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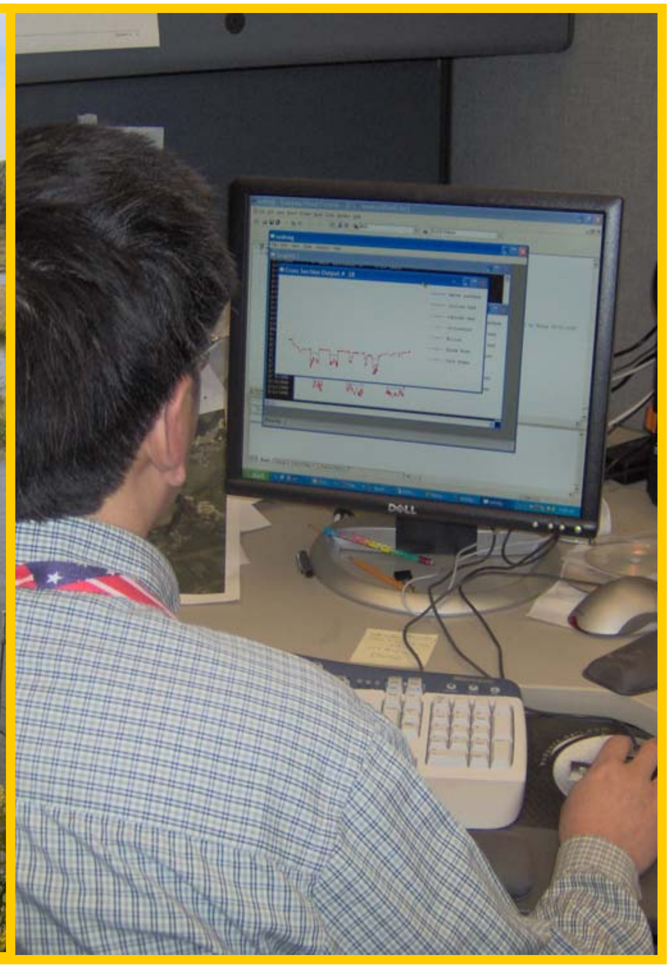
Platte River Sediment Transport and Riparian Vegetation Model



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Mission Statements

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Platte River Sediment Transport and Riparian Vegetation Model

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Various sediment transport subroutines in SedVeg Gen1 originate from Dr. Francisco Simões' (currently U.S. Geological Survey (USGS), formerly of the Bureau of Reclamation (Reclamation)), Sedimentation and River Hydraulics Group) development of version 2.0 of GSTARS.

Dr. Peter J. Murphy (Reclamation, Sedimentation and River Hydraulics Group) developed the SedVeg Gen1 code incorporating sediment subroutines from GSTARS version 2.0, vegetation subroutines from Simons and Associates, and writing improved code for sediment transport computations. He also developed the first and second (original and historical) Platte River models, and wrote the first draft of this report in 2001. Dr. Murphy continued to refine the SedVeg Gen1 code until his demise in 2002, and he remains first author of this technical report.

Dr. Gilbert Cannelli (Simons and Associates) contributed to development of vegetation subroutines of the SedVeg Gen1 code.

Dr. Robert Simon (Simons and Associates) contributed to the 2001 draft of this report, describing vegetation subroutines of the SedVeg Gen1 code developed by Simons and Associates.

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Timothy J. Randle (Reclamation, Sedimentation and River Hydraulics Group) contributed to development of the original GSTARS subroutines incorporated into SedVeg Gen1, contributed to the 2001 draft of this report, wrote all revisions to the SedVeg Gen1 code (SedVeg Gen2), and wrote many revisions to the SedVeg Gen2 code (SedVeg Gen3).

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EXECUTIVE SUMMARY

Introduction

SedVeg is a one-dimensional numerical sediment transport model that incorporates the effects of vegetation growth and removal on bank resistance values, and allows inclusion of managed mechanical changes to the channel. The model is process-based and was developed to evaluate the linkages between fluvial geomorphology, hydrology, river hydraulics, topography and channel geometry, sediment transport, erosion and deposition, and vegetation growth and mortality. SedVeg studies of the Central Platte River increase understanding of the geomorphology of the river. The model is used to estimate how modifications in river flow and sediment supply, combined with mechanical actions, will induce changes to the channel geometry and channel plan form over time, and affect the presence of vegetation in the flood plain. The model predicts these changes by simulating the linked processes with a one-day computation interval over a period of several decades to a century. The model is a time- and cost-efficient tool for evaluating habitat quality for various species of birds and fish, under a myriad of management options. SedVeg was developed to provide a quantitative method for comparing alternatives in support of the Platte River Environmental Impact Studies. The Platte Rive Program has also reaped benefits from the SedVeg numeric model through improved descriptions of complex processes, improved definition of the extent of process impacts, and in identification by type and location of less dominant processes.

Model Input

Input requirements for the model include hydrographs of mean-daily river flow for various points along the river, river cross sections to define the channel geometry (defined as a series of points across the channel), and sediment grain size distributions for each cross-section point. Additional required model inputs include the initial composition of up to four general vegetation species at each cross section point, vegetation growth rates, and removal criteria for each species. The program assigns a value of channel roughness to each point in the channel cross section depending on base values for bare sand and base values for general species and age of vegetation. Sediment inflow to the Platte River is entered in one of four ways determined by the location along the river and the generation of the code (SedVeg Gen1, SedVeg Gen2 or SedVeg Gen3). The cross section spacing for SedVeg Gen3 is one cross section every 1.4 miles, and the model begins in the south channel of Jeffreys Island between Lexington and Overton, and ends at Chapman, NE, 90 miles downstream.

Model Output

The model simulates the movement of sediment downstream, the evolution of the width to depth ratio of the channel geometry1 and sediment grain-size distributions, and the vegetation growth and removal for each general indicator species. River flow is the dominant variable affecting

[1] SedVeg, as a one-dimensional sediment transport model provides good information on general trends in cross section geometry, but detailed predictive information on cross section geometry at specific locations is best determined from a two-dimensional sediment transport model.

channel width, but channel width also responds to the inter-related effects of channel aggradation or degradation and the resulting changes in vegetation encroachment.

During the model run, display windows of selected cross sections illustrate changes to the geometry and presence of vegetation in the channel section over time. At the completion of the run, model output includes:

- hydraulic information on flow velocities, and main channel and side channel flow depths and wetted widths;
- annual cross-section points for plots presenting the initial and the predicted channel geometry, and the age of four general species of vegetation at each point in a section;
- daily sediment transport, deposition, and erosion rates for each cross section;
- grain size distribution for every cross-section point at daily intervals; and
- Biologic measures including vegetation free channel width for whooping cranes, seasonal specified flow depths for sand hill cranes and forage fish, and nesting and fledgling days for least terns and piping plovers.

Model Development

In 6 years, the SedVeg code and Platte River Model has proceeded through several cycles of development, calibration, verification, and sensitivity testing. The code and model has also been reviewed externally on several occasions, and undergone two major revisions based on internal assessments and external reviews that defined areas for improvement.

There have been four Platte River Models distinguished by the input data and the generation of the code used in development of the model. The four models are:

- SedVeg Gen1 Platte River Model, the original developmental model;
- SedVeg Gen1 Historical Platte River Model, used for calibration of SedVeg Gen1 code;
- SedVeg Gen2 Platte River Model, used in the Platte River Draft Environmental Impact Statement (DEIS), U.S. Department of the Interior (USDOI) (2003); and
- SedVeg Gen3 Platte River Model, used in the Platte River Final Environmental Impact Statement (FEIS) (USDOI, 2006).

Model Results

Results from the SedVeg models of the Platte River were interpreted on a reach basis since several different trends can be identified in the length of river assessed by the model. Each reach consists of multiple cross sections and the locations identified are approximate only.

The SedVeg Gen1 and SedVeg Gen2 Platte River models showed aggradation for several miles downstream of North Platte, NE.

Downstream of the Johnson-2 Return, pronounced degradation is present, diminishing with distance downstream, as sediment inputs increase from bed and bank erosion, tributary inputs of sand, and sediment inputs from the confluence with the north channel of Jeffreys Island. Depending on the years analyzed, this trend ends between Elm Creek, NE and Kearney, NE.

Downstream of Elm Creek, a dip in sediment transport indicates a reach of aggradation from Kearney, NE to Mindon, NE, followed by a reach of degradation from Mindon, NE to Gibbon, NE. Due to a shortage of measured cross sections in this reach, synthetic cross sections are employed to bridge the gap. A lack of quality cross section data in the gap somewhat decreases the confidence in information from this reach.

In the reach between Gibbon, NE and Wood River, NE, at a location presumably dependent on the flow years considered, there is aggradation for approximately 5 miles. This condition appears to be due to the upstream reaches having generally greater transport capacity then the downstream reaches.

From Wood River, NE to Chapman, NE, the river appears generally stable under present conditions. However, when the model is run for 61 years beyond 2005, using a repeat of 47 years of hydrologic record (1947 to 1994) that is adjusted for present day river operations (reservoirs, canals, hydropower production), this reach develops a trend of degradation.

Model Assessment and Future Directions

This sediment transport model provides a cost efficient and time effective approach, and the continued use of SedVeg Gen3 is recommended as an evaluation tool under the adaptive management plan of the Platte River Program. The most beneficial improvement to the SedVeg Gen3 Platte River Model at this time would be the addition of quality base data and field test data. This information would aid hypothesis development, allow more definition of complex processes, and support continued model calibration and verification efforts.

Table of Contents

1.0 Introduction

This report describes the development and application of the SedVeg numerical models to simulate geomorphic changes to the river resulting from the river hydrology, topography, flow hydraulics, sediment transport, life cycles of riparian vegetation, and mechanical and managed actions to the river channel. SedVeg has been developed as a tool to evaluate the relative performance of environmental impact statement (EIS) alternatives for the Platte River in the critical habitat area between Lexington, NE and Chapman, NE (Figure 1.1). Information on the Central Platte River habitat recovery program (Colorado, Nebraska, Wyoming, and the U. S. Department of the Interior, 1997), which addresses concerns over diminishing habitat for the threatened or endangered species: Whooping Crane, Least Tern, Piping Plover, and Pallid Sturgeon, is introduced in the report by the National Research Council (2005) and described by the FEIS by the USDOI (2006).

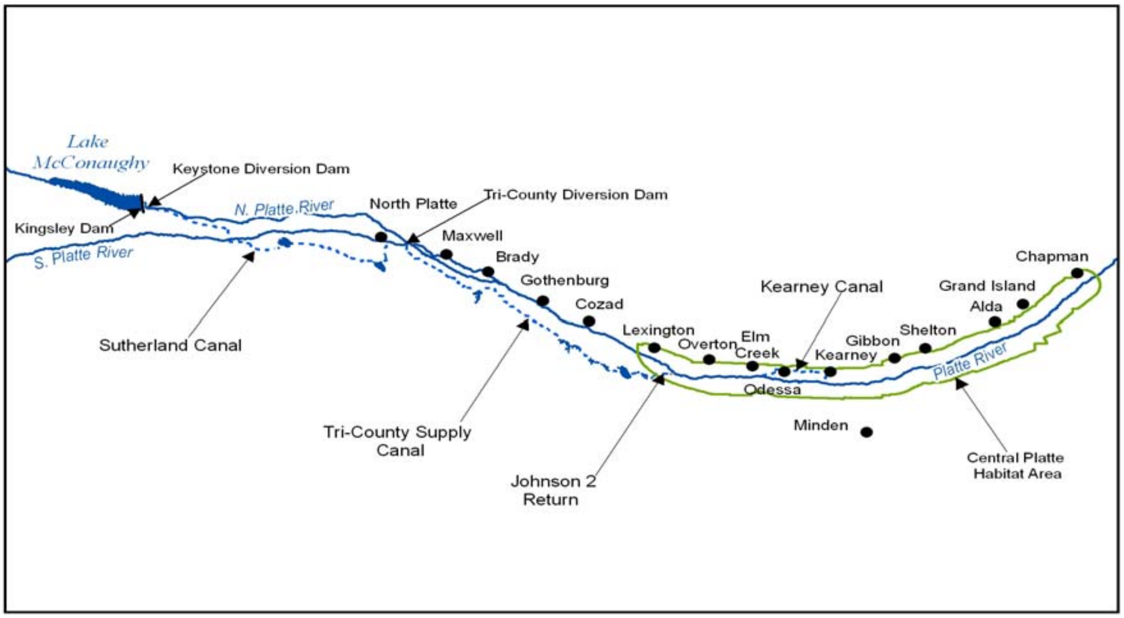

Figure 1.1. Location map of the Platte River

The most recent version, and the focus of this report, is the SedVeg Gen3 Platte River Model. However, the development of the SedVeg Gen1 and Gen2 codes are also presented with the development of their associated models. There are four Central Platte River Models distinguished by the input data and the generation of the code used in development of the model. The four models are:

- SedVeg Gen1 Platte River Model - the original development model;
- SedVeg Gen1 Historical Platte River Model - used for a historical calibration of the SedVeg Gen1 code;
- SedVeg Gen2 Platte River Model - used in the DEIS (USDOI, 2003); and
- SedVeg Gen3 Platte River Model - used in the Platte River FEIS (USDOI, 2006).

1.1 Background

The present channel plan form of the Platte River in central Nebraska has changed from the channel plan form shown in original U.S. Geological Survey (USGS) topographic maps from 1896 to 1902 (USGS, 1896-1902). Substantial changes are also apparent in comparison to channel plan form observed in 1938 aerial photographs (Fish and Wildlife Service (FWS) 1938). Upstream of Overton, NE (Figure 1.1) reaches of predominantly wide, braided river have evolved to narrow and single-channel, meandering river, while downstream of Overton, NE, reaches of wide, braided river have evolved to reaches of anastomosed river interspersed with braided river (USDOI, 2006). Anastomosed river is identified by the vegetated islands, which divide multiple side channels. Braided river also exhibits multiple side channels at low flows, but are divided by sand bars with limited vegetation. Under high flow conditions in braided river, the sand bars are inundated creating a generally single, wide channel. Periodic inundation of the sand bars generally limits the growth of vegetation. Changes in channel plan form and width to depth ratios are generally attributed to changes in flow or stream power (flow and longitudinal river slope), sediment, and bank stability (Bridge, 1993).

Within the Platte River, the primary influences on channel plan form and cross-section geometry are identified as (USDOI, 2006):

- Reductions in the annual peak and volume of river flow (Williams, 1978; Eschner *et al.*, 1983; Simons and Associates, 2000; and Randle and Samad, 2003);
- A disruption in sediment transport (Simons and Associates, 2000) resulting from the diversion and return of the Tri-County Supply Canal (Randle and Samad, 2003; and Murphy *et al.*, 2004) with this impact intensified by the construction of the Jeffreys Island dike (Holburn *et al.*, 2006); and
- Topographic features (a bank stability factor) formed by higher flows in the nineteenth century or earlier (remnant braid scars, remnant terraces, and remnant sand bars) and topographic features constructed by man in the twentieth century (dikes, bridge abutments and reinforced banks) (USDOI, 2006). Through flood plain width these topographic features either promote braiding and preferred habitat (remnant sand bars, bridges[2], and some dikes and reinforced banks) or promote non-desirable anastomosed plan form (widely spaced terraces).

Secondary factors that are understood to have impacts on channel plan form not as pronounced or as well-defined as primary factors include:

- The coarsening of the riverbed sediment from channel incision (i.e., erosion of finer particles from the bed of the channel) and a shift in sediment grain-size supply (i.e., an increase in supply from South Platte River in comparison to supply from North Platte River) (Simons and Associates, 2000; and Murphy *et al.*, 2004);
- The expansion of riparian vegetation into the nineteenth century flood plain (Eschner *et al.*, 1983; Sidle *et al.*, 1989; Currier, 1997; Johnson, 1997; and Simons and Associates, 2000); and
- Reductions in slope resulting from bed degradation (USDOI, 2006).

[2] Prior to the FEIS (USDOI, 2006), only detrimental effects to river plan form had been associated with human structures.

The coarsening of grain sizes is a sediment factor influencing the erosion resistance of the channel; the expansion of riparian vegetation into the flood plain is a bank stability factor influencing the erosion resistance of the river bank, and a change in slope is a stream power factor influencing the plan form of the river and sediment transport.

Processes describing the interaction of many of these primary and secondary factors are introduced by Murphy *et al.*, 2004, while the conceptual impact of all factors on the channel plan form and cross-section geometry are summarized by USDOI, 2006. The physical processes that link these multiple factors are complex and interrelated.

1.2 Approach

Geomorphic, hydraulic, and sediment transport analysis techniques have been developed over the past several decades. Simons, Li & Associates (1982) present a three-level approach to applying these analysis techniques to river studies. The first level is a qualitative geomorphic analysis. The second, and more detailed level, includes quantitative engineering and geomorphic analysis. The third, and most detailed level of analysis, includes quantitative computer modeling. The ASCE Task Committee on Hydraulics, Bank Mechanics and Modeling of River Width Adjustment (1998) presents a similar tiered approach to analysis of river channel morphology. These three-level approaches promote understanding of physical processes governing the flow of water, transport of sediment, effects of topography, and the growth and removal of vegetation on the resulting river width and depth. Each subsequent level of analysis builds on the understanding developed by the previous level, and any inconsistencies tend to be reconciled concluding with mutually supportive and scientifically justifiable results. This approach ensures that important governing geomorphic principles are considered and that the results of more technical and detailed analyses (including computer modeling) are consistent with universal principles.

An assessment of the issues and available technologies suggests that the relatively simplified geomorphic and engineering analysis techniques (the first two levels of the three-level approach) alone can not sufficiently evaluate future channel response. There is a need to evaluate the interaction of a future hydrograph over the next several decades, or an even longer period, with external management actions. A model that incorporates key processes would be required to analyze these interactions in the third level of analysis in order to track current and future changes to the channel.

This tiered approach is applied to the present study of the Platte River. The first two levels of analysis were outlined in Chapter 1.1 of this chapter. The third level of analysis, computer modeling using the SedVeg code for a Platte River model, is described in the following chapters of this report. The SedVeg code incorporates various algorithms that describe the key processes (time step by time step) in calculating the response of the river over the length of a multi-decade daily flow hydrograph. The model results are then compared with the first two levels of analyses to ensure accurate and reliable results. This approach is designed to provide an appropriate balance between actual and modeled complexity of the river system and feasibility in obtaining a reasonable solution. The SedVeg code, like all numerical programs, contains certain assumptions and simplifications. However, within the framework of these assumptions the model simulates the dominant processes and interrelationships so as to be an effective tool in evaluating alternative flow, alternative sediment regimes, and mechanical management strategies.

1.3 Objectives

The SedVeg numerical model can help assess how changes in river flow, sediment supply, and mechanical management actions will cause the channel characteristics to change over time. These characteristics are then used to evaluate the habitat quality for whooping crane, least terns, piping plovers, sand hill cranes, and the forage fish for some of these species. The objectives of this study are to:

- Describe and present a tool, SedVeg Gen3, which can aid in evaluating future changes to the river resulting from natural conditions and managed actions;
- Describe the development of the SedVeg Platte River Model including calibration studies, verification studies, sensitivity studies, and reviews; and
- Apply the model to help assess the current geomorphic condition of the Central Platte River.

Provided in Chapter 2 is a general description of assumptions, methods, and computations employed by the SedVeg code, and Chapter 3 outlines the governing equations of the code. Development of the SedVeg Gen1 and Gen2 codes are described in Chapter 4, including model calibration, verification, sensitivity studies, reviews, and code and model revisions based on these efforts. Additional details of calibration and sensitivity studies can be found in Appendix D and Appendix E, and responses to specific review comments can be found in Appendix B. The development of the SedVeg Gen3 Platte River Model and the results describing sediment transport in the Central Platte River are presented in Chapter 5. Chapter 6 contains an assessment of the current SedVeg Gen3 code and Platte River Model and recommends future directions for this study.

2.0 General Methods and Assumptions

A description of the model begins with input data and parameters, follows with a general discussion of the computations made by the SedVeg code, and concludes with the nature of the information provided in the output. Input files and output files for the SedVeg Gen3 Platte River Model under Present Conditions can be found in Appendix A.

2.1 Input Data

The results and detail of a numerical model are dependent on the data entered. The river cross sections form the skeleton of the physical condition being modeled. Information on volume and location of daily flows, sediment gradations, vegetation types and ages, sediment boundary conditions, soil conditions, air temperatures, and other parameters all help to build upon this skeleton to represent key aspects of the physical world. The goal is to best reflect the significant conditions of a three-dimensional world with generally, for this type of modeling[3], a one-dimensional palette.

2.1.1 Flow Data

The flow rate of the water in the Platte River varies with time and river mile, and that variation is caused presently by a combination of natural processes and man-made controls. Two principal natural processes are rainfall and snowmelt. Man-made controls consist of a series of large storage reservoirs on the North Platte and South Platte Rivers, diversion dams, and canals. These structures help to regulate, but not completely control, the natural flow of the Platte River. Principal structures that affect Central Platte River flows include: the Kingsley Dam (forming Lake McConaughy) on the North Platte River, the Keystone Diversion Dam on the North Platte River, the Korty Diversion Dam on the South Platte River, the Tri-county Diversion Dam on the Platte River, the Tri-county Supply Canal, the Johnson-2 Return of the Tri-county Supply Canal, and the Kearney Diversion Dam on the Platte River (Figure 1.1).

River flow rates are defined as a series of mean-daily flows (TEMPFLOWNS.PRN file) that can represent over a century of time. Flow rates are separately defined for locations (INPUT18.DAT file) throughout the modeled reach. At each location, the mean-daily flow rate is assumed to be constant over the daily time step. The beginning year, the number of years of the run, and the daily air temperatures are also entered in the TEMPFLOWNS.PRN file.

The input river flows for the Platte River Models (excluding the SedVeg Gen1 Historical model used for calibration), were computed by the OpStudy hydrologic model (Stroup and Anderson, 2006). These flows were based on a 48-year period of USGS gage data (1947 to 1994) that were adjusted using the OpStudy model to represent flow management operations for the principal reservoirs, canals, and hydropower facilities in the year 1998. This 48-year-period of record, adjusted to current operating procedures in the Platte River system, was then used to predict conditions 48 years into the future. The flows used for modeling future conditions in the SedVeg Gen3 Platte River Model also include adjustments for the maximum depletions allotted to the states of Nebraska, Wyoming, and Colorado. See Appendix C for more information on the flows

[3] One-dimensional modeling is often recommended (ASCE, 1998) as the base study for understanding the transport of sediment across long and continuous reaches of river.

used in the SedVeg models.

River flows used in the SedVeg Gen1 Historical Platte River Model were based on USGS flow gage records with no adjustments, because they represented a period with no major flow management operations (Appendix C). Flows used for the "warm-up period" of the SedVeg Gen 3 Platte River Model were based on USGS gage records from 1989 to 2005 and not adjusted since they represented the same period.

2.1.2 Cross-Section Data

The SedVeg Platte River Models use a series of cross sections spaced along the Platte River to represent the varying channel geometry. These cross sections are oriented perpendicular to the flow and are described by a series of data points that define the distance across the channel and the elevation of the river bed (INPUT18.DAT file). The number of points in every cross section varies. However, most cross sections have between 80 and 250 points. A description of the models and the number of cross sections in each model are listed in Table 2.1.

Table 2.1. Description of SedVeg Models.

Model	Application	Reach Length	Reach Begins	Reach Ends	Cross Sections
SedVeg Gen1 Platte River Model	Developmental	151 miles	North Platte, NE	Chapmen, NE	17
SedVeg Gen1 Historical Platte River Model	Calibrate SedVeg Gen1	151 miles	North Platte, NE	Chapmen, NE	17
SedVeg Gen2 Platte River Model	DEIS alternatives evaluation	151 miles	North Platte, NE	Chapmen, NE	33
SedVeg Gen3 Platte River Model	FEIS alternatives evaluation	92 miles	Johnson-2 Return (between Lexington & Overton, NE)	Chapmen, NE	62

The sediment grain-size distribution and the age in months of four vegetation species can be initially defined for each point within each river cross section (INPUT18.DAT file), and these values can vary to reflect locations within the floodplain, including the channel bed, banks and terraces. An age of 0 months for all four species of vegetation at a point designates that location as bare sand. In addition to cross section geometry, sediment gradation, and vegetation age in months, the INPUT18.DAT file links the correct flow input data and sediment input data for each cross section.

2.1.3 Sediment Data

Sediment enters the model (boundary conditions): from the upstream main channel, from tributaries discharging to the river, and as augmented sand that is mechanically added to the river. The SedVeg Gen1 and SedVeg Gen2 method for adding sediment across the boundaries of the model is a computation of sediment transport capacity (i.e., maximum volume of sediment that can be transported at the cross section) based on the river flow, hydraulic conditions, and the bed material grain-size distribution at the supplying cross section (SED.DAT file). Maximum transport capacity is then multiplied by the coefficient, Fraction of Sediment Transport Capacity.

The newest version of the model, SedVeg Gen3, has three additional methods for introducing sediment at specified locations, such as the upstream main channel, side channels and tributaries, and where mechanical augmentation occurs. These additional methods for incorporating sediment input include:

- the use of a sediment rating curve to input varying sediment loads (SED.DAT);
- a specified fraction of an annual load (TRIBSEDLOADS.PRN file); and
- a specified but varying daily load entered as a sediment input file (UPSTREAM.CN6 file).

Within the river model (not an input boundary condition), sediment is also added or removed from the flow as the cross section geometry changes to reflect erosion or deposition. Sediment transport parameters are input in the SED.DAT file.

2.1.4 Mechanical Actions

Mechanical changes to the channel resulting from management actions are entered in the XSECADJ.PRN input file. This file specifies the day and year when the change is to occur, the cross section and points where the change is to occur, and specifies whether vegetation is to be removed, or a cut or fill is to be made to the channel cross section.

2.1.5 Vegetation Inputs

As described under cross section data (2.1.2), the initial age of each vegetation species at every point in a cross section is entered in the INPUT18.DAT file. Vegetation parameters for growth and mortality are input in the VEGCOEF.DAT and ICE.DAT files.

2.2 General Description of Model Computations

After developing input files, a model run will advance in specified time steps through routines which address and track hydraulics, sediment transport, grain size, deposition and erosion, and vegetation growth and mortality computations. As each time step progresses, each cross section will automatically adjust accordingly.

2.2.1 Hydraulic Computations

For each time step, the river hydraulic parameters are computed at each cross section under conditions of steady uniform flow. The computed hydraulic parameters include water-surface elevation, depth, width, and velocity. The water-surface elevation is assumed to be level across each section. The groundwater elevation is also assumed to be level and equal to the water surface elevation of the wetted channel. Both average and point-by-point hydraulic parameters are computed for each cross section. For each cross section, the water-surface elevation and flow width for each daily flow are calculated based on the average hydraulic properties of the wetted channel. The computed average-channel roughness accounts for any vegetation present in the cross section. Flow is distributed across each section using the local conveyance associated with each point of the cross section. Local water velocity at each point is computed based on the lateral flow distribution. Local water depth is computed as the elevation difference between the water surface and the channel bottom.

The assumptions of uniform and steady daily flow were critical to the computations of the above mentioned hydraulic parameters. Uniform flow exists at a cross section when flow conditions there are not affected by the flow conditions at either upstream or downstream locations (e.g., backwater from a bridge constriction or diversion dam), and when the water-surface slope, the thalweg slope (longitudinal slope along the lowest points of the channel), and the slope of the energy grade line are all parallel. The water depth under uniform flow conditions is called normal depth. The normal depth assumption is valid because the cross sections are generally widely-spaced in a basin-wide assessment. Because of the wide spacing, the hydraulic computations at the cross sections are nearly independent from one another.

However, the thalweg slope provides a hydraulic link between cross sections. The thalweg is the lowest elevation at which water flows in each cross section. The change in thalweg elevation between cross sections divided by the downstream distance between cross sections is the thalweg slope. The thalweg slope of the Platte River from North Platte, NE to Grand Island, NE is fairly consistent and averages 0.0012 ft/ft. The thalweg slope is used in calculating normal depth and is the hydraulic connection between the normal depths at two neighboring cross sections. Depending on the cross-section spacing, the change in thalweg elevations between cross sections can be 10 ft or more, and deposition and erosion may change the elevation of the river bed a few feet.

One fixed thalweg elevation is added to the SedVeg model downstream from the last cross section for sediment transport computations across the downstream cross section.

One-dimensional Uniform Flow

Manning’s equation is commonly used to describe conditions of one-dimensional, uniform flow. This equation (relating the mean velocity, average depth, width, channel roughness and thalweg slope with flow rate) is presented in Chapter 3 of this report. Main-channel and the floodplain properties are averaged separately in applying Manning’s equation. The equation is solved to determine the daily water-surface elevation at each cross section and the average velocities for the main channel and floodplains. During model simulation, the changing daily flow rate and river bed may cause these hydraulic variables to vary daily at each cross section.

Transverse Flow Distribution

Local depth at each cross-section point is determined by the water-surface elevation and the bed elevation. Local river hydraulics are calculated by assuming that Manning’s equation can be applied at each point to determine local velocities from the local depth, width and roughness associated with each wetted point of the cross section. In the Platte River, this is a reasonable assumption due to the wide and shallow (large width-to-depth ratio) nature of the river. Local flow rates, calculated as velocity times width times depth, are summed and scaled to assure equality with the given daily flow rate. These local properties are later used to calculate the sediment transport associated with each cross-section point.

2.2.2 Sediment Transport and Grain Size Computations

Equilibrium sediment transport occurs as sediment is carried downstream by the flowing water without depositing sediment on, or eroding sediment from, the river bed or banks. Both the elevation of each point in the river bed and the fractional composition of the bed material (fractions of each grain size) at those points do not change when the sediment transport process is in equilibrium. Because the river bed is not assumed to be in equilibrium, a typical sediment transport formula based on equilibrium is modified in this application.

The differences in sediment transport rates (for each grain size) between consecutive cross sections determine the amount of channel erosion or deposition. This mass-balance process is applied to each grain size so there is mass conservation. The elevation of each cross-section point is adjusted accordingly at the end of each time step based on the amount of net erosion or deposition that is calculated to occur. Within the same cross section and time step, some points and grain sizes can erode while deposition can occur at other points or for other grain sizes.

Sediment-transport capacity rates, for the river bed material, are computed for each daily time step using both the average and point-by-point hydraulic parameters at each cross section. Yang's (1979 and 1984) unit-stream-power equations are used to compute the sediment transport capacity for sand and gravel. The transport-capacity equation for silt and clay is taken from the GSTARS 2.0 computer model (Yang, et. al., 1998). First, the average main channel hydraulic parameters are used to calculate sediment -transport capacity at each cross section. The sediment transport capacity rates of the different grain sizes are adjusted to account for any armor layer limits that may occur for that daily flow condition. Then, the sediment transport rate for each mobile grain size is distributed across the cross section using the local transport rate associated with the hydraulics for each point of the cross section. Finally, sediment transport rates are converted to concentrations of sediment that move with the water as it flows to the next downstream cross section.

Multiple Grain-Size Transport

Yang's equilibrium-sediment-transport equation (1979) is applied for each sand grain size of the riverbed material to calculate the initial daily downstream sediment transport capacities. The effects of both sediment availability and bed armoring are also included in the calculations. If an armor layer of coarser bed particles forms, the finer particles beneath the armor layer are not available for transport unless the armor layer is eroded by higher velocity flow. The sediment transport capacities are computed twice, as an average for each cross section and again for each point within the section. The point-wise sediment transport capacities of each grain size are then adjusted to conform to the average sediment transport capacities.

Bank Stability

Bank stability is modeled by limiting the angle (above the horizontal) between adjacent cross section points whenever one point is wet and its neighbor is dry. If the bank angle is too steep, and erosion occurs at the riverbed point, then the model erodes material from the top of the bank (even though it is above water) instead of the toe of the bank.

Transverse Riverbed Slopes

Because uniform flow is assumed, the highest velocities in each cross section occur at the deepest points of each cross section. These high velocities tend to scour the riverbed and deepen those deepest points. These scour holes are unrealistic because backwater effects between cross sections actually lower the velocities at very deep points. Further, transverse riverbed slopes are caused by curves, such as meanders, in the plan form of the river, and the Platte River is notably straight. Transverse slope stability is, therefore, modeled by limiting the angle (measured above the horizontal plane) between adjacent cross section points whenever both points are wet. If the transverse slope is too steep and there is erosion at the lower riverbed point, then the model erodes material from the top of the transverse slope instead of the toe of the slope.

Sediment Input by Sediment Transport Capacity

The unsteady variation of upstream, sediment-transport boundary condition can be represented by a series of constant, mean-daily sediment transport rates. The upstream sediment loads are set equal to the calculated sediment transport capacities (for each grain size). In SedVeg Gen1 and SedVeg Gen2 sediment input by sediment transport capacity was assigned for the separate North and South Platte River channels at the town of North Platte, NE. Two wide cross sections were used to include both river channels just upstream from their confluence with the Platte River. No sediment supplies from downstream tributaries (including the Johnson-2 Return flow) were included in these earlier versions of the model. Algorithms to add sediment at tributaries and through mechanical augmentation have been added to SedVeg Gen3.

Sediment to Downstream Cross Sections

Sediment concentrations are calculated for both average and point-wise flow conditions at each cross section. The average concentration is determined such that the sediment transport is equal to the equilibrium sediment transport capacity. This average concentration is used, together with the cross-sectional flow rates, to transfer sediment from one cross section to the next downstream section.

Transverse Deposition/Erosion in River Bed

A new approach is used with all versions of the SedVeg code to handle the transverse distribution of sediment from the upstream cross section. Total sediment concentration from each upstream cross section is redistributed using the Rouse equation for the vertical distribution of concentration to obtain the point-wise sediment concentrations at the downstream cross section. The point-wise sediment concentrations from upstream are adjusted to conform to the average sediment concentrations at the cross sections.

