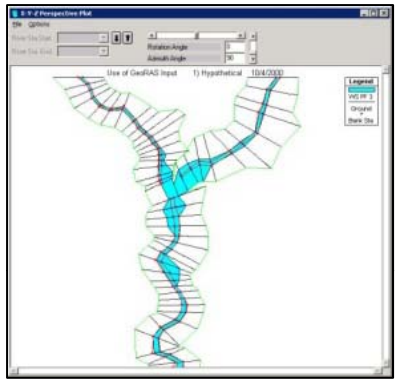
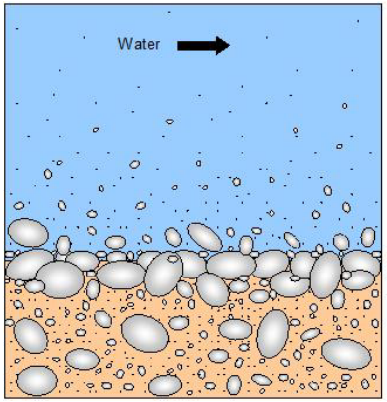
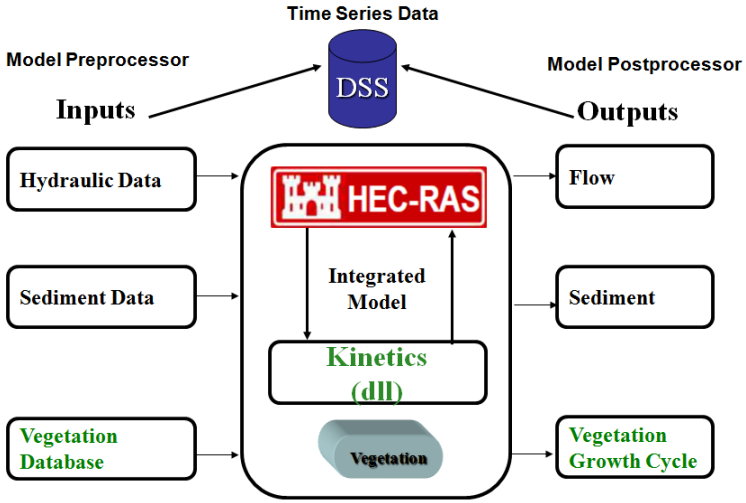
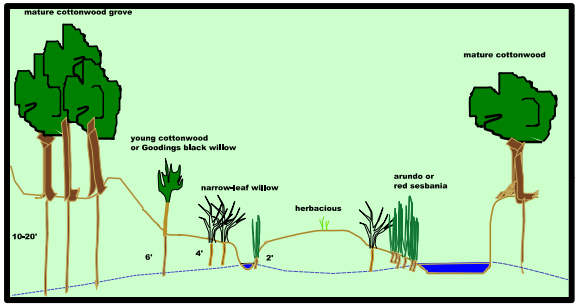
Modeling Interactions of Flow and Riparian Vegetation for Improved Riverine Ecosystem Management

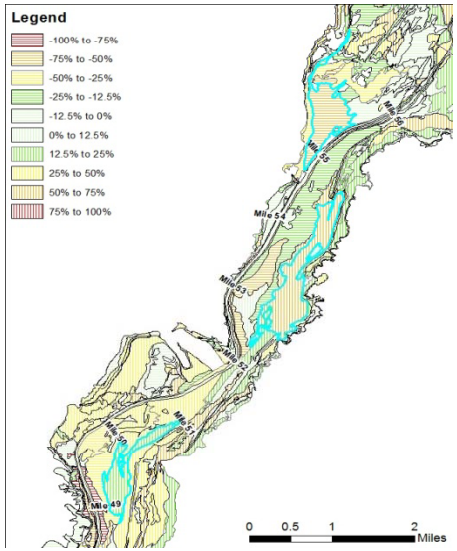
EMRRP Webinar Series











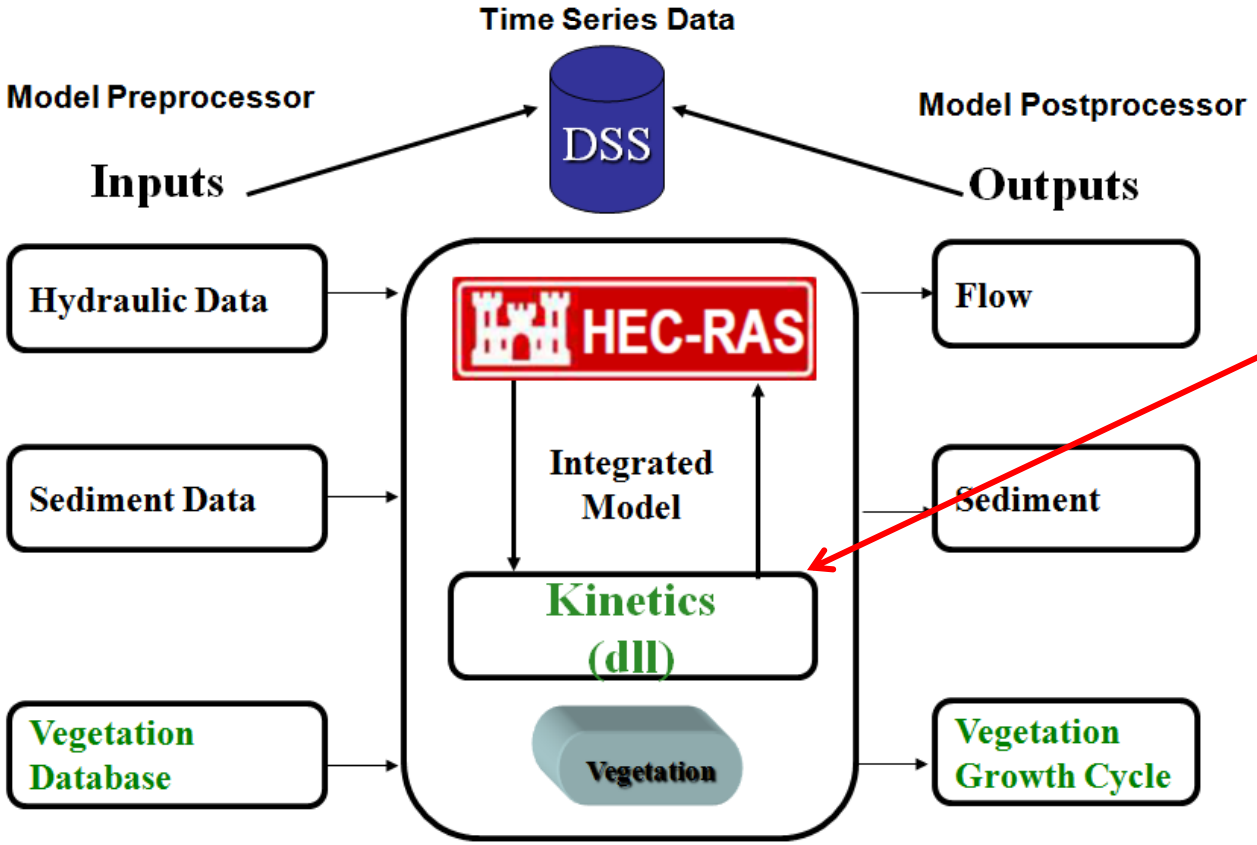
Billy Johnson, Zhonglong Zhang, and Blair Greimann
March 25, 2014

Questions to Answer

Vegetation in riparian zones play an important role in controlling channel morphology and maintaining favorable habitat for aquatic organisms

- How can vegetation be incorporated into restoration projects without increasing flood risks?
- What set of riverine operations can be used to encourage recruitment and survival of native vegetation (and control the spread of invasive species)?
- How will management actions impact habitat for endangered and threatened species?
- What impact does riparian vegetation have on local flood conditions?

R&D Approach



Riparian Vegetation Simulation Module – Stand alone module that will be integrated with USACE and USBR riverine models. This work will enhance USACE modeling capabilities and support continued collaboration in this area between the two agencies.

RVSM will be developed based on work done by the USBR in SRH-1DV.

