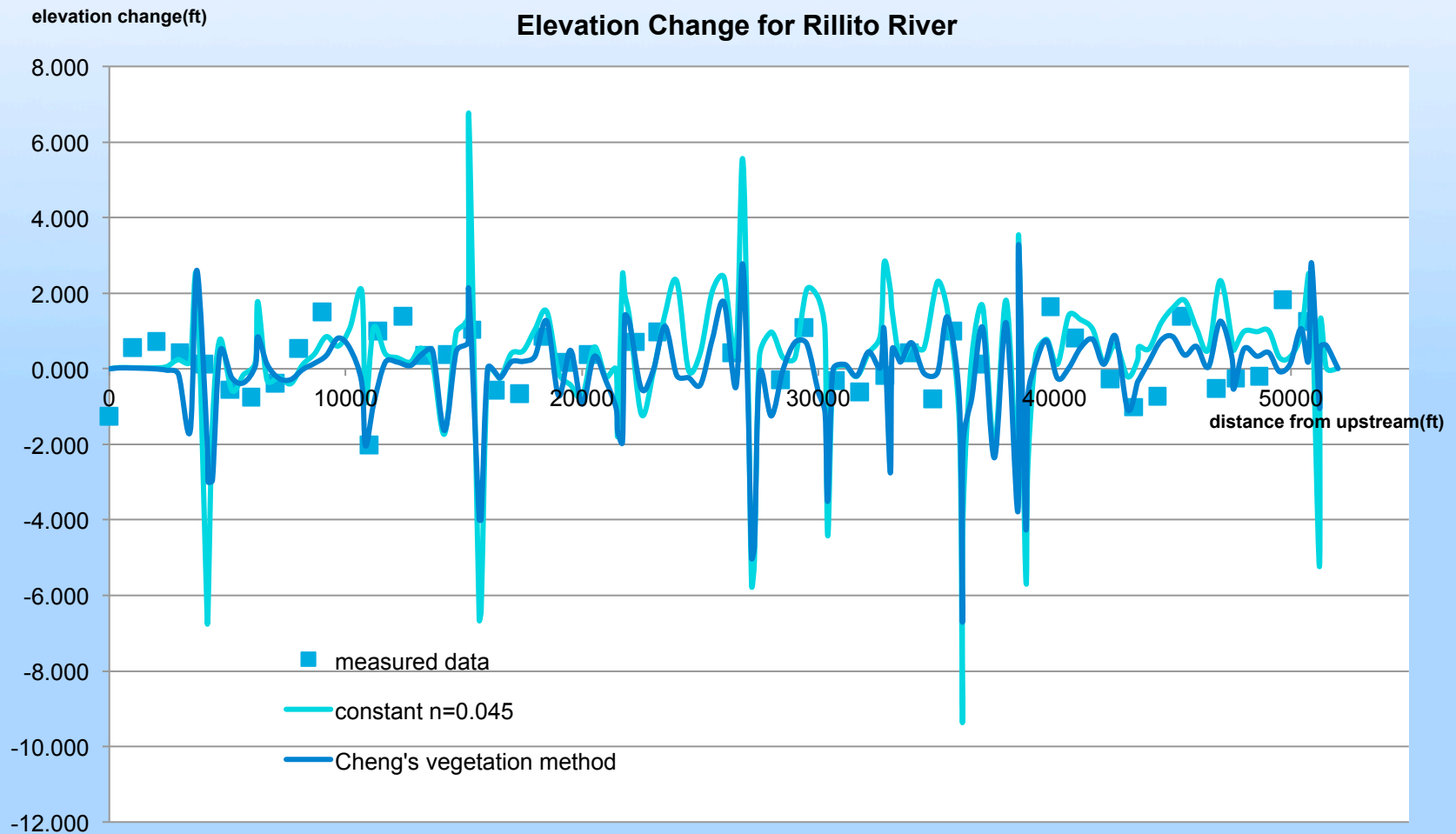
Simulation and measured flow rate result at La Cholla, Rillito River