Sediment Mass Balance

Sediment mass balances, at a particular cross section, are based on the average daily concentration from the upstream cross section, the average concentration (calculated from the sediment transport capacity) at the downstream cross section, and the deposition and erosion at the downstream cross section. This cross-sectional average mass balance is calculated for each of the ten sediment grain sizes. Some sizes may have average deposition, while others have average erosion.

While the average concentrations are dependent on the average sediment transport capacity, river bed dimensions are determined by the daily, point-wise, sediment mass balances of each grain size with corresponding deposition-and-erosion changes in bed elevation. The depths of deposition or erosion are based on the volumes of sediment deposited or eroded from the bed area corresponding to each point affected by the daily flow. These mass balances are checked to confirm that the sum of the deposition and erosion volumes conforms to the average mass balances between cross sections.

The thickness and composition of the top layer of bed sediments at each point are updated after each daily sediment mass balance. Two other bed material layers are calculated for each daily sediment transport process, but those layers are not carried over directly to the next daily time step.

- The thickness of the moving sediment layer at each point in the cross section is deter-mined such that the volume of particles (of each grain size) is at least equal to the volume of suspended sediment particles moving in the water above the bed. The thickness of the moving layer may be greater than the thickness of the top layer of bed sediments, in which case, the thickness and composition of the moving layer within the underlying sediment layer are also included in the mass balance calculation for that point.
- An armor layer may form at any point in the cross section if the daily flow conditions are not strong enough to move all of the coarser grains in the moving layer. These immobile, coarse grains prevent the motion of the finer grains beneath the armor layer if enough immobile grains are present to form a layer at least one grain diameter thick. This armor layer may limit the sediment transport capacities determined by the equilibrium sediment transport equation to the transport of the finer material in and above the armor layer.

2.3 Vegetation Computations

Before discussing and evaluating the vegetation model subroutines, it is necessary to first understand the basic physical and biological processes that interact in a river environment regarding the balance between vegetation and flow. In order for vegetation to exist, seeds must germinate on suitable substrate. Once germinated, in order for a plant to grow, it must survive a variety of events. As flow and corresponding water levels typically recede through the summer growing season, soil moisture available to roots is reduced possibly resulting in desiccation (death by drought). Pulses of high flow associated with thunderstorms, ice formation and breakup, and the snowmelt peak for the next year may scour vegetation. The following excerpt is from Murphy *et al.*, 2004.

> *Cottonwoods (Populus sp.) and willows (Salix sp.) of the family Salicaceae share a similar life history pattern. They are pioneer species (Johnson,1998) that are relatively fast growing and they require sites relatively free of other vegetation in order to become established. Cottonwoods have small light seeds in "cottony" enclosures that facilitate wind dispersal in late May to early June. Willows have a similar type of seed that is dispersed around the same time period as cottonwoods (Harlow et al., 1979, Johnson, 1994). This corresponds to the natural period of high flow recession so that seeds tend to be deposited on moist sandbars more suitable for germination and the establishment of seedlings (Rood and Mahoney, 1990). Seeds of cottonwoods and willows are viable for only two to four weeks and require continuous moisture (Harlow et al., 1979, Rood and Mahoney, 1990, Johnson 1994). Seedlings tend to be restricted to an elevation range near the river level.*
>
> *Conditions are probably not ideal for the establishment of seedlings on a yearly basis. Root growth of cottonwoods must maintain contact with the water table as it recedes following flooding (Rood and Mahoney, 1990). If the water table falls too quickly and root growth does not keep up, seedlings will desiccate and die. Once roots are deeply established, after 2 or 3 years, cottonwoods become more tolerant to drought by the ability to tap into the water table. However, if the water table was to drop below the reach of roots, and root growth does not keep up, mortality can occur within a few months. On average, cottonwoods live approximately 100 years, but their longevity is influenced by environmental factors, most notably drought stress (Rood and Mahoney, 1990). Willows live from 10 to 30 years (Bellah and Hulbert, 1974).*
>
> *There are several environmental factors that regulate vegetation growth on sand bars: June flows, summer drought, and winter ice scour (Johnson 1994). When winter flows are high enough and temperatures cold enough, ice scours sand bar vegetation causing high rates of seedling mortality of Populus and Salix. Seedling survival after ice scour is highly dependent on elevation (Johnson 1994), i.e., whether or not the ice gets high enough to reach the vegetation. High June flows tend to inundate sand bars and mobilize sediment causing seedling mortality, and summer low flows allow for the establishment of seedlings. Annual peak flows of sufficient magnitude that may occur at other times of the year may also be capable of scouring seedlings. If drought conditions exist, summer flows can become low enough that seedlings are unable to get water and die back as a result of desiccation. Severe drought can cause the death of older more established seedlings as well as relatively new growth (Johnson,1994). Johnson (1997) found that seedling mortality was highest in the winter as a result of ice scour (up to 98 percent), and that during the period of 1985 to 1996 mortality was so high that there was a low probability that a seedling would survive 3 to 4 growing seasons (the amount of time generally needed for it to become highly resistant to*

erosion). High mortality rates are also seen following flood events. However, once vegetation becomes established in these areas, such as river banks and high sandbars, where there is abundant water just below the surface, the roots of plants stabilize these areas and make them more resistant to erosion. Therefore, the history of the flow in the first years of life of vegetation is important in the establishment of more permanent, mature vegetation. Under normal rainfall conditions, reduced flows that minimize the effects of high flows and ice scour lead to excellent growing conditions for cottonwood and willow seedlings.

2.3.1 Vegetation Accounting

Hydraulic and sediment transport modeling is conducted on a mean daily basis. For a large-scale watershed such as the Platte River, this level of detail is used since changes in flow generally do not respond much more rapidly than can be reasonably accounted for on a daily basis. The SedVeg model also tracks the daily status of the four indicator plant species at every point in a cross section. The model changes the age, height, and root depth of each vegetation class on a monthly basis (at the daily end-of-month time step). The model allows multiple vegetation categories to be present at the same coordinate point, but does not track the relative distribution of the vegetation categories and allows only one age, height and root depth per category per point. As vegetation grows, it is assumed to cause an increase in the hydraulic roughness of the river bed at the points where vegetation is growing. An increase of 0.002 in Manning's *n* is assumed for each month of growth, from the bare sand value 0.035 to the flood plain value of 0.070.

In addition to the overall summary of vegetation existence and age by species at each point, the program also provides a summary of the frequency of each mortality mechanism. Options regarding the desired level of detail for model output are available depending on the needs for a particular model run.

As the model cycles through the time steps, the vegetation subroutines determine vegetation establishment and growth, as well as the potential for removal by various factors. If vegetation is established and survives, each month the vegetation becomes one month older. If the vegetation is removed due to one of the limiting factors, the vegetation is reset to zero (for each particular species and point in the cross section), leaving a barren substrate. The hydraulic and sediment model continually adjusts the cross section and utilizes the vegetation information for updating resistance to flow and relative stability of various portions of the riverbed.

2.3.2 Vegetation Subroutines

The model tracks the establishment and growth and potential removal of vegetation over time at each point within each cross section. The model assumes that new vegetation is established during the germination season (depending on the general species type), and that vegetation is established at elevations above the river water-surface elevation on barren (non-vegetated substrate). When bare sand is colonized by new vegetation, the distribution of vegetation categories is a function of the elevation above the water surface and the month of the year. Water is assumed to transport seeds downstream and prevent seeds from taking root.

The new plants continue to grow during the growing season of each year unless they are removed by flow scour, prolonged inundation, prolonged drought, or ice scour. Vegetation removal is determined by algorithms describing the previously mentioned processes. The removal of vegetation as a result of flow scour can be modeled by one of three elected methods. Only one of the scour routines, empirical velocity relation, active layer thickness scour, or stream power scour, is utilized for a given model run, never both. Early versions of SedVeg Gen1 used stream power; later versions of SedVeg Gen1 and SedVegGen2 models used the active layer routine, while the SedVeg Gen3 model used the empirical velocity routine.

Independent of the scour routine used, vegetation algorithms track the growth of the plant stem and the extension of plant roots deeper into the channel bed. Where vegetation is present, river flow velocities and sediment-transport rates both decrease due to the increased resistance to flow from the larger plants. The resistance to flow parameter in the model is increased at each point with increasing age and size of vegetation. Because of these processes, the likelihood that vegetation will be scoured generally decreases with time as the plants grow larger and hydraulic stresses decrease. Sediment deposition is more likely to occur at vegetated points because the sediment transport rates decrease with velocity, as the roughness from the plants increases over time.

2.3.3 Germination/Growth

The germination/growth subroutine determines whether or not and where vegetation can germinate and grow. The model allows germination to occur only during the seed germination season for each type of vegetation. This is controlled by the GERM variable, which can be set at either 0 or 1 for each month of the year and for each vegetation type. A zero indicates that no germination for that particular species of vegetation occurs during that month. A one indicates that germination is possible for a given month and for a given species of vegetation. Germination is not allowed at any point where a given species of vegetation already exists, but multiple species can germinate at a given point. As a result, no competition between species occurs at this point in the model.

Vegetation establishment is limited to those areas of the cross section that are not inundated during the germination season and that have recently been exposed as the water drops, leaving moist, barren substrate. The model computes the water surface elevation for the maximum flow during the month and the end of the month, based on mean daily flow from the hydraulics model. This difference in elevation is the vertical band within which vegetation can germinate. This band of elevation can be increased or decreased by two input parameters (CODA and CODE, the lower and upper limits of germination above the maximum water surface elevation for the month or below the water surface elevation at the end of the month). Establishment of vegetation is further limited by a factor (VEGFAC) that ranges from 0 to 1. When set to zero, no establishment of vegetation is allowed within the elevation band and when set to 1, there is a potential for establishment to fully occur within the band. Two germination subroutines are provided in the model (VEGESTLO and VEGESTHI). One subroutine focuses germination in the upper portion of the elevation band, and the other focuses germination in the lower portion of the elevation band. The use of two subroutines to model germination is based on the concept that some types of vegetation tend to germinate in lower elevation zones, while other types of vegetation tend to germinate in upper elevation zones.

Once established during germination, the seedlings begin to grow. Both root and stem growth are computed based on variable monthly growth rates for each, which are typically zero when the plant is dormant and non-zero during the growing season. Depending on vegetation type, root growth is limited by the level of the water table or capillary fringe above the water table. In other words, the root tip does not grow below the top of the water table or capillary fringe (depending on type of vegetation). Willows present an exception to this rule, as their roots can extend below the level of the water table. In addition to tracking the status of root and stem growth, the model also monitors the existence of each species of vegetation and corresponding age at each point.

2.3.4 Inundation

Vegetation can be removed by excessive inundation. There can be two criteria for mortality: the maximum length of continuous inundation beyond which the plant dies, and a requirement for a minimum depth of flow over the root-crown. Only one maximum length of inundation can be assigned to all vegetation types in SedVeg Gen1 and there is no requirement for a minimum flow depth over the root crown. In SedVeg Gen2, the inundation mortality code was turned off. As one species of vegetation is more sensitive to inundation than another, the SedVeg Gen3 code was revised so a value for maximum length of inundation could be assigned to each vegetation type. A minimum flow depth requirement over the root crown was also added to the SedVeg Gen3 version of code.

Values for maximum length of inundation are assigned in the VEG.DAT file, while minimum inundation depth of water over the root crown, and is specified within the code.

The model tracks the length of continuous inundation for each type of vegetation at each point in each cross section. Application of the algorithm with the input parameter (DURMAX) defining the maximum allowable length of continuous inundation by species results in removal of vegetation if the inundation criteria are met.

2.3.5 Desiccation

Vegetation can be removed by desiccation as the water table and associated capillary fringe drops faster than the roots can grow, leaving the plant without sufficient moisture for survival. The rate of water surface decline is computed by the difference between the maximum water surface elevations from one month to the next. This change in river water-surface elevation is compared to the root-tip elevation of each plant.

Vegetation is removed by desiccation if the water table drops faster than the roots can grow, leaving the plant without sufficient moisture for survival. Allowable rates of water level recession are set for each species of vegetation and for several age categories within each type of vegetation.

The rate of recession of the water surface is compared to allowable rates for vegetation depending on age and species. If the rate of recession exceeds the allowable rate for a particular species, then mortality occurs. Thus, the differing tolerances of the various species and ages within species are considered with respect to mortality by desiccation. This mode of mortality is only allowed to occur during the growing season, when vegetation is actively growing, as defined by the end of dormancy to the beginning of dormancy for each type of vegetation.

2.3.6 Ice Scour

Removal of vegetation by ice scour can occur due to moving ice during the period of ice breakup as it shears off vegetation or pulls it out of channel bed or banks. Johnson (1990, 1992, 1993, 1994, and 1996) demonstrated that ice scour is a major factor, if not the most significant factor, that causes mortality of vegetation under current conditions. An analysis of ice formation (Simons & Associates, 1990) showed that ice formation is strongly correlated with minimum air temperature. No statistically significant correlation was found between ice and the magnitude of flow. Data show that ice cover begins to form and then builds up to 100 percent coverage once an adequate length of time of sufficiently cold weather occurs. Similarly, ice breaks up once an adequate length of time of sufficiently warm weather occurs.

An algorithm of ice formation and break up was developed based on a 7-day weighted moving average of minimum air temperature being less than a certain temperature for formation and another 7-day weighted moving average minimum air temperature being greater than another temperature as dictated by the data. A binary approach was utilized such that only a 100 percent ice cover condition is accounted for rather than any occurrences of partial ice coverage.

Similarly, ice break up is simulated as a single event of complete break up. The ice subroutine first determines the occurrence of ice formation based on an evaluation of minimum air temperature data entered in the TEMFLOWNS.DAT input file. If ice is formed (and once the temperature criteria dictate the occurrence of ice breakup), the flow during ice breakup is used to determine the extent of removal of vegetation by ice. This is accomplished by defining a vertical zone at specific distances above and below the water level for the flow during which ice break up occurred. These set distances are input parameters that can be adjusted based on data or as part of the calibration process. Vegetation within this zone of ice effect during a break up event was initially removed independent of age under one model formulation.

2.3.7 Flow Scour

Vegetation can be removed by flow scour and the SedVeg code contains three methods of computing vegetation removal by flow scour that cannot be applied together: velocity, active later, and stream power. The first approach uses simple velocity-based criteria. The second approach removes vegetation when sediment is scoured from the elevation zone below the root crown down to a portion of the root zone (from the crown to tip) or below. The stream power method is computed from shear stress and velocity.

Velocity Scour

This method uses maximum allowable velocity criteria. In the empirical velocity routine, velocity is used as a surrogate for actual erosion and removes vegetation whenever allowable velocity criteria are exceeded. The velocity criteria are variable parameters in VEGCOEF.DAT that depend on the type and age of vegetation, and assume that vegetation becomes more resistant to scour/velocity with increasing age. This assumption is generally valid up to some point in the lifespan of the vegetation, beyond which there may be a decline in resistance to scour. The velocity-based code (SCOURV) applies vegetation removal criteria as follows. When the mean velocity in the channel cross section (for the maximum daily flow within the month) exceeds the allowable velocity for each type and age of vegetation, the vegetation that is affected by the flow (i.e., vegetation whose base-initial elevation point on the bed when germinated is under water) is removed. The SedVeg Gen3 Platte River model uses velocity scour.

2.4 Active Layer Scour

The sediment transport approach (ACTIVELAYER) considers scour or disturbance of substrate from the root zone as the agent in removing vegetation. This method compares the root depth to the depth at which the riverbed sediments are mobilized. The bed mobilization depth is assumed to increase with the sediment transport concentration, which is primarily a function of velocity and energy slope. If scour of the substrate surrounding the root zone is sufficient, the plant can be removed. The amount of scour and active disturbance of sediment is determined in sediment transport algorithms. If the bottom of the active layer extends below the actual root tip or some percentage of the total root zone, as defined by controlling parameters in the VEGCOEF.dat file, the vegetation is removed. Controlling parameters are set for each type of vegetation based on the zone of scour or disturbance compared to its position with respect to the root zone. The position and length of the root zone is determined based on the elevation of germination in the cross section and growth since germination. Later versions of SedVeg Gen1 and the SedVeg Gen2 model applied the active layer algorithm.

2.5 Stream Power Scour

The stream power (bed shear stress multiplied by velocity) option was used only in early versions of SedVeg Gen1. It uses the bed form description of Simons and Albertson (1963) wherein flat bed, ripples, dunes, plane bed transition and antidunes are characterized by stream power and bed grain size. Ripples are assumed to remove plants up to one year old, dunes to remove plants up to 2 years old, plane bed transition and antidunes to remove plants up to 3 years old, and plants older than 3 years are assumed to be permanent.

2.6 Model Run and Output

2.6.1 SedVeg Model Run

The entire process of computing the variable response at each cross section, including river hydraulics, sediment transport, erosion and deposition, and resulting cross-section elevation adjustments, is repeated for each daily time step through the end of the simulation period. Vegetation establishment, growth, or removal is modeled using the appropriate variables within each month.

The model is often run initially for a “warm up” period of several years to one or two decades depending on the input data requirements and cross section selection. The warm up period can be used to form the armor layer in the model which matches the armor layer existing in the modeled reach of river. During the warm up period, vegetation can also be grown to a desired age for the modeled run, rather than individually entering the estimated ages of vegetation for each vegetation type, at each point in every cross section.

Display windows for up to five cross sections (depending on the computing capacity of the hard drive) can be assigned in the INPUT18.DAT file. During computations, the windows illustrate the evolving shape of the channel, the water surface, and the growth and removal of vegetation at the cross section over time.

At the conclusion of the run period specified in the TEMPFLOWNS.PRN files, the model generates several series of output defining channel conditions throughout the run including:

- cross section geometry with the presence of four vegetation types at each point tracked;
- daily measures of total wetted width (width of the wetted surface of the channel) at a cross section, side channel wetted widths, and maximum observation widths of the channel (maximum width measure of line of sight 3 ft above the water surface not interrupted by vegetation, or ground features such as islands and sand bars) for every cross section;
- daily values of water depth and velocity across the channel for every cross section;
- daily sediment transport rates for each of 10 grain sizes, at every point in every cross section, indicating conditions of erosion, deposition or stability;
- bed material grain-size distribution at every point of every cross section on every day of the run;
- monthly values for vegetal growth and root length, or type of mortality (flow scour, desiccation, inundation or ice removal) for four vegetation types at every point of every cross section (vegetation adjusts the roughness value of every point in the cross section); and
- habitat availability, including water surface elevations for non-inundated nesting days for least terns and piping plovers, water surface elevations for studies of wet meadows, channel widths with 3 to 9 in water depths for forage fish, and channel observation widths for

whooping crane.

2.6.2 SedVeg Output Files

This section provides guidance to the SedVeg Gen3 Platte River Model output, the model presented in the FEIS (USDOI, 2006). Output formats and file names may differ slightly from the SedVeg Gen2 Platte River output used in the DEIS (USDOI, 2003), with a wider range of information available in the FEIS files. SedVeg Gen3 was revised to provide three additional summary files and an additional set of cross section data files.

The three summary files are: SEDIMENT TRANSPORT AND DEPOSITION.DAT, SUMMARY.DAT, and VEGDEATH.DAT, and the new series is VEGCOD**.DAT. The OUT.CN**.DAT (ex: OUT_CN25.DAT), OUT_HY**.DAT, and OUT_WH**.DAT files contain daily data for one cross section. In SedVeg Gen3 there are 62 files in each series. The OUT_CN**.DAT files contain data on sediment concentrations, flow depths, and widths for forage fish. The OUT_HY**.DAT contains hydraulic flow information calculated daily at normal flow depths. The OUT_WH**.DAT files contain channel width information for wetted widths and open view width. Width and depth measures of specific habitat can be found in the OUT_CN**.DAT files.

The SEDIMENT TRANSPORT AND DEPOSITION.DAT file contains annual summary data totaled at the end of each year. Data in the SUMMARY.DAT file are calculated annually at an assigned reference flow. A reference flow of 2000 cubic ft per second (cfs) was used for most cross sections in the SedVeg Gen3 Platte River Model.

Annual data for plotting cross sections can be found in the VEGCOD*.DAT series of files. The files contain the initial cross section at year one, the cross section at the noted year, and the age in months of the vegetation type at that year. Vegetation type 1 is cottonwood, type 2 is willow, type 3 is spike rush, and type 4 is cord grass. Each VEGCOD*.DAT file contains approximately 8 years of data.

3.0 Governing Equations

The governing equations for model computations are grouped into two categories, hydraulics and sediment transport.

3.1 Hydraulics

Hydraulics of the SedVeg model is based on uniform flow at each of the isolated cross sections. Uniform flow is the simplest method that includes realistic cross-section geometry and supports sediment transport equations, including deposition and erosion. The uniform flow analysis can approximate flow when not affected by backwater that can occur from manmade structures or resistant natural features.

3.2 Uniform Flow Equations for Water Surface Elevation

The SedVeg computer model tracks the daily hydraulic history for the length of reach modeled. The distance of the river reach, the transverse distance (across the channel), and the elevation of any point are described by the variables *X*, *Y*, *Z*, and time is described by the variable *T*. The position of the lowest point in the channel at each cross section is the thalweg, (X_0, Y_0, Z_0), of that cross section. The total width of water in a cross section is described by *B*, and the average depth of water by *H*, such that the cross sectional area can be calculated as $A = BH$. A wide-channel assumption is made so that the hydraulic radius, *Rh*, can be approximated as *H*. This assumption is valid based on the geometric configuration of the Platte River. The average streamwise velocity in a cross section is described by *V*, such that the flow rate can be calculated as $Q = VA$. In the Platte River Models, the flow rate, *Q*, varies both in time and along the reach of river.

3.2.1 Manning's Equation

The roughness of any point within a cross section is described by the Manning's *n* roughness coefficient. The roughness coefficient is based on two components, the roughness associated with bare sandy-sediment and the roughness associated with vegetation of different sizes. The intensity of the average turbulent velocity fluctuations, which are associated with most of the friction force between the water and the river bed, is described by the friction velocity, *V**, where γ is the unit weight of water. The elevation of the energy grade line at a cross section is equal to the sum of the average bed elevation, the average water depth, and the average kinetic energy per unit weight of water at that cross section.

The downstream slopes of the thalweg and energy grade lines are described by S_0 and *Sf*, respectively. The relation that determines *V* as a function of the channel geometry is

Manning's equation:

$$V = \frac{1.49}{n} R_h^{2/3} S_f^{1/2} .$$

The equations for uniform flow are: $S_f = S_0 = -\Delta Z_o / \Delta X$

The equation for the friction velocity is: $V_* = \sqrt{\gamma HS_f}$

3.2.2 Transverse Distribution for Velocity and Depth

In addition to descriptors of the average flow, variables are used to express the transverse variation of flow in each cross section. The maximum depth of water at the thalweg is described as *D*. The local width of water associated with each wetted point in the river bed is described by *b*, and the corresponding local average depth is *h*, so that the local cross-sectional area can be calculated as $\Delta A = bh$. The local average velocity associated with each point is described by *v*, and the local friction velocity is represented by v_*... Manning's equation with the wide channel assumption is assumed to apply to the local average velocity. However, *v* must be adjusted such that $\sum Qp = \sum v\Delta A = VA = Q_t$, i.e. the $\sum Qp$ computed from the sum of the parts defined by the cross section points, equal *Qt* computed for the cross section as a whole. This is done by rescaling:

$v_t \Leftarrow v_p (Q_t / \sum v\Delta A)$. The sum of $v\Delta A$ from the left bank to any point in the channel defines the flow to the left of that point. This sum is sometimes called the stream function of the flow.

3.3 Sediment Transport

The SedVeg code also tracks the daily sediment transport history of the modeled reach of river. The upstream sediment sources can be based on transport capacity, sediment rating curves, a set percent of annual load, or a varying but specified daily load. SedVeg Gen1 and SedVeg Gen2 use transport capacity of the North and South Platte Rivers and the flow rates near the USGS gaging stations on the North and South Platte Rivers at North Platte, NE (USGS No. 06693000), North Platte River at North Platte, NE (USGS No. 06765500), South Platte River at North Platte, NE.

The return flow from the Sutherland Canal enters the South Platte River just downstream from the USGS streamflow gaging station on the South Platte (Fig. 1.1), and that return flow is added to the flow. The North Platte River is assumed to be the source of sediment based on the equilibrium transport capacity of the flow and bed material in that river, and the South Platte is assumed to be the source of sediment based on the equilibrium transport capacity of the flow and bed material in that river.

The SedVeg Gen3 Platte River Model does not extend upstream to the North and South Platte Rivers but uses a rating curve to input sediment at the Johnson-2 Return (Fig. 1.1) based on the amount of daily discharge from the Johnson-2 Return. Sediment is also input from the North Channel of Jeffreys Islands a varying and specified daily volume. This varying daily sediment load is defined by sediment transport records from SedVeg Gen2 for the same location.

The fraction, by weight, of the sediment for each of the 10 grain sizes, *dk*, at each point (*i*) in the native (initial) river bed is described by *Pni* (both *n* and *k* are used to designate grain size depending on the subroutine). The sum of the *Pni* at any point is 1.0. The 10 grain size ranges are sieve-based by factors of two: 16-8 mm, 8-4 mm, 4-2 mm, etc. The native bed material of the sediment sources and the lowest part of the Platte River bed do not change with time. Only the top layer of the river bed moves due to the force of the flowing water. The sediment-size fraction, by weight, for each of the 10 grain sizes [at each point in the top layer of the river bed] is described by *Pi*. The sum of the *Pi* at any point and at any time is 1.0. The composition, *Pi*, and thickness, *Tl* , of the top layer of the river bed at any point affected by flowing water changes with time. The model also calculates and tracks the average composition, *Fbi*, of the top layer at each cross section. The sum of the *Fbi* at any cross section is 1.0000.

3.3.1 Transport Capacity Equations

The daily rate of transport, in tons per day, of sediment of any grain size past each cross section is described by the equilibrium sediment transport capacity, *Qs*. Because small grains of sediment on the bed of the Platte River are easily suspended in the moving water, the fall velocity, *w*, of the sediment grains is an important descriptor in the dynamics of the sediment movement. The dimensionless ratio V_* / w, plays a key role in the equilibrium sediment transport equation that determines *Qs*. The threshold of motion is important for coarse particles and for low flow rates. That threshold is described by the critical velocity ratio, V_c / w. Another key dimensionless ratio is the fall velocity Reynolds Number, Re, defined by $Re = wd / \upsilon$, where υ is the kinematic viscosity coefficient, for each grain size. Yang's equations (1973 and 1984, or 1979 and 1984) are used for Equilibrium Sediment Transport. For each grain size class:

$$Q_{si} = 0.0027 \times Q \times F_{bi} \times 10^{y_i}$$

Where: $y_i = B_1 + C_1 \log_{10}(V_* / w_i) + [B_2 - C_2 \log_{10}(V_* / w_i)]\log_{10}(VS / w_i - V_c S / w_i)$,

Where: $$\begin{cases} V_c / w_i = 2.5/[\log_{10}(V_* d_i / \upsilon) - 0.06] + 0.66 & \text{for } 1.2 < \dfrac{V_* d_i}{\upsilon} < 70, \\ V_c / w_i = 2.05 & \text{for } \dfrac{V_* d_i}{\upsilon} > 70, \end{cases},$$

And where B_1, B_2, C_1, and C_2 are constants (functions of *Re***)** for each grain size.

3.3.2 Transverse Distribution of Transport Capacity

In addition to descriptors of sediment transport past each cross section, variables are used to express the transverse variation of sediment transport within each cross section. The equilibrium sediment transport capacity, *qs*, associated with each point in a cross section is calculated using the local average flow properties (*b, h, v, v**) in the equilibrium sediment transport equation. The point-wise sediment transport capacities are adjusted to conform to the average sediment transport capacities at the cross sections: $\sum q_s = Q_s$. As with the flow rate, the sum of *qs* from the left bank to any point in the channel defines the sediment transport to the next downstream cross section from the left of that point. The mean concentration, *C*, of sediment moving downstream from a cross section is obtained by calculating the volumetric rate of sediment transport using the specific volume, $\forall$, and assuming that the sediment moves with the mean velocity, *V*. Thus, $CVA = CQ = Q_s \forall$ where Qs = CQ and $\forall$=1. This average concentration is used, together with the two cross-sectional flow rates, to transfer the sediment *Ci*, leaving from any cross section; to the sediment entering the next downstream cross section, i+1; $C_i Q_i = C_{i+1} Q_{i+1}$. The transverse variation of sediment concentrations, *c*, from upstream is determined using a variation of the Rouse (1937) equation for the vertical distribution of concentration:

Rouse Equation: $c = c_0 \left(\dfrac{h}{D-h} \right)^{w/k v_*}$, for $D - h > 0.1$; $c = c_0 (19.0)^{w/k v_*}$, for $D - h < 0.1$.

The dimensionless ratio $w/k\nu_*$ is called the Rouse number, and it describes the uniformity of the vertical distribution of the sediment concentration. The value of *k* is discussed in the Sensitivity of Sediment Transport Parameters section, 4.1.4, of this report. The point-wise sediment concentrations from the upstream cross sections, *ci+1*, are adjusted to conform to the average sediment concentrations at the cross sections by determining c in terms of *C*: $\sum cvbh = CQ$. As with the flow rate, the sum of $cvbh$ from the left bank to any point in the channel defines the sediment transport from upstream to the left of that point.

3.3.3 Transverse Distribution of Mass Balance

Sediment mass balances at a particular cross section, described by area *Ai*, are calculated using the volumetric rate of sediment deposition Ω_i and the average mass balance equation for each grain size: $C_{i-1}Q_{i-1} - Q_{si}\forall = \Omega_i$. If Ω_i is negative for a particular grain size, then erosion of those particles occurs at that cross section. Riverbed dimensions are determined by point-wise, daily, sediment mass balances of each grain size with corresponding deposition and erosion changes in bed elevation using the local volumetric rate of sediment deposition, ω_i , and the local mass balance equation for each grain size: $cvbh - q_s\forall = \omega$. These mass balances are checked to confirm that the deposition and erosion volumes conform to the average mass balances between cross sections: $\sum \omega = \Omega$.

3.3.4 Changes in Bed Elevation

The local deposition rate is converted to the daily change in bed elevation *Z* at each point using the local bed area, *a*, the porosity of the bed Φ and the definition of the volumetric deposition rate: $(Z_T - Z_{T-1})a(1-\Phi) = \omega T$, with *T* = 1 day.

The thickness *Tl* and composition *P* (fractions of each grain size) of the top layer of bed sediments at each point are updated after each daily sediment mass balance. Sediments of each grain size that come from upstream and deposit at any point in a cross section are added to the top of the top layer of that point, and sediments of the other sizes that are eroded from the top layer are subtracted from the bottom of the top layer. If the entire top layer is eroded for any grain size, the native bed below the top layer, with composition *Pn*, , is eroded to the depth needed to satisfy the demands of the equilibrium sediment transport capacity equation.

The depth, δ , of the layer of bed sediment at a point in the cross section needed to provide moving bed sediment according to the equilibrium sediment transport capacity equation for each daily flow rate is determined such that the volume of particles of each grain size of the moving bed layer is at least equal to the volume of suspended sediment transport of those bed particles moving in the water above the bed plus the particles eroded from the bed: $\delta aP(1-\Phi) = Cah - \omega\_T$. (Note: $\omega\_$ is negative on eroding particles.) The maximum value of δ for all grain sizes is used as δ for that point, unless $\delta > T_l$ or unless the bed is affected by an armor layer. If $\delta > T_l$, then $[(\delta - T_l)P_n + PT_l]a(1-\Phi) = Cah - \omega\_T$.

The daily rate of sediment transport may be limited by creation of an armor layer if the coarser grain sizes do not move, or if only a small fraction of those coarser particles move. If *Qs* = 0 for grain sizes $\geq d_k$, then $\delta = \sum_{k}^{\max} dP \geq d_k$. Only particles with grain sizes finer than d_k and within the depth δ can be used to satisfy the equilibrium capacity equation. If some coarse grain sizes, >dk_1, do not move and if only a fraction of the particles of the next finer grains, >dk_2, are moved by the equilibrium capacity equation, then $\delta = \sum_{k_1}^{\max} dP + \sum_{k_2}^{k_1} (dP - \frac{Ch}{1-\Phi}) > d_{k_2}$. Again, only particles with grain sizes finer than dk_1 and within the depth δ can be used to satisfy the equilibrium capacity equation. Particles with grain sizes finer than *dk2* have their sediment transport capacity limited by the armor layer. The updating of the thickness of the top layer, *Tl*, uses the maximum of the old top layer thickness, *Tlo*, the sum thickness of the moving bed material layer, δ , and the thickness of the deposition layer, $\omega_+ T / a(1-\Phi)$, where ω_+ is positive for the depositing grain sizes: $T_l = \max(T_{l0}, \delta + \omega_+ T / a(1-\Phi))$. The updating of the composition of the top layer is a volumetric accounting of the particles of each grain size of the original top layer and the deposition and erosion of each grain size to and from that layer, including the effects of the new top layer thickness and the possible movement of some of the native bed material below the top layer. If $\delta \le T_{l0}$, the native bed material does not move. Then, $P = [PT_{l0} + \omega T / a(1-\Phi)] / T_l$. If $\delta > T_{l0}$, then some of the native bed material is included: $P = [PT_{l0} + P_n(\delta - T_{l0}) + \omega T / a(1-\Phi)] / T_l$.

The transverse slope between pairs of points along each cross section is limited by a maximum transverse slope specified in the SED.DAT input file. The variation and effects of the transverse slope are discussed further in 4.1.2 Sensitivity of SedVeg Gen1. If the transverse slope between two points exceeds the specified value, then erosion at the base of the slope is avoided by transferring that erosion to the point at the top of the slope. This process, using a bank angle instead of the transverse slope, can even erode points above the waterline at the banks of channels.