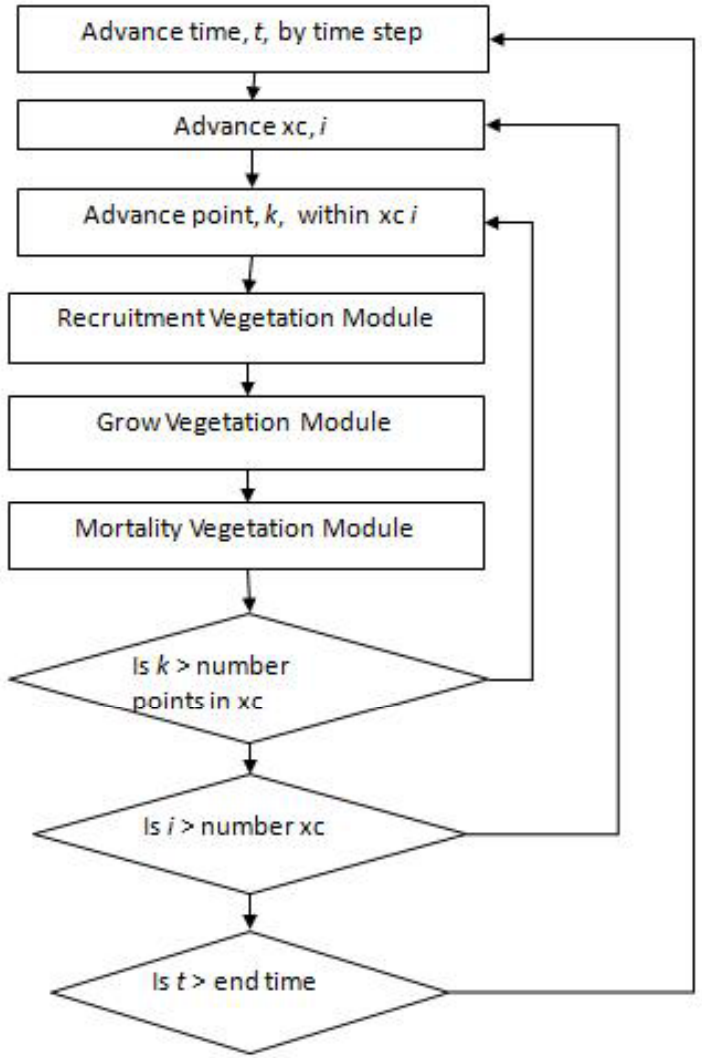
Model Capabilities

- Reach scale
- Cross section based 1D unsteady flow, sediment transport, and vegetation model
- Predicts:
  - Water surface elevations
  - Erosion and deposition
  - Groundwater elevation
  - Riparian Vegetation establishment, growth, and survival
  - Impacts of vegetation on flow regime

Riparian Vegetation Simulation Module (RVSM) Overview

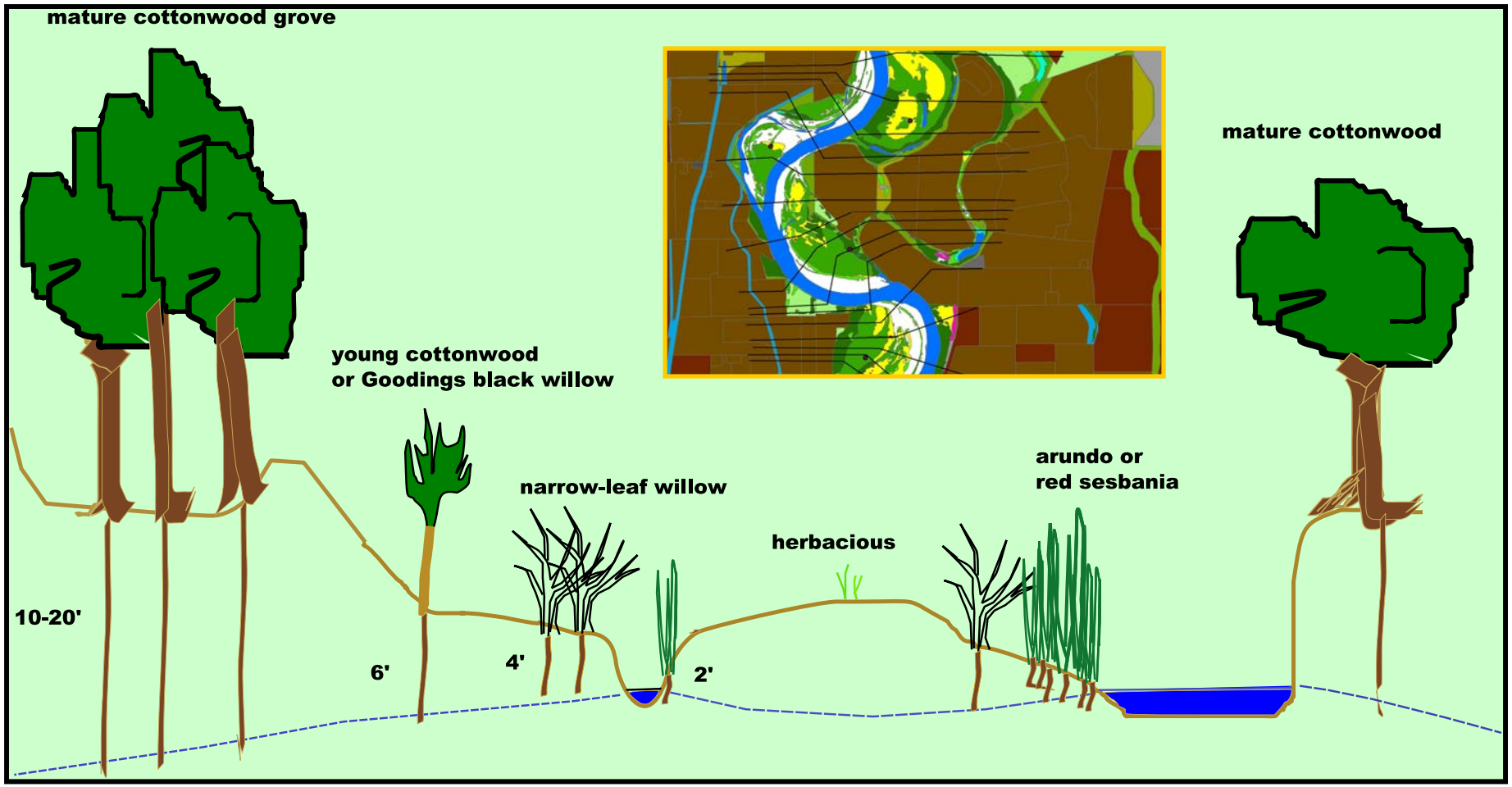
- RVSM will be designed to simulate the processes of:
  - Seedling establishment
    - ► Germination period
    - ► Seed dispersal
  - Plant growth
    - ► Growth rate (stalk, root)
    - ► Max height/depth for stalk/root
    - ► Effects on roughness through growth
  - Mortality
    - ► Competition
    - ► Scour (high flows on young plant)
    - ► Drowning (inundated for duration)
    - ► Desiccation (root growth < GW drop)
    - ► *Ice, burying*
  - Hydraulic and Sediment transport functionality provided by HEC-RAS