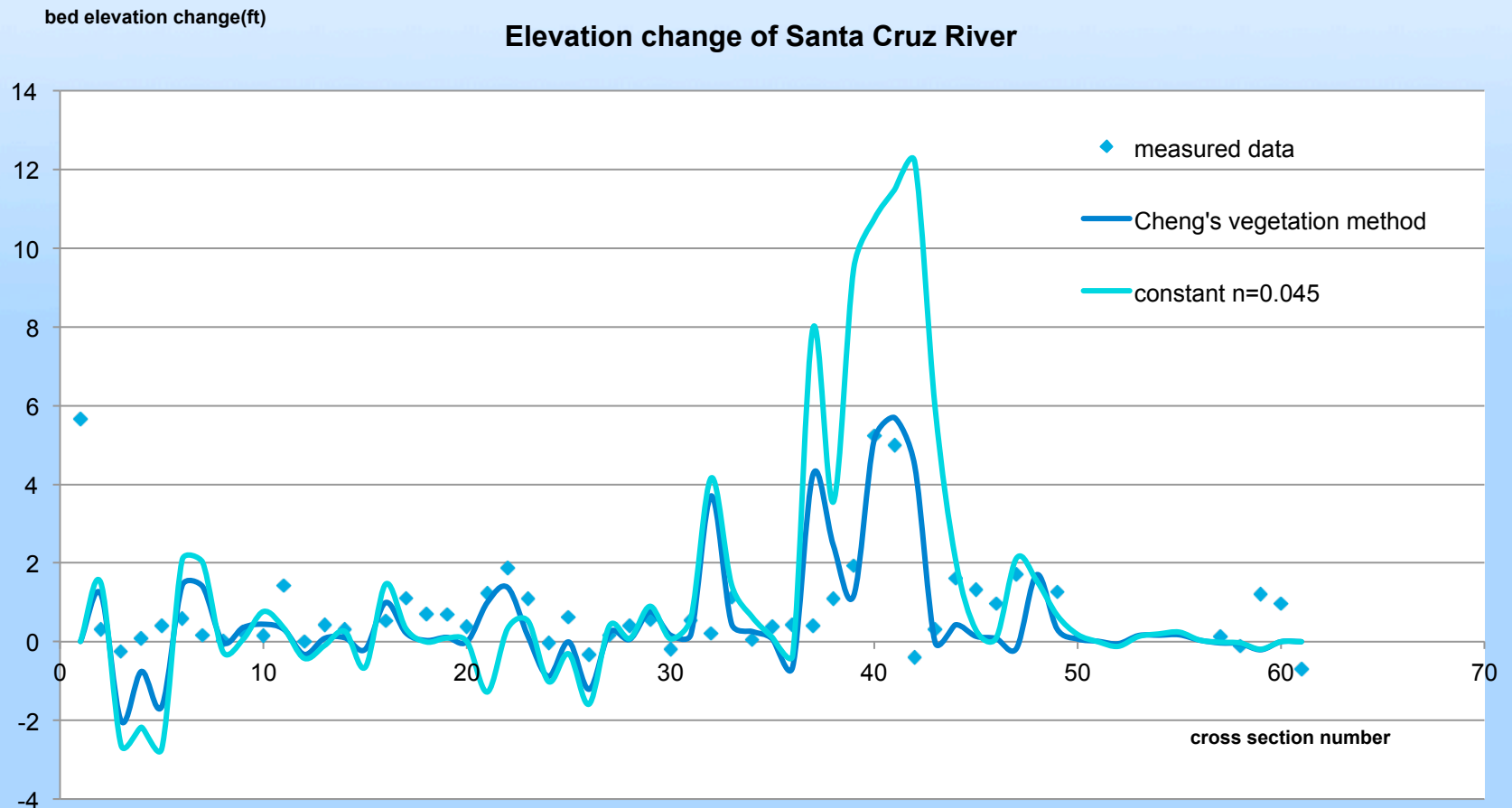
# Flow Hydrograph



# Bed Elevation Changes



# Bed Elevation Changes



# Conclusions

- Vegetation increases flow resistance, but can result in different bed forms as seen in natural rivers.
- Vegetation at high density enhances deposition, while causes localized scour around vegetation at low density.
- Hydraulic models need to include the impacts of vegetation on flow velocity and bed shear stresses to accurately simulate morphologic processes in rivers.