4.0 Development of Earlier Versions of SedVeg

The Bureau of Reclamation (Reclamation) began development of the SedVeg code (SedVeg Gen1) in 1999 for the Platte River studies. The goal was to incorporate the vegetation growth effects into a one-dimensional sediment transport model to provide a quantitative tool capable of tracking the complex and interrelated effects of hydrology, hydraulics, sediment transport, vegetation growth impacts, and characteristics of fish and wildlife habitat. In 2003, an important revision (SedVeg Gen2) by Reclamation provided an automated method for incorporating mechanical changes to specified channel cross sections. Thus the model could be used to assess impacts on channel form resulting from changes to flow and sediment transport, variations in mechanical management of channel cross sections, and evolving bank resistance values due to vegetation growth and mortality.

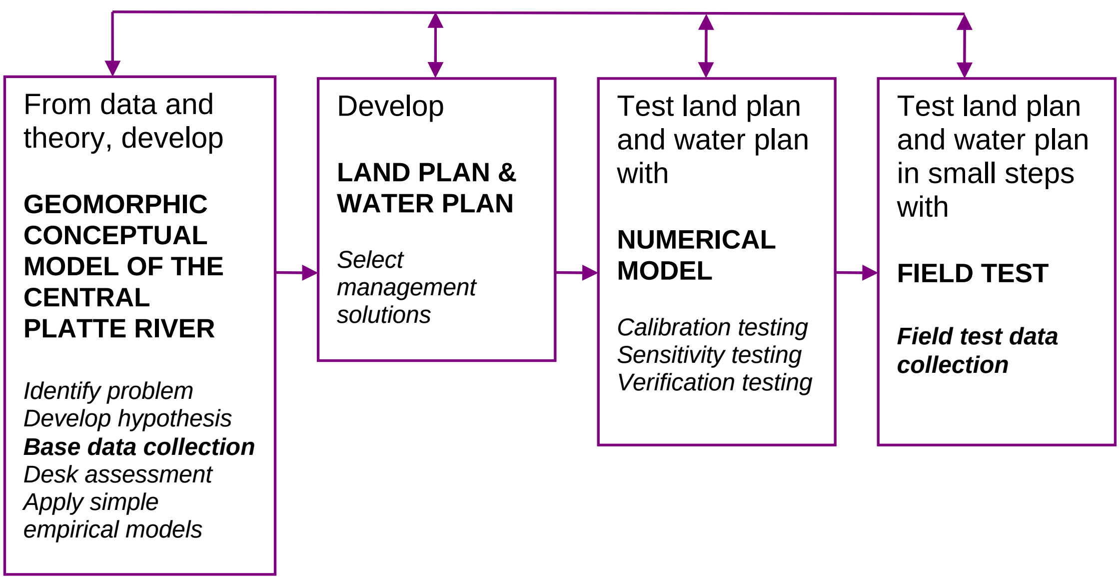

Figure 4.1. Study approach for the Platte River geomorphic and habitat-rehabilitation investigation.

Figure 4.1 outlines the approach taken by Reclamation for the Platte River Geomorphic study. Development of a conceptual model is the first step, based on a foundation of geomorphic theory and available data. Similar to the three level approach proposed by Simons and Simons (1996), or the hierarchical approach proposed by the ASCE Task Committee on Hydraulics, Bank Mechanics and Modeling of River Width Adjustment (ASCE Task Committee) (1998), this step includes problem identification, development of hypothesis, data collection, desk assessment, and the application of simple empirical models. Based on the conceptual model, the next step is to propose feasible solutions through managed actions (develop land plan and water plan). In the third step, the proposed solutions are challenged through the use of numerical modeling, as suggested by Simons and Simons and the ASCE Task Committee. And in the final step, field testing for calibration, verification, and sensitivity testing may provide solutions, or may engender a loop back in the cycle if hypotheses prove to be invalid. With respect to the Platte River study, the fourth step applies to both the EIS analysis and the Adaptive Management Implementation plan. The numeric model, SedVeg Gen3, was intended as a screening tool to aid evaluation of alternatives prior to the costly steps of field implementation.

The current code, SedVeg Gen3, is discussed in Chapter 5.0 along with the general results from the SedVeg Gen3 Platte River Model. However, the development of SedVeg Gen1, the original code, and SedVeg Gen2, the succeeding version, are briefly described in this chapter along with their associated Platte River models. The three versions of the SedVeg Platte River Model represent three loops in the evaluation approach shown in Figure 4.1. The following sections of Chapter 4 contain summaries of the evolution of the SedVeg code and Platte River model including revisions, calibration and verification, sensitivity testing, and model reviews. Several appendices contain more detailed descriptions of specific aspects of the model development:

- Appendix B. Review comments and responses on SedVeg Gen1 and SedVeg Gen2 Platte River Models;
- Appendix C. Basis of the Platte River flows;
- Appendix D. Basis of Vegetation Subroutines; and
- Appendix E. SedVeg Gen1 Calibration and the Historic Platte River Model.

4.1 SedVeg Gen1

Reclamation developed the SedVeg Gen1 code by incorporating sediment subroutines from GSTARS version 2.0, by incorporating vegetation subroutines written by Simons and Associates, and by improving code for sediment transport computations. Under contract to Reclamation, Simons and Associates provided the vegetation subroutines in 2000. The vegetation subroutines had previously been applied and tested by the contractor, to the Platte River in the 1980s and to the Snake River in Idaho (Johnson, *et al.*, 1995) (Appendix D). Simons and Associates have a contractual agreement that specifies the vegetation subroutines be used only for the Platte River studies.

4.1.1 Development of SedVeg Gen1 Platte River Model and Historic Platte River Model

The original input data, including sediment gradations, daily flows, and 17 cross sections, were assembled to represent 160 miles of the Platte River from North Platte to Chapman, NE. The cross-section geometry and bed material that were measured in 1989 supplied the initial conditions required by the model to begin the simulation of future conditions.

Bridges divide the central (or Central) Platte River, between Lexington and Grand Island, into thirteen segments of roughly equal length (5 to 10 miles). Thirteen cross sections, surveyed by Reclamation in 1989 (Holburn *et al.*, 2006), were selected to describe the average width and depth of the river channel in those thirteen bridge segments. Four additional cross sections were included in the SedVeg Gen1 model to extend the modeled reach upstream, from the main study area, to the North and South Platte Rivers. The cross section representing the North Platte River and the cross section representing the South Platte River, both upstream of the confluence, were surveyed in 1984. The cross sections were chosen to represent the channel geometry typical of each bridge segment, avoiding zones near bridges, where the channel could be narrowed by the constrictions of the bridge embankments.

The origins of the daily flows used in this model are described in Appendix C. The SedVeg Gen1 Platte River Model was applied for development and testing of the SedVeg Gen1 code. As part of the testing, Reclamation also constructed the SedVeg Gen1 Historical Platte River Model to evaluate and calibrate the SedVeg Gen1 code. The flow data used in the Historical Platte River Model is based on historic USGS gage data. Flows for modeling present and future conditions in the Platte River model are based on USGS gage data that has been adjusted to present operating conditions. The flows are adjusted using the hydrologic model, OpStudy (Stroup and Anderson, 2006). A description of the flow input for the models can be found in Appendix C.

Direct measurements for the Historic Platte River Model were always used where available, and in the absence of direct measurements, data were constructed from measurements at other locations or times. Some data were used to specify the model's initial or boundary conditions, while other data were used to independently verify the model results.

4.1.2 Calibration of SedVeg Gen1

The model calibration and verification studies addressed hydraulic, sediment transport, and channel vegetation processes. Information on the calibration and verification studies on SedVeg Gen1 Historical Platte River Model and the SedVeg Gen1 Platte River Model are presented in Appendix E. As part of the contract to Reclamation, Simons and Associates calibrated the vegetation subroutines in SedVeg Gen1 and that information is presented in Appendix D.

The calibration using the Historic Platte River Model and the Platte River Model demonstrated that SedVeg could replicate the general conditions that occurred during the different periods. From 1865 to 1909, conventional wisdom holds that the river was in a state of dynamic equilibrium and channel width, under a condition of dynamic equilibrium, was assumed to be relatively stable. Calibration results for this 45-year period indicated that the wide, shallow cross sections remained in a near equilibrium condition, with a slight aggrading trend. Vegetation grew and occupied all high-elevation portions of the channel that were not frequently inundated, and vegetation grew at the fastest rate during low-flow periods. Some cross sections aggraded while others degraded, but no cross sections changed vertically by more than a few feet. The same coefficients, which produced this stable channel condition, were then used in a later model run.

4.1.3 Verification of SedVeg Gen1

After 1909, changes in flow, sediment transport, and vegetation on the Platte River, and the subsequent responses reflected by change in channel form, provide a useful test of model performance. For a verification procedure, hydrology data were appended to the earlier period of 1865 to 1909 to produce a daily flow record that extended from 1865 to 1998. The same model parameters that were calibrated for the earlier period of 1865 to 1909 were also used without adjustment to simulate the period 1865 to 1998. Model results of the active channel width, described as a vegetation-free width, were then compared with measured average conditions based on an analysis of aerial photograph from 1939, 1959, 1983, and 1998.

In the verification run, the cross sections narrowed due to encroachment by vegetation during the transition period (1910 to 1969), then became stable once again in the recent period (1970 to 1994). This study confirmed that SedVeg was not predisposed to one trend, but could replicate changing conditions. See Appendix E for more information on the sediment calibration and verification studies, and see Appendix D for more information on calibration of the vegetation studies.

4.1.4 Sensitivity Testing of SedVeg Gen1

Sensitivity analysis helps determine how rapidly model results will change in response to a change in an input parameter. Sensitivity analyses were performed in 2002 on various input parameters related to river hydraulics; sediment transport, and erosion and deposition; and vegetation growth and removal. Some of these input parameters have been adjusted through model calibration, but the parameter adjustments are all within a reasonable range of typical values. Therefore, the sensitivity analyses do not extend beyond the range of typical values.

A systematic series of sensitivity tests were performed on the hydraulic and sediment transport parameters using a simplified river model with a trapezoidal, low-flow channel within a trapezoidal, high-flow channel. With the exception of the cross-section data and flow data, the input data and parameters matched the input used in the SedVeg Gen1 Platte River Model. The parameters were then systematically varied with only one parameter modified per run. Sensitivity testing of the vegetation parameters proceeded under a separate series of model runs.

Sensitivity of Hydraulic Parameters

River hydraulics is a function of river flow, cross-section shape, and channel roughness. River hydraulic conditions directly affect sediment transport rates and the growth and removal of vegetation. Water temperature affects viscosity of flow, which influences the fall velocity of suspended sediment particles and the sediment transport rate. The model assumes that ice will form if the air temperature is sufficiently cold for long periods. The formation of ice can cause additional scour of vegetation.

The effects due to the change in river flow, both with river mile and over time, are of particular interest in this study. Several simulations were performed in which the river flows vary considerably over both time and distance. Therefore, a separate sensitivity analysis of varying river flows was not included in this set.

Cross-section shape

At the time of the sensitivity studies, cross sections of the Platte River channel were available from surveys in 1989 and again in 1998, 1999, and 2000. For these surveys, the horizontal distance is accurate to within 1 foot, and the vertical elevation is accurate to within a few tenths of 1 foot. However, the development of cross sections representing 1865 conditions requires considerable judgment. Therefore, a second method was used to develop cross sections that likely represented 1865 conditions. In this second method, a spreadsheet was used to develop all cross sections using the same number of coordinate points with the same relative horizontal and vertical spacing. In the spreadsheet, the total width, mean bed elevation, and standard deviation about this mean are specified separately for each cross section. The sensitivity of the model output to a second method of cross section development and the standard deviation of channel bottom elevations was tested.

Manning's *n* roughness coefficient

The Manning's *n* roughness coefficients that are used in the model as initial conditions are based on the values published in a flood insurance study for Platte River at Lexington, NE (0.035 for the active river channel and 0.07 for the wooded floodplains). These initial roughness values were not changed in the model calibration. However, the model allows the roughness coefficients to change over time as vegetation grows. Sensitivity of the model output to changes in roughness values was tested.

Sensitivity of Sediment Parameters

Sediment transport rates are a function of the channel hydraulics and the bed-material grain-size distribution. Longitudinal differences in sediment transport rates determine the amount of erosion or deposition at a particular cross section. The amount of erosion or deposition affects the bed-material grain-size distribution so that rates of erosion or deposition would change with time, due to grain size changes, if the river were flowing at a constant rate. River-bed erosion can also lead to the removal of vegetation. If significant erosion occurs over a narrow portion of the channel, the river flow may be contained within the narrow channel, and vegetation would grow on the wider portions of the channel abandoned by the flow. Deposition on the channel bottom would raise the water table, cause low-elevation vegetation to drown, and result in a wider channel. Sensitivity analyses were conducted on the parameters that cause the amount of deposition and erosion to change.

Sediment transport equation

Because normal depth is assumed at each cross section, only a transport equation based on unit stream power can be used in the model. A transport equation based on shear stress would predict that sediment transport rates would increase with water depth. As vegetation grows, the channel roughness and water depth would increase along with the sediment transport rate. This sequence of events does not make physical sense.

Therefore, the sensitivity of the model output to a different sediment transport equation, the Engelund-Hansen equation, which is also based on unit stream power, was tested.

North Platte River sediment supply

Prior to water resource development, the sediment supply rate from the North Platte River was thought to be roughly ten times the supply rate from the South Platte River. However, the historic sediment transport rate from the North Platte River is not precisely known. Therefore, the sensitivity of the model output to the sediment supply rate from the North Platte River was tested by varying the width of the channel on the North Platte River. Because the sediment supply rate from the South Platte River is relatively small, sensitivity testing was not as necessary but was included in the testing.

Initial bed-material grain size distribution

The known river-bed grain-size data are limited to a few tens of samples taken in 1931, 1979-80, 1989, and 2000. Many samples were collected near bridges and may not have been typical of the reaches between bridges. Therefore, sensitivity of the model to variations in the grain-size data was tested.

Transverse bed slope

The slope between two underwater points in the riverbed can be set to a maximum value to represent island and bar slopes and characteristic transverse bed slopes of a river by a transverse-slope angle. The mechanism used to characterize the transverse bed slope was the erosion of material from the top of the transverse slope instead of the toe of the slope. This effectively adds a transverse bed-smoothing interaction whose strength is governed by the size of the limiting transverse-slope angle. Lower critical slope results in a flatter bed. This mechanism also affects the sediment transport rate by supplying sediment from shallower sections of the cross section. Sensitivity of sediment transport to the transverse bed slope was tested.

Bank slope

The river bank slope parameter prevents the slope between any underwater point in the riverbed and a neighboring dry point on the bank from exceeding a limiting bank-slope angle. This variable represents a value less than the maximum angle of repose of the bank material, to allow for erosion at modeled flow velocities that do not include the higher erosive velocities resulting from secondary flow currents. The mechanism used to characterize bank slope was the erosion of material from the top of the bank slope instead of the toe of the slope. Sensitivity of the model to the bank slope parameter was tested.

Vertical distribution of suspended sediments (Rouse number)

The model uses the vertical distribution of suspended sediment to separate the transverse locations of sediment coming from upstream. Because the model uses a total load sediment transport formula, the Rouse Number of the vertical distribution is increased to effectively suspend the coarser particles that move as bed load. The effect of variation of the Rouse Number on the sediment transport of one coarse grain size is that higher Rouse Numbers result in the transport of more very coarse sand past Chapman. Sensitivity of the model to the Rouse Number was tested.

Bed material armor layer thickness

The model uses an armor layer whose vertical dimension is only one immobile grain-size thick (D_{90}), multiplied by an armor layer coefficient. This thickness is a parameter which affects the total sediment transport rate by limiting that rate whenever an armor layer forms. If the thickness required to form an armor layer were doubled, the effects on the transport rate would be smaller. Sensitivity of the model to a variation of this armor-layer thickness coefficient was tested.

Cross section spacing

The distance between cross sections is used to compute volume of sediment transport from area changes at the cross section and is used in the active layer scour computations. Changing the spacing between cross sections should have no effect on sediment transport, however the effect of changing the spacing was evaluated in the sensitivity test series.. The spacing between cross sections was first assigned an even spacing, then assigned a repeat pattern of short spacing followed by long spacing, and the final test was spacing that matched the SedVeg Gen1 Platte River model.

Results of Sensitivity Testing of Hydraulic and Sediment Transport Parameters

The results of the study are shown in Table 4.1. The sediment transport load was used as the indicator of sensitivity, and was compared against the sediment transport load from other runs in the series. For example, the sediment transport output for a run with a roughness value of 0.035 was compared against sediment transport from runs with roughness values of 0.025, 0.030, 0.040, and 0.045. For most series, the variation in sediment transport loads represents a reasonable range in values. However, this study did detect one shortcoming in the code: the model was sensitive to cross-section spacing. Alternating short and long spacing between cross sections introduced excessive variations in sediment transport. The flawed link to cross section spacing in the scour routine was found and improved in the associated code.

Table 4.1**a.** Results of SedVeg Gen1 Model Sensitivity Testing

	XS4-17 Average Width	Ave No. Channels	Elev Change XS3	Elev Change XS	ft	XS 5-17 Ave Change Bed Elev. InChan	NonCha	3-17 Ave. Grain Size	4-10 Ave. Grain Size	11-17 Ave. Grain Size	Transport NP&SP	Average XS5-17	Deposition at XS3	Average XS5-17
Base Run	3900	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,233,432	469,086,415	216,811,181	-11,722,703
Armor Layer														
1	4186	1	1.8	9&10	0.3	0.2	0	0.60	0.62	0.59	551,216,700	441,524,704	218,108,815	-11,361,703
1.5	4100	1	1.8	9	0.3	0.2	0	0.60	0.61	0.59	551,298,162	455,623,617	216,556,728	-11,065,144
2	3900	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,233,432	469,086,415	216,811,181	-11,722,703
2.5	3729	1	1.8	mult	0.2	0.1	0	0.60	0.61	0.6	551,290,074	483,452,240	215,823,487	-12,510,913
3	3643	1	1.8	4	-0.3	0.1	0	0.60	0.61	0.6	551,349,956	497,515,561	214,799,403	-12,605,555
Hkappa														
0.5	4414	1	1.8	4&5	0.4	0.2	-0.1	0.59	0.59	0.59	549,681,957	406,635,960	223,901,341	-13,427,372
0.8	4214	1	1.8	9	0.3	0.2	0	0.59	0.6	0.59	551,044,111	439,976,421	215,452,310	-11,998,643
1	3900	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,233,432	469,086,415	216,811,181	-11,722,703
1.2	3500	1	1.9	mult	0.2	0.1	0	0.61	0.63	0.6	551,186,743	498,291,319	213,700,294	-13,335,398
1.5	3071	1	1.8	4	-0.4	0	0	0.62	0.65	0.6	551,602,992	529,146,469	210,497,417	-14,626,114
Channel Rn														
0.025	3843	1	2.7	mult	0.2	0.2	0	0.60	0.62	0.58	787,144,606	595,179,486	327,988,885	-12,713,833
0.03	3900	1	2.1	mult	0.2	0.2	0	0.60	0.61	0.59	648,873,191	513,160,463	265,380,155	-12,531,499
0.035	3900	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,233,432	469,086,415	216,811,181	-11,722,703
0.04	3957	1	1.7	mult	0.2	0.1	0	0.60	0.61	0.59	478,029,895	431,786,239	186,067,133	-13,655,052
0.045	4214	1	1.4	mult	0.2	0.1	0	0.60	0.61	0.6	422,253,312	403,531,871	157,265,284	-13,920,554
Bank Slope														
0.38	3900	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,233,383	469,009,618	216,810,144	-11,696,632
0.48	3900	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,233,383	469,009,618	216,810,144	-11,696,633
0.58	3900	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,233,432	469,086,415	216,811,181	-11,722,703
0.68	3900	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,233,432	469,140,325	216,811,054	-11,714,867

Table 4.2**b.** Results of SedVeg Gen1 Model Sensitivity Testing

	XS4-17 Average Width	Ave No. Channels	Elev Change XS3	Elev Change XS	ft	XS 5-17 Ave Change Bed Elev. InChan	NonCh	3-17 Ave. Grain Size	4-10 Ave. Grain Size	11-17 Ave. Grain Size	Transport NP&SP	Average XS5-17	Deposition at XS3	Average XS5-17
Rate Veg Rn Change														
0	4700	1	1.7	mult	0.3	0.2	-0.1	0.60	0.6	0.59	551,374,250	471,936,312	209,543,918	-15,296,537
0.001	4243	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,432,302	461,849,082	212,488,642	-12,995,777
0.002	3900	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,233,432	469,086,415	216,811,181	-11,722,703
0.003	3814	1	1.8	mult	0.2	0.1	0	0.60	0.61	0.59	551,185,742	460,730,814	219,374,187	-14,439,311
0.004	3743	1	1.8	mult	0.2	0.1	0	0.61	0.63	0.59	552,492,128	538,911,213	209,008,124	-11,459,456
N.Platte Width														
3300	3929	1	1.8	mult	0.2	0.1	0	0.60	0.61	0.59	557,623,162	470,648,746	220,526,632	-11,583,716
4800	3929	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	552,499,693	469,275,908	217,606,575	-11,668,760
6300	3900	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,233,432	469,086,415	216,811,181	-11,722,703
7800	3843	1	1.7	mult	0.2	0.2	0	0.60	0.61	0.59	551,341,579	468,576,231	216,802,802	-11,525,859
S.PlatteWidth														
1500	3957	1	3.9	4	0.3	0.1	0	0.60	0.61	0.59	858,548,270	472,492,551	487,811,080	-11,642,344
2300	4014	1	2.4	mult	0.2	0.1	0	0.60	0.61	0.59	665,108,867	470,214,726	314,202,806	-12,316,104
3100	3900	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,233,432	469,086,415	216,811,181	-11,722,703
3900	3900	1	1.3	mult	.2/-.2	0.1	0	0.61	0.61	0.59	478,644,696	472,688,660	148,308,589	-11,449,877
Std Dev Bed														
0.8	3900	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,233,432	469,086,415	216,811,181	-11,722,703
1.1	4314/23	3.0	1.8	4	-0.3	-0.1	0	0.64	0.64	0.65	552,353,106	484,389,598	209,904,225	-11,340,883
1.4	2071/15	2.0	1.7	4	-4.9	-0.7	0	0.72	0.78	0.66	547,811,342	546,526,794	181,535,783	-9,121,932
1.7	2507/98	3.9	1.5	4	-2.3	-0.4	0	0.65	0.68	0.62	556,199,059	582,239,308	150,570,592	-12,587,284
SedTransEq														
Yang	3900	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,233,432	469,086,415	216,811,181	-11,722,703
Enghans	4557	1	2.3	13&16	0.4	0.2	-0.2	0.61	0.62	0.59	943,320,499	808,478,569	310,550,752	-14,980,861

Table 4.3c**.** Results of SedVeg Gen1 Model Sensitivity Testing

	XS4-17 Average Width	Ave No. Chan nels	Elev Change XS3	Elev Change XS	ft	XS 5-17 Ave Change Bed Elev. InChan	NonCh	3-17 Ave. Grain Size	4-10 Ave. Grain Size	11-17 Ave. Grain Size	Transport NP&SP	Average XS5-17	Deposition at XS3	Average XS5-17
OddSpaceXS														
even	3900	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,233,432	469,086,415	216,811,181	-11,722,703
short long	4443	1	1.9	17	0.8	0.3	0	0.61	0.63	0.59	551,478,652	-58,177,561	217,838,738	194,952,388
short long s	4026/38	1.4	1.7	11	-1.6	0	0.1	0.65	0.61	0.68	552,474,418	358,273,563	190,546,393	-2,932,436
existing	4086	1	2.3	16	-0.8	0.2	0	0.59	0.6	0.58	525,757,319	450,801,775	203,531,704	-8,755,937
GrainDistrib														
est 1865 - s	3900	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,233,432	469,086,415	216,811,181	-11,722,703
std&gi	4071	1	1.8	15	0.4	0.2	0	0.61	0.61	0.61	551,233,432	459,751,321	216,811,181	-7,501,837
std&k&gi	4143	1	1.8	11	-2.6	0.1	0	0.55	0.61	0.48	551,233,432	501,461,984	216,811,181	-8,025,967
std&ov&k&	4357	1	1.8	11	-9.7	-0.4	-0.1	0.65	0.81	0.49	551,233,432	450,326,252	216,811,305	-4,990,494
coz&ov&k&	4354	1	2	11	-13.8	-0.7	-0.1	0.75	1.02	0.5	548,527,470	374,874,117	247,977,609	-9,679,930
Channel Width														
1500	1504	1	-2.6	4	-1.8	-0.8	-0.1	0.73	0.74	0.71	601,230,514	843,505,351	-74,447,581	-12,227,638
3100	3074	1	1	mult	-0.3	-0.2	-0.1	0.76	0.79	0.71	563,470,734	568,404,971	69,995,967	-17,577,175
3100 MPts														
4700	3869	1	1.8	14&15	0.3	0.2	-0.1	0.61	0.62	0.59	554,076,320	518,930,027	161,780,564	-12,488,393
6300	3900	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,233,432	469,086,415	216,811,181	-11,722,703
7900	3957	1	1.9	4	-0.5	0.2	0	0.60	0.61	0.59	549,331,265	446,441,684	256,821,533	-11,052,115
9500	4014	1	2	4	-0.8	0.2	0	0.60	0.6	0.59	548,360,973	429,358,742	280,747,894	-9,685,536
Critical Slope														
0.22	3929	1	1.8	mult	0.2	0.1	0	0.60	0.61	0.59	551,264,512	468,747,030	216,841,200	-11,912,841
0.27	3871	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,263,081	468,897,479	216,854,061	-11,738,394
0.32	3900	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,233,432	469,086,415	216,811,181	-11,722,703
0.37	3929	1	1.8	mult	0.2	0.2	0	0.60	0.61	0.59	551,231,739	468,643,881	216,779,130	-11,621,218
0.42	3843	1	1.8	mult	0.2	0.1	0	0.60	0.61	0.59	551,206,638	468,846,223	216,688,234	-11,905,072

Sensitivity Testing of Vegetation Subroutines

Sensitivity testing of the vegetation subroutines was addressed under a separate sensitivity test series. Response of the vegetation algorithms is primarily controlled by the variable input parameters associated with each algorithm. Vegetation subroutines were tested individually to ensure that they were conceptually correct in terms of responding to the given hydraulic conditions and model parameters. This testing was conducted first by applying the individual subroutines to simplified channel geometry. Documentation of these initial tests is not provided at this time since the results of these simplified tests (similar to the ones found in the initial testing of the original model by Simons & Associates, 1990) are elementary. Response of various individual subroutines was tested on Platte River channel geometry to demonstrate their performance under conditions consistent with actual model calibration and application runs.

The initial runs covered a time period of just over 500 months (44 years), and therefore, he maximum age that vegetation could reach for this run was 44 years. For annual vegetation, no individual plant lives more than a year, and an age greater than 12 months indicates the annual persistence of that particular type of vegetation at a given location. The calibration runs began with an initial condition of no vegetation of any type at any point. Other initial conditions are possible. The barren condition was selected so that vegetation could be predominantly controlled by the germination process. The barren condition represents a condition devoid of vegetation that is close to representing an actual case where vegetation is relatively sparse. In previous modeling of the Platte River it was found that vegetation rapidly establishes its own portion of the landscape in a condition of dynamic equilibrium that is consistent with hydrologic and hydraulic conditions (assuming the hydrology is not undergoing some significant long-term trend of its own).

Germination

Under this test case germination of vegetation was allowed to occur at all points in the cross section but did not allow any mortality by any cause. The results demonstrated that vegetation grew at all points in the cross section if no mortality was allowed to occur.

Velocity Scour

Scour due to excessive velocity was demonstrated using an initial set of controlling parameters. These parameters caused removal of vegetation to occur at a range of velocities depending on the age of vegetation. An individual set of parameters exists for each type of vegetation. This initial test showed that at some of the points, particularly the lower lying points in the cross section, vegetation either does not exist (zero age) or is very young, having recently been removed. Vegetation persisted at one cross section, possibly indicating a hydraulic problem in which reasonable velocities were not achieved.

Ice Scour

Removal by ice results in a fairly significant portion of the vegetation being removed and also results in some variation in age of the remaining stand of vegetation. More removal occurred at higher points in a cross section than at lower points, probably because the ice was only allowed to affect a band of elevation surrounding the water surface elevation for the flow at the time of ice break-up. Again, the same cross section indicated little removal by ice scour and was recommended for additional investigation.

Inundation

The results showed, as would be expected, most mortality by inundation occurred at the lowest points in the cross section. Some mortality occurred at points of intermediate elevation with moderate-aged vegetation remaining, while some types of vegetation reached maximum age at the higher points. One cross section, the same one mentioned above, only had mortality at the very lowest point in the cross section.

Desiccation

This test considered mortality by desiccation due to an excessively rapid and large drop in water surface elevation during the growing season. For the set of parameters selected in this test, no mortality occurred. While current data show that mortality by desiccation is relatively limited (except perhaps for the youngest vegetation), the parameters selected were probably extremely limiting.

Model Sensitivity

Sensitivity of model results to the various vegetation parameters are described in the previous tests. Some runs showed virtually complete vegetation of the channel, while others showed a range of vegetation removal depending on the parameters. The entire spectrum of vegetation, or lack thereof, could be generated by the model depending on the parameters selected for use. This provides a great deal of flexibility in model calibration but also dictates a difficult calibration process given the wide range of results that can be generated.

4.1.5 External Reviews of SedVeg Gen1

Three outside reviews addressed some aspect of the SedVeg Gen1 code and/or Platte River Model. The first review focused on the SedVeg Gen1 code structure. The second review, by Parsons (2003), was the most in depth and considered the code, the model, and the theory upon which the model was based. The third review by the National Research Council (2005) considered general capabilities of the SedVeg Gen1 Platte River Model.

Code Structure Review

During development of SedVeg Gen1, Reclamation sought an independent review of the code structure. No written record of this review could be found due to the sudden demise of Dr. Murphy. However, based on discussions with Dr. Murphy prior to his death, two main comments from the reviewer were: more written comments should be incorporated into the code; and more division of code should be used for the main subroutine, PLAT0.FOR. Written comments have increased substantially in SedVeg Gen2 and SedVeg Gen3. However, the single, large and complex subroutine, PLAT0.FOR, remains undivided since it would require a major revision of the program for this refinement.

Review by Parsons

The states of Colorado, Nebraska, and Wyoming contracted with Parsons for a review of the Platte River Program, including the SedVeg numerical model. Simons and Associates, authors of the vegetation subroutines in SedVeg, subcontracted to Parsons to review the sediment subroutines in SedVeg. Dr. Carter Johnson was also subcontracted by Parsons, and provided comments on vegetation aspects of the SedVeg numerical model. Many model comments in the review pertain to the SedVeg Gen1 Platte River Model. The review comments address the model and basic theory behind the model.

Comments from the technical memorandums by Parsons (2003) were submitted as comments on the DEIS (USDOI, 2003). Written comments on the basis of the model and on the SedVeg Gen1 Platte River Model, and the responses presented in the FEIS (USDOI, 2006) can be found in Appendix B. The comments included in the appendix were not all authored by the Parsons team, but in most cases refer to information presented in the Parsons technical memorandums. The response to every DEIS comment submitted was organized under either a Summary Comment or addressed individually in the FEIS. An excerpt from Summary Comment 20 LF-19 outlines the actions taken in response to the review comments.

Summary Comment 20: General concerns with the SEDVEG code and model.

Summary Response: These comments on the SEDVEG code and Platte River Model in most cases originate from the model review presented in the Parsons Report (2003). Dr. Cannelli of Simons and Associates, as a subcontractor to Parsons, reviewed a May 2001 version of SEDVEG code and Platte River Model. His comments are presented in the B2 Technical Memorandum – Independent Assessment of "SED" Concepts in SEDVEG Model. Dr. Cannelli's comments can be divided into three categories:

- Technical or conceptual concerns that have been addressed through code and model revisions [Revisions to SedVeg Gen1 and SedVeg Gen2 are listed in revision sections of Chapter 4 and Chapter 5 of this report]. Examples include the increased number of cross sections and the inclusion of tributary sediment inputs in the model.
- Technical or conceptual concerns that were incorrect or are now addressed. Examples include assumptions that the model had not been calibrated or tested, assumptions that hardwired algorithms fix maximum scour depth, and the concern that predictive capabilities of the 2001 version of the model were poor based on an analysis which evaluated the 2D aspects of this 1D Model.
- Suggestions that are not critical but would improve 1D modeling capabilities. Items in this category have been added to a list of proposed improvements for the next major revision of the SEDVEG code and Platte River Model [See Chapter 6 of this report]. Examples include replacing the existing normal depth algorithms with step-backwater computations, adding a mechanism that eliminates vegetation based on a minimum depth of burial by sediment, and a second calibration of the vegetation removal by ice mechanism.

Review by the National Research Council

By invitation from the Governance Committee of the Platte River Recovery Program, the National Research Council (NRC) reviewed the Platte River Program in 2003. Papers, reports and the 2001 version of the SedVeg Gen1 code were made available to the review committee. The final report by NRC was Endangered and Threatened Species of the Platte River, 2005. As reported in the text, pg 13:

> *Since the early 1990s, more data have become available, and the USBR has conducted considerable cutting-edge research on a new model (SEDVEG) that should update earlier calculations but is not yet in full operation (and was not reviewed by this committee).*

From page 153 of the NRC text:

> *Thus, Murphy et al. (2001) [the draft of this report] use a pseudo-one-dimensional model to include the possibility of having a channel cross section with nonuniform shapes. That approach is generally accepted, and many models use different schemes to represent sediment and lateral flow distribution among the various lateral cross sections. Several unproven assumptions have been used for the lateral distributions of flow and sediment in the current pseudo-one-dimensional model. The vegetation resistance should be determined from the field data instead of from other references. Some of the longitudinal intervals between two cross-sectional sections are too long to yield any reliable hydrogeomorphic relationships. If properly calibrated and validated, this model can give qualitative impressions of sediment and flow analyses, including the evaluation of the effect of vegetation removal and management.*

Responses to the points raised are:

- The scheme for lateral distribution of sediment has proven very satisfactory to date;
- It is our understanding that field data has been used in the estimation of vegetation resistance;
- We agree that cross-section spacing in the SedVeg Gen1 model was large, and cross-section spacing in SedVeg Gen3 has been reduced from one cross section per 7 miles, to one cross section per 1.4 miles; and
- We concur that calibration and verification testing are important to the modeling process, and descriptions of SedVeg testing are included in Chapter 4, Chapter 5, Appendix D, and Appendix E of this report.