Riparian Vegetation Simulation Module (RVSM) Flowchart

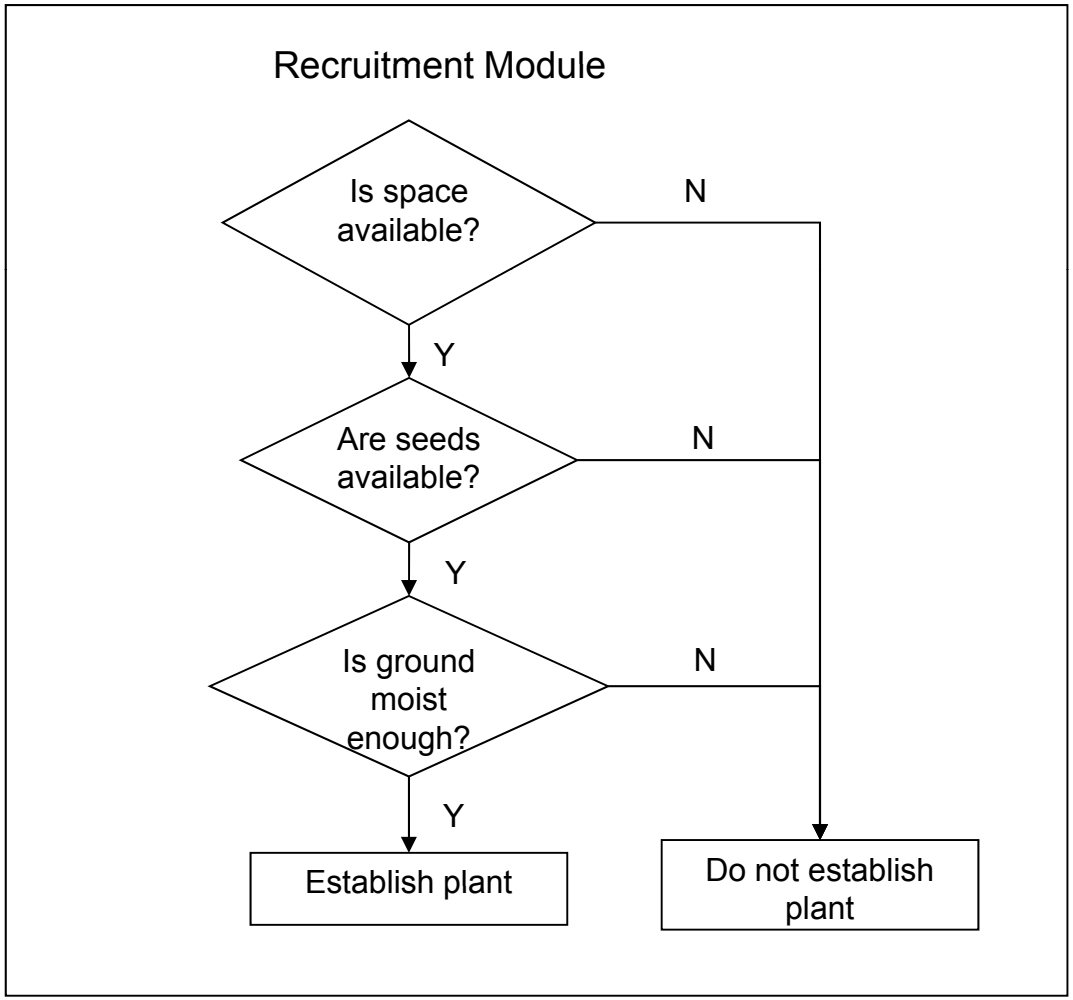


- Cross section based
- Predicts at every point in a cross section:
  - Water surface elevations
  - Erosion and deposition
  - Groundwater elevation
  - Riparian establishment, growth, and survival

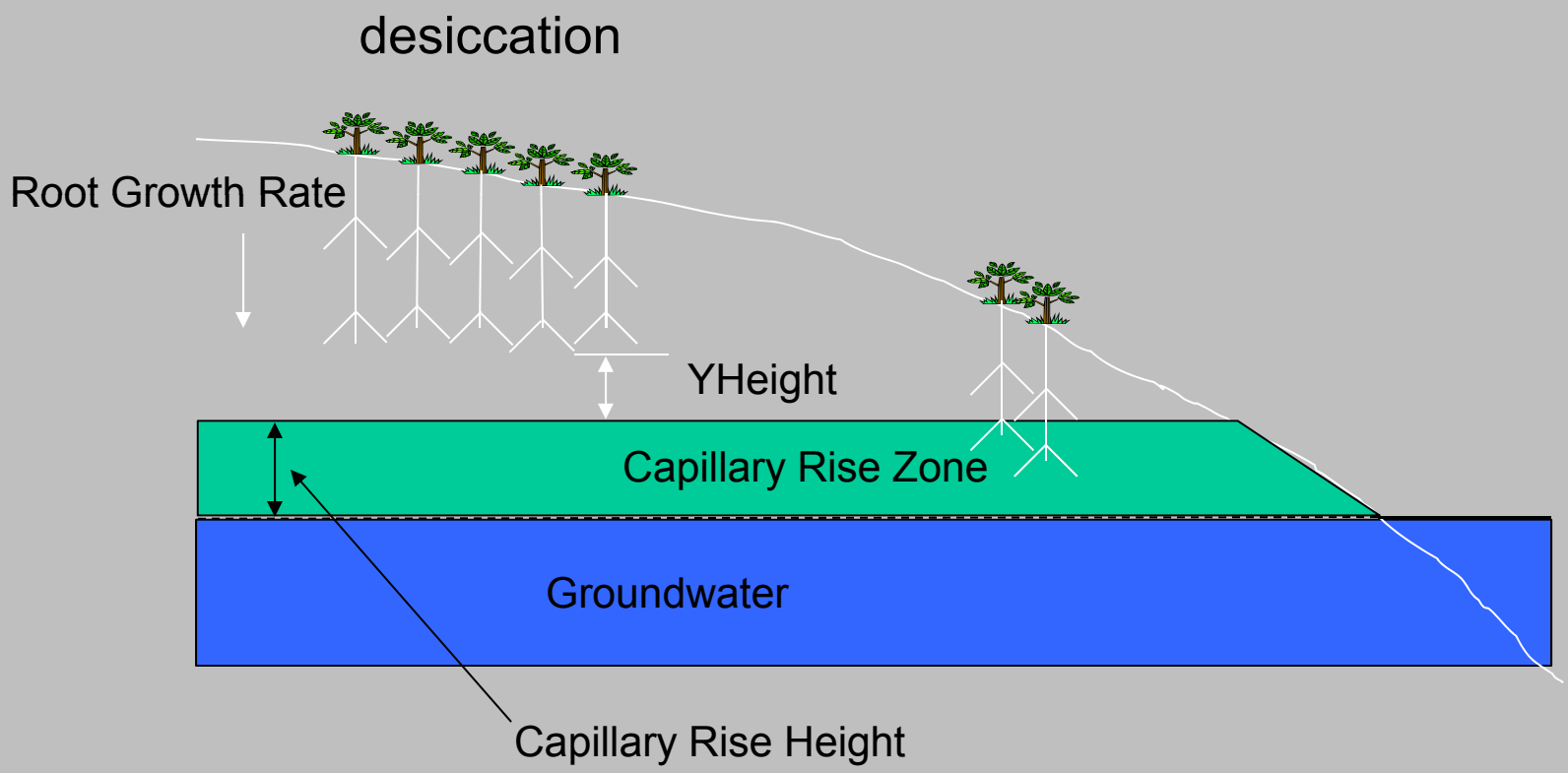
Vegetation is represented by plants at each point in a cross section