The National Research Council (2005) also assessed the value of SedVeg to the Platte River Program on page 154:

> *Current USDOI model developments, including the emerging SEDVEG Model, are likely to be helpful and useful in both understanding and managing the Platte River.*

4.2 SedVeg Gen2 Platte River Model

Prior to the DEIS, revisions were made to the SedVeg Gen1 code in response to internal and external reviews. A calibration analysis eliminated any biasing tendencies at individual sections. At a steady flow, the slope of each section was adjusted to transport an equivalent volume of sediment, i.e., no sections could be inherently degrading. A sensitivity study was also carried out. The analysis of data from the SedVeg Gen2 Platte River Model was presented in the DEIS (USDOI, 2003).

Thirty-three river cross sections were used to represent 168 miles of the Platte River, beginning at the confluence of the North Platte and South Platte Rivers (river mile 328.1), and extending downstream towards Chapman, NE (river mile 159.7). Due to the extensive length and limited number of cross sections, the model results represent average conditions and trends for reaches, rather than an absolute prediction of conditions at a specific site. The computational methods are essentially the same for SedVeg Gen1 and SedVeg Gen2.

Comments related to SedVeg Gen2 that were submitted on the DEIS, and the written responses presented in the FEIS (USDOI, 2006), are also included in Appendix B of this report. Theoretical concepts of the model were also informally reviewed by Dr. Shen of the University of California-Berkeley, during a fact finding meeting for the National Academy of Sciences review. As discussed later, there is no written documentation of the oral review with Reclamation.

4.2.1 Revisions to SedVeg Gen1 Platte River Model

One of the improvements was to increase the program's capacity for the number of cross sections. The original code (SedVeg Gen1) had 17 sections for testing and developing, while SedVeg Gen2 was increased to 33 cross sections to be used for evaluating alternatives in the DEIS. A second significant revision to the code was the automation of mechanical management actions, such as clearing and leveling islands. SedVeg Gen1 could not track the interrelated effects of changes in flow and sediment, and mechanical management actions, such as cuts or fills in the cross section and vegetation clearing. Additional code revisions included:

- An increase in the number of flow inputs from 5 to 17;
- modification to the fixed bed capabilities;

- automation of elevation adjustments for data points in a cross-section input file;
- new code for tracking forage fish depths;
- modification to sandhill crane periods and roosting depths for habitat tracking;
- modification of the location of sediment inputs to upstream of a cross section; and
- Refinements from Simons and Associates on ice scour and flow scour in the vegetation subroutines.

The Platte River Model was also revised with:

- the addition of 16 duplicate cross sections in the target habitat reach and centered in program lands;
- a new hypothetical land plan developed by the Grand Island Office of the US Fish and Wildlife Service, and by the Platte River EIS Office in Denver;
- adjustments to stable root fraction values; and
- Adjustments in the roughness elevation values at sections.

4.2.2 Description of SedVeg Gen2 Platte River Model

The SedVeg Gen2 Platte River Model uses 33 cross sections spaced along the river to represent channel geometry. Seventeen cross sections are the same sections used in SedVeg Gen1 and SedVeg Gen 2 models the same reach of river as the original model.

The number of coordinates per cross section ranged from 35 to 322. Under the 3 land plans considered, land management actions were proposed in 8 of the 13 bridge segments (bridge segments 1, 2, 5, 6, 8, 9, 10, and 11). At each bridge segment containing a proposed land management area, the cross section in that bridge segment was shifted upstream or downstream to the midpoint of the land management area. The elevation points of the shifted cross section were adjusted to preserve the average slope of that Platte River bridge segment.

In order to quantify the longitudinal extent of the land management area, the measured cross section was replicated twice and placed both upstream and downstream from the managed area. The measured cross section was replicated to evaluate the effects of the management action by direct comparison with the upstream and downstream unmanaged sections, which all initiated with the same geometry. Elevations of all points within the replicated cross sections were also adjusted to be consistent with the average river slope of the bridge segment. A total of 33 cross sections were used in the model, including 16 replicated cross sections for eight bridge segments, and 17 cross sections from SedVeg Gen1that originate from the 1989 survey (Holburn *et al.*, 2006). Table 4.4. shows the location of SedVeg Gen1 and SedVeg Gen2 cross sections, and duplicated sections are designated by d/s (downstream) or u/s (upstream) after the bridge segment number to indicate their location within the segment.

The model cross sections used for simulation of the land management actions were located such that each section characterized an average representation of the land management areas or areas upstream and downstream of land management areas. Due to the extended length of the modeled river and the limited number of cross sections, the cross sections in this model functioned more as an average representation of a reach, rather than as a descriptor of a specific site.

Table 4.4. Cross section locations in the SedVeg Gen1 and SedVeg Gen2 Platte River Models.

SedVeg Gen1 Cross Sections			SedVeg Gen2 Cross Sections			Description
River Mile	Bridge Segment	Section Number	*Bridge Segment	River Mile	Section Number	
328.1		1		328.1	1	North Platte nr Hershey, NE
325.0		2		325.0	2	South Platte nr Hershey, NE
310.2		2		310.2	3	Platte R. nr Maxwell, NE
258.3		2		258.3	4	30-mile Canal, nr Darr, NE
250.5	13	5	13	250.5	5	downstream of Lexington, NE
244.0	12	6	12	244.0	6	Jeffreys Island
237.5	11	7	11 u/s	237.9	7	nr Overton, NE
			11 mid	235.2	8	
			11 d/s	232.2	9	nr Elm Creek, NE
228.7	10	8	10 u/s	228.7	10	downstream of Elm Creek
			10 mid	226.0	11	
			10 d/s	224.5	12	nr Odessa, NE
			9 u/s	222.3	13	
			9 mid	219.9	14	Long Island
218.8	9	9				
			9 d/s	216.9	15	upstream of Kearney, NE
			8 u/s	213.9	16	downstream of Kearney, NE
			8 mid	212.1	17	
209.8	8	10				
			8 d/s	209.7	18	Kilgore Island
203.3	7	11	7	203.3	19	Fort Farm Island
			6 u/s	200.9	20	Clark Island nr Gibbon, NE
199.5	6	12				
			6 mid	198.6	21	
			6 d/s	196.8	22	upstream of Shelton, NE
			5 u/s	194.2	23	Downstream of Shelton, NE
			5 mid	191.5	24	
189.3	5	13	5 d/s	189.3	25	nr Wood River, NE
183.2	4	14	4	183.2	26	Shoemaker Island
178.4	3	15	3	178.4	27	Morman Island
			2 u/s	172.3	28	
170.3	2	16				
			2 mid	169.4	29	nr Grand Island, NE
			2 d/s	168.1	30	nr Grand Island, NE
			1 u/s	166.0	31	
162.2	1	17	1 mid	162.2	32	
			1 d/s	159.7	33	upstream Chapman, NE

- d/s = downstream of land management area, mid = middle of land management area, and u/s = upstream of land management area. Upstream (u/s) and downstream (d/s) sections are duplicates of original (mid) surveyed section.

Parameters Assigned to Points within Cross Sections

The roughness coefficient (Manning's *n*), sediment grain-size distribution, and vegetation species composition including bare sand were initially defined for each coordinate point within each river cross section. Ten sediment grain sizes and four species of vegetation were tracked at each cross-section point. One of five sediment size gradations was assigned to each modeled cross section to represent the initial bed material conditions. One size gradation was initially assigned to the North Platte River; one gradation initially assigned to the South Platte River, and one of three gradations were initially assigned to each cross section along the central Platte River. Finer sediment size gradations were assigned to the downstream cross sections along the central Platte River.

Initial conditions for vegetation at each cross section were based on the analysis of 1998 aerial photographs and field observation data. The four vegetation types simulated by the model were cottonwood trees, river willow, spike rush, and prairie cord grass. For each segment of river cross section where one of these vegetation types was identified, the initial age of this vegetation type was set equal to 16 months for all the cross-section points within the segment. The 16 months of initial vegetation growth correspond to about 3 years of age. The initial age of 16 months was only assigned to one vegetation type per cross-section point, but the model may allow all four types to grow at the same point. For coordinate points that described the active river channel, the initial age was set to zero for all four vegetation types. An initial or "warm-up" period of 3 years was added to the beginning of the model simulation for the alternatives analysis to allow for minor adjustments to the initial vegetation age and bed-material grain-size values assigned to each cross-section point.

Boundary Conditions and Flow Inputs

The user supplied boundary conditions of river discharge for the North Platte River, the South Platte River, and for 15 downstream locations on the Platte River to account for changes in flow resulting from canal diversions, irrigation return flows, groundwater losses, and tributary inflows. The model automatically computed the sediment supply from the North and South Platte Rivers based on sediment transport capacities and the river flow, hydraulics, and the bed material grain size at these tributary cross sections. One additional boundary condition was imposed by assigning a longitudinal slope to the downstream most cross section. There were no inputs of sediment downstream of the North Platte and South Platte Rivers.

The river flow rates were defined as a series of mean-daily flows for a period of 61 years. Flow rates were separately specified for seventeen locations throughout the modeled reach. At each location, the mean-daily flow rate was assumed to be constant over the daily time step. The river flows were based on historical USGS stream gage data adjusted by the OPSTUDY hydrologic model (Stroup and Anderson, 2006) to current operating conditions (Appendix C). OPSTUDY provided 48 years of daily flow data. Years 24 through 36, of the 48-year record, were repeated at the front end of the 48-year record to create a total flow data set of 61 years.

The first 13 years of the 61-year flow record is a representative subset of the subsequent 48 years. The mean, standard deviation, and distribution of flows during this continuous 13-year period most closely correspond to the conditions over the 48-year period.

Specified Sediment and Vegetation Coefficients and Parameters

The first 3 years represented a start-up period of land acquisition, research, and baseline monitoring, followed by 10 years of land management actions. Flow management occurs over all 13 years of this period and for the succeeding 48 years. Year 61 includes the first 10 years of land management actions and 61 years of flow management. Therefore, 61 years of modeling tests the sustainability of land management actions and provides an understanding of channel changes resulting from proposed flow conditions with no accompanying augmentation of the sediment supply.

The SedVeg models are largely deterministic, but do require the user to specify some coefficients. All of the specified coefficients in SedVeg Gen2 are within a reasonable range. For example, Manning's *n* roughness coefficients are based on a FEMA Flood Insurance report and range from 0.035 for the main channel to 0.07 for the forested flood plain. The model adjusts the roughness value between these limits depending on extent of vegetation growth. The sediment coefficients used for the SedVeg Gen2 Platte River analysis are shown in Table 4.5, and the vegetation coefficients are shown in Table 6.4.

In most cases, the sediment coefficients were identical to the values used in the calibrated and tested SedVeg Gen1 Platte River Model. With the exception of Stable Root Fraction, the vegetation coefficients were calibrated by Simons & Associates, who developed the vegetation code for the SedVeg Gen1 Platte River Model under contract to Reclamation.

Table 4.5. SedVeg Gen2 Platte River Model sediment transport coefficients used for the DEIS comparison of alternatives.

Description of Sediment Transport Coefficients	Coefficients Used
Number of Size Fractions (NF)	10
Sediment armor layer thickness ($C*D_{90}$)	0.5
Fraction of sediment transport capacity input for North Platte River	0.13
Fraction of sediment transport capacity input for South Platte River	0.38
Rouse Number (Hkappa)	0.80
Range of Manning's roughness value for channel bed and banks, Rn	0.035 to 0.070
Manning's roughness value of thalweg	0.035
Maximum river bank slope for erosion control (BANKSLOP)	0.58
Maximum transverse bed slope between 2 points for erosion control (CRITSLOP)	0.32

Table 6.4 – SedVeg Gen2 Platte River Model vegetation coefficients used for the DEIS comparison of alternatives.

Description of Vegetation Coefficients	Cottonwood	Willow	Spike Rush	Cord Grass
Vegetation removal by active layer scour, desiccation, and ice scour				
Root growth rates for March to October (ft/mo)	-0.500	-0.375	-0.062	-0.125
First month root growth rate for Cottonwoods (ft/mo)	-0.16	NA	NA	NA
Extent of Capillary Fringe, with respect to water table (ft)	0.20	0.20	0.20	0.20
Limit of root growth with respect to water table or capillary fringe (ft) (+ is above and – is below)	0.0	-99.0	-0.5	+1.0
Capillary fringe as base (=1) or water table as base (=0)	1	1	1	1
Stable root fraction, measured up from tip (0.00 to 1.00)	0.75	0.75	0.75	0.75
Germination season	Jun-Jul	Mar-Sep	Mar-Sep	Mar-Sep
Dormancy season	Oct-Apr	Nv-Mar	Nv-Mar	Nv-Mar
Vegetation factor for each vegetation type	1.0	1.0	1.0	1.0
Drop coefficients (drop in water surface elevation) for each vegetation and age (ft)	-0.58 -0.30 -0.15	-0.40 -0.20 -0.10	-0.20 -0.10 -0.05	-0.10 -0.07 -0.03
End of dormancy (month) when veg becomes susceptible to drops in W.S. elevation	May	May	May	May
Beginning of dormancy (month)	Oct	Oct	Oct	Oct
Representative size fraction for bed material (mm)	0.50	0.40	0.60	0.35
Vegest Subroutine Lo (1) or Hi (2)	1	1	1	1
Hiband (code), Loband (code)	0.00 0.00	0.00 0.00	9.00 0.00	99.00 0.00
Manning's base roughness for each veg type when present	0.035	0.035	0.035	0.035
Annual roughness increase for each veg type	.002	.001	.001	.002
Manning's roughness value for sand is 0.035.				

Mechanical Actions

One vegetation clearing plan, and two clearing and island leveling plans were considered in the SedVeg Gen2 Platte River Model. Land management actions for the clearing plan were simulated in the model by removing all vegetation from islands and active channel banks at six cross sections on July 1 of Year 4. At each point in the cross section located in the segment designated for clearing, the four vegetation parameters were reset to zero months of growth. The input included year of the action, the cross section where the land management action occurred, and two points which bounded the segment of clearing.

Land management actions for the clearing and leveling land plans were simulated in the model by removing the vegetation and reshaping a segment of the cross section on July 1 of every year that island leveling began at a cross section. The clearing and leveling land plan also included sediment augmentation, with sediment added to the river daily during the summer field season. New geometry was entered on that date at specified locations in the cross section as average elevations for cut and fill between two points. In general, islands were leveled to the bed of the channel as a cut, and where feasible, some side channels were filled in (i.e., consolidating flow) to help create a wider main channel. The model modified the section to the fill elevation. At every point in the segment of cut or fill, the vegetation was cleared by setting the age of the four species of vegetation to zero.

Table 4.5 contains the model input specifying clearing and leveling for one land plan. The input includes the date of the action, the cross section where the action occurs, two points which bound the segment of cut or fill and clearing, and the average elevation of the cut and fill.

Table 4.5 – SedVeg Gen2 model input for clearing and leveling land plan number 1.

July 1 of	Cross Section	Left Station (ft)	Right Station (ft)	Average Elevation (ft)
Year 4	8	1572.3	1606.5	2277
Year 4	8	2420.4	3332.4	2273
Year 4	8	4067.6	4283.9	2277
Year 4	8	4746.8	4779.9	2277
Year 4	8	5055.2	5328.6	2277
Year 4	8	5492.3	5687.4	2275.4
Year 8	11	152.09	464.04	2213
Year 9	14	2397.59	2882.21	2175.7
Year 10	17	5230	5472.2	2122.5
Year 10	17	5528	5625.8	2122.5
Year 10	17	5692.4	6005.1	2122.5
Year 11	21	16.4	82.8	2038
Year 11	21	1233.8	1539.5	2034
Year 11	21	1858.2	1959.9	2034
Year 12	29	4695	5084.67	1849.5

4.2.3 Calibration and Sensitivity Studies for the SedVeg Gen2 Platte River Model

The SedVeg Gen2 model was calibrated for constant conveyance, and the root scour depth was calibrated to observation width of the channel. Sensitivity studies of SedVeg Gen2 included examination of the root scour depth and investigation of the number of years over which widening actions on the channel were maintained by river flows.

Calibrating for Constant Conveyance in all Cross Sections

Prior to modeling the alternatives, a calibration procedure was performed with the SedVeg Gen2 Platte River Model. The calibration procedure was designed to prevent any integration of bias in the model towards a narrowing channel and focused on the conveyance of flow and sediment at each cross section.

As presented in the section Development of Cross sections, the 33 cross sections used to compare alternatives for the DEIS include 17 surveyed cross sections from SedVeg Gen1, and 16 duplicates of these sections (Table 4.2). Most of the cross sections were shifted longitudinally to represent average reach conditions, and the elevations of the points in each cross section were initially adjusted based on an average slope for the bridge segment. In the calibration, the elevation of points in every cross section, and subsequently the slope of the channel, were adjusted a second time to make the transport of sediment through each section equal. Longitudinal slope is based on the thalweg (lowest) elevation in the cross section. Because rivers have a natural sequence of pools and riffles, which on the Platte River can vary the longitudinal depths by at least 2 ft, the random location of surveyed cross sections with respect to the pool-riffle system can create an error in the average longitudinal slope of 2 vertical ft. For example, a cross section surveyed in a pool section (bend) of the river would have a thalweg elevation at least 2 ft lower than the average longitudinal slope due to bend scour at that location. With the exception of several cross sections at the extreme upstream and downstream locations in the model, most of the cross sections were adjusted within this 2-foot maximum value. A steady flow of 5,000 cfs was assigned to all 33 cross sections in the calibration model run.

The purpose for this conveyance calibration was to eliminate any bias in the model towards an aggrading or degrading condition due to random selection of widely spaced cross sections. The same cross sections, river miles, and point elevations, which produced this stable condition of sediment transport, were then used to compare the alternatives for the DEIS. Predictions of aggrading or degrading conditions by the model for DEIS alternatives were therefore due to discontinuities in the river flow and sediment transport of each alternative, rather than an inherent bias in the model.

Calibrating for Root Scour Depth

The initial SedVeg Gen2 model produced a channel that had overly high resistance to erosion by river flows due to vegetation. The depth of active bed movement, rather than flow velocity (used in SedVeg Gen3), was the elected basis of vegetation scour in the SedVeg Gen1 and SedVeg Gen2 Platte River Models. After a sensitivity study of the root depth values, a calibration of the scour root depth was carried out to reduce the bank resistance due to the presence of vegetation. The coefficient, stable root fraction (Table 4.4), was adjusted to a value of 0.75.

4.2.4 External Reviews of SedVeg Gen2 Platte River Model

DEIS Review

The SedVeg Gen2 Platte River Model was applied for the comparison of alternatives in the DEIS (USDOI, 2003). In addition to the analysis described in the DEIS text, a description of the SedVeg Gen2 Platte River Model was included in the Appendices of the DEIS, and is in some cases, the basis of comments.
The DEIS public review is described by the following excerpt from the FEIS (2006).

> *The official public comment period on the DEIS began January 26, 2004 and, at the request of the States, was extended twice by Federal Register notice on March 31, 2004 and May 26, 2004. Both extensions were to allow the public time to review the DEIS along with the National Academy of Sciences report entitled, "Endangered and Threatened Species in the Platte River Basin", which was released in May, 2004. The public was invited to submit comments by email, letter, or fax, or through testimony at the DEIS public hearings. The comment period concluded September 20, 2004.*

The Platte River EIS Office received and addressed submissions from 23 Federal, State, local, and city agencies; 16 irrigation, power, and conservation districts, natural resource departments, and water user associations; 13 local agencies in Colorado, Nebraska and Wyoming; 15 environmental groups; and 33 private citizens. In addition, nearly 7,000 postcards and letters were received through conservation groups, including the National Wildlife Federation and

American Rivers. All written and oral comments are on file with the Reclamation.

As presented in a previous section of this report, Review of the SedVeg Gen1 Platte River Model, many of the USDOI comments pertain to the Parsons review of the SedVeg Gen1 model. However there are some comments that focus on the SedVeg Gen2 Platte River Model, including concerns over the conveyance calibration and parameters used for the DEIS studies. All DEIS comments and responses on SedVeg and the theory behind SedVeg are reported in Appendix B.

Informal Discussion

Dr. Hsieh Shen of the University of California-Berkeley, met with Reclamation personnel in 2003 on a fact finding visit, as a committee member of the National Research Council (NRC). A review of the SedVeg code was not included in the study; however Dr. Shen was interested in sediment transport studies on the Platte River and in the SedVeg model. The theoretical basis and sediment transport algorithms of the SedVeg Gen2 code were discussed in detail. During this informal session, Dr. Shen recommended the velocity modeling approach of vegetation scour, over the active layer depth approach of vegetation scour used in the SedVeg Gen1 and SedVeg Gen2 models. This recommendation was incorporated into the SedVeg Gen 3 Platte River Model.

5.0 SedVeg Gen3 Platte River Model

The numerical sediment transport model used in the evaluation of FEIS (USDOI, 2006) alternatives is the SedVeg Gen3 Platte River Model. Descriptions of the model revisions; calibration, verification and sensitivity studies; and a general description of sediment transport in the Central Platte River based on Present Condition flows are reported in this chapter. Program code, input files, and output files are included in electronic format in Appendix A and in the River Geomorphology Appendix of the FEIS. The FEIS also contains input and output files for the four alternatives considered in that document: Governance Committee, Water Emphasis, Full Water Leasing and Wet Meadows. See the FEIS (DOI, 2006) for the analysis of the alternatives.

5.1 Revisions to the SedVeg Gen2 Platte River Model

Major revisions to the SedVeg Gen2 code and Platte River Model by Reclamation occurred from fall of 2004, through the spring of 2005. Revisions originated from application of the SedVeg Gen2 Platte River Model by Reclamation, and from DEIS public review comments.

5.1.1 Revisions to the Code

Modifications to the SedVeg Gen3 code include an additional sediment mass balance algorithm and additional model capabilities, such as increased cross section capacity and mechanisms for tributary sediment inputs, which allow a more detailed analysis of the Platte River system.

An improved sediment mass balance was added to the program code with an associated set of output files (DBG##.dat) for quality control. The mass balance is checked at every cross section and at every time step for:

mass balance 1 = incoming sediment + tributary sediment - out coming sediment
mass balance 2 = bed changes used
mass balance 3 = sediment deposition/erosion calculated from the geometry change, and
mass balance 4 = sediment that should be deposited on the bed.

In conjunction with this revision, several errors in the code were found and corrected, including:

- A mass balance error associated with calculating transport at the first and last point in a cross section;
- SedVeg Gen2 did not allow neighbor cross-section points to have the same elevation and added a small value to one of the points, creating a small error in the mass balance; and
- SedVeg Gen2 did not compute the bed geometry change if the erosion and deposition was small, creating a small mass balance error.

Revisions to the SedVeg Gen2 code which improve or give SedVeg Gen3 increased capabilities include:

- an improved sediment mass balance applied across each cross section was added to the program with a set of mass balance check files;
- an increased capacity for number of cross sections (100 sections);

- activation of the velocity-based option for vegetation scour, which replaced vegetation scour based on depth of active layer and the sediment concentration;
- added a counter for tracking the vegetation mortality associated with each process (i.e. desiccation, inundation, ice scour, velocity scour);
- Re-activated inundation as a vegetation removal process. Due to an error in the code, this process was not activated in SedVeg Gen2;
- added an individual parameter of depth of inundation over the root crown for each of the four vegetation types;
- replaced a user defined input value of roughness elevation with an automated system of dividing main channel from overbank area for hydraulic calculations;
- incorporated three additional methods of sediment input: a sediment rating curve, CN**.DAT sediment files (output from the cross section of a previous run), or a specified standard daily volume (the original method was a specified fraction of the transport capacity at a cross section);
- added the reference flow mechanism, which measures channel geometry variables of a section at an assigned flow at the end of each year;
- added sediment transport summary file and channel characteristics summary file;
- improved code for bank erosion by equalizing the left bank and right bank computational method; and
- Added a display window to the code to allow monitoring of daily water surface elevations, changes to the channel cross section, and growth and mortality of vegetation at a cross section during the model run.

The equalization of the left bank and right bank computation method is described here as an illustration of one of the revisions made to the code. In addressing bank failures, the SedVeg Gen2 code could produce asymmetric channel degradation within a symmetric channel. This result was due to the differences between computational procedures for left bank slope treatments in comparison to right bank procedures. On the left bank, the erosion of the station was first calculated, and then the armoring layer calculation was performed. If the bank slope was exceeded, the erosion and armoring layer calculations were corrected. On the right bank, the erosion of the station was also calculated first. However, if the bank slope was exceeded, the erosion was corrected next. Lastly, the armoring layer calculation was performed. This caused inconsistencies between the results for the left and right banks.

To correct this occurrence, the code was rearranged. For both banks the deposition / erosion is still calculated first. Next, if the bank slope is exceeded, the erosion is corrected for all cross sections (left and right bank), and finally, the armoring layer calculation is performed. The modified model was tested with a simple trapezoidal channel and the result is shown in Figure 5.1.

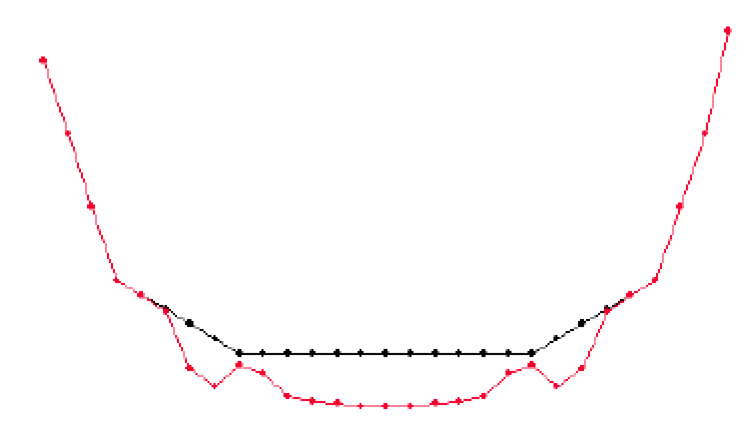

Figure 5.1. Cross section showing change in channel geometry due to bed erosion (degradation) and exceedance of the maximum bank slope. The geometry of the left and right bank widening in this symmetrical channel are identical.

The bank slope calculation shifts the local erosion to the next point that does not exceed the maximum bank slope, or to the first point out of the water surface, or to the end point, whichever is encountered first. The mass balance was also checked for this algorithm and was found to be conserved.

5.1.2 Revisions to the Platte River Model

The SedVeg Gen3 Platte River model was reduced to 84 miles beginning at the Johnson-2 Return downstream of Lexington, NE, and ending at Chapman, NE, while the number of cross sections was increased to 62. This increased the density of cross sections from one cross section every 4.9 miles in the SedVeg Gen2 Platte River Model, to one cross section every 1.4 miles in the SedVeg Gen3 Platte River Model. Of the 62 sections in the SedVeg Gen3 model, 46 are surveyed cross sections or habitat transects, and 16 are synthetic sections that are duplicates or modified cross sections.

In addition to the increased density of cross sections, the SedVeg Gen3 Platte River Model was restructured to begin at the Johnson-2 Return for information on sediment transport processes in the south channel of Jeffreys Island. The SedVeg Gen1 and Gen2 Platte River Models provide sediment transport information on the Platte River from North Platte, NE downstream to the North Channel of Jeffreys Island. However, these previous versions omit the south channel of Jeffrey Island.

Revisions to the features and input, other than the code, that produce the SedVeg Gen3 Platte River Model include:

- increased number (62) and density (averaging 1 section per 1.4 miles) of cross sections with 46 surveyed sections and 16 synthetic sections that are duplicates or modified cross sections;
- modeling of the south channel at Jeffreys Island since the model now begins at the Johnson-2 Return;
- revised OpStudy river flow input that includes depletion flows;
- new land plan that incorporates consolidated flow with cutting banks and islands at most program land sites;
- sediment input at the upstream end of the model is now determined by a sediment rating

curve at the Johnson-2 Return, and sediment input from the north channel of Jeffreys Island is determined by a specified daily input, replacing the sediment transport capacity method at the North Platte and South Platte Rivers;

- addition of 8 tributary inputs of sediment from drainages, including Plum Creek, Spring Creek, Elm Creek and North Dry Creek;
- addition of sediment augmentation at one site as part of the mechanical management actions reviewed in the FEIS;
- an extended “warm-up” period of 17 years to grow vegetation and equilibrate large changes in sediment gradation, with flow input from 1989 (year of most section surveys) to 2005 (first increment of the Program begins in 2006); and
- Increase in the number of data points near a river bank in many cross sections to improve the bank failure mechanism and definition of bank failure in the model.

5.2 Description of the SedVeg Gen3 Platte River Model

Rather than starting at the confluence of the North and South Platte Rivers, the SedVeg Gen3 model begins at the Johnson-2 Return, upstream of Overton, NE. The model ends at Chapman, NE, and a distance of 89 miles downstream from the Johnson-2 Return. The density of cross sections in the model averages one cross section per 1.4 miles for a total of 62 cross sections. The SedVeg Gen3 model excludes the Platte River from the North Platte, NE to the North Channel of Jeffreys Island, but includes the south channel of Jeffreys Island beginning at the Johnson-2 Return. The south channel of Jeffreys Island was not modeled in the Gen1 or Gen2 Platte River Models.

5.2.1 Cross Section Information

The river mile and bridge segment for each cross section in the SedVeg Gen3 Platte River Model are shown in Table 5.1. The origin of the cross-section data is also identified, along with the sediment gradation type, the flow input file, the locations where tributary sediment and managed sediment augmentation occur, and the locations of mechanical actions (consolidating flow and cutting banks and islands)[4]. The first cross section is a synthetic section representing the trapezoidal shape of the Johnson-2 Return structure. The first 6 sections convey flow from the Johnson-2 Return only. A new flow file at cross section 7, near Overton, NE, represents the Jeffreys Island confluence (point at which the north and south channels of Jeffreys Island converge) and the addition of flows discharged from the North Channel. The initial sediment gradation changes at cross section 6 from the coarse Overton gradation to the Grand Island gradation that is finer. This is the only sediment gradation change in the SedVeg Gen3 model. Shown in 5.2, 5.3 and 5.4 are reference maps of the SedVeg Gen3 cross-section locations, with colors differentiating between surveyed and synthetic cross sections.

[4] *The location of land plan sites modeled with SedVeg Gen3 is hypothetical. The actual location of land management actions will be dependent on willing sellers and leasers.*

Table 5.1 SedVeg Gen3 Platte River Model- Cross Sections and Inputs

Black	Surveyed cross-section (XS) or transect (Tr). Transect may have elevations adjusted for a small shift in location upstream or downstream.
Red	Synthetic section- duplicates of other sites or modified sections from other site
CF&Cut	Land plan section – consolidating flow (CF) and bank and island cutting (Cut). *The location of land plan sites modeled with SedVeg Gen3 is hypothetical. The actual location of land management actions will be dependent on willing sellers and leasers.*

River Mile (RM) is a COE measure of main channel distance upstream from the Missouri River. Sediment augmentation at RM 239.9 is 150,000 tons annually. CO = coarse Overton gradation, GI = Grand Island gradation, XS = cross section

	Cross Section Number	River Mile (RM)	Bridge Segment	Origins of Cross Section	Initial Sed Gradation	Flow Files	Tributary Inputs of Sediment
Johnson-2 Return	1	247	12	manmade	CO	1	
	2	246.5	12	Surveyed XS	CO	1	
	3	246	12	surveyed XS	CO	1	
	4	244	12	surveyed XS	CO	1	Plum Cr
	5	243.1	12	S2 Tr1	CO	1	
	6	241.1	12	239.9mod	GI	1	
Confluence Sediment Aug	7	239.9	12	surveyed XS	GI	2	N. Ch Jeff & 1rst minor cr
	8	237.5	11	surveyed XS	GI	2	2nd minor cr
CF&Cut	9	237	11	237.5	GI	2	
CF&Cut	10	234.8	11	233.8	GI	2	
	11	233.8	11	surveyed XS	GI	2	
	12	231.5	11	surveyed XS	GI	2	Spring Cr
	13	230	10	surveyed XS	GI	3	Elm/Buff Cr
	14	228.7	10	surveyed XS	GI	3	
	15	227.2	10	surveyed Tr 4-6	GI	3	
	16	226.7	10	surveyed Tr 4-4	GI	3	
	17	226.2	10	surveyed Tr 4-2	GI	3	
	18	225.1	10	surveyed XS	GI	3	
	19	224.3	10	surveyed XS	GI	3	S. Channel
	20	222	9	surveyed XS	GI	4	
	21	221.2	9	222mod	GI	4	
CF&Cut	22	219.8	9	219.8	GI	4	
CF&Cut	23	219	9	surveyed tr 5-1	GI	4	
CF&Cut	24	218.1	9	surveyed tr 5-3	GI	4	
	25	217.1	9	222mod	GI	4	
KearnyBr	26	215	9	228.7	GI	4	
	27	212.9	8	222mod fr221.2	GI	5	
CF&Cut	28	212.6	8	212.9	GI	5	
	29	210.6	8	surveyed XS	GI	5	N. Dry Cr
	30	208.6	8	surveyed XS	GI	5	
	31	206.6	7	surveyed XS	GI	6	
	32	203.3	7	surveyed XS	GI	6	
	33	201.2	6	surveyed XS	GI	7	

Black	Surveyed cross-section (XS) or transect (Tr). Transect may have elevations adjusted for a small shift in location upstream or downstream.
Red	Synthetic section- duplicates of other sites or modified sections from other site
CF&Cut	Land plan section – consolidating flow (CF) and bank and island cutting (Cut). *The location of land plan sites modeled with SedVeg Gen3 is hypothetical. The actual location of land management actions will be dependent on willing sellers and leasers.*

River Mile (RM) is a COE measure of main channel distance upstream from the Missouri River.
Sediment augmentation at RM 239.9 is 150,000 tons annually.
CO = coarse Overton gradation, GI = Grand Island gradation, XS = cross section

	Cross Section Number	River Mile (RM)	Bridge Segment	Origins of Cross Section	Initial Sed Gradation	Flow Files	Tributary Inputs of Sediment
	34	199.8	6	199.5	GI	7	
CF&Cut	35	199.5	6	199.5	GI	7	
CF&Cut	36	199.1	6	199.5	GI	7	
	37	197.4	6	surveyed XS	GI	8	
	38	194.9	5	surveyed XS	GI	8	
	39	193.9	5	surveyed XS	GI	8	
	40	192.6		Mod 193.9	GI	8	
	41	191.2		Tr 8b4 1986	GI	8	
	42	189.3	5	surveyed XS	GI	8	
	43	188.3	5	surveyed XS	GI	8	
	44	187.4	5	surveyed XS	GI	8	
	45	186.0	4	Mod 183.2	GI	8	
	46	184.5	4	Mod 183.2	GI	9	
	47	183.2	4	surveyed XS	GI	9	
	48	182.1	4	surveyed XS	GI	9	
	49	180.3	3	surveyed XS	GI	9	
	50	178.4	3	surveyed XS	GI	9	
	51	177.3	3	surveyed XS	GI	9	
	52	175.5	3	surveyed XS	GI	9	
	53	174.6	2	surveyed XS	GI	9	
	54	172.6	2	surveyed XS	GI	9	
	55	170.3	2	170.3	GI	9	
	56	167.9	2	surv XS & Tr 167.9	GI	9	
	57	166.9	1	surveyed XS	GI	10	
	58	165.9	1	surveyed XS	GI	10	
	59	162.2	1	surveyed XS	GI	10	
Cut	60	160.9	1	217.1mod from 222mod	GI	10	
	61	158.9	1	157.2	GI	10	
	62	157.2	1	surveyed XS	GI	10	

5.2.2 Flow Information

The SedVeg Gen3 flows are input daily (TEMPFLOWNS.PRN). Flow values originate from the OpStudy model (Stroup and Anderson, 2006), and in contrast to the DEIS, the future depletion flows for the States of Nebraska, Wyoming and Colorado have been included in flow computations (Appendix C). SedVeg Gen3 calculates sediment transport daily, calculates vegetation growth at the end of each month, and takes summary measurements of channel configuration at the end of each year. The summary measurements are based on a reference flow of 1,000 cfs for cross sections 2 to 6, and 2000 cfs for all cross sections from 7 to 62. These reference flows were selected to represent a flow occurring in most years and facilitate an equal comparison between all alternatives.

There are three main flow periods totaling 78 years (Table 5.2): years 1 to 17 of the run (17 years) represent the warm-up period; years 18 to 30 of the run (13 years) represent the First Increment of the Program ; and years 31 to 78 (48 years) represent the succeeding years. The warm-up period is used primarily for growing vegetation, equilibrating sediment gradations, and for model calibration. During the second period, sediment augmentation and mechanical actions of the land plan commence. In the third period, annual sediment augmentation is maintained; however, mechanical actions of the land plan cease. Additional information related to river flows can be found in Appendix C.

Table 5.2. Summary of SedVeg Gen3 Flow Periods

Flow Periods in Model					Flow Record Years	Flow Record Source
Period	Begin SedVeg Year and Calendar Year	End SedVeg Year and Calendar Year	Begin Day Count	End Day Count		
Warmup	Year 1, Jan 1989	Year 6, Dec 1994	1		Jan 1989 to 1994	Present Condition Flows from DEIS
Warmup	Year 7, Jan 1995	Year 15, Sept 2003			1995 to Sept 2003	USGS flow records
Warmup	Year 15, Oct 2003	Year 17, Dec 2005		6209	Oct 2003 to Dec 2003 is repeat of 2002 flows 2004 is repeat of 2002 flow record 2005 is repeat of 2003/2002 combination of existing flow record	
First Increment	Year 18, Jan 2006	Year 30, Dec 2018	6210	10957	1970 to 1982	OpStudy Flows Including Depletions
Succeeding Years	Year 31, Jan 2019	Year 78 Dec 2066	10958	28489	1947 to 1994	OpStudy Flows Including Depletions

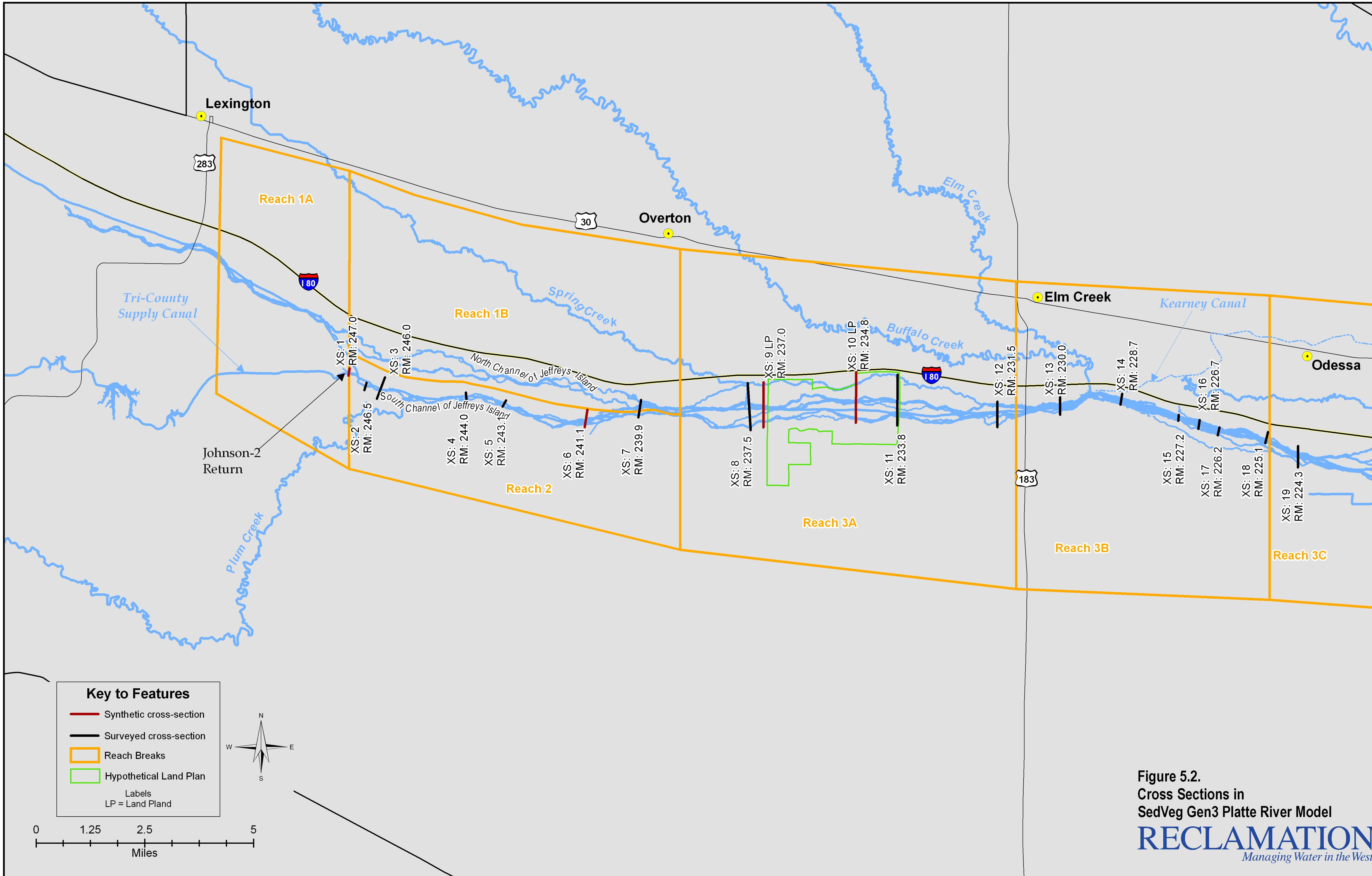

Figure 5.2.
Cross Sections in
SedVeg Gen3 Platte River Model

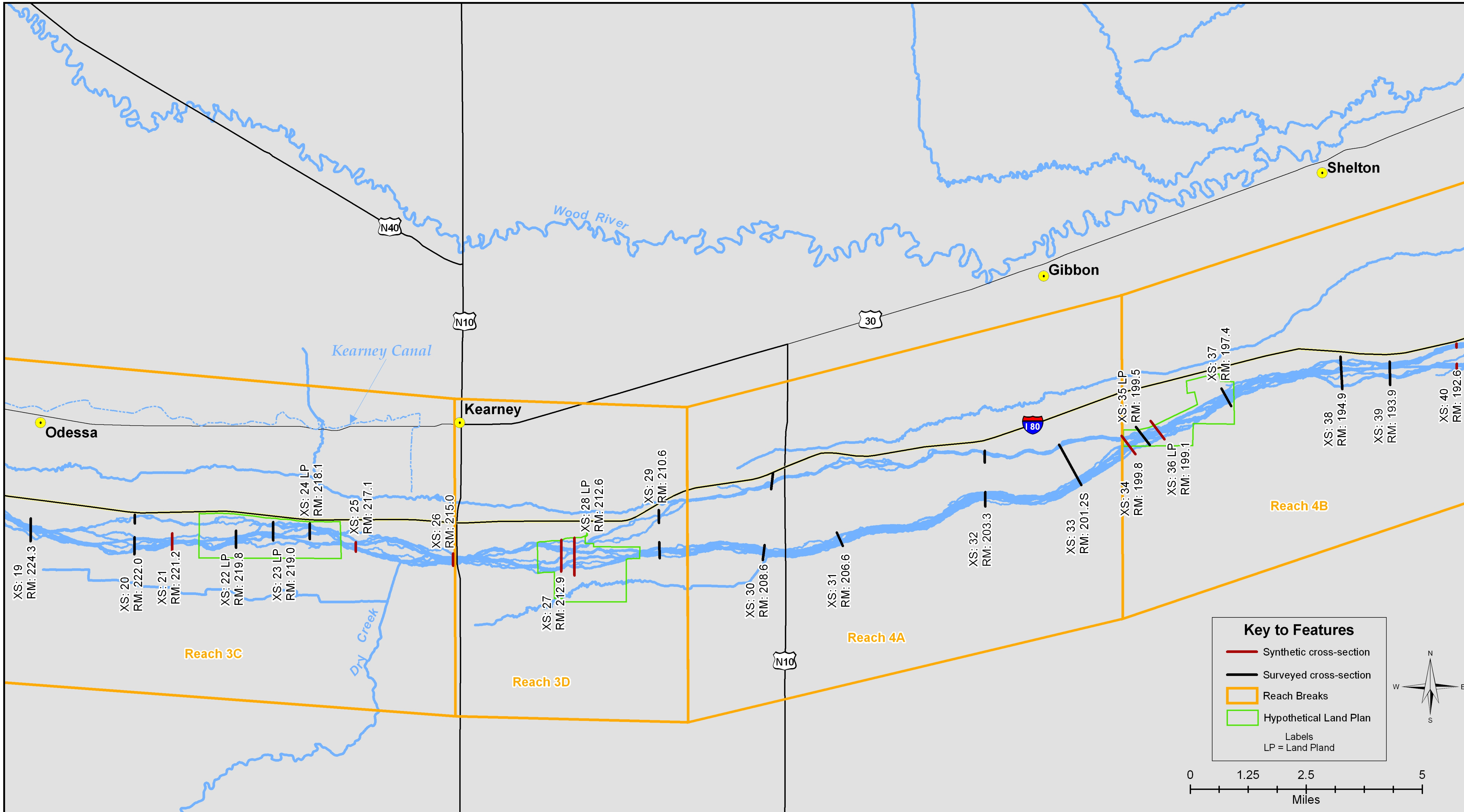

Figure 5.3.
Cross Sections in
SedVeg Gen3 Platte River Model

RECLAMATION
Managing Water in the West

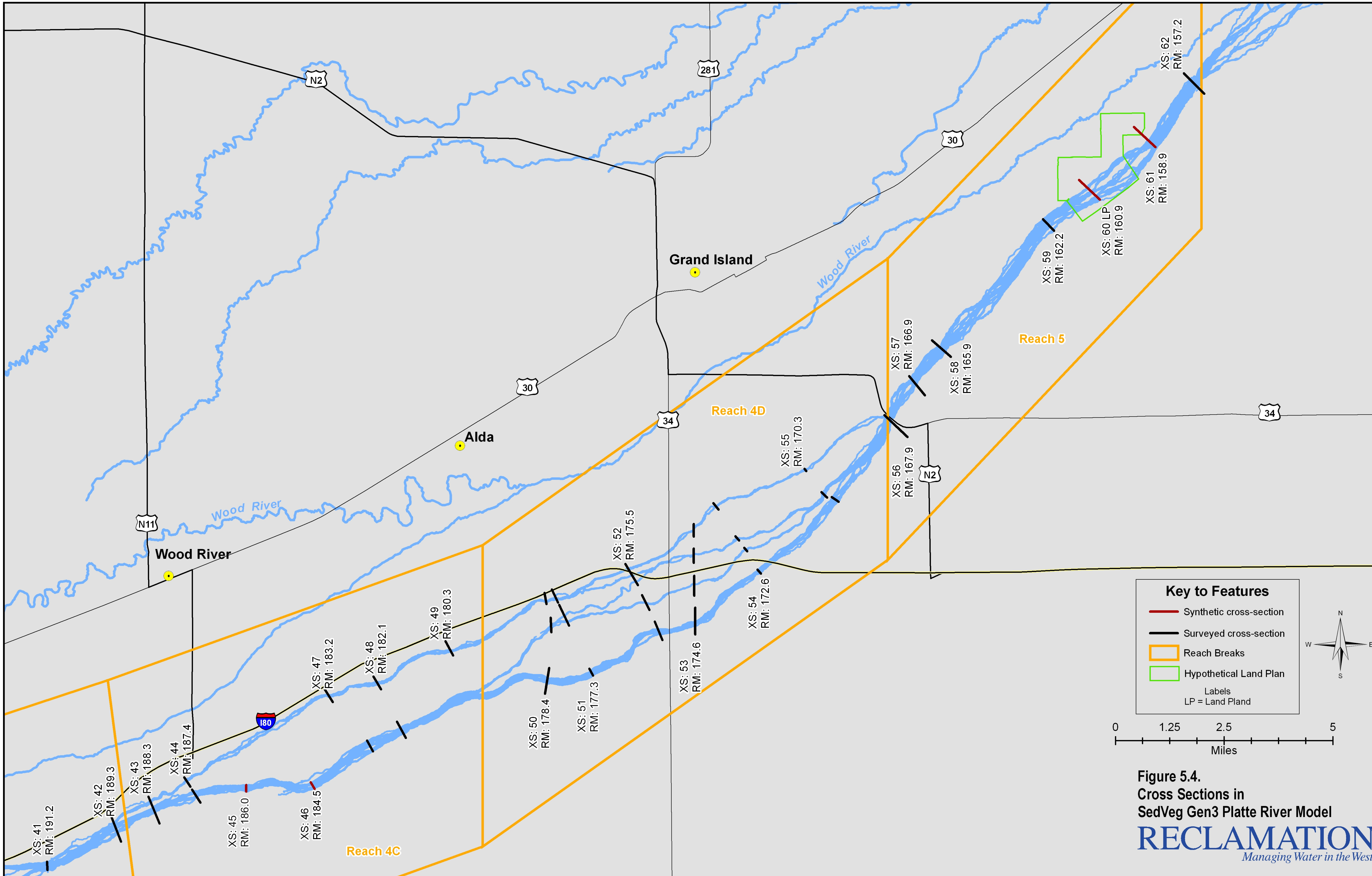

Figure 5.4.
Cross Sections in
SedVeg Gen3 Platte River Model

RECLAMATION
Managing Water in the West

5.2.3 Sediment and Vegetation Coefficients and Parameters

Coefficients and parameters used in the SedVeg Gen3 Platte River Model are listed in Table 5.3 and Table 5.4.

Table 5.3. SedVeg Gen3 Platte River Model Sediment Transport Coefficients used for the FEIS Comparison of Alternatives

Description of Sediment Transport Coefficients	Coefficients Used
Number of Size Fractions (NF)	10
Sediment armor layer thickness (C* D_{90})	0.5
Sediment Rating Curve (total load equation) at the Johnson-2 Return	Coefficient 0.0 Exponent 1.29
Rouse Number (Hkappa)	0.80
Range of Manning's roughness value for channel bed and banks, Rn	0.035 to 0.070
Manning's roughness value of thalweg	0.035
Maximum river bank slope for erosion control (BANKSLOP)	0.15
Maximum transverse bed slope between 2 points for erosion control (CRITSLOP)	0.55

5.2.4 Mechanical Actions and Sediment Augmentation Plan

The input for mechanical actions is entered in the XSECADJ.DAT file and implements non-natural changes to the channel. Examples are: grazing by livestock, mowing fields, harvesting crops, and the cut and fills of river management actions, when these actions occur in areas represented within a model cross section. The XSECADJ.DAT file is not used with the Present Condition alternative; however two XSECADJ.DAT files were used to represent mechanical actions in the FEIS alternatives (DOI, 2006). The XSECADJ.DAT file used for the Governance Committee, Full Water Leasing and Wet Meadow alternatives is listed in Table 5.5. The Water Emphasis plan was similar but with no actions at cross sections 28, 35, and 36.

Table 5.4. SedVeg Gen3 Platte River Model Vegetation Coefficients used for the FEIS Comparison of Alternatives

Description of Vegetation Coefficients	Cottonwood	Willow	Spike Rush	Cord Grass
Vegetation removal by velocity scour, desiccation, inundation and ice scour				
Root growth rates for March to October (ft/mo)	-0.500	-0.375	-0.062	-0.125
First month root growth rate for Cottonwoods (ft/mo)	-0.16	NA	NA	NA
Extent of Capillary Fringe, with respect to water table (ft)	0.20	0.20	0.20	0.20
Limit of root growth with respect to water table or capillary fringe (ft) (+ is above and – is below)	0.0	-99.0	-0.5	+1.0
Capillary fringe as base (=1) or water table as base (=0)	1	1	1	1
Germination season	Jun-Jul	Mar-Sep	Mar-Sep	Mar-Sep
Dormancy season	Oct-Apr	Nov-Mar	Nov-Mar	Nov.-Mar
Maximum scour velocity for 1-yr plants	2.5	2.1	1.8	1.5
Maximum scour velocity for 2-yr plants	3.0	2.6	2.3	2.0
Maximum scour velocity for 3-yr plants	4.0	3.5	3.0	2.5
Maximum scour velocity for 4-yr plants	5.0	4.4	3.7	3.0
Maximum scour velocity for >4-yr plants	6.0	5.1	4.3	3.5
Max. duration of inundation (months) for 1-yr plants	1	3	12	2
Max. duration of inundation (months) for 2-yr plants	1	12	12	2
Max. duration of inundation (months) for 3-yr plants	1	36	12	2
Max. duration of inundation (months) for 4-yr plants	24	48	12	2
Max. duration of inundation (months) for >4-yr plants	24	48	12	2
Minimum inundation depth over root crown	0.25			
Vegetation factor for each vegetation type	1.0	1.0	1.0	1.0
Drop coefficients (drop in water surface elevation) for each vegetation and age (ft)	-0.58 -0.30 -0.15	-0.40 -0.20 -0.10	-0.20 -0.10 -0.05	-0.10 -0.07 -0.03
End of dormancy (month) when veg becomes susceptible to drops in W.S. elevation	May	May	May	May
Beginning of dormancy (month)	Oct	Oct	Oct	Oct
Representative size fraction for bed material (mm)	0.50	0.40	0.60	0.35
Vegest Subroutine Lo (1) or Hi (2)	1	1	1	1
Hiband (code), Loband (code)	0.00 0.00	0.00 0.00	9.00 0.00	99.00 0.00
Manning’s base roughness for each veg type when present	0.035	0.035	0.035	0.035
Annual roughness increase for each veg type	.002	.001	.001	.002
Manning’s roughness value for sand is 0.035				

Table 5.5. SedVeg Gen3 model input for mechanical action plan used for the Governance Committee, Full Water Leasing, and Wet Meadow alternative in the FEIS

Date of Action	Cross Section	Action	Left Station	Right Station	Set Elevation	River Mile
1-Jul-09	9	cut	1437.6	1930.7	2282.9	237
1-Jul-09	9	fill	2987.4	3215.8	2287.8	237
1-Jul-09	9	fill	3967.0	4268.4	2287.8	237
1-Jul-09	10	cut	1483.4	2169.4	2268.7	234.8
1-Jul-09	10	fill	3396.0	3733.6	2273.6	234.8
1-Jul-10	22	fill	0.0	1885.4	2173.2	219.8
1-Jul-10	22	cut	1998.6	2982.8	2168.0	219.8
1-Jul-11	23	fill	80.0	684.0	2168.4	219
1-Jul-11	23	cut	726.0	1709.0	2162.7	219
1-Jul-11	23	fill	2375.0	2680.0	2168.7	219
1-Jul-12	24	fill	0.0	182.0	2161.1	218.1
1-Jul-12	24	cut	192.0	1757.0	2156.5	218.1
1-Jul-12	24	fill	2528.0	2732.0	2161.0	218.1
1-Jul-09	28	fill	1110.8	1490.0	2127.0	212.6
1-Jul-09	28	cut	1830.0	2826.8	2120.9	212.6
1-Jul-10	35	fill	0.0	153.0	2042.0	199.5
1-Jul-10	35	cut	955.5	1971.6	2034.2	199.5
1-Jul-10	35	fill	1997.4	2563.2	2041.0	199.5
1-Jul-11	36	fill	16.4	82.8	2035.5	199.1
1-Jul-11	36	cut	957.0	1959.9	2031.8	199.1
1-Jul-11	36	fill	1975.1	2514.4	2037.0	199.1
1-Jul-12	60	cut	2010.0	2810.0	1787.7	160.9

Actions to consolidate flow are represented by a fill, and actions to level banks and islands are represented by a cut.

5.3 Calibration and Sensitivity Studies

In the two earlier versions of the model, the calibration, sensitivity, and verification testing of the model focused on checking the models capabilities to accurately reflect trends resulting from interrelated processes of flow, sediment, vegetation growth and managed mechanical actions. With SedVeg Gen3, the emphasis in calibration, verification and sensitivity testing shifts towards improving selection of input data and critical boundary conditions. The desired consequences are a better defined river system through an improved one-dimensional representation of the three-dimensional physical world.

5.3.1 Calibration Studies

Several parameters and coefficients were calibrated in the SedVeg Gen3 model including:

- Initial sediment gradations of the channel using changes in bed elevation and sediment transport curve;
- Bank slope based on changes in channel width at the cross sections downstream of Elm Creek;

- Depth of inundation of root crown using wetted widths and observation widths compared to map width measures from 1998 and 2002 infra-red aerial photographs;
- Inputs of tributary sand using the sediment transport curve over the 17 year warm-up period and over the long term (61 years beyond warm-up period).

The bank slope was set at 0.15 ft/ft. When this angle is exceeded, the bank fails and the river widens. This value partially represents the soil parameter, angle of repose, but is also a reflection of the secondary currents in a river which can not be modeled. A one-dimensional model can only track uni-directional velocities, although the secondary flow patterns in rivers produce higher velocities that erode banks. This value should be less than the angle of repose of the soils, but is based on model calibration at locations with measured bank failures. Repeat surveys of cross sections and habitat transects (Holburn *et al.*, 2006) near Elm Creek, where 100 ft of bank erosion occurred over a 13- to 15-year period, was the basis of this calibration

A more detailed explanation of the sediment gradation calibration is presented here as an example of the calibration studies. Initial sediment gradations of the channel (SED.DAT) assigned to every point in the cross section was calibrated using surveyed cross section information and the sediment transport estimates from the SedVeg Gen3 model. An example is shown in Table 5.6 in which changes in the elevation of the cross section thalweg (+ aggradation, - degradation) from cross section surveys over approximately 13 years are compared with model estimates at the same locations for the same time span. Model estimates do not create smooth transitions from section to section since the spaced cross sections are a skeletal representation of the physical world. The surveyed changes in bed elevation do not indicate smooth transitions either since the channel bed is responding to varying localized conditions, in addition to general trends, that may not be included in the boundary conditions input to the model.

Table 5.6 Calibration of sediment gradation using changes in bed elevation as measured at the river bed thalweg. Coarse Overton gradation is used for river mile (RM[5]) 246 to RM 239.9, while the finer Grand Island gradation is used from RM 237.5 downstream.

River Mile (RM)	From Survey usually 1989 to 2002	13 year SedVeg Gen3 calibration Run	Difference between Measured and Modeled Bed Degradation (ft)	Sediment Gradation
246	-4.5	-5.1	-0.6	Coarse Overton
244	-3.8	-2.4	1.4	Coarse Overton
243.1	-3.5	-4.6	-1.1	Coarse Overton
239.9	-2.1	0.1	2.2	Coarse Overton
237.5	-0.6	-2.6	-2.0	Grand Island
233.8	-0.1	-0.7	-0.6	Grand Island
231.5	-0.5	-0.4	0.1	Grand Island
228.7	-1.3	-2.5	-1.2	Grand Island
227.2	-0.1	-1.1	-1.0	Grand Island
226.7	-1.2	-0.8	0.4	Grand Island
226.2	0.6	-0.1	-0.7	Grand Island

The SedVeg Gen2 model used three initial sediment gradations to represent the main channel, and the calibration indicated that only two gradations were needed when using the 17 year warm-up period. The Overton gradation from the SedVeg Gen2 model was coarsened slightly, and this

[5] River mile (RM) is a COE measure of main channel distance upstream from the Missouri River.

modified gradation was used to represent the coarser grain sizes of the south channel of Jeffreys Island resulting from degradation and armoring that has occurred in this reach. The Grand Island gradation was used for all of the cross sections downstream of Overton. The SedVeg Gen2 model used a middle Kearney gradation that was eliminated in SedVeg Gen3 due to discontinuities it created in the sediment transport curve.

5.3.2 Sensitivity Studies

Sensitivity testing included consideration of specific parameters, the cross-section structure and cross section points, and algorithms. Sensitivity studies were an important and continuous endeavor in the development of the SedVeg Gen3 Platte River Model.

Some of the sensitivity investigations for the SedVeg Gen3 Platte River Model include:

- Sensitivity of vegetation to velocity scour;
- Comparison of vegetation removal between the velocity scour algorithm and the active layer scour algorithm using the vegetation mortality counter;
- The effect of vegetation on sediment transport;
- The effects of smoothing the longitudinal bed slope on the sediment transport curve (conclusion was elevation adjustments of cross sections did not significantly smooth sediment transport of disparate cross sections, and therefore, no slope corrections were made);
- Sensitivity of sediment transport curve to volume and location of mechanical sand augmentation;
- Sensitivity of sediment transport curve to the addition of synthetic cross sections between widely spaced surveyed sections (this was beneficial, and four cross sections were added);
- Ability of river to widen through bank slope if degradation undercuts the banks;
- Sensitivity of bank failure/widening mechanism to increased number of points near the bank using the wetted width of the river at the reference flow (this was beneficial, and the number of bank points in many cross sections were increased); and
- Sensitivity of sediment transport curve to cross sections with limited floodplain information, examined over long periods to include effects of high flow events.

Check of Velocity Scour Algorithm

One example of the sensitivity testing relates to the velocity scour algorithm. The display window was used in conjunction with a 15-day flood of 5,000 cfs, simulated at the beginning of the second year, to check the vegetation removed through velocity scour. The tests were done in two steps. In the first step, all available vegetation removal methods were activated to determine if the flood could remove the vegetation. Figure 5.5 and Figure 5.6 show the geometry and vegetation at cross section 3 before and after the flood. The vegetation is removed at the end of the month since vegetation growth and mortality information are updated monthly. In the second step, only the velocity scour method is activated and the other vegetation removal methods are turned off. Figure 5.7 and Figure 5.8 show the geometry and vegetation of cross section 3 before and after the flood. Comparison of the figures indicates that the velocity scour algorithm was effective in removing the vegetation and that the algorithm correctly removes vegetation in the wet area only.

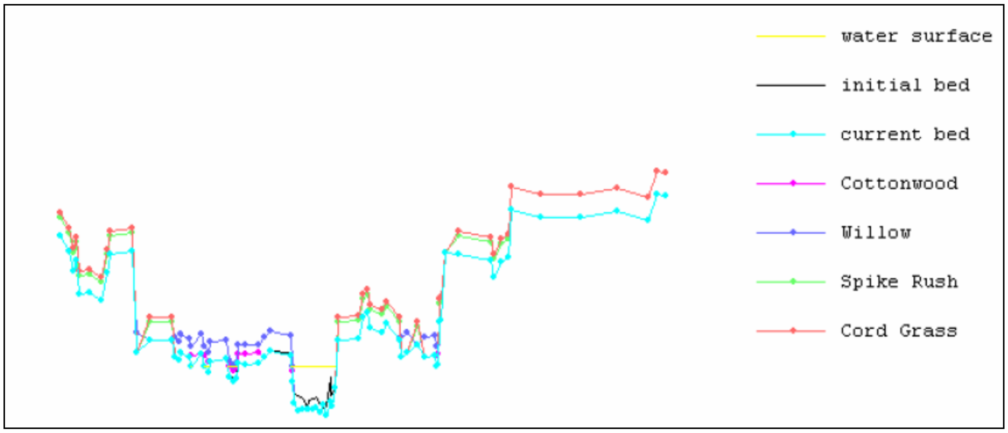

Figure 5.5. Geometry and vegetation of cross section 3 after 1 year simulation and before the flood of 5000 cfs with the velocity scour, desiccation, inundation, and ice scour vegetation removal methods selected

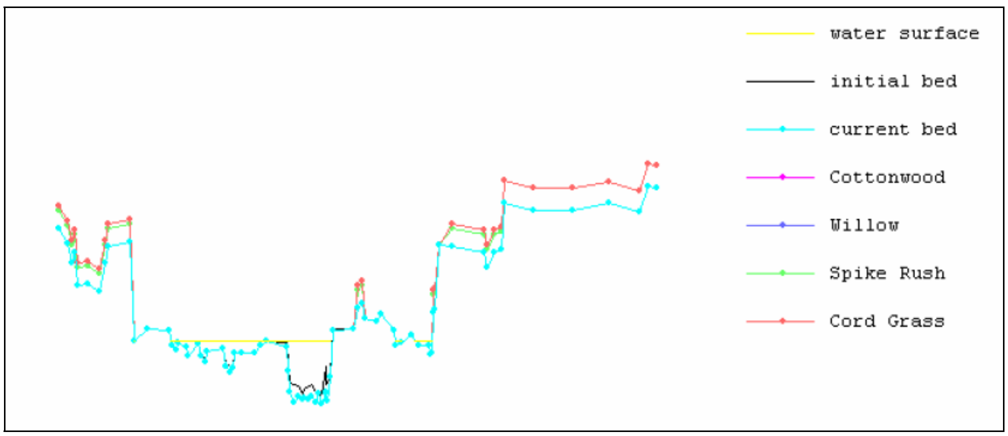

Figure 5.6. Geometry and vegetation of cross section 3 after 1 year and 1 month simulation and after the flood of 5000 cfs with the velocity, desiccation, inundation, and ice scour vegetation removal options selected

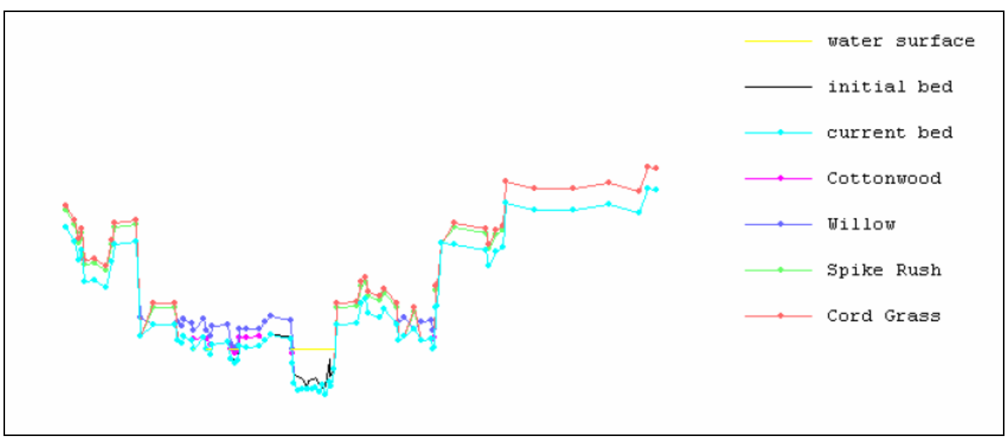

Figure 5.7. Geometry and vegetation of cross section 3 after 1 year simulation and before the flood of 5000 cfs with velocity, desiccation, inundation, and ice scour vegetation removal options selected

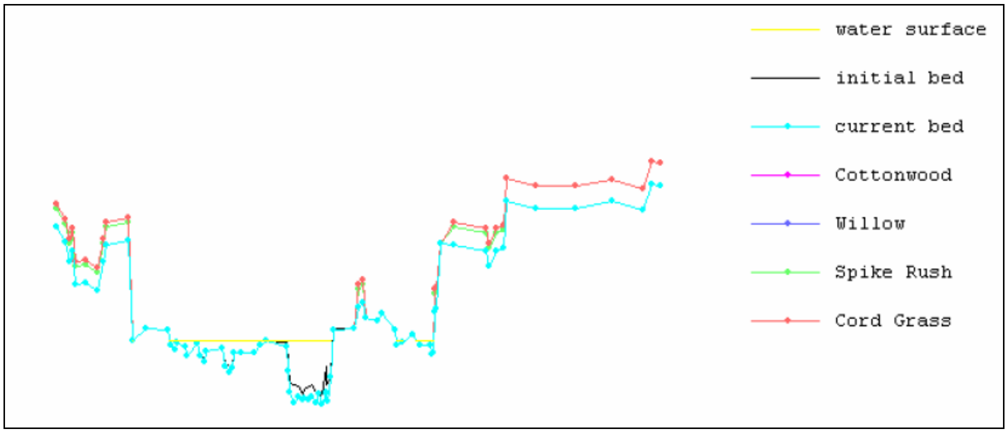

Figure 5.8. Geometry and vegetation of cross section 3 after 1 year and 1 month simulation and after the flood of 5000 cfs with only the velocity scour removal option selected

Impacts of Vegetation on Sediment Transport

A second example of sensitivity testing was a consideration of the impacts of vegetation on sediment transport. The SedVeg Gen3 model was used to calculate the sediment deposition and erosion with and without vegetation. Figure shows the cumulative sediment deposition/erosion comparison with and without vegetation in a river reach. Results show that with vegetation, the reach experienced less erosion. Vegetation can induce greater friction losses, reduce flow velocity, and reduce sediment transport capacity, thereby generally reducing the rate of sediment transport.