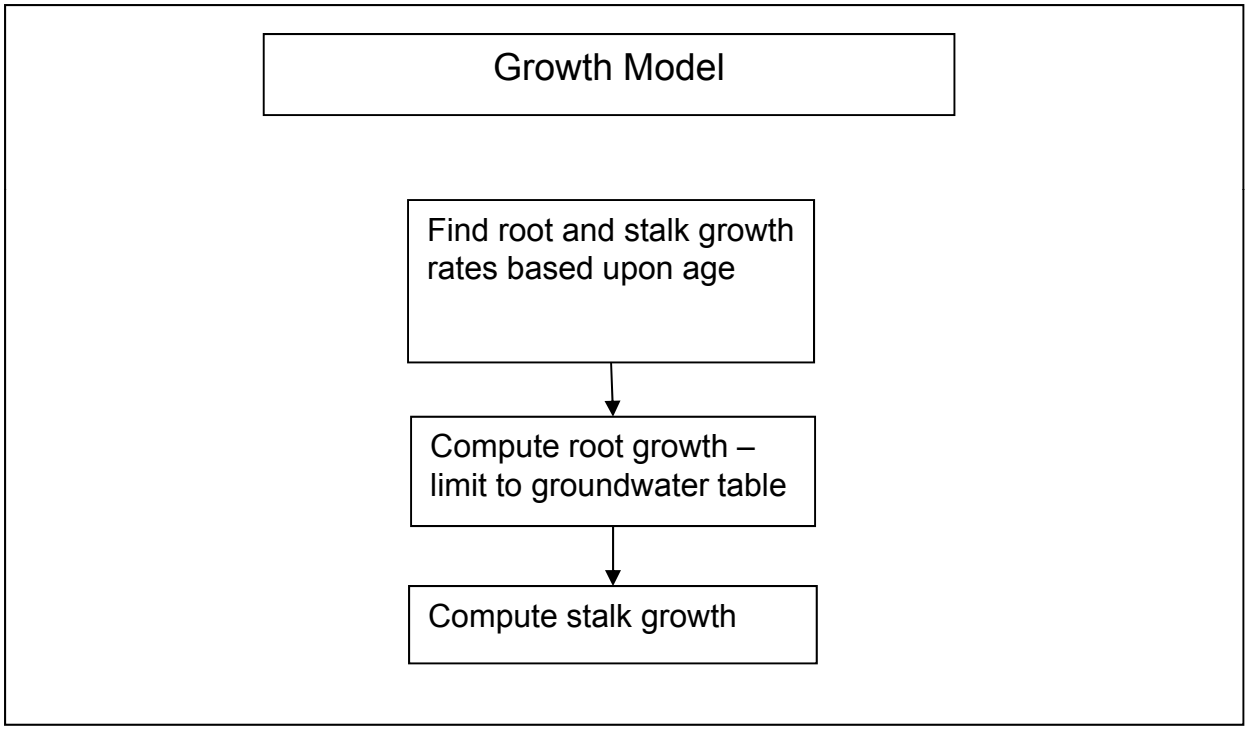
RVSM: Vegetation Recruitment



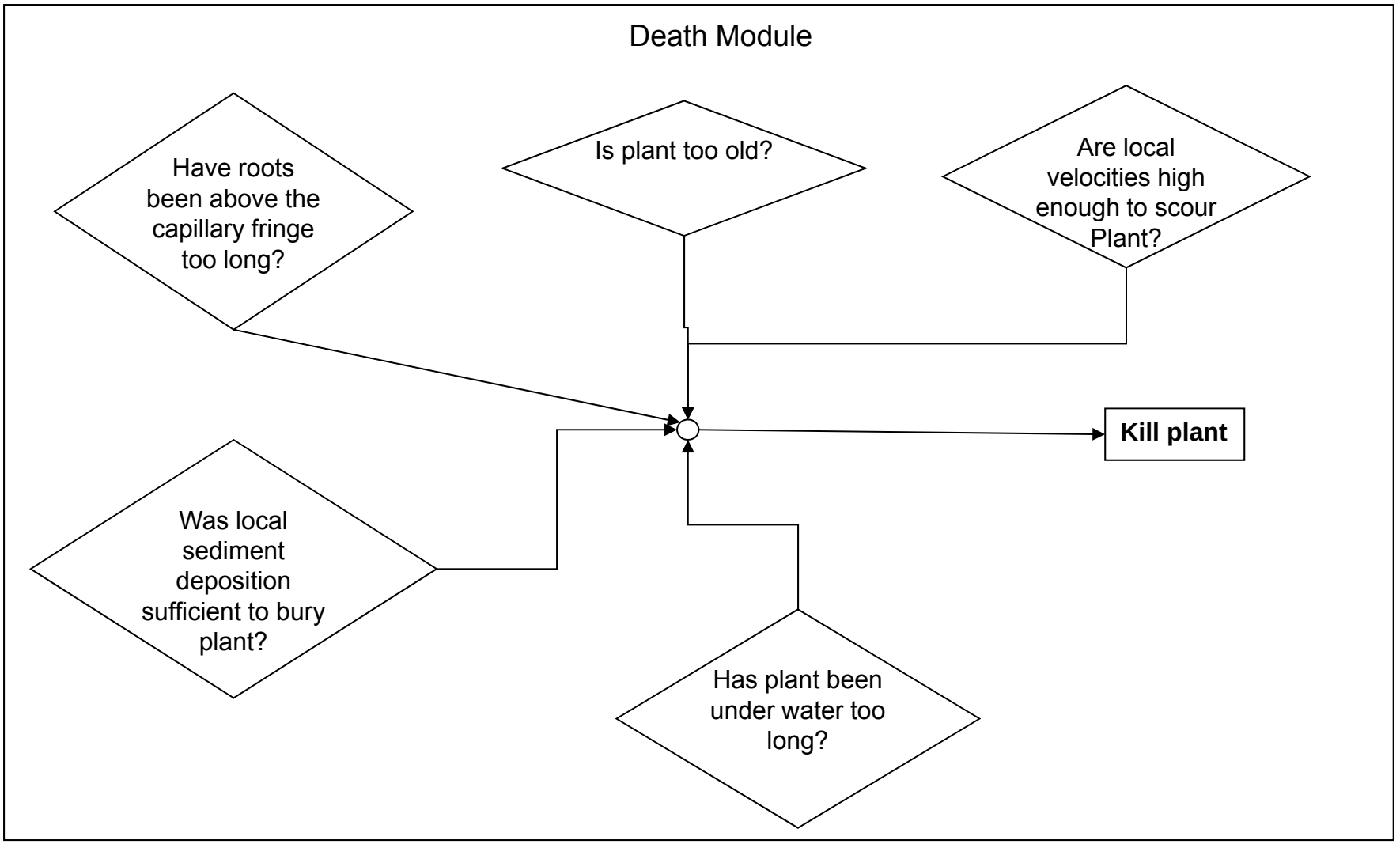
RVSM: Vegetation Recruitment Model



RVSM: Vegetation Growth



RVSM: Vegetation Mortality



Model Calibration Data Needs

- Hydraulic Model
  - Water surface elevation data
- Sediment Model
  - Sediment load data
  - Historical aggradation and degradation
- Groundwater Model
  - Groundwater
  - Boundary conditions at each xc
- Vegetation Model
  - Area of vegetation recruitment and survival over the course of many seasons

Model Input Requirements

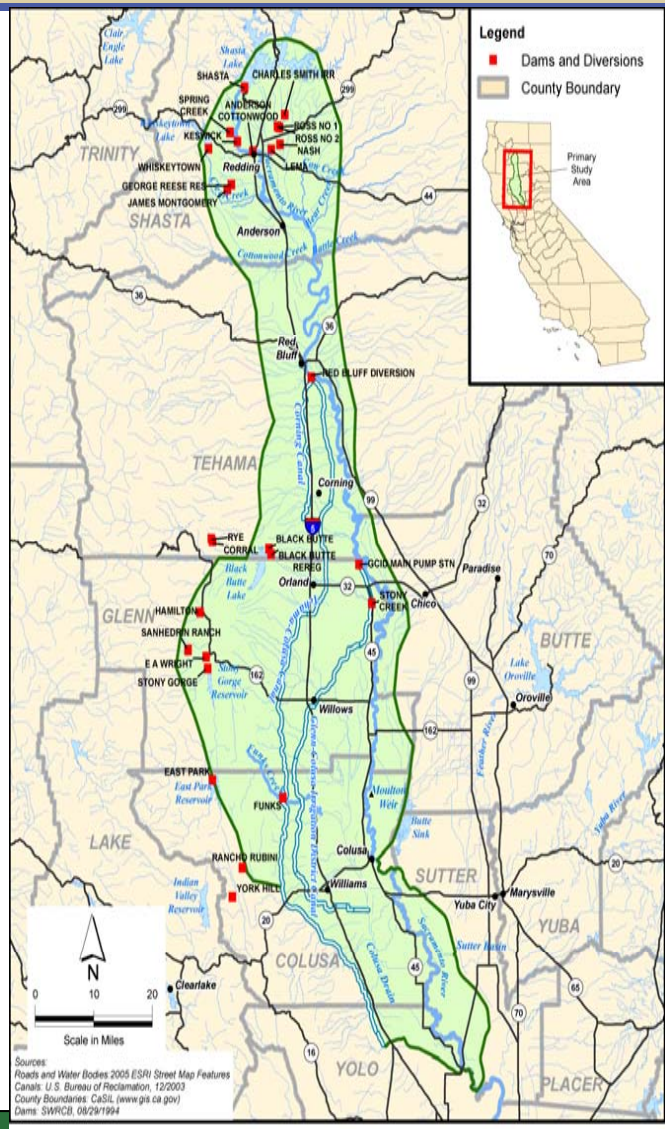
- Hydraulic Model
  - Geometry
  - Cross section data
  - Boundary conditions (including tributaries)
- Sediment Model
  - Sediment inflows
  - Bed material
  - Boundary conditions
- Vegetation Model:
  - Establishment parameters
  - Growth parameters
  - Mortality parameters
  - Simulating Initial Conditions

Example Project performed by SRH-1DV

SACRAMENTO RIVER CALIBRATION

- Used to evaluate the effect of a off-stream storage reservoir on the Sacramento River (NODOS) in California.
- Changing flow conditions were simulated by a flow operation model and downscaled to daily data.