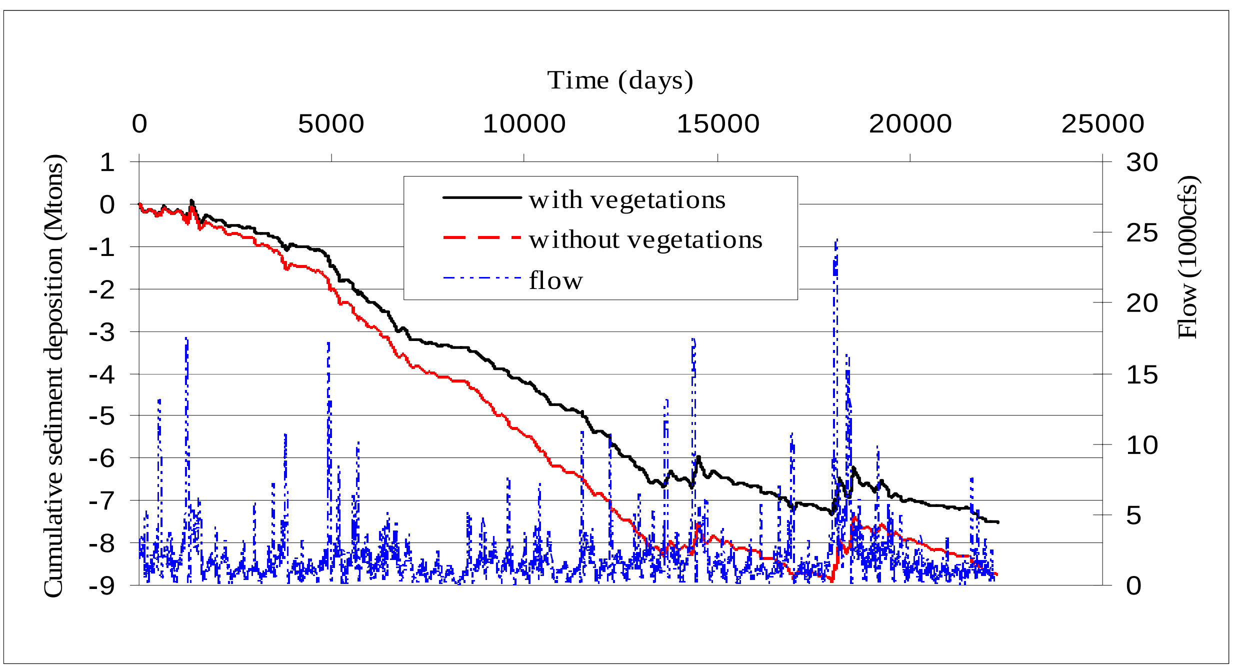

Figure 5.9. Deposition/erosion comparison from SedVeg Gen3 with and without vegetation

5.4 Results and Verification

The input and output of the SedVeg Gen3 Platte River Model can be found in electronic format in Appendix A. Sediment transport data from the model are first calibrated using sediment rating curves from Randle and Samad (2003), then verified using survey data from Holburn *et al.* (2006). Several sediment transport curves collectively provide insight on the movement of sediment through the Central Platte River and are the basis of a general sediment budget.

5.4.1 Calibration of Sediment Transport (Absolute Values)

The sediment transport curve shown in Figure was developed from the SEDIMENT TRANSPORT AND DEPOSITION.DAT output file and shows the average annual transport for the years 1989 to 2001, the first 13 years of the SedVeg Gen3 run (average of years 1-13). When sediment transport is increasing in Figure 5.10, either the bed or banks of the river are eroding to supply sand, or sediment is being added at the tributaries. When sediment transport is decreasing, some of the sediment load is settling or aggrading on the bed of the channel.

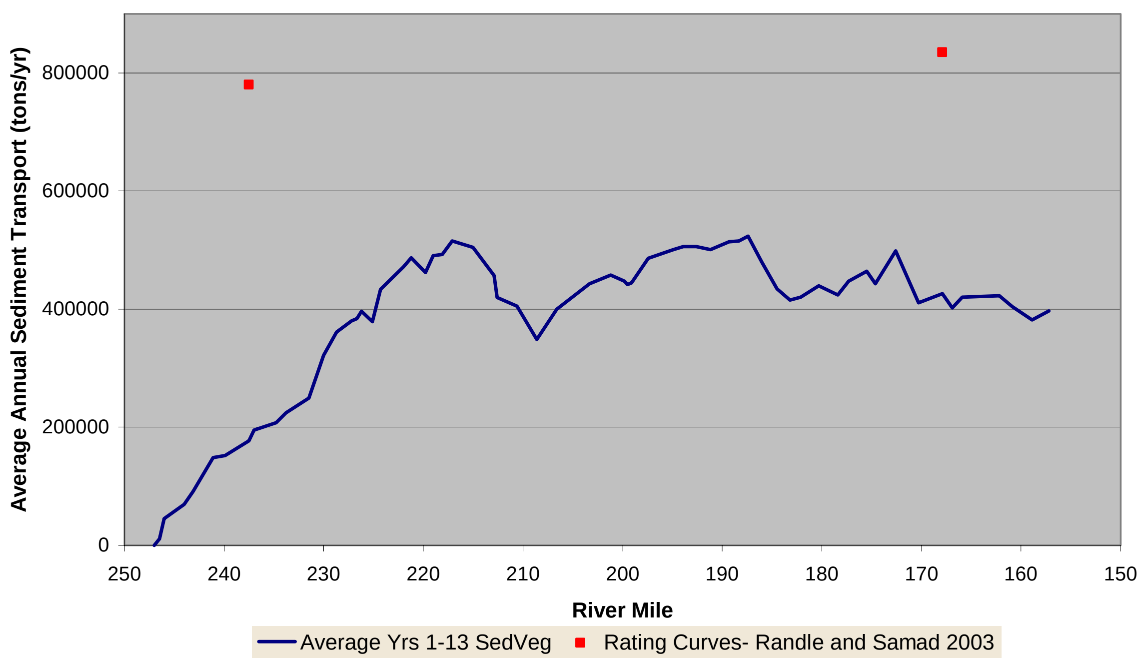

Figure 5.10. SedVeg Gen3 Platte River Model sediment transport as an annual average from years 1989 to 2001, years 1 through 13 of the model run.

Numerical sediment transport models are good for generating relative values of sediment transport (i.e., sediment transport increases beginning at river mile (RM) 247 and is relatively consistent after river mile 185); however, the absolute values are dependent on the sediment transport equation used for the computation, and on the flow years over which the estimates are developed (Figure 5.11). The Yang (1973 and 1984, or 1979 and 1984) total load transport equations, modified to compute transport by size fractions were used for the SedVeg Gen3 runs, and the flow years in this period were relatively wet.

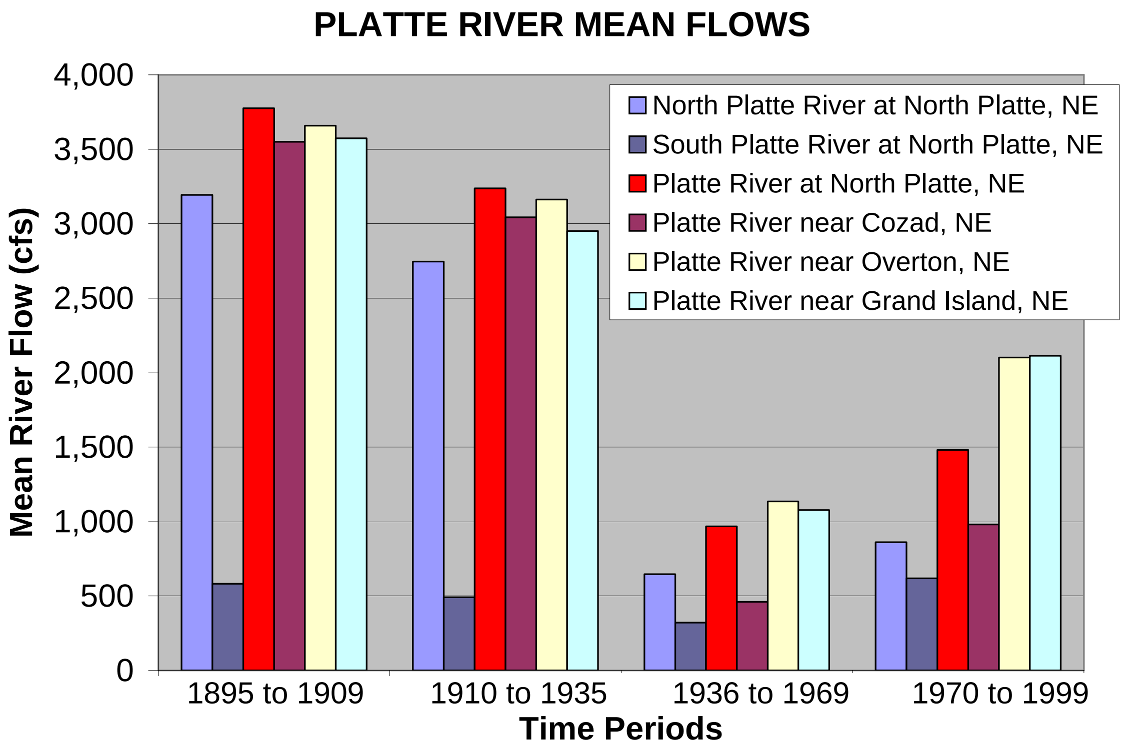

Figure 5.11. Platte River mean flows (Randle and Samad, 2003).

For purposes of improving sediment management estimates, a calibration of the absolute values of the SedVeg sediment transport curve can be accomplished with the sediment rating curves from Randle and Samad (2003). Randle and Samad estimates are computed using sediment rating curves from Simons and Associates (2000) and Kircher (1983), and USGS streamflow records. The Simons and Associates and Kircher rating curves are based on USGS sediment sampling and are specific to the location of data collection. Figure 5.10 and Table 5. 5.7 show average annual point estimates of sediment transport at Overton (RM 240) and Grand Island (RM 168) computed by Randle and Samad (2003). The period of flow years for this estimate is 1970 to 1999, also a relatively wet period.

Table 5.7. Platte River average annual sediment loads (Randle and Samad, 2003).

Platte River Stream Gage Location	Average Annual Sediment Load (tons/year) for Each Time			
	1895 to 1909	1910 to 1935	1936 to 1969	1970 to 1999
based on sediment rating curve by **Simons and Associates, Inc. (2000)**				
Platte River at North Platte, NE	1,530,000	1,380,000	500,000	812,000
Platte River near Cozad, NE	1,730,000	1,300,000	132,000	396,000
Platte River near Overton, NE	1,810,000	1,380,000	347,000	817,000
Platte River near Grand Island, NE	1,670,000	1,270,005	381,000	845,000
based on sediment rating curve by **Kircher (1983)**				
Platte River at North Platte, NE	2,130,000	1,670,000	365,000	680,000
Platte River near Cozad, NE	1,540,000	1,190,000	126,000	361,000
Platte River near Overton, NE	1,600,000	1,260,000	335,000	760,000
Platte River near Grand Island, NE	1,680,000	1,250,000	365,000	826,000

The comparison of values in Figure 5.10 shows the absolute values from the SedVeg Gen3 estimate and from the rating curve estimate differ by a factor of 2. Sediment transport at Grand Island was estimated to be 800,000 tons per year based on the rating curve data and 400,000 tons per year based on the SedVeg-Gen3 estimate. This difference is presumably due to differences in the sediment transport equations and is within reasonable limits for the equations, but to improve estimates of sediment transport for this study, the SedVeg Gen3 values at all locations are multiplied by a factor of 1.5. This adjusts the SedVeg Gen3 estimate of sediment transport volume to a mean value (mean of rating curve method, 800,000 tons annually, and SedVeg Gen3 estimate, 400,000 tons annually) of 600,000 tons annually at Grand Island. While this affects the absolute values of the sediment transport, relative comparisons between various alternatives remain unchanged.

5.4.2 Verification of Sediment Transport (Relative Values)

The relative changes in the SedVeg Gen3 sediment transport curve can be verified for years 1 to 13 (1989 to 2001) by comparing the SedVeg curve to a sediment transport curve developed from repeat surveys (Holburn *et al.*, 2006) during the same period. A measurement of the change in cross-section area multiplied over the longitudinal distance between cross sections provides an estimate of the change in sediment volume (+ aggradation, - degradation). Where the distance was greater than 4 miles between cross section, a maximum volume was determined by multiplying the area by a 4 mile distance. These volumes only relate to two subsequent cross sections. Therefore, in order to develop a sediment transport curve across the study reach, a transport rate must be known at one location.

Table 5.8 displays the computations for a survey-based sediment transport curve with an absolute value assigned to Grand Island (RM168) of 600,000 tons annually (see previous section for development of this value). The change in area measured at each cross section originated from values presented by Holburn *et al.* (2006). In their study, initial surveys occurred between 1985 and 1989, and cross sections were surveyed again between 1998 and 2002. The surveys and computations of change in area are described in Holburn *et al.* (2006). Estimates for tributary sediment were calculated using the Universal Soil Loss Equation (USLE) and coefficients for the USLE are from Yang (1996).

Table 5.8. Average annual sediment budget for the Central Platte River computed from repeat cross section surveys from 1985 to 2002 (Holburn *et al.*, 2006). Values of sediment transport are dependent on the absolute value of sediment transport assigned to the location of the Grand Island Bridge.

Location	River Mile (RM)	From Holburn *et al.*, 2006, Ave annual change in xsec area (sqft)	Ave annual sediment from bed and banks (tons/yr)	Tributary sand (USLE) (tons/yr)	Sediment transport (tons/yr)
	262				
	258	-9	-9,504		231,504
	254				
Lexington	255.6				
	251.6	103	69,340		162,164
	250.5	10	2,376		159,788
	249.8	5	2,970		156,818
	246				
	248				
d/s end of north channel Jeffreys Island	244	-161	-170,016		326,834
	240				
u/s end of south channel of Jeffreys Island	247				0
	246.5	-181	-23,892		23,892
	246	-129	-42,570		66,462
Plum Cr	244	-81	-22,453	44,160	133,075
	243.9	-68	-6,283		139,358
	243.3	-81	-6,950		146,308
	243.25	-87	-2,297		148,605
	243.1	-66	-27,443		176,048
Confluence & 1rst M.Trib.	240.1	-68	-34,109	6,720	543,711
Overton (Bridge)	239.3	-14	-2,033		545,744
	239	-72	-17,107		562,851
2^{nd} Minor Tributary	237.5	35	24,024	6,720	545,547
	233.8	-8	-7,075		552,622
Spring Cr	231.5			19,200	571,822
Elm Cr. Bridge	230.8	-29.4	-19,792		591,614
Elm Cr (& Buffalo.Cr.)	229.3			52,800	644,414
d/s Kearny Diversion	228.7	-55	-24,684		669,098
	227.4	-35	-16,632		685,730
	225.1	-9	-4,039		689,769
S. Channel Platte R.	224.3			13,440	703,209
	224	33	22,216		680,994
	220				
N. Dry Cr	216			15,360	696,354
Kearney	214.6				
	210.6	10	6,336		690,018
Bridge	209.8	22	7,841		682,177
Bridge	207.9	19	6,521		675,656

Location	River Mile (RM)	From Holburn *et al.*, 2006, Ave annual change in xsec area (sqft)	Ave annual sediment from bed and banks (tons/yr)	Tributary sand (USLE) (tons/yr)	Sediment transport (tons/yr)
	207.2	-20	-2,376		678,032
	207	-22	-1,162		679,194
	206.8	-15	-792		679,986
	206.6	18	713		679,273
	206.5	-16	-422		679,695
	206.4	-28	-1,109		680,804
	206.2	-28	-1,478		682,283
	206	-13	-515		682,797
	205.9	-44	-15,682		698,479
	203.3	-28	-13,675		712,154
Bridge	202.2	-33	-16,553		728,707
	199.5	93	68,746		659,961
	196.6	-6	-2,376		662,337
	196.5	-15	-396		662,733
	196.4	-1	-26		662,760
	196.3	-12	-950		663,710
Bridge	195.8	61	36,234		627,476
	191.8				
	195.2				
	191.2	-5	-2,838		630,314
	190.9	3	1,544		628,770
Bridge	187.3	8	8,131		620,639
S.Ch. Platte R./Dry Cr	183.2			0	620,639
	185.9				
Bridge	181.9	0	0		620,639
	178.38	8	3,780		616,858
	178.32	1	15		616,844
	178.27	0	0		616,844
	178.23	5	59		616,784
	178.18	18	1,972		614,812
	177.4	-1	-116		614,928
	177.3	-10	-198		615,126
	177.25	14	185		614,942
	177.2	0	0		614,942
	177.15	10	132		614,810
	177.1	0	0		614,810
Bridge	175.2	21	12,474		602,336
	172.6	-10	-8,712		611,048
	168.6				
	171.85				
Grand Island Bridge	167.85	20	10,560		600,488
	167.85				
	163				
	159	12	6,811		593,676

Location	River Mile (RM)	From Holburn *et al.*, 2006, Ave annual change in xsec area (sqft)	Ave annual sediment from bed and banks (tons/yr)	Tributary sand (USLE) (tons/yr)	Sediment transport (tons/yr)
	158.7	-23	-1,366		595,043
	158.55	16	3,379		591,663
Bridge	157.1	-26	-15,272		606,936
	154.1				
Total				158,400	

A comparison of the SedVeg Gen3 sediment transport curve and the Survey transport curve, with average values for the years 1 to 13 (1989 to 2001), are shown in Figure 5.12. The SedVeg Gen3 values have been multiplied by a factor of 1.5 as presented in the previous section.

Both curves demonstrate an increase in sediment transport for the Central Platte River from the Johnson-2 Return to Elm Creek or Kearney, and a decrease in transport (aggrading condition) beginning at either river mile 203 or 187. The aggrading reach extends approximately 5 miles, and then a relatively stable reach begins that continues to Chapman.

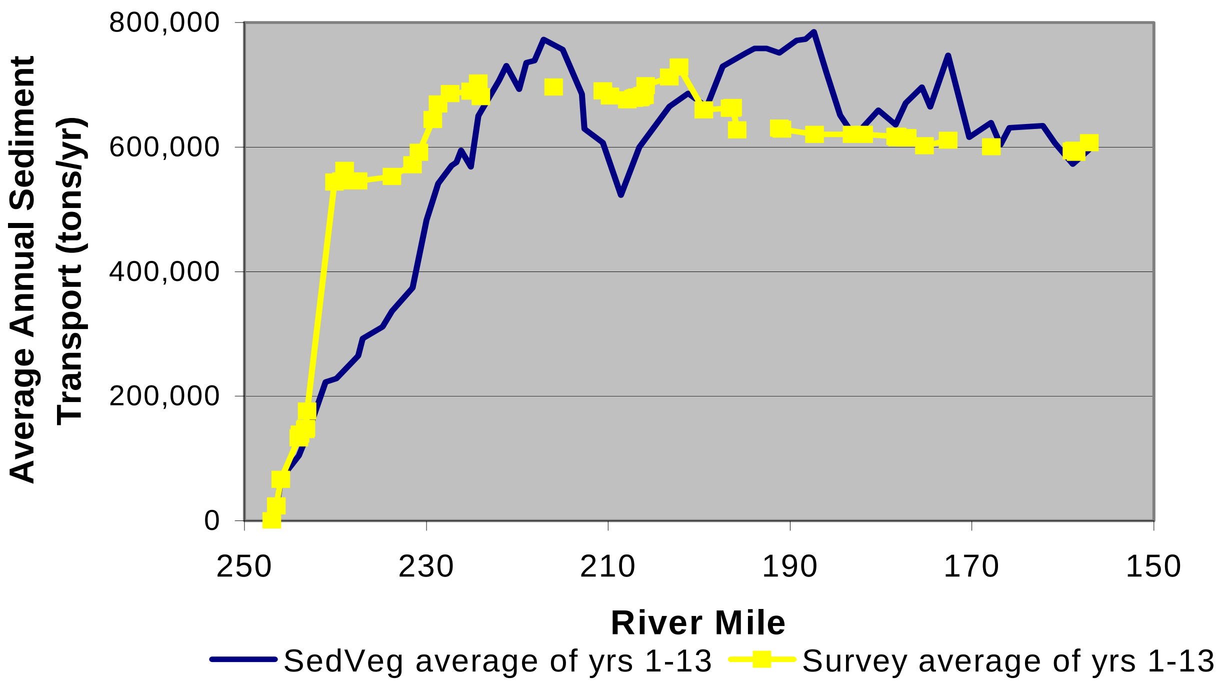

Figure 5.12. Comparison of sediment transport curves from SedVeg Gen3 and from a Survey computation, for the years 1 to 13 (1989 to 2001) for the Central Platte River. The curves begin in the south channel of Jeffrey Island and end at Chapman, NE.

5.4.3 Description of Sediment Transport in the Central Platte River

Two additional sediment transport curves from the SedVeg Gen3 Platte River Model are included in Figure 5.13 with the two 1-17 year sediment transport curves from Figure 5.12. The three SedVeg Gen3 curves have been adjusted by a factor of 1.5. Curves from Figure 5.12, representing the wetter years from 1 to 13 (1989 to 2001), transported more sediment than the curves representing an average of the years 1 to 30, and an average of the years 31 to 78. A comparison of the average sediment transport for years 1 to 30, and for years 31 to 78, show similar peak and average transport rates indicating similar hydrologic periods. These averages were not as wet as the average for years 1 to 13.

Transport at Overton

Sediment transport at Overton varies widely depending on the curve considered. The 1 to 13 year Survey estimate is as high as 545,000 tons annually while the 1 to 13 year SedVeg Gen3 has the lowest estimate at 225,000 tons annually. This variation may be accounted for by the estimate of sediment coming from the North Channel of Jeffreys Island. Based on one repeat cross section, the Survey estimate assumes a large volume of sand contributed by what may be a head cut advancing up the North Channel of Jeffreys Island. The SedVeg Gen3 model does not represent this large influx of sediment until some period beyond year 15. More field data and studies are needed to determine if there is a head cut advancing up the North Channel of Jeffreys Island and to obtain a better estimate of the sediment contributed by the North Channel.

Downstream Extent of Erosive Condition

If a large sediment discharge from the North Channel of Jeffreys Island is available, the longitudinal extent of erosion downstream of the Jeffreys Island confluence (near Overton, RM 240) is reduced. Depending on sediment contributions from the North Channel of Jeffreys Island, and depending on the water year, the sediment deficit (indicated by the presence of channel erosion) may end at Elm Creek or continue to Kearney. Defining the end of the sediment deficit is difficult at this time for two reasons:

- There is a lack of information from cross sections on the sediment transport in the north channel of Jeffreys Island; and
- There is an eleven mile gap in cross-section data between RM 222 and RM 211 that affects both Survey and SedVeg-Gen3 methods for estimating sediment transport.

However, at this time, the erosive condition, originating from the clear water flows at the Johnson-2 Return and acerbated by the dike across the south channel of Jeffreys Island, appears to end by Kearney (RM 215).

A Dip in Transport

The SedVeg Gen3 curves reflect a decrease followed by an increase in sediment transport at RM 214 or RM 210, depending on the curve considered, that is reflected to a lesser degree in the Survey transport curve. This dip may be more pronounced due to the synthetic cross sections and the habitat transects used to fill in the gap in available cross-section data in this region. Synthetic cross sections and transects may be inadequate at some locations due to insufficient flood plain data. The width of the flood plain often extends 5,000 ft in this reach, and habitat transects are often only 1,000 ft wide. Habitat transects were sometimes synthetically extended through estimates of the topography for use in SedVeg.

The dips in the sediment transport curves may also be due, at least partially, to the flow withdrawals and returns for the Kearney diversion, and to increases in flow downstream of the Kearney return. The increase in flow downstream of the Kearney Canal Return, and continuing to river mile 200, results from groundwater flows and small tributary discharges. Average annual flow that is computed from the 78 years of flow record that are input as a boundary condition of SedVeg Gen3 is shown in Figure 5.14.

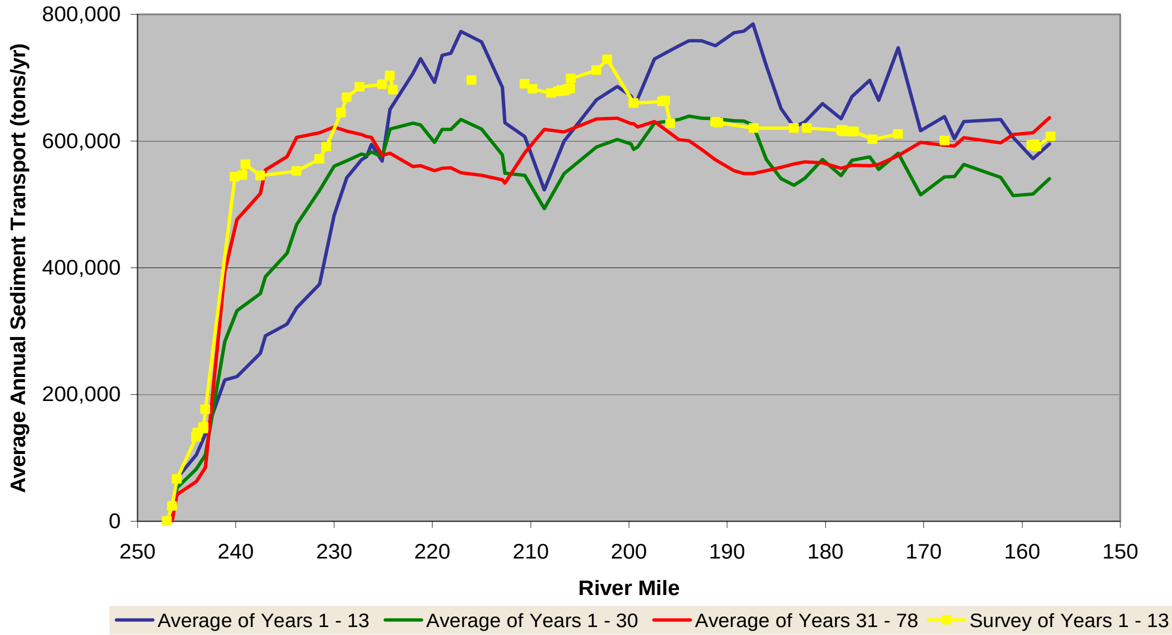

Figure 5.13. Sediment transport estimates from the SedVeg Gen3 Platte River Model for the periods year 1 to year 13 (1989 to 2001), year 1 to year 30 (1989 to 2018), and year 31 to year 78 (2019 to 2066). All values are multiplied by a factor of 1.5.

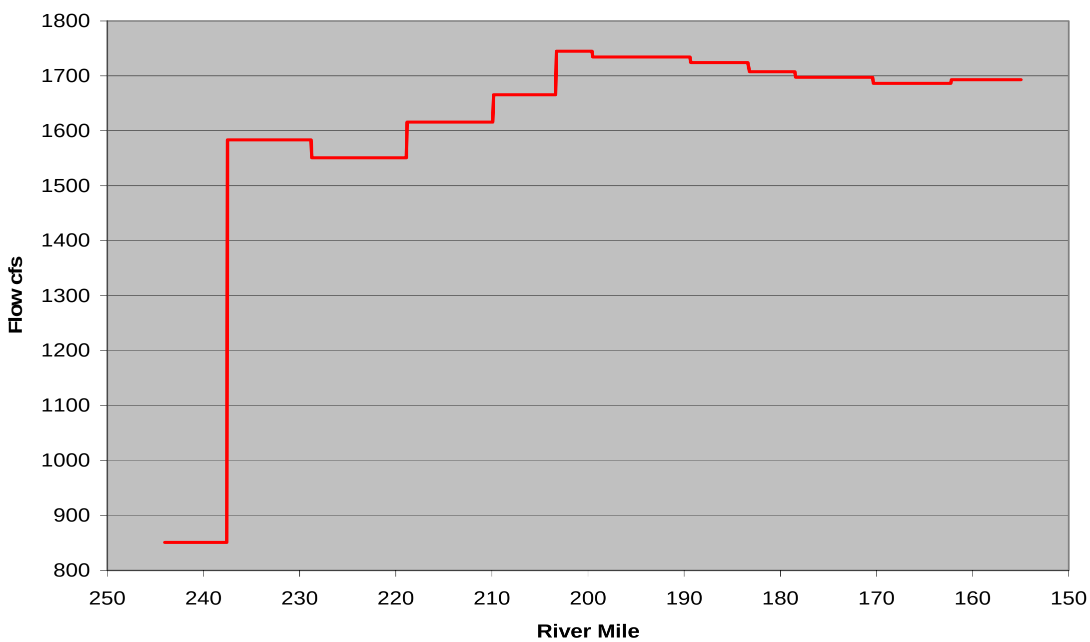

Figure 5.14. Average annual flow computed from 78 year flow record that is input for SedVeg Gen3.

This is a priority area for future studies to better determine the existence, cause and location of this sediment transport irregularity in the Central Platte River. This irregularity is relative small in comparison to the sediment shortage at the Johnson-2 Return but presumably has impacts on the preferred habitat in the study area.

A Reach of Aggradation

Between RM 203 and RM 183, SedVeg Gen3 indicates an aggradational reach of approximately 5 miles in length, where the river deposits as much as 100,000 tons of sediment annually. The river upstream of this aggradational reach, beginning near Elm Creek, NE, appears to have a higher transport capacity then the downstream reach, which extends to Chapman, NE.

The Downstream Stable Condition

A stable condition exists under current conditions (1 to 30 years) at the downstream end of the project reach. Depending on the curve considered, sediment transport reaches a plateau between RMs 197 to 183. In contrast, the average sediment transport curve for years 31 to 78 shows increasing sediment transport, which indicates a reach with degradation.

5.4.4 Sediment Transport Budget

The sediment transport curves are calibrated to 600,000 tons of sediment passing Grand Island (RM 168) annually. SedVeg Gen3 transport curves for the years 1 to 30 and years 30 to 78, and the Survey estimate for years 1 to 13, indicate that sediment passing Overton (RM 239) may range from 285,000 to 5,45,000 tons annually. Based on the SedVeg Gen3 model computations and the survey estimate, estimated volumes of sediment transport include:

- 85,000 (years 31 to 78) to 175,000 tons annually from the bed and banks of the South Channel of Jeffreys Island;
- 125,000 to 370,000 tons received from the North Channel of Jeffreys Island (up to 170,000 tons from the bed and banks);
- 50,000 to100,000 tons eroded annually from the bed and banks between Jeffreys Island (RM 241) and Overton (RM 239);
- 45,000 tons from Plum Creek (RM 244);
- 115,000 tons annually from tributaries downstream of Overton (RM 239):
- 180,000 tons eroded annually from the bed and banks of the river between Overton (RM 239)and Wood River (RM 183);
- 40,000 to 50,000 tons eroded from the bed and banks between Kearney (RM 215) and Wood River (RM 183)
- 50,000 to 60,000 eroded annually from the bed and banks of the river between Wood River (RM 183) and Chapman (RM 156) in the future (years 31 to 78);
- up to 100,000 deposited annually between Minden (RM 203) and Wood River (RM 183); and
- Braided reaches appear to transport a relatively consistent sediment load of less than 600,000 tons annually, while anastomosed reaches appear to transport loads greater than 600,000 tons.

6.0 Assessment of SedVeg Gen3 and Recommendations for Future Studies

Comment on the DEIS (DOI, 2006)

Comment 14215: *We recognize that the limitations of the SEDVEG model means that its results can only be used in a comparative sense, but would like a more detailed description of the EIS team's view of the model's performance since it began working with it.*

6.1 Assessment of the SedVeg Gen3 Platte River Model

As with any new model, the focus with the first version of SedVeg (SedVeg Gen1) was checking the code to ensure the inter-related physical processes were being aptly represented in the Platte River model. The emphasis with the second version, SedVeg Gen2, began to shift towards expanding model capabilities to allow adequate definition of all significant boundary conditions and factors as they were identified. In applying the latest version, SedVeg Gen3, problems rarely originate from the code, but instead stem from the availability of quality data for expanding the model.

The SedVeg model is a powerful tool, and as the Platte River Model continues to advance in complexity, so too does our knowledge of the Central Platte River. This tool was originally developed to aid evaluation of the alternatives in the EIS. As written in the 2001 draft of this report, "The model results are most accurate when the model is used to make relative comparisons of alternative strategies." However, the Platte River Study has reaped equivalent benefits from the SedVeg numeric models in improved descriptions of complex processes, better definition of the extent of impacts from these processes, and in identification by type and location of less dominant processes.

6.2 Benefits from the SedVeg Model Studies

In general, revisions have contributed to a more stable model that have improved the description of the river processes with items such as an increased number of cross sections, inclusion of tributary sand, improved vegetation inundation algorithm, code improvements to the bank failure routine, and reference flow measurements for improved standards of comparison. The end result of the model revisions is a more detailed description of the sediment transport process and the processes of vegetation and bank response.

Equally significant benefits from application of the SedVeg numeric model has included improved definition of occurrences of the dominant processes and the identification of less distinct processes in the study area. At the onset of sediment transport modeling, degradation immediately downstream of the Johnson-2 Return was easily detectable from field observations. However, the extent of degradation, the identification of a shorter reach of aggradation and a shorter reach of degradation, and the identification of a potential headcut process that may strongly affect sediment transport in the habitat area, are all examples of advances in understanding that have emerged from the modeling studies.

6.3 Recommendations for Future Directions

The SedVeg code and Platte River Model were developed to aid the evaluation of EIS alternatives. Hundreds of SedVeg Gen3 runs were used to study the dominant factors and to select the most successful options for the proposed alternatives, even prior to comparing the final alternatives. This numeric sediment transport model is a cost efficient and time effective tool. As the Platte River Program moves into the implementation stage under the adaptive management plan (AMP), the efficacy of this model continues. The adaptive management plan allows field testing of proposed actions prior to full implementation. Field tests are often conclusive, but also are generally expensive and time consuming. Use of the numeric model serves as a screening tool for actions to be tested in the field, conserving budget dollars for the most promising and multifarious options. The continued use of SedVeg Gen3 is recommended as an evaluation tool. Potential improvements for the one-dimensional model SedVeg Gen 3 are listed below by perceived priority. Also listed are recommended areas for future investigations in better defining sediment transport on the Central Platte River.

6.3.1 Recommendations for the SedVeg Gen3 Platte River Model

Recommendations for improvements to SedVeg Gen3 have been organized by high, medium, or low priority. Basic data collection and field testing are awarded the highest priority and presumably would provide the greatest benefits to the geomorphic study of the Central Platte River.

High Priority- Basic Data

As discussed above, the greatest benefits to the SedVeg Gen3 Platte River Model can be realized at this time, not through code changes, but through additional and improved data. This data could soon be available through the integrated monitoring and research program (IMRP). The IMRP is a systematic data collection and monitoring program supporting efforts under the AMP. Some of the priority needs for data collection to improve numeric modeling include:

- cross-section data to replace synthetic sections and reduce gaps in the model;
- new cross sections of the full flood plain width in the gap upstream and downstream of Kearney (RM 225 to 210);
- new cross sections between Lexington and Overton including the north channel of Jeffreys Island;
- new cross sections in anastomosed reaches of river between Wood River and Chapmen;
- an extension of habitat transects for the full width of the flood plain;
- a survey of the longitudinal profile of the bed of the river from Lexington to Chapman (suggested point spacing of 100 ft) to better define spatially changing slope conditions in the model;
- sediment sampling of tributaries, the north channel of Jeffreys Island, and possibly downstream of high banks, to better define sediment inputs;
- cross sections at identified high eroding banks to better define sediment inputs; and
- for future modeling where only the main channel may be included in a section, discharge measurements at locations where flow diverges to two main channels.

High Priority- Field Test Data

Field test data is equally important as basic data collection to confirm or refute hypothesis and to support and improve the SedVeg Gen3 Platte River Model through calibration and verification testing. Field testing could be based on mechanical actions (consolidating flows in a test reach), sediment actions (sand augmentation in a deficient reach), or flow releases (peak flow releases of 5,000 to 9,000 cfs). The initiation of testing would begin after a complete sampling and testing system is in place.

Medium Priority- Restructure Platte River Model at Flow Divisions

Downstream of Kearney in the island reaches, the Platte River Model currently models all the main channels of island splits with one cross section. A future option may be to focus the model on the main channel by dividing the cross sections flows and sediment loads and retaining only the main channel conditions since no interaction occurs between these channels. This option improves definition of the main channel, but also requires basic knowledge of flow and sediment divisions.

Low Priority- Construct an Upstream Model

A Platte River model upstream of the existing model would provide additional information on the headcut and sediment source from upstream. The original model included this reach but was based on few and sparsely spaced cross sections.

Low Priority- Construct a Downstream Model

Pallid sturgeon habitat is located downstream of Chapman in the Lower Platte River, outside the extent of the existing model. The habitat for this species is dependent on a sediment load that creates bedform features, and a numeric model could be used to translate Program impacts in the Central Platte River to impacts on Sturgeon habitat in the Lower Platte River.

Low Priority- Revise SedVeg Gen3 Code to Incorporate Backwater Modeling

SedVeg Gen3 currently bases flow and geometry computations on normal depth. Step-backwater computations would provide a more accurate estimate of water surface elevation, most notably at areas of restricted flow caused by natural obstructions (canyons, rock outcrops, woody debris dams, and other natural features) and manmade features (undersized bridges and confining levees). This improvement would provide better estimates of water surface elevation, but would require a major code change to SedVeg Gen3. A change of this nature would offer an improvement to model predictions upstream of the Kearney Diversion. However, influences of backwater on the Platte River are generally weak and limited to small areas, which is why the normal depth computation was originally selected for the SedVeg Gen1 model.

Low Priority- Refinements to Vegetation Growth and Removal Subroutines

Add refinements to the vegetation subroutines including a new calibration of the ice removal algorithms, re-examine vegetation removal by burial, re-calibrate open view width, and the replacement of the four vegetation types with four more representative vegetation communities. These actions are anticipated to bring limited improvements to bank resistance values and habitat measures and are placed in the grouping of lower priority recommendations.

6.3.2 Recommended Areas for Future Sediment Studies

Recommendations for future investigations to expand the current description of sediment transport in the Central Platte River are:

- Investigate the potential decline and rise (i.e., the dip) in sediment transport downstream of the Kearney Canal Diversion to confirm/refute existence, and to determine magnitude, location, cause, affects on local habitat, and impacts to future sediment transport;
- Confirm/refute the occurrence of a head cut in the north channel of Jeffreys Island, and investigate location, magnitude, implications to future sediment transport, and affects on upstream habitat;
- Investigate whether sediment transport in an anastomosed reach can be reduced through a plan form change to braided river;
- Improve estimates of sediment input from tributary sources; and
- Begin development of a master plan for balancing sediment in the future, which focuses on means of reducing mechanical sediment augmentation (tributary sources, head cut management, plan form changes).

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Contents of Appendices

Appendix A – SedVeg Gen3 Platte River Model

The input and output data from the SedVeg Gen3 Platte River Model for Present Conditions is available from a CD with hard copies of this report, or is available as a separate folder with electronic versions of this report.

Appendix B – Comments and Responses on SedVeg Gen1 and SedVeg Gen2 Platte River Models

Comments and responses in this appendix are selected from the FEIS (USDOI, 2006) and pertain to sediment transport, the SedVeg Gen1 and SedVeg Gen2 Platte River Models, and the geomorphology of the Central Platte River.

Public Comments on the DEIS and Responses from the EIS Team

Introduction

The purpose of this “Comments and Responses” section is to describe how the comments received on the Platte River Recovery Implementation Program Draft Environmental Impact Statement (DEIS) were considered and addressed in the Final Environmental Impact Statement (FEIS).

The official public comment period began January 26, 2004 and, at the request of the States, was extended twice by Federal Register notice on March 31, 2004 and May 26, 2004. Both extensions were to allow the public time to review the DEIS along with the report entitled, “Endangered and Threatened Species in the Platte River Basin,” by the National Research Council of the National Academy of Sciences which was released in May, 2004. The public was invited to submit comments by email, letter, fax, or through testimony at the DEIS public hearings. The comment period concluded September 20, 2004.

The Platte River EIS Office received and addressed submissions from 17 Federal, state, local, and city agencies; 21 irrigation, power, and conservation districts, electric power organizations, and water user organizations; 9 miscellaneous local organizations in Colorado, Nebraska and Wyoming; 16 environmental and conservation groups; and 27 private citizens. In addition, nearly 7,000 postcards and letters were received through conservation groups, including the National Wildlife Federation and American Rivers. All written and oral comments are on file with the Bureau of Reclamation (Reclamation).

Changes made to the FEIS as a result of public comments ranged from minor editorial changes to significant changes in alternatives and analysis. The significant changes are listed in chapter 1.

Organization of the Comments and Reponses

Some submissions provided one comment while others expressed comments on multiple subjects. Members of the EIS team carefully reviewed each comment. Some issues were raised by more than one commenter or several times by the same commenter. To reduce repetition and provide one comprehensive response, repeated comments are described in a “summary comment” and addressed with a “summary response”. All other comments are addressed individually. Comments included in this document were quoted directly from the submissions whenever possible. However, some lengthy comments were edited to shorten the length of this document. Many of the responses include references to other documents. More information on most of these can be found in the “Bibliography” of the FEIS, volume 1. If the referenced document was not used in the FEIS, the additional information is provided in a footnote. Some of the referenced documents are included in volumes 2 and 3 of the FEIS. The document names are in italics. Volume 3 contains technical reports related to the FEIS. A compact disk (CD) of volume 3 is available upon request at <http://www.platteriver.org/>. There are also references to parts of the Governance Committee Program Document. The Governance Committee Platte River Recovery Implementation Program Document (Draft), September 6, 2005, is included on a CD in volume 1 of the FEIS. This is the version used for the FEIS analysis. Final versions may be requested at <http://www.platteriver.org/>.

How Comments Were Addressed

The National Environmental Policy Act (NEPA) requires that the agency preparing an EIS consider and respond to all substantive comments on the DEIS. In most cases these are comments asking for more information about the alternatives or their impacts, comments indicating specific factual errors or omissions in the document, or suggestions for additional alternatives. The EIS Team has attempted to address all such comments through changes in the EIS analysis or the document.

Some types of comments received do not require an agency response, as directed by NEPA regulations. These are:

- Comments expressing a position or a preference regarding one or more of the alternatives.
- Comments asking the proponent (the Governance Committee) to make modifications to its proposal. This included a relatively small number of comments.
- Comments or information not relevant to the EIS scope. Again, a relatively small number.

All other comments received a response. The response to some comments is, “Comment noted”. These comments are usually expressions of a viewpoint about the document or a general statement about the document which has been considered by the EIS Team but which may not be associated with a specific change to the document.

[Note: Not all comments from the FEIS are listed below. Comments have been selected for relevance to the topics of channel change (geomorphology), sediment transport processes, and vegetation growth and removal processes, and include comments specific to the SedVeg code and the Platte River Model.]

Summary Comments and Responses

This section lists summary comments and summary responses, that is, comments developed to summarize a number of similar comments or the same comment from multiple parties. The summary comments and responses are organized by topic area.

SEDVEG Model Used for EIS Analysis

Summary Comment 21: *The SEDVEG code and model has not been calibrated, tested, or reviewed.*

Summary Response: Calibration and Sensitivity Testing. A series of calibrations for the first version of the code (SEDVEG Gen1) and Platte River Model were reported and made available in the draft of the report, Platte River Sediment Transport and Riparian Vegetation Model (Murphy and Randle, 2001). An initial set of sensitivity tests were carried out during the same period. Parsons (2003[6]) reported in the B2 memorandum on the initial calibration of SEDVEG Gen1, "Unfortunately, there is no way around the issue of the sparseness of historic data. Given this situation, the overall initial calibration and verification approach appears to be reasonable; however it could be improved by a more detailed effort in order to focus calibration on shorter periods of time involving more adequate data." A first revision of the SEDVEG code (SEDVEG Gen2) and Platte River Model were used for the DEIS analysis, and a second series of calibrations were carried out at that time that focused on shorter periods with more available data. The two calibration test series and the sensitivity test series were summarized in the DEIS River Geomorphology Appendix. The SEDVEG code (SEDVEG Gen3) and Platte River Model were revised a second time for the FEIS. A third set of calibration tests and a second series of sensitivity tests were conducted for this version. Summaries of the three sets of calibration testing and two sets of sensitivity testing are reported in *Platte River Sediment Transport and Riparian Vegetation Model* (Murphy et al., 2006) in volume 3. Data used for calibration of the Platte River SEDVEG Model are presented in Murphy et al. (2004) and Holburn et al. (2006) in volume 3 of the FEIS.

Outside Reviews. The first review by an outside party addressed code structure of SEDVEG Gen1. This review was both informal and undocumented due to Dr. Murphy's demise in 2003. Dr. Cannelli of Simons and Associates, as a subcontractor to Parsons, also provided a review of the SEDVEG Gen1 code and Platte River Model. Dr. Cannelli's comments are reported in the B2-Independent Assessment of "Sed" Concepts in SEDVEG Model, a section of the Parsons Report (2003). The third outside review by Dr. H. W. Shen of the University of California, Berkeley, was also informal and undocumented, but occurred in conjunction with the National Academies of Sciences Investigation. This review focused on theoretical concepts of the SEDVEG Gen1 code. General comments reported in Endangered and Threatened Species of the Platte River (NRC 2005), included in volume 2 of the FEIS, do not reflect topics of discussion from Dr. Shen's review.

Internal Reviews. Internal peer reviews of numerical models at Reclamation focus on the written documentation for the code. The 2001 draft version of *Platte River Sediment Transport and Riparian Vegetation Model* by Murphy and Randle, was peer reviewed by Dr. Mohammed A.

6 Parsons (2003). "Platte River Channel Dynamics Investigation," prepared for States of Wyoming, Colorado and Nebraska.

Samad. The final version of *Platte River Sediment Transport and Riparian Vegetation Model* (Murphy et al., 2006) was reviewed by Dr. Victor Huang. Simons and Associates have provided the vegetation subroutines and a calibration of their program subroutines. Over the five years of development, four code writers at Reclamation have contributed to the SEDVEG Gen3 code: Dr. Peter J. Murphy, Timothy J. Randle, Dr. JiachunV. Huang and Dr. Yong G. Lai. Dr. Lisa M. Fotherby, and Elaina R. Holburn contributed to construction and modification of the Platte River SEDVEG Model. Each modeler implemented improvements based on review of the SEDVEG code and/or Platte River Model.

Summary Comment 22: *General concerns with the SEDVEG code and model.*

Summary Response: These comments on the SEDVEG code and Platte River Model in most cases originate from the model review presented in the Parsons Report (2003). Dr. Cannelli of Simons and Associates, as a subcontractor to Parsons, reviewed a May 2001 version of SEDVEG code and Platte River Model. His comments are presented in the B2 Technical Memorandum – Independent Assessment of "SED" Concepts in SEDVEG Model. Dr. Cannelli's comments can be divided into three categories:

- Technical or conceptual concerns that have been addressed through code and model revisions. Examples include increased number of cross sections and inclusion of tributary sediment inputs in the model.
- Technical or conceptual concerns that were incorrect or are now addressed. Examples include assumptions that the model had not been calibrated or tested, assumptions that hardwired algorithms fix maximum scour depth, and the concern that predictive capabilities of the 2001 version of the model were poor based on an analysis which evaluated the 2-D aspects of this 1-D model.
- Suggestions that are not critical but would improve 1-D modeling capabilities. Items in this category have been added to a list of proposed improvements for the next major revision of the SEDVEG code and Platte River Model. Examples include replacing the existing normal depth algorithms with step-backwater computations, adding a mechanism that eliminates vegetation based on a minimum depth of burial by sediment, and a second calibration of the vegetation removal by ice mechanism.

The model output should not be indiscriminately applied. Interpretation of the model should be restricted to the capabilities within the realm of a 1-D model, and in some cases the model may only identify locations where more in-depth analysis is required. However, within these limitations, SEDVEG Gen3 is the best available tool for analyzing Platte River alternatives, and the application of a 1-D model for this level of assessment is recommended by the industry (ASCE Task Committee on Hydraulics, Bank Mechanics and Modeling of River Width Adjustment, 19987). The National Research Council (2005) whose comments are based on early versions of SEDVEG, 2001 and 2002, also urge continued use of the model. "Current DOI model developments, including the emerging SEDVEG Model, are likely to be helpful and useful in both understanding and managing the Platte River". For additional general comments on the model, see response to Summary Comment 23.

Summary Comment 23: *EIS analysis should use methods other than SEDVEG, or in addition to SEDVEG to assess existing conditions and to assess the alternatives.*

7ASCE Task Committee on Hydraulics, Bank Mechanics and Modeling of River Width Adjustment (1998). "River width adjustment. II: Modeling," Journal of Hydraulic Engineering, ASCE, v. 124, n. 9, pp. 903-917.

Summary Response: The geomorphic study of the critical Habitat Area is based on available data and the application of generally accepted theoretical concepts. Our understanding of past and current trends in Platte River geomorphology is based on: USGS flow measurements and statistical analysis of these values; surveyed cross sections and sediment sampling; and plan form studies of historical maps and aerial photos. The "River Geomorphology" sections in chapters 2 and 4 have been revised to focus on available data and theoretical concepts. The analysis of sediment transport in chapter 4 includes an estimate based on sediment rating curves and repeat cross section surveys, and a 1 dimensional (1-D) numerical model is used to compute a second, more detailed, estimate.

The power of a one dimensional numerical model is its capacity to compute and track multiple elements of complex processes, over long distances (90 miles of the Platte River), and over long periods of time (50 years or more). This 1-D computation tool: helps extend our understanding of the base concepts; tracks the complex interactions of processes; provides more detail on the system; provides quantitative values for a relative comparison of approaches; and serves as a screening tool for options to be tested in the field. The use of a numerical model is cost efficient, effective and timely. Over 200 different scenarios were considered for the Central Platte River using SEDVEG Gen3, in the 6 months previous to the FEIS.

Numerical models apply, but do not generate, geomorphic concepts. If model results do not support base concepts, the program code and input data are re-examined for potential errors. The manner in which data is input accounts for the vast majority of irregularities in output. Irregularities occur because input data must represent a 3-dimensional world in a 1-dimensional format. The 1-D model is a very useful tool when the limitations of the model are understood. For additional general comments on the model, see responses to Summary Comment 22 in this section on general concerns with the early SEDVEG Gen1 code and model, and Summary Comment 21 on the calibration and testing of SEDVEG Gen3.

The "River Geomorphology" sections of chapters 2 and 4 are based on analysis of data and geomorphic concepts; however, the sediment budget from SEDVEG Gen3 for Present Condition is introduced in chapter 4. In chapter 5, model results from the 1-D SEDVEG Gen3 are used, in addition to data and theoretical concepts, for comparative analysis of the alternatives. Under this Programmatic FEIS, results from existing data, theoretical concepts, and 1-D modeling are used to evaluate differences between broadly outlined alternatives.

Implementation of the preferred alternative is anticipated to require greater definition of theoretical concepts and greater definition of the action plans. This extended investigation should proceed with the aid of: the IMRP to provide more detailed field and laboratory data; an expanded 1-D numerical model and site specific 2-D modeling studies based on new IMRP data; and an implementation test program of water, sediment and mechanical action plans under the adaptive management plan. Expansion of theoretical concepts, data collection, and numerical modeling all provide screening tools and support for implementation of adaptive management in the field. The adaptive management plan is founded on an approach of small-scale testing advancing, by small steps based on successful implementation, towards full-scale implementation.

Summary Comment 24: *Sediment input at the upstream end of the reach was incorrectly modeled at capacity in SEDVEG-Gen1 and SEDVEG-Gen2, and there were no tributary inputs of sediment which predisposed the model towards degradation.*

Summary Response: Transport at capacity at the upstream model boundary is a common approach when better data are not available and when there is a significant distance with intermediate cross sections between the boundary and main study reach. This was the case for the original SEDVEG Gen1 Model.

However, one of the improvements to SEDVEG Gen3 is increased options for sediment inputs. The upstream end of the modeled reach now begins at the Johnson-2 Return in the FEIS Platte River Model (see Murphy et al., 2006, in volume 3 of the FEIS). In the current model, sediment input at the first section is assigned by a rating curve. Sediment input from the North Channel at Jeffreys Island is specified from a SEDVEG Gen2 sediment transport file. Sediment at seven tributary locations is input as daily volumes during the six higher flow months of the year. In addition, sand is augmented at one location for the alternatives, bringing the total to ten locations where sand is input to the river.

Summary Comment 25: *The SEDVEG-Gen1 and SEDVEG-Gen2 Platte River Models used an insufficient number of cross sections and did not adequately represent the study reach.*

Summary Response: The first SEDVEG (SEDVEG Gen1) and Platte River Model, the version reviewed in the Parsons report, had 17 cross sections for 143 miles from North Platte to Chapman, NE. The current SEDVEG Gen3 Platte River Model begins at the Johnson-2 Return in the South Channel of Jeffreys Island (RM 247), and continues to Chapman, NE, (RM 157.2), a distance of approximately 90 miles. The model uses 62 cross sections, of which 16 are shifted or synthetic. Shifted and synthetic cross sections are used when there are no available surveyed sections to represent a reach. The depth data of synthetic cross sections are not as reliable as the width data, but these sections are occasionally useful to smooth sediment transport across abrupt changes in adjacent but disparate surveyed sections. See the report *Platte River Sediment Transport and Riparian Vegetation Model* (Murphy et al., 2006) in volume 3 for more detail on model cross sections.

Because every available Reclamation cross section not influenced by a bridge has been incorporated into the model, the spacing in the current Platte River SEDVEG Model is one cross section per 1.45 miles. As the Program moves into implementation studies under the AMP, it is hoped that the IMRP will supply additional surveys that allow selective incorporation of cross sections into the 1-D numerical model.

Summary Comment 26: Why are relative values from SEDVEG output used rather than absolute values with defined accuracy and precision?

Summary Response: The degree of accuracy and precision for each indicator is not listed since absolute values are generally not used. The model predictions are consistent with accepted geomorphology theory and concepts so relative values are used for the alternatives comparison in chapter 5 of the EIS analysis. Any errors associated with the model input and assumptions are applied equally among alternatives compared. This conservative approach generally uses only relative comparisons based on percent change from Present Condition. Sediment transport values are one exception where absolute values are used to analyze the sand augmentation plan, with values compared in chapter 4 to available sediment transport data for an estimate of accuracy.

There is also no focus on single cross sections and the analysis instead considers trends by reach. Average values for a reach represent multiple cross sections. With respect to temporal certainty, the analysis is based on average values from a 48-year period of hydrologic record to reduce the biases from wet and dry periods and from high flow years.

Geomorphology

Summary Comment 27: *Throughout the DEIS, the Platte River is portrayed as a degrading river and the DEIS assumes that the channels of the Platte River have not come into a dynamic equilibrium with current water management. However, 15 years of data systematically collected by Dr. Johnson, Parsons (2003), and fieldwork conducted by NPPD verify the fact that channel width has changed very little since the narrowing which occurred during the 1950s drought. The*

EIS team should have acknowledged all theories, data sets, and the conclusions reached by other scientists and why the team has settled on the one they did.

Summary Response: Dr. Johnson's studies have been taken into consideration; however, dynamic equilibrium is not defined singly by changes in vegetation expansion. Although spatial measures of vegetation are recognized as an indicator of changes in channel width, the definition of dynamic equilibrium is based on sediment transport. A reach of river is defined as being stable (in dynamic equilibrium) when the volume of sediment entering the upstream reach equals the volume of sediment leaving the downstream end of the reach, a definition attributed to Mackin (1947). Sediment transport studies presented in the "River Geomorphology" section of chapter 4 indicate the Platte River is degrading from Jeffrey Island (RM 147) downstream to approximately Elm Creek. More sediment is leaving than is entering this reach. The river appears to be aggrading between Gibbon and Wood River. Between Wood River and Chapman sediment transport is currently stable, or in dynamic equilibrium, but the analysis shows gradual degradation over time due to upstream changes. Repeat cross section surveys and development and refinement of sediment transport budgets help to determine degrading or aggrading reaches of channel, while measurements of vegetation expansion provide feedback on the width dimension of the channel and the dominant hydrologic regime in the channel. See Holburn et al. (2006) in volume 3 of the FEIS for data on repeat survey measurements.

The DEIS describes and the FEIS adds more detail and data about the forces currently affecting the river channel habitat, documenting the fact that the Central Platte River is not in equilibrium. This analysis is also reported in Murphy et al., (2004), and has been reviewed by the National Research Council (2004) at the request of the Governance Committee.

Summary Comment 28: The current morphologic condition of the Central Platte River is also due to climate and not fully attributable to the reduction in peak flows resulting from water resources development.

Summary Response: As presented in the FEIS, large water diversion systems have impact on flow and the supply of sediment downstream, and climate patterns appear to have lesser impact on both flow and sediment (Murphy et al., 2004).

From page 152 of the National Resource Council publication (2005) "Regardless of climate change, water-resources development will continue to affect Platte River flows as long as there is a net irrigation water consumption and reservoir evaporation. The human controls on flow are the most important controls on a daily, monthly, or annual basis, but the longer term effects of climate change are a background control worthy of further investigation."

Sandbars

Summary Comment 30*: No data is presented describing historic versus current trends in the frequency, distribution, size, and elevation of sandbars. In addition, there is no quantitative discussion of the required river stage change, the number of days needed to create sandbars, how that information is accounted for in the model, or whether it historically occurred.*

Summary Response: See discussion in "River Geomorphology" sections of chapters 4 and 5 on differences in water surface elevations and sandbar height potential for Present Condition and alternatives. See discussion in "River Geomorphology," sections of chapters 4 and 5 and "Central Platte River Channel" in chapter 2 on the relation between plan form and the frequency and distribution of mid-channel sandbars. The actions proposed in the FEIS and AMP focus more on flow peaks than duration of flows because sandbar-building potential in theory and in literature are more directly dependent on the peak flow.

Individual Comments and Responses

The following are individual comments received on the DEIS. They are taken from the submitted letters or transcribed testimony from public hearings. The comments are listed in numerical order.

Comment 13677: *The 2003 Biological Assessment for the Missouri River Master Manual concluded that measures being proposed for the Missouri River similar to those was being touted for the Platte would not be successful. The assessment concluded that a change in the dominant discharge of the river will be required to change the alluvial process in order to create and wash away sandbar suitable for nesting terns and plovers; a message the Parson's report has stated time and again. This fact was further supported by the FWS's 2003 Missouri River BiOp, which concluded that the 2000 RPA would not accomplish the intended habitat objectives and that the flow previously stated by the FWS would cause further erosion of the riverbed.*

Response: The Platte River and Missouri River are not equivalent systems; however the Missouri River analysis highlights the fact that managing flow without managing sediment can lead to problems, such as those that exist in the Central Platte River today. Having a sediment management plan in conjunction with a flow plan is a key element of the proposed Platte River Alternatives.

Comment 13705: *All of the action alternatives except GC-1 assume that it is possible to augment sediment so that the appropriate quantity and quality of sediment will be freely available as flows enter the area of interest. The EIS team anticipates that GC-2 would add to the river approximately 300,000 cubic yards of sediment on average per year of the Program, but the DEIS does not indicate how that would be accomplished. The DEIS provides no guidance on how sediment augmentation might be implemented, no indication of the rate or frequency for adding sediment or whether attempts will be made to match sediment augmentation with flows or sediment deficits. The FEIS needs to look at the practical problems with providing sediment.*

Response: Sediment augmentation through bank cutting, island lowering or from activities such as wet meadow development is described broadly in chapter 5 for this Programmatic FEIS, and also outlined in the AMP. Repeat surveyed cross sections, sediment transport measurements and numerical modeling provide preliminary estimates of the average volume of sediment needed. However implementation of a specific sediment augmentation program will also depend on the lands acquired from willing sellers, the flow regime that occurs during implementation from both managed and climatic effects, and the results of continuous monitoring under the IMRP both upstream and downstream of the managed sight. The AMP allows for modification of Program actions on a site-specific basis. An additional resource is consultation with administrators of other ongoing augmentation projects nationwide, such as the Trinity River in California, for input on successful techniques and shortcomings.

Comment 13706: *Any procedure developed will need to take into account the potential for large quantities of sediment added to the river to cause a localized deposition, channel splits or flooding. For example, page 3-47 and Figure 3-10 show how a cross-section of NPPD's Cottonwood Ranch habitat area is to be modified by clearing a high wooded island, lowering it closer to the average water surface elevation, and pushing the scraped sediment into the river. At Cottonwood Ranch, most islands are wider than the channels. Carrying out the suggested cross-section modifications would remove enough material from the top of the islands to completely fill the channel. Thus, it is unlikely that the channel has the capability to accept all the sediment as portrayed in a short period of time without adverse impacts. The FEIS needs to* *make realistic assessments of the potential for augmentation measures to impact riparian landowners or adversely impact downstream habitat or structures due to miscalculation or simply the impracticality of augmentation operations that closely match flows and sediment deficits.*

Response: Existing aggradation in the Central Platte River is described in chapters 2, 4, and 5. The technique of consolidating flow is valuable for preventing river narrowing resulting from deposition in anastomosed channels. Monitoring to prevent unacceptable impacts from sand augmentation is also an integral part of the proposed management actions. Also see response to Comment 13705.

Comment 13707: *The SEDVEG model and DEIS comparisons of the action alternatives assume a river with no man-made structures or actions to interfere with the shaping of channels. In reality, numerous bridges cross the central Platte River, and Interstate-80 established a new north bank for almost the entire reach from Lexington to Grand Island, cutting off much of what was once active river channel. In addition, over the past century, landowners have installed tens of thousands of "hard points" to stabilize their property. The EIS team dismisses these structures as insignificant, but viewed collectively these man-made structures stabilize the channel on a significant percentage of the river.*

Response: Banks with riprap that restrict the width of the historic flood plain can, in some instances, aid in promoting a braided plan form. The hardened bank, like bridge foundations, could be beneficial if it prevents the main channel flows from splitting into side channels that meander independently in a wide river corridor. Each riprap location must be assessed independently to determine if the effect is beneficial or detrimental. As demonstrated in chapter 4, a desirable river corridor width is less than 3,000 ft wide and the ideal flood plain width (river corridor) may be closer to 2,000 ft. The estimate of length of protected banks has been removed in the FEIS since it is no longer identified as having solely a detrimental impact. See response to Comment 14231 for bridge impacts.

Comment 13710: *Roads, bridges, channel stabilization structures and accretion recovery collectively stabilize a substantial percentage of the riverbanks in the central Platte River. It seems imprudent, and contrary to the interests of the species and habitat, simply to assume that their impacts are insignificant. The SEDVEG model's inability to take this extensive channel stabilization into account is a further reason that the Program should investigate sediment augmentation measures with caution, as described in the proposed Program.*

Response: SEDVEG Gen3 has the capability to represent hardened (riprap or otherwise reinforced) riverbank, but it has not been applied to date. The model does account for earth dykes but the dykes were not represented as hardened in the model due to the spacing of cross sections. The stabilization measures should extend over a majority of the distance represented by a cross section, to be represented in the model. The original spacing in the SEDVEG Gen1 model was 6.8 miles, the current spacing in the SEDVEG Gen3 version of the Central Platte River Model is now an average 1.45 miles. This capability of SEDVEG Gen3 should be utilized in the future as more cross section data becomes available to further reduce spacing, and as this spacing better represents distances of hardened bank. Also see response to Comment 13707.

Comment 13713: *USBR applied the full dynamic wave "unsteady flow" model, written by the National Weather Service (D.L. Fread, 1971, 1975, 1978, 1988), to the North Platte and Platte Rivers, with input parameters calibrated until the simulated results matched the measured discharge hydrographs for a 1984 flood along the Platte River. When calibrated from this single event, the model suggested that a pulse would propagate through the system with no attenuation. The 1984 peak flow used by DOI in its calibration, however, is not representative of peak flows that might be supplemented with environmental account water.*

This peak came at the end of a long term and extensive flooding event (only a few days earlier measured flows were higher than the peak used by USBR in its model), in the wettest cycle of the last 50 years, when average annual flow rates exceeded 6,000 cfs. In light of the saturated condition of lands adjacent to the river, the EIS team's assumption that the river gained only 5 cfs per mile seems highly unlikely. In addition, precipitation records indicate that rainfall tracked with this peak flow the length of the central Platte River valley, not merely at Grand Island as suggested by USBR, so that the entire reach likely experienced increasing precipitation run-off far in excess of 5 cfs per mile, sustaining and adding to the pulse as it propagated downstream.

Central believes that calibration of the wave propagation model with data from more characteristic peak flow events would be prudent, particularly since Central's sixty years of experience managing releases and Dr. Lewis' report both suggest that as peaks propagate downstream, they attenuate. In discussions with FWS regarding using releases to create or supplement a pulse in the current dry conditions, the Districts have indicated that they anticipate attenuation of a peak in excess of 50 percent between North Platte and Overton. Dr. Lewis aptly observes that larger flows are more likely to be attainable through using alternative means of increasing flow deliveries, located closer to the habitat, than increasing the carrying capacity at North Platte. The proposed Program includes investigations of both peak flow propagation and alternative measures, and the FEIS should be written broadly to accommodate whatever proves to be a practical option.

Response: In agreement with this comment, Reclamation switched from the previous National Weather Service unsteady flow model to a HECRAS unsteady flow model with a groundwater subroutine to address the large losses to groundwater after dry periods, which need to be accounted for. Initially, releases with multiple peaks were considered as a way to produce a short duration near-bankfull flow event of approximately 5,000 to 6,000 cfs at Grand Island during very dry conditions. Based upon HECRAS modeling, if conditions are very dry, the first flow peak may be eliminated through temporary bank storage prior to reaching Grand Island, and the second peak may also experience substantial attenuation. Because of these findings, additional release patterns continue to be evaluated for very dry conditions.