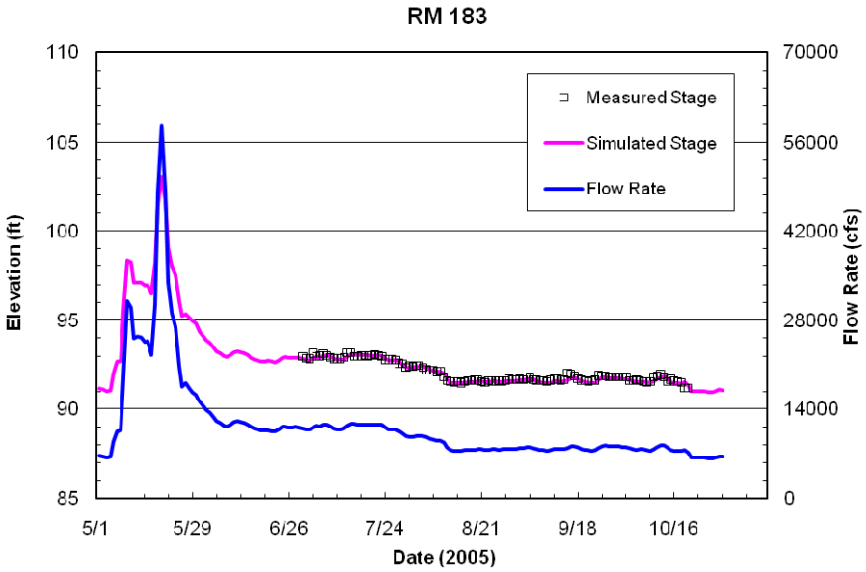
Note: Vegetation dynamics are programmed tightly within SRH-1DV and are not a separate sub-model.



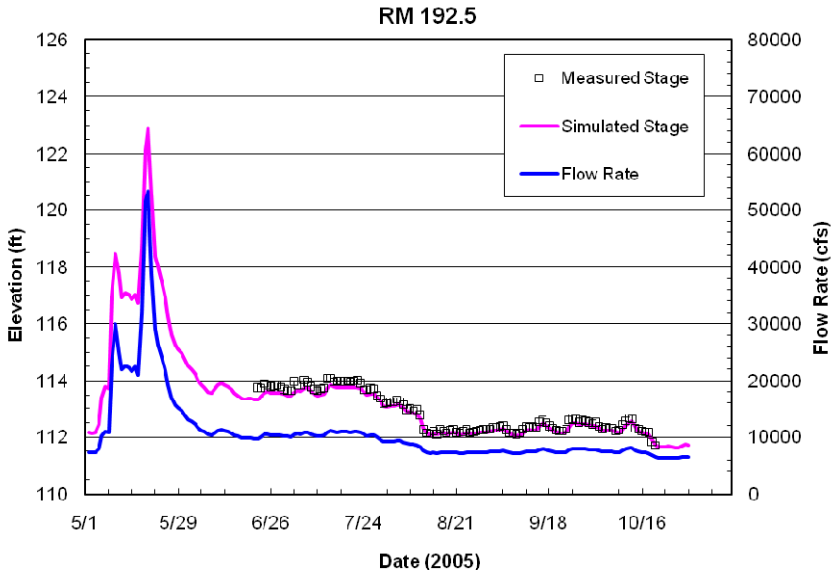
Calibration Studies During Model Development

- Flow and Groundwater
- Sediment Transport
- Cottonwood Establishment and Seedling Desiccation
- Survival of Multiple Vegetation Types

River Stage

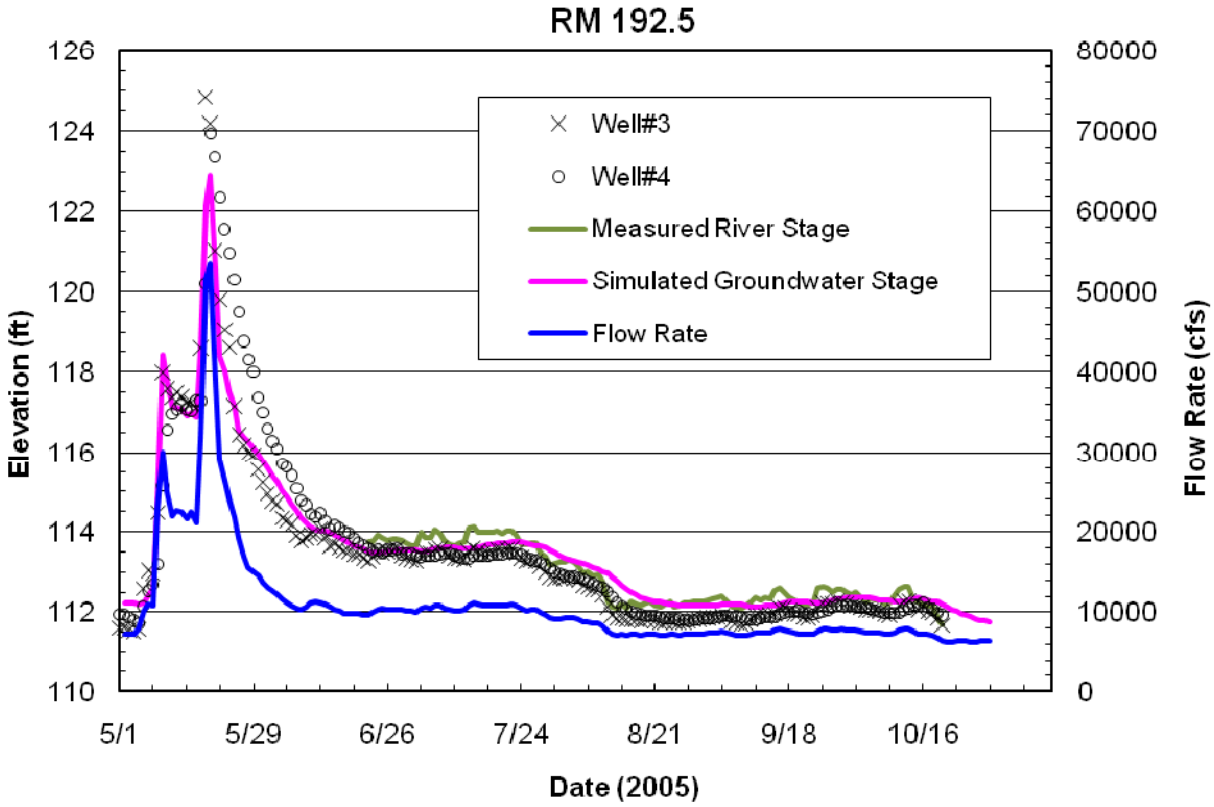


Comparison between simulated and measured river stage at CDWR RM 183. The flow rate is also shown.



Comparison between simulated and measured river stage at CDWR RM 192.5. The flow rate is also shown

Groundwater



Comparison between simulated and measured ground water elevation at CDWR RM 192.5.