Comment 13773: *The sediment issue was taken up many notches about 5 years ago when sediment modelers joined the EIS team. While sediment is unquestionably a key issue on any regulated river, its singular importance in affecting vegetation seems to have been exaggerated relative to hydrology. This is true in the SEDVEG model itself, where sediment dynamics are detailed to a fine level while vegetation is simulated at a very coarse level, and in the DEIS overall. While the effects of changes in sediment supply can appear quickly in localized areas, such as below dams and diversions, they are generally slow to be expressed in less altered sections. The rate of change below structures often attenuates quickly with distance in braided rivers; however, slow, insidious effects can occur associated with grain size shifts, for example, as brought up frequently in the DEIS.*

Response: In the Central Platte River, variations in flow, sediment and topography produce distinct variations in plan form, while varying affects of vegetation on plan form are less pronounced ("River Geomorphology," chapter 4). However the sediment transport model, SEDVEG Gen3, incorporates all of these factors in a 1D analysis. Main concepts that SEDVEG Gen3 integrates in the analysis are: the stability (dynamic equilibrium) of a river is defined by sediment transport; vegetation affects sediment transport through bank resistance; and sediment transport and vegetation are both affected by flow.

Comment 13774: *The rates of woodland expansion from the late 30s to present correlate very strongly with changes in hydrology (Johnson 1994). Rates of change in some reaches were* *extremely high over very short periods of time associated with droughts. For example, approximately half of the active channel of the river became colonized by vegetation over just a three-year period during the drought of the mid-1950s. Sediment could not have caused such a rapid change. Except for small sections of the channel with obvious incision, historic changes in the channel/woodland balance appear to be controlled by hydrology, not by sediment. This is contrary to the tone in most of the DEIS that emphasizes the importance of sediment for the river as a whole. On page 4-34, however, the DEIS states "…because incision advances downstream slowly, sometimes requiring centuries to reach an end or stable condition." Lastly, the DEIS does not provide data to support the sentence, "But under this Program, that seeks to begin offsetting substantial channel incision . . ." (page 5-61).*

Response: We disagree that the DEIS emphasizes the importance of sediment as determining the consequences for the river geomorphology. Quite the opposite, the DEIS and the FEIS stress the importance of understanding and taking account of the multiple variables which control the geomorphology of the river and hence the impact on the species habitat. As presented in the FEIS ("River Geomorphology," chapter 4), flow and the expansion of vegetation are very closely linked, while flow, sediment and bank stability (including resistance to flow from bank vegetation) have impacts on channel morphology. See "River Geomorphology," chapter 4 of the FEIS, and/or Holburn et al. (2006), or Murphy et al. (2004) in volume 3 of the FEIS for discussions of incision.

This multiplicity of causal factors is one of the most important reasons for constructing the SEDVEG Model which can integrate the changes across many variables. In the past, much work and publication on the Platte River has been handicapped by focusing too much on single-variable explanations of river dynamics.

Comment 13775: *There may be unintended consequences of island leveling to liberate sediment. There are three problems associated with acting quickly to address the sediment supply issue on the Platte River. The first is that we have very few frequently re-measured cross-sections away from bridges, dams, and diversions. The bed elevation of the river is known to be variable in the short-term, even under conditions with no net change in the long-term. Thus, one or two measurements over several decades time, which are the best data we have, could lead to either type I or type II error: thinking we have a problem when we don't, or not thinking we have a problem when we do. The second problem involves scientific uncertainty. Oversupplying the river with sediment, either by island leveling or by sediment augmentation may cause downstream channel aggradation and alteration of channel flow splits. The DOI has ignored a peer-reviewed journal article (Johnson 1997) that sediment oversupply from island leveling may have caused rapid channel narrowing and vegetation expansion near Grand Island. The third problem is that of time. While correcting obvious channel degradation problems in specific locations has merit, such as that below the J-2 Return, it might be prudent to study the problem more thoroughly and employ small-scale experimentation before large-scale experiments are conducted in more natural reaches. Data from often re-measured cross-sections by the USGS at Cottonwood Ranch and from my nearby cottonwood demography plots will soon be available to examine the effects of woodland clearing on channel conditions. There is time to increase our level of certainty about sediment before conducting large-scale experiments.*

Response: See responses to Comment 13869 and Summary Comment 27 on dynamic equilibrium and Summary Comment 23 for the role of the IMRP and the AMP. Although Johnson (1997) speculates on the possible cause of change in a side channel near Grand Island, no data or analysis was performed related to this observation. A theory was put forward that vegetative clearing in the main channel led to sediment mobilization and downstream deposition which caused the riverflow to back up several miles and increase flow in the observed side channel. However, absent any field measurement of any of these processes, this remains speculation, and does not support a general presumption about the effects of vegetation clearing. As described in the Program Adaptive Management Plan, channel restoration activities will first be tested on a small scale, with intensive monitoring, before increasing the scale of restoration.

Comment 13778*: A more complex example of a management action that could produce an unintended consequence if implemented is the following. The management scenarios in the DEIS propose introducing a peak flow in May while reducing flows in June to protect tern and plover nests from inundation. My work found an incredibly strong correlation between the rates of woodland expansion historically and means June flow (averaged over a number of years). Thus, creating higher sandbars in May (even though most pre-dam peaks occurred in June) and lowering June flows (counter to the natural hydrograph) will likely cause woodland expansion, if the very strong statistical relationships are borne out. Twenty years of plant demography research and monitoring has shown that tree seedling survival is highest on mid-level sandbars (Johnson 2000). Bars created in May and then exposed by reduced flows remain colonizeable for the whole cottonwood/willow seed dispersal season (mid-May to mid-July). Later peaks (June) have a lower risk of tree establishment (page 3-13). Even if May peaks were to produce habitat for terns and plovers in the short-term, it may reduce open channel habitat for all three listed birds in the long-term.*

Response: Johnson (1994) found that vegetation encroachment into the channel was most strongly associated with reductions in both June peak flow and volume. The Program simply does not manage enough water to keep the riverbed submerged throughout the seed dispersal period in June, as historically occurred. Therefore, the Program must use its limited water supply to build sandbars and scour new vegetation from the channel using short-duration pulse flows, and supplemented with mechanical clearing. The timing of a short duration high flow event in May is set by the species requirements for least tern and piping plover. The recurrence interval for the short duration high flow event is approximately 1.5 years, and on average, two short duration high flows occur every three years. Woody vegetation established on sandbars longer than 3 to 5 years (National Research Council, 2005) cannot be removed by scour, but the succeeding high flow occurring in the second or third year of vegetation growth is anticipated to be capable of removing new vegetation. This would be an area of continued investigation under the Adaptive Management Plan.

Comment 13786: *My estimate (Johnson 1994) that about 10 percent of the blank area on plat maps between the high banks was occupied by small, un-surveyed islands is used in several places in the DEIS (see Table 2-9). It needs to be clarified in the DEIS that the 10% estimate refers to un-surveyed islands only, many other larger islands did occur and were present on the plat maps. This relationship is misstated on page 2-42 and on 2-43 as well where it implies that all islands comprised 10% of the area between the high banks, not just the area of small, un-surveyed islands.*

Response: Corrections have been made to the table and this section has been clarified in chapter 2.

Comment 13790: *Most if not all of the elevation difference between mean river level and the tops of old wooded islands is due to normal aggradation from past floods (especially the 1983 flood), not from channel degradation, as stated in Figure 3-9. This is a very serious issue; if the EIS team has hard data showing otherwise, it should be brought up in this section.*

Response: Aggradation alone can not account for the height of Jeffrey Island with respect to the mean river level of the south channel of Jeffrey Island, or solely account for this elevation difference in the balance of the degrading reach which extends downstream to approximately Elm Creek. Also see response to Comment 13865.

Comment 13792: *Page 4-32. The first paragraph is important but needs clarification. The meaning of the phrase "final state" is not clear. Why not call a spade a spade and use the published phrase and geomorphic term—dynamic equilibrium? The river actually reached dynamic equilibrium in the 1960s for most reaches, i.e., 50 years ago, not just some time in the 20th century. This paragraph needs more detail to be clear.*

Response: The phrase "final state" has been corrected. Although vegetation is a generally useful indicator, the geomorphic definition of dynamic equilibrium is based on sediment transport. As presented in the National Research Council (2005), large changes in river width as defined by borders of vegetation, have not been apparent since the 1960s. However, surveyed repeat cross sections from the late 1980s to the present (Holburn et al., 2006) provide more precise measures of channel change and estimates of sediment transport ("River Geomorphology" sections of chapters 4 and 5). These measures show several reaches of the river that cannot be described as stable or in dynamic equilibrium. The section referred to in this comment has been revised, and a definition of dynamic equilibrium has been added to chapter 4, to help clarify this point. Also, see response to Summary Comment 27.

Comment 13798: *Page 5-56. Maintaining a "stable channel width" not only shouldn't be a priority of the action scenarios, but it couldn't be achieved. Expansion and contraction of active channel area and woodland area are desired outcomes because they occur naturally during wet and dry weather cycles and allow establishment of new woodland patches to replace those either eroded or senescent.*

Response: One of the adaptive management objectives of the Program is to offset ongoing erosion of the channel which leads to further deepening and narrowing of the channel and further loss of habitat. It is hoped the IMRP and AMP will provide additional data and avenues to explore the role and influence of senescence on bank stability and vegetation resistance in the critical Habitat Area of the Platte River.

The EIS Team does not see any natural forces that currently can produce an "expansion of the active channel area". The largest floods in recent times (1983) did not increase channel area or width. The ongoing erosion continues to narrow the channel. More channel area became vegetated during the recent drought. It appears that significant restoration of lost habitat will require significant mechanical intervention and flow and sediment management.

Comment 13824*: The review of the SED component of the SEDVEG model showed that the procedure utilized in the model development did not properly address the sediment mass continuity or the Exner Equation. The Exner Equation is a partial differential equation, which has been utilized in the development of sediment transport models to replicate the sediment mass balance at each time step along a reach near or between cross sections. In order to be applied in mathematical models, the variables of the differential equation need to be expanded to an equivalent discrete form. It is mandatory that any differential equation discretization must conform to basic mathematical rules, one of the most important being the verification of independence of variables. There are two dependent variables in the Exner Equation that were considered independent in the SEDVEG model: the time step duration (dt) and the distance between cross sections (dx). The dependency between the two variables causes the results of the total sediment transport in the channel to be different for a range of dx/dt values. Increasing the cross section spacing emphasizes the bed material impact in the computation of the sediment transport capacity, and increasing the time step magnifies the sediment supply rule. The cross sections in the SEDVEG model are separated by an average distance of 17 miles, which is nonstandard in sediment transport modeling. Each river, depending on the complexity of the physical system, requires a proper spacing of cross-sections and, in general, should not be more than a mile. If this equation is not adequately balanced in the model's algorithm, the sediment* *transport calculation will be computed erroneously and may derive too much scour, also known as China syndrome, or can cause excessive aggradation.*

Response: Although the original model that was reviewed (SEDVEG Gen1 Platte River Model) had a spacing of one section every 6.8 miles, the current Platte River SEDVEG Model has an average spacing of one cross-section every 1.45 miles. With this spacing, the concern over the Exner Equation is not an issue.

Comment 13836: *The DEIS proposes that native riparian forests be bulldozed and burned, and then the resulting land should be pushed into the flowing water to overburden the stream with sediment. They conclude there are no negative impacts associated with such activities. Nowhere though do they address the potential negative biological impacts such as reductions in populations of species of concern such as yellow-billed cuckoos or Bell's vireos. Nor do they address social impacts such as possible property boundary changes if channels of the Platte River shift due to such Program activities. The DEIS clearly states that flooding has become a problem near North Platte due to channel aggradations that has reduced transport capability, yet they do not address this same issue in the central Platte River even though the goal is to cause channel aggradations.*

Response: The goal of sediment management is to offset ongoing channel erosion, and achieve sediment balance, not to create aggradation. A desired outcome for both species improvement and adjacent landowners is that the channel in all reaches of the critical Habitat Area become stable (dynamic equilibrium) over time. Present information ("River Geomorphology," chapter 4) indicates the channel in the critical Habitat Area is degrading from the Johnson-2 Return to Elm Creek and aggrading between Gibbon and Wood River. As appears to be the case between Gibbon and Wood River, aggradation can provide benefits by widening channels and improving conditions for target species. At North Platte, aggradation is reducing flow conveyance through this reach and causing flood impacts to nearby infrastructure. An important component of the land plans and sand augmentation plan is monitoring upstream and downstream of these actions ("River Geomorphology," chapter 5) to prevent any undesirable impacts. Monitoring these sites is specified in the Draft Adaptive Management Plan (AMP) (2005), and is an element of the IMRP. Also see response to Summary Comment 19.

Comment 13853*: Page 2-21. These depletion numbers only make sense if the 7-year period of 1902 to 1909 is an actual valid baseline for flow in the central Platte (see discussion in Murphy 2003, which cites Randle and Samad 2003). The EIS is referencing their own work to support their positions. Please indicate why a 7-year period should be considered baseline in an area known for climatic cycles that often exceed a decade.*

Response: The development of river enhancement actions does not rely on selecting a "baseline" condition but does rely on understanding that the river conditions at the turn of the century vary largely from conditions today. The 1895 to 1909 flows are the earliest available estimates of gauge information and are from Randle and Samad (2003) and Simons and Associates (2000). Estimates from this period:

- Are used to help understand the water budget and flow depletions that have occurred since that period,
- Are used to understand the processes that produced the plan form shown in USGS topographic maps from 1896 to 1902, and
- Are compared to flows in later periods to understand the processes of plan form change that occur between these periods.

Comment 13865*: Page 3-46 Figures 3-9. The whole theory on island elevation is wrong for the* *majority of cases. The bed does not incise and then the island vegetates. Vegetation gets established on moist mineral soil near the water surface then as it grows it increases channel roughness and higher subsequent flows deposit material on the bar and the landform increases in height. The vegetation grows through the new substrate increasing its root zone and becoming better established. This process keeps working until island height is near peak flow levels. Since the DEIS theory on how islands are formed is wrong their approach to fixing it stands a large chance of not working with out continued mechanical intervention. The lowering of islands just sets the process back and with out mechanical maintenance these islands vegetate this is why the FWS now disks 40 miles of river. The pulse flows identified could exasperate low bar formation and thus increase vegetation encroachment just as easily as fix the problem.*

Response: The text in the referenced sidebar and in the "River Geomorphology" section of chapter 2 has been changed to reflect that vegetation has colonized expanded areas in the historic flood plain primarily due to reduction in flows, and not necessarily due to channel incision, although in the degrading reach of the river this is also a factor. Continued disking of vegetation on channel lands is currently required due to a lack of bankfull flows that could remove new vegetation.

Comment 13868: *Page 4-31. Why was sediment augmentation simulated throughout the analysis period? If 50 acres of islands need to be squished per year in the first increment why not in subsequent years? How long does it take for the sediment to move through the system? What is the potential for causing channel narrowing in the stretches that are currently widest thus most prone to sediment deposition?*

Response: The sediment augmentation plan is simulated throughout the 48 years of hydrologic record in the FEIS to assess performance over a wide range of conditions. The model results reflect both sediment erosion as well as deposition. Also see response to Comment 13705.

Comment 13869: *Page 4-32. The DEIS claims channels are still changing with no reference or data presented. Please provide data or reference. Cottonwood and willows at least do not colonize the higher elevation sandbars.*

Response: Data on repeated surveys of the river channel, and the rates of degradation are presented and cited in the DEIS (see page 2-40). Additional data is presented in the FEIS. Also see Holburn et al. (2006) and Murphy et al. (2004) in volume 3 of the FEIS.

Comment 13885: *Page 5-42. High flows alone will not discourage vegetation establishment. Flows at the wrong time may actually promote vegetation establishment.*

Response: A numerical model (SEDVEG Gen3) is used to help track the response of vegetation to flows and to track water surface elevations and susceptible bank areas during cottonwood germination periods. Vegetation mortality is currently analyzed for scour based on velocity, inundation of the plant, ice effect, bank stability, and desiccation when the groundwater level drops faster than root growth.

Comment 14171: *P. 4-39 The DEIS should reference the data supporting the statements made regarding sandbar formation and annual peak discharge, bed size, and sediment transport. The DEIS states that RM206-160 has a greater potential to build sand bars and in an earlier section under present conditions, that over a half million tons of sediment is being deposited in this reach. The DEIS should describe the frequency and distribution of sand bars in this reach as opposed to other reaches, together with the number of terns and plovers that have nested and fledged chicks in this reach. The actual conditions do not appear to support the opinions here*

Response: This section has been revised in the FEIS. Also, the discussion of sandbars has been expanded to include consideration of plan form since in-channel sandbars are found predominantly in braided reaches, and chapter 4 contains a more detailed breakdown and description of river reaches and plan form. Also see chapters 4 and 5 for an indicator of sandbar height potential.

Comment 14184: *There is no data or evidence suggesting that the addition of sediment will result in the formation of more sand bars at higher elevations. In is unclear how high the stage change may need to be and the duration of the event. In addition, the effects of lateral forces versus horizontal forces in the formation of sandbars is ignored by the DEIS.*

Response: See response to Comment 14602. Smith (1971[8]), 34 years ago, had accepted the influence of peak flow and water surface elevation on initial bar height, and was looking at subsequent and more detailed mechanisms of bar morphology in lateral and transverse directions.

Comment 14189: *The DEIS should also talk about the timing of the actions. How long does it take to create a wider channel via land management verses the hypothetical processes, which are outlined.*

Response: The referenced discussion has been added to chapter 5 in the FEIS.

Comment 14192: *P. 5-61 The DEIS states that a channel is stable when it does not aggrade or degrade. Please explain if a braided channel is a stable channel. If it is aggrading, then one would assume it is unstable and can not be maintained over time. Why is the DEIS seeking to create a form which cannot be maintained from a fluvial geomorphic standpoint? Maintenance of sufficient habitat via mechanical means for the benefit of the species is an attainable goal; the DEIS appears to establish an unattainable situation.*

Response: A braided condition is not synonymous with an aggrading or unstable condition (Leopold and Wolman, 1957; Yalin[9], 1992; Thorne, 1997)

Comment 14215: *We recognize that the limitations of the SEDVEG model means that its results can only be used in a comparative sense, but would like a more detailed description of the EIS team's view of the model's performance since it began working with it.*

Response: See the final report *Platte River Sediment Transport and Riparian Vegetation Model* (Murphy et al., 2006) in volume 3.

Comment 14231: *For a first time reader, the analysis of the impact of bridges, as described in the DEIS, suggests their effects are great on necking down the river (on average, a mile for each bridge), but their removal (of one or more) is dismissed in the screening report with little explanation other than that it would be costly. Why?*

Response: The analysis of bridges has evolved since the DEIS. (See discussions on bridges in "River Geomorphology" sections of chapters 2 and 4 in the FEIS.) It is now recognized that bridge foundations, under Present Condition, can reduce an overwide river corridor (historic flood plain) and consolidate flows into a single channel. A reach of river with anastomosed plan form changes to braided river at many bridge crossings when side channel flows are diverted back to the main channel by the bridge abutments or protected banks. The bridge is a disturbance factor so the braided river at the bridge is not valued as good habitat, however the braided plan form can persist for a short distance downstream. Therefore, the removal of bridges is not considered as a management objective since it would result in the loss of some braided reaches of river.

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8 Smith, N.D. (1971) "Transverse Bars and Braiding in the Lower Platte River, Nebraska", *Geological Society of America Bulletin*, v. 82, pp. 3407-3420.

9 Yalin, M.S. (1992). *River Mechanics*. Pergamon Press, Tarrytown, New York, 220 pp.

Comment 14590*: Use of SEDVEG as the best available science is strictly contrary to ASCE's Task Force findings on width adjustment modeling, on which Dr. Walter Graf, who served as the Chairman of the NAS review committee, is listed as a member. The ASCE Committee's report is listed as a reference in Murphy et. al (2004), but its significance is not acknowledged in the DEIS. The Task Force concluded that width adjustment modeling has not advanced to the point presumed by the EIS Team. Based on conclusions of the ASCE Task Force, it cannot be concluded that using SEDVEG or any similar model for predicting future width adjustments, either for 13 and 61 years, is within the realm of available science or technology.*

Response: The article by the ASCE Task Committee on Hydraulics, Bank Mechanics and Modeling of River Width Adjustment[10] (Task Force Committee) warns that there are no simple standard approaches which can be uniformly applied to all situations. The Task Force Committee also identifies shortcomings in modeling river widths and advises, with these constraints understood, the application of numerical models to predict river width changes.

A quote from the abstract is "The hierarchical approach to analysis of width adjustment is based on field, analytical, and numerical modeling techniques. The principal limitations of existing field-based and numerical modeling approaches are listed."

The recommendation in Step 5, the Application of Numerical Models, is "Initially a 1-D Model should be applied to the study reach to provide the overall setting of any additional detailed modeling. . .Selection of numerical models appropriate for this purpose may be guided by the comments provided in this paper."

The first conclusion in the article is "1. Present knowledge of bank processes and flow modeling is sufficient to allow some tentative predictions of width adjustment to be made."

Dr. Murphy used the information presented in this article in 1998 to provide improved capabilities in the SEDVEG Gen1 code. One example is the subroutines included in SEDVEG to address the resistance aspects of vegetation which vary through space and time. As reported by the Task Force Committee (1998), "None of the reviewed models account for the effects of vegetation on flow".

Also in SEDVEG Gen1, sediment was distributed across the width of the channel based on grain size and flow velocities, rather than being uniformly distributed across a section. Uniform distribution was a shortcoming identified for 1D model in the Task Force Committee paper.

This paper also identifies several shortcomings associated with the mechanics of cohesive bank failure. Because the Platte River has predominantly non-cohesive banks (sand), these shortcomings have less relevance. The Platte River also has low sinuosity reducing the complexity of river geometry which allows more utility from a 1D model and from the river widening analysis by the model. However, as the Program advances towards more detailed studies of specific short reaches of river, including restoration sites on Program lands, the need for 2-D models is anticipated to increase. This would be consistent with the hierarchal approach of predicting river width changes as recommended in this paper by the Task Force Committee.

Finally, it should be noted that Dr. Graf is not listed as one of the members of the ASCE Task Force Committee on Hydraulics, Bank Mechanics and Modeling of River Width Adjustment (1998, page 916).

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10 ASCE Task Committee on Hydraulics, Bank Mechanics and Modeling of River Width Adjustment (1998). "River width adjustment. II: Modeling," Journal of Hydraulic Engineering, ASCE, v. 124, n. 9, pp. 903-917.

Comment 14592: *The SEDVEG model was used for evaluating the EIS alternatives. Yet, as shown in the supporting documentation, "Application of the Sediment and Vegetation Model to EIS Alternatives," (DOI 2003), the model could not be calibrated using the long-standing, but refuted, definition of active channel width as the unvegetated channel width. In order to calibrate SEDVEG to measured data, the EIS Team made a late change in the definition of active channel, increasing it to include vegetation younger than three years. No scientific or other basis for this late change is provided, and the revised definition is no better than the previous definition for use as a geomorphologically-relevant term.*

Response: We are unable to locate any text in the DEIS appendix which gave rise to this comment, however the appendix has been updated and descriptions of the sensitivity and calibration testing are provided in the final report *Platte River Sediment Transport and Riparian Vegetation Model* (Murphy et al., 2006) in volume 3 of the FEIS.

Comment 14594: *The B3 chapter of Parsons' report proves that the algorithms selected in SEDVEG are predisposed to degradation. Even DOI acknowledges this on p. 12 of their report, "Application of the Sediment and Vegetation Model to EIS Alternatives," (DOI 2003) where triple calibration was required to "prevent any integration of bias in the model towards a narrowing channel.*

Response: This conclusion from the B3 chapter of Parsons11 (2003) pertained to SEDVEG Gen1. There is debate as to whether the original code (SEDVEG Gen1) was predisposed to degradation, however the second calibration eliminated any possibility of bias prior to the DEIS. The full context of the excerpt describing the purpose of the calibrations is:

"Prior to modeling the alternatives, three calibration procedures were carried out with the SEDVEG numerical model. The first two calibration procedures were designed to prevent any integration of bias in the model towards a narrowing channel. The first calibration procedure addressed model sediment coefficients, the second calibration procedure focused on the conveyance of flow and sediment at each cross section, and the third calibration procedure tested vegetation coefficients."

"The purpose for this conveyance calibration [second calibration] was to eliminate any pattern in the order or shape of selected cross sections, which would bias the model towards an aggrading or degrading condition. The same cross sections, section locations, and point elevations, which produced this stable condition of sediment transport, were then used to compare the alternatives for the PEIS [DEIS].

Predictions of aggrading or degrading conditions by the model for the PEIS [DEIS] Present Condition and alternatives, should be due to discontinuities in the riverflow and sediment transport of each alternative, rather than an inherent bias in the model."

Comment 14595: *Calibration of SEDVEG was described by the DEIS as a process of adjusting the slope of the channel to get an "equilibrium" river (no widening). River slope is measurable and need not be estimated. Because it provides the energy for water and sediment transport and for shaping of the stream, it cannot be arbitrarily altered. Precise measurements of the highly variable slopes of the Platte are provided by the USGS (1983), but were not incorporated in the DEIS.*

Response: In the Central Platte River it is estimated that the pool-riffle geometry of a channel can introduce at least plus or minus one foot of variation into the average profile of the river at a

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11 Parsons (2003). "Platte River Channel Dynamics Investigation," prepared for States of Wyoming, Colorado and Nebraska.

surveyed cross section. This was the general range assumed for one of the calibrations on the DEIS SEDVEG Gen2 Model. However no slope adjustments were made in the FEIS SEDVEG Gen3 Model and the thalweg elevations, as surveyed, define the profile of the river.

Comment 14597: *The unvegetated width is an acceptable parameter relative to species needs, but is not a geomorphic term. The error of assigning morphologic attributes to the unvegetated width continues to mislead the EIS Team and could be detrimental to the species. The use of unvegetated width as a geomorphologic indicator is unprecedented and misleading. No citations to literature describing this as a valid geomorphic term are provided. The unvegetated width of a river is not a measure of its equilibrium width, effective discharge width, or "active" channel width, all of which are described in geomorphologic literature. Changes in the unvegetated width should not be correlated with anything except vegetative expansion. Far more relevant measures of active channel width are available in the literature, but were not applied.*

On p. 2-35, the term "active channel width" is used in the DEIS in the same context as unvegetated width. This failure to use a geomorphic term in defining channel width is one of the primary concerns by the states' representatives. The two are demonstrably not the same. Even the most recent release of the White Paper (Murphy et. Al 2004) uses the term "active" channel width in the first sentence of Section 1.2 describing "The Concern," yet the figure being referenced (Fig. 1.3) has as its title, "Reductions in unvegetated channel width…" Figure 4.1 of the same report is a plot of the same data as Fig. 1.3, but the title has been changed to "Comparisons of active channel width…" The two are not synonymous yet have been repeatedly used synonymously by the EIS Team over the years. An appropriate definition of active channel width is missing in the entire development of the DEIS.

The USGS and others established that there is a direct correlation of effective discharge and associated active channel width. This relationship is acknowledged in the EIS Team's 2003 report on Platte River Flow and Sediment Transport Between North Platte and Grand Island (pp. 38-55), yet the DEIS does not rely on this relationship. Instead, the unvegetated width (which in no way reflects a geomorphologic measure) is correlated with annual peak flows.

Response: Unvegetated width of the river is a reflection of the flow regime as pointed out by Johnson (1994) and National Research Council (2005), and flow regime is a critical geomorphic parameter. Flow regime encompasses both mean and high flow events. Reclamation continues to recognize the utility of the unvegetated width measure as did Platte River researchers such as Williams (1978), Eschner (1983), and Peak et. al (1985), as a general indicator of channel change. Repeat cross section surveys provide more detailed information on channel stability and change and, more recently, plan form is used since it allows a more comprehensive and process-based approach to understanding channel change.

Comment 14598: *The DEIS' claim that climate is not significantly instrumental in shaping today's river morphology is inconsistent with the data, literature, and scientific understanding.*

- The DEIS and supporting documents discredit climate as a significant factor in 20th century morphology, which overlooks a significant body of scientific truth. Climatic factors adequately and accurately explain the forces shaping channel morphology and vegetation leading to and during the 20th Century, especially when basin wide precipitation is compared with streamflow volumes (see the A3 chapter in Parsons 2003a). This cause-effect correlation is unquestionably strong, yet it is not acknowledged nor adequately discussed in the DEIS.

- The preponderance of scientific literature documents the existence of geomorphic thresholds (borders between different planforms and profiles) and of dramatic geomorphic changes known to be singly associated with climate changes in Great Plains rivers. These processes did not magically cease to function at the turn of the century as alleged in the EIS Team's 2004 White Paper.
- Strong evidence exists showing that climate cycles have raised and lowered the Platte by tens of feet over time and shifted it through numerous thresholds, and are recognized by the majority of experts as the primary factor affecting morphology of Great Plains Rivers throughout history and to the present.
- The literature cited and analysis in the A1 and D1/D2 chapters of the Parsons report prove that only climate swings can produce the kind of far-reaching changes in planform and vegetation expansion that have occurred in the Platte over the past 150 years, whereas storage and diversion projects do not, and cannot, produce the same far-reaching morphologic changes alleged in the DEIS.

Response: Chapter 2 of the EIS notes that "some have suggested that a drier climate, rather than upstream water use, diversion, and storage, may be the primary reason much of the Central Platte River has changed from a braided to an anabranched channel form", and goes on to describe various reasons why "the available climate record does not support this interpretation." Chapter 2 also cites the National Research Council (2005) review of Platte River issues, including the Council's conclusion that "direct human influences are likely to be much more important than climate in determining conditions for the threatened and endangered species of the central and Lower Platte River" (although, as noted in the FEIS, the Council also stated that "longer-term background effects of climate are worthy of further investigation"). The Council reached these conclusions after reviewing the Parsons report cited in the comment.

Comment 14600: *Scientific evidence strongly refutes the DEIS' claims regarding causes of, and remedies for, the reduction in North Platte channel capacity. Statements on p. 2-40 and elsewhere in the DEIS contend that the North Platte River at North Platte is aggrading. The only known scientific analysis of this was conducted by Parsons (2003b) for CNPPID, which did not support this hypothesis. Proof of this claim should be provided in the DEIS.*

Remedies for the reduction in capacity at North Platte were developed by Parsons for CNPPID, which appears to be the basis for Fig. E-12 of the DEIS even though the Parsons study is not credited with having published the list. However, the DEIS only recommends one option, dredging, which was the only remedy not recommended in the CNPPID study. Dredging was not recommended due to the fact that several independent studies reveal that this reach has reached a state of equilibrium and that significant bed material transport passes through this location on a daily basis. The transported sediment (currently estimated as about 400,000 tons per year) would quickly fill the void caused by dredging, restoring the quasi-equilibrium state that now exists (several publications that document this transport rate and equilibrium are cited in Parsons 2003a).

Dredging was discounted in the CNPPID study as not being commensurate with the causative processes. The North Platte River's average transport of 1100 tons per day of sediment through this location by far exceeds any opportunity to successfully or economically dredge a four to six mile segment of the river. Instead, means of reversing the causes of the capacity reduction were described in the attached Parsons CNPPID study, and some combination of them should have been recommended in the DEIS action plans.

Response: See JF Sato & Associates (2005) for the latest work on this concern. Note their conclusion that, “The decrease in the channel conveyance is due to aggradation.” (page 2).

Comment 14601: *As noted earlier, the DEIS alleges that reductions in unvegetated channel width “mirror” increases in sediment size, and that this “coarsening” of sediment results in channel deepening and narrowing. The Parsons report (2003a) proves that there is more-than-sufficient uncertainty in the limited data on sediment sizes to preclude formulation of management actions based on the “coarsening” theory. Among other examples given in the B1 chapter of the Parsons report, the variability in sediment gradations independently measured by the COHYST/USGS scientists across single cross-sections in the summer of 2001 is greater than the variability being used in the DEIS to allege that coarsening is occurring in the downstream direction.*

A 1983 federal government assessment of sediment sizes in the Platte (USGS 1983) reveals that the median bed material size decreases from Central City downstream, and no such theory of coarsening is described in their report.

It is counter-intuitive, and scientifically incorrect, to state that a river with a coarse-grained bed would only deepen itself. Several sections of the DEIS make this claim. Coarse sediments increase the resistance to deepening, and any competent energy for sediment removal would apply itself to the banks, most likely resulting in widening of the channel. Even if the river has insufficient energy to transport the coarser bed materials, it would still seek out the finer-grained bank materials to satisfy its transport capacity.

Response: The FEIS notes that the coarsening of grain sizes coincides with degrading reaches (see “River Geomorphology” sections of chapters 2 and 4). Bed erosion and the coarsening of grain sizes is a commonly recognized sediment transport process. Parsons (2003) found the grain size changes to be statistically significant.

Comment 14602: *The DEIS’ theory of sand bar dynamics is refuted by actual Platte River data collected and described by the USGS and University of Illinois. A key inaccuracy in the DEIS is that “high” sand bars can only be created by sufficient flow in the river to cause a “high” water surface that occupies the full width of the river between banks. This is one-dimensional thinking that disregards the complexity of localized perturbations in the bed and bars and of the flow and sediment processes disclosed by Smith. Smith (1971) describes transverse bar formation and dissection of the bars by moderately low flows, far below those needed to occupy the entire bank-to-bank complex. The explanation for this is that even moderately low flows approaching these transverse bars in the shallow channel segments will result in local rises in water levels as high as levels achieved by full horizontal occupation of the river. Smith confirmed this by concluding that “at low and intermediate discharges, transverse bars form” creating characteristic “variations in depth and velocity over short distances.” Energy gradients at these obstructions are sufficient to raise levels locally, transporting water and sediment over some of the dissected bars. A braided river does not require complete inundation of the bed and bars to experience change. The DEIS claim that the high elevation sandbars “were most likely formed during the large spring floods” is not of sufficient scientific certainty to institute a regimen of high flows, especially in light of Smith’s findings. Smith’s reports are not referenced in the DEIS.*

A continuing problem with the DEIS sand bar theory is that if it is true, the high flow each year would need to exceed last years’ high flow. Otherwise the new vegetation on last years’ sand bars could not be removed. Unless each years’ flow is higher than the previous, under the DEIS assumptions the river would soon be filled with vegetated bars.

Response: Smith (1971) discusses the evolving form of bars in the Lower Platte as discharge decreases. He describes how bars enlarge laterally and in the downstream