Gravel Bedload Data

Sediment Transport

Sediment transport of individual size fractions is simulated, both bed load and suspended load

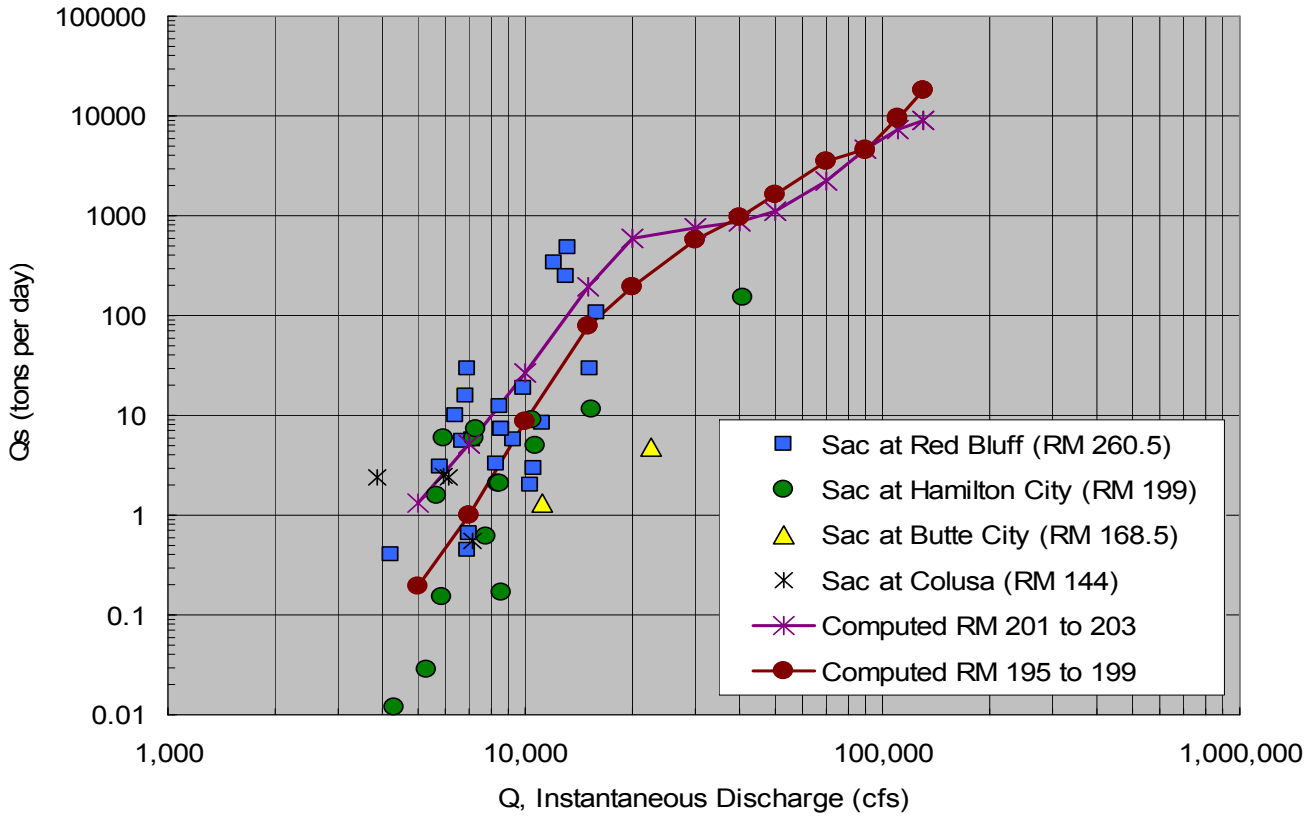
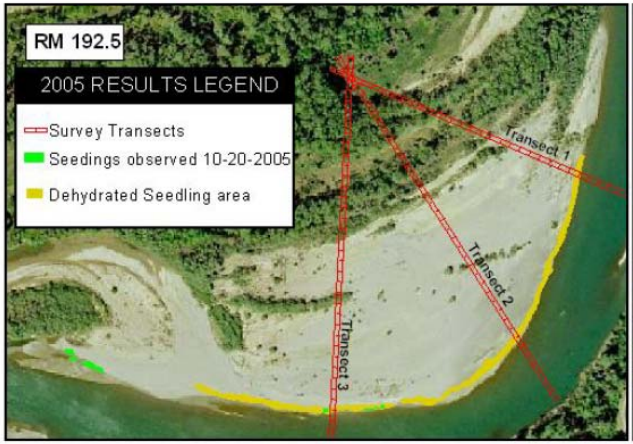


Figure 12. Seedlings before July 28th (left) were very healthy. The right photo, taken on August 23rd at RM 183, shows dehydrating seedlings following a recession exceeding root growth capabilities.



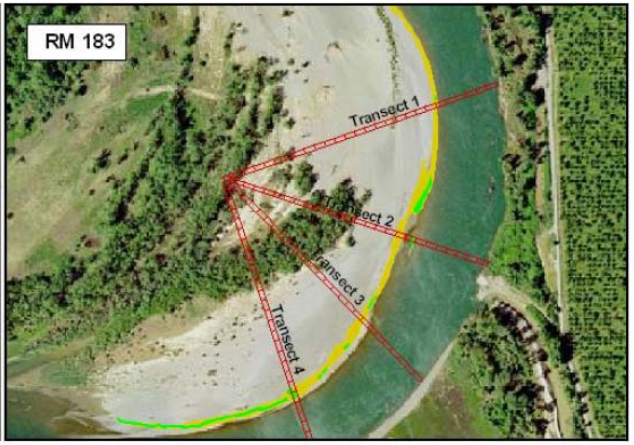
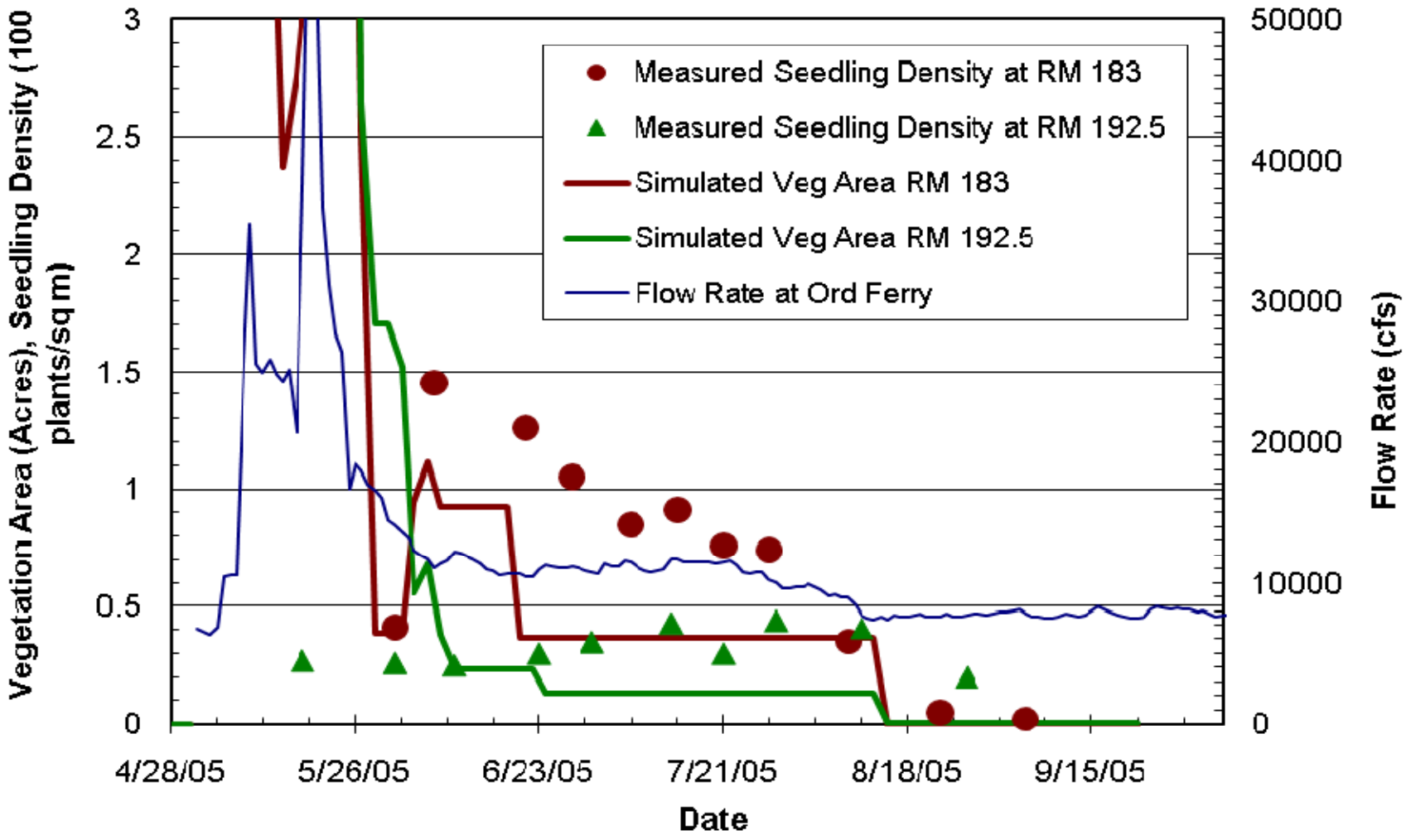


Figure 13. The study site aerial photographs show the dehydrated areas that were very healthy in July before the recession. The remaining seedlings that were still observed on October 20th were limited to an average 2 seedlings/m^2.

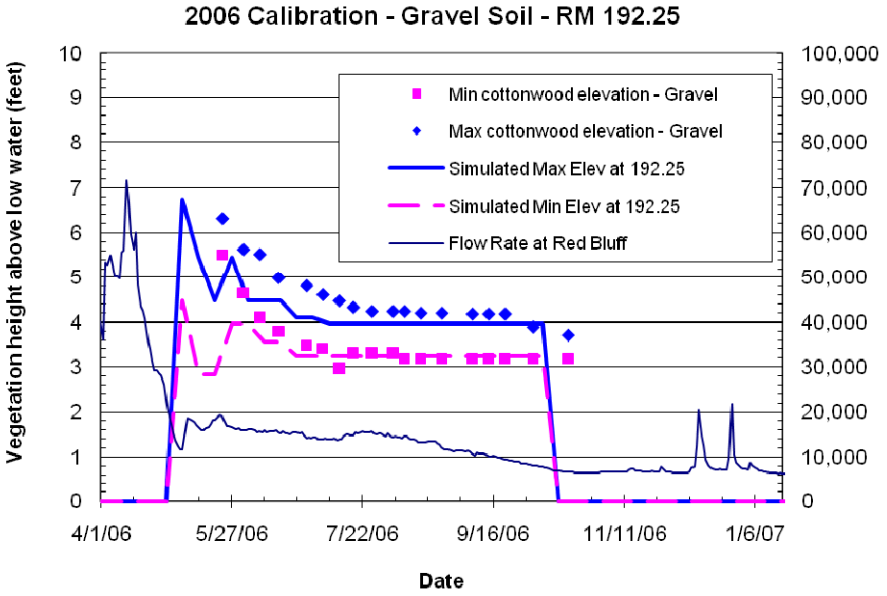
Simulation of Cottonwood Establishment at a point bar scale

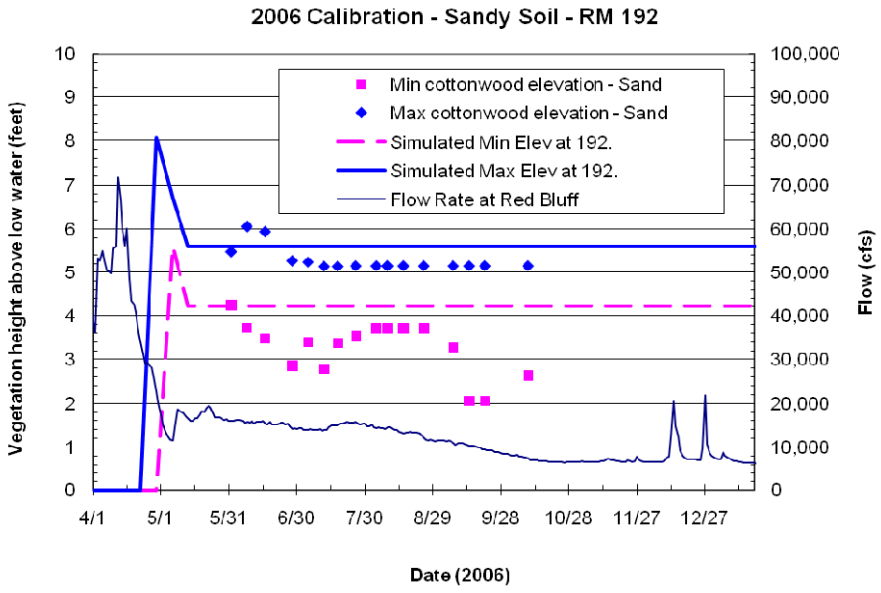
2005. Simulated area of cottonwood recruitment at RM 183 and RM 192.5 compared to measured seedling density



2006 Results

Measured and simulated values are compared to daily flow at the Red Bluff CDWR gage





Gravel Soil

Simulated elevation above low water (6,000 cfs) of cottonwood recruitment, compared to measured elevations of recruitment in 2006. Site has gravel soil on a point bar at RM 192.25.

Sandy Soil

Simulated elevations above low water (6,000 cfs) of cottonwood recruitment compared to measured elevations in 2006. Site has sandy soil on a point bar at RM 192.

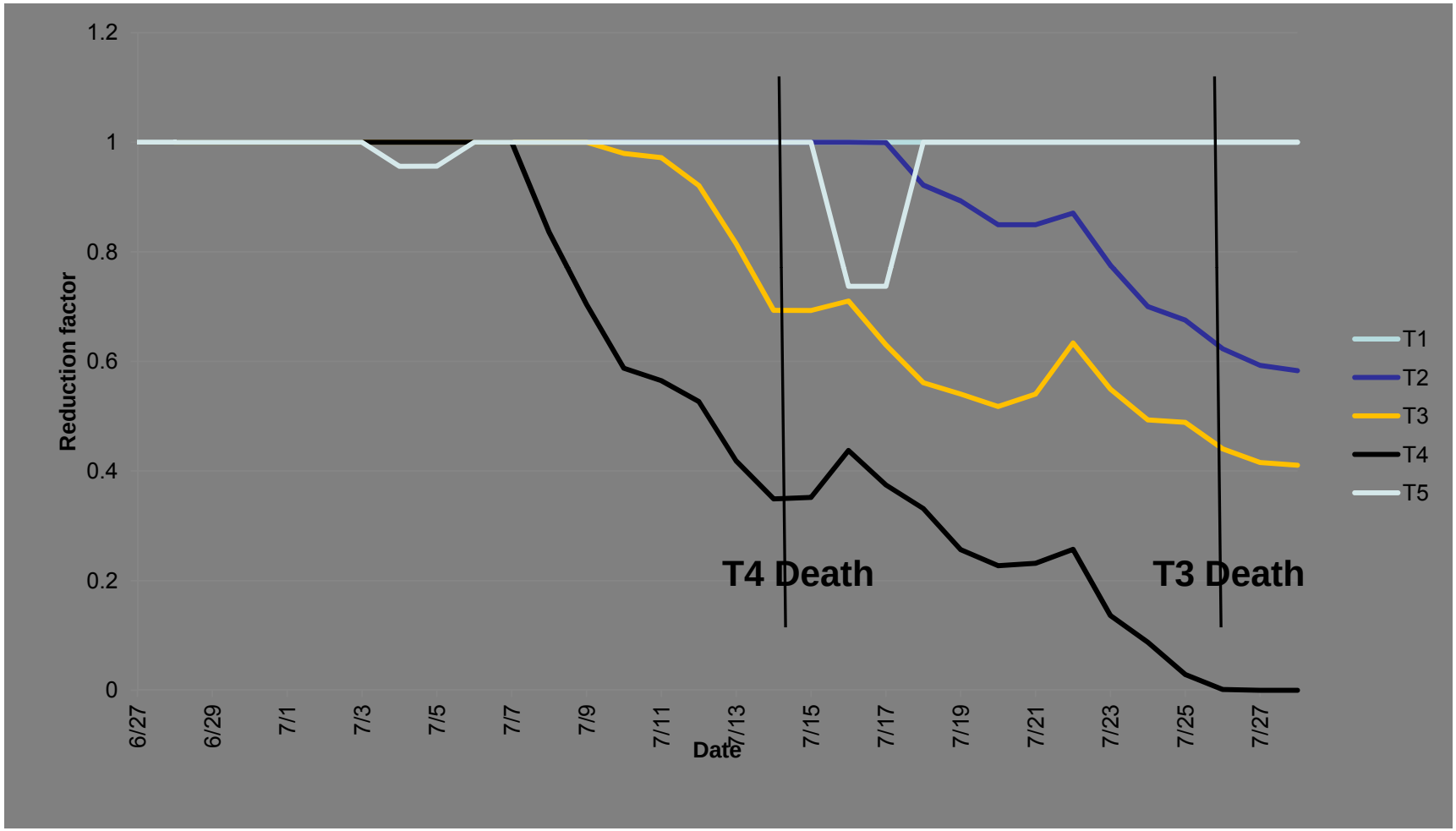
Improved desiccation and inundation mortality parameters from controlled laboratory experiments on cottonwood seedlings

Laboratory study by Stockholm Environment Institute, UC Davis, for the Mid-Pacific Region

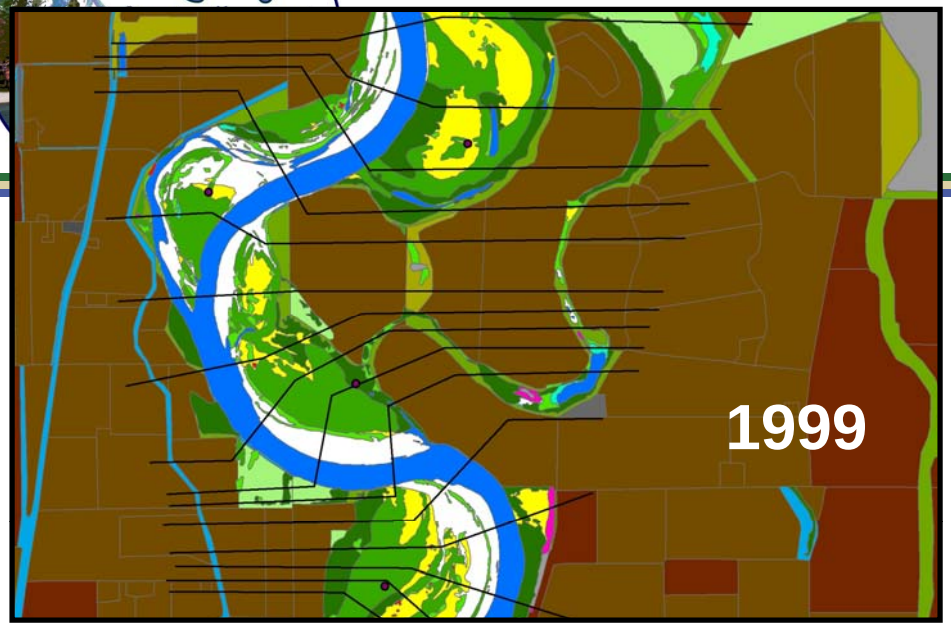
Irrigated Free Drainage

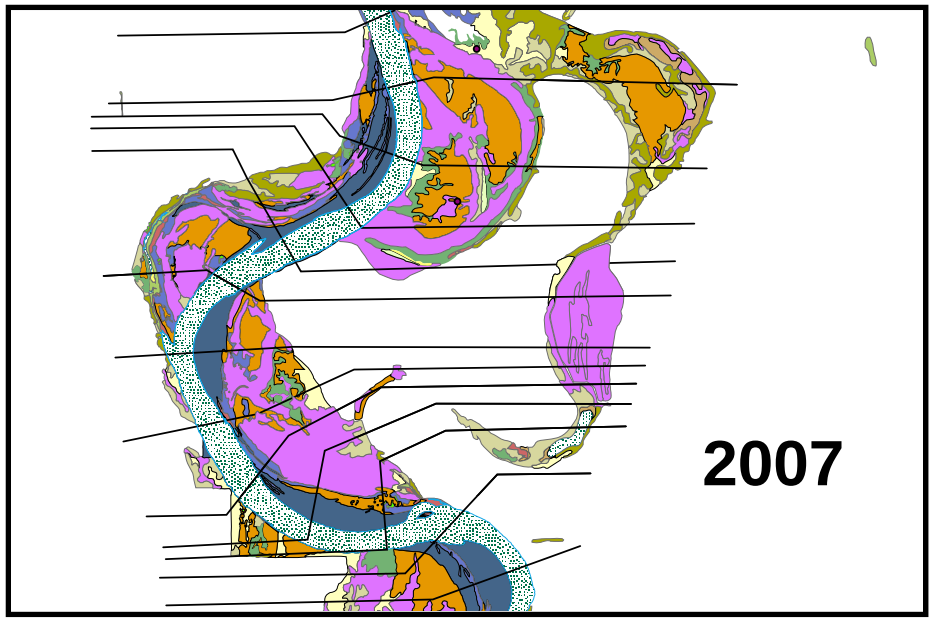
Water Table Decline, 1 cm/d

Drought Stress on cottonwood from laboratory study by Stockholm Environment Institute



Calibration using Vegetation Mapping





Compared change in model simulated vegetation coverage to GIS mapping changes in vegetation coverage

Viers, J.H., and R.A. Hutchinson. 2008. Sacramento River Vegetation Cross-Walk Comparison and Calibration Between Maps, Created in 1999 and 2007. A Technical Report to the CAL-FED Ecosystem Restoration Program. University of California, Davis

Calibration of Multiple Vegetation Types

	Year	Forests	Riparian	Invasives
		cottonwood & mixed forest	Gooding's black willow and narrow leaf willow (model) riparian veg and riparian scrub (mapping)	Invasive (model) or Giant reed (mapping)
Model (sand)	Year 1 ave acres	14,268	4,658	2
	Year 8 ave acres	15,074	6,340	3
	Year 1/ Year 8	1.06	1.36	1.81
Mapping	Year 1 ave acres	11,158	4,322	77
	Year 8 ave acres	10,993	6,036	131
	Year 1/ Year 8	0.99	1.4	1.71

Results of Sacramento River Calibration of SRH-1DV

- Flow calibration
- Groundwater estimates compared to groundwater wells at 2 gage station locations on Sacramento River
- Sediment transport – not as confident so turned off
- 2 yr field study on cottonwood germination at 3 Sacramento River sand bars
- 1999 and 2007 GIS vegetation mapping comparison – forests riparian - invasive (arundo) – not as confortable, removed

Applicability to USACE Projects Nation Wide

- HEC-RAS – RVSM tool will be able to be applied across the U.S.
- RVSM is being build from knowledge learned by the USBR in developing SRH-1DV. We will build the RVSM database from the vegetation database parameters USBR has already developed.
- The vegetation database included within RVSM will be further expanded to include more vegetation types across the U.S.
- Procedures will be developed to help guide planners and engineers in further developing more localized parameters for individual projects.

Capabilities to USACE

- *Combines physical processes and ecological performance* aiding in better understandings of river processes
- Provides a quantitative assessment of environmental response (vegetation and habitat)
- Is a predictive tool to evaluate management actions
- Simulation routines can be used for all riparian vegetation types

Specifically this work:

- Will allow the assessment of riparian vegetation interactions with riverine flows and sedimentation in support of the USACE ecosystem restoration and management mission.
- Model results can be used for environmental impact statement (EIS) and habitat studies, to support predictions of future physical conditions, and to inform alternative comparisons for restoration and maintenance actions.

Project Milestones

Status Report

FY13

- Evaluate USBR Riparian Vegetation Model and Plant Database - Completed

FY14

- Develop Riparian Vegetation Simulation Module (RVSM) suitable for integration with HEC-RAS – Currently underway
- Integrate the RVSM into HEC-RAS and develop the graphic user interface (GUI) – Will commence later in the FY and continue into FY15

FY15

- Integrate the RVSM into HEC-RAS and develop the graphic user interface (GUI) – Continued
- Data gathering, preparing data for model inputs, test the model integration and validate the HEC-RAS – RVSM model
- Develop documentation and tutorials

FY16

- Develop material for and perform model certification.

Products

- Software
  - Riparian Vegetation Simulation Module (RVSM)
  - Updated HEC-RAS model with riparian vegetation modeling capabilities (Certified Model)
- Documentation
  - ERDC Technical Report and Technical Note
  - HEC-RAS – RVSM Fact Sheet
  - Updated HEC-RAS User's Manual
  - Journal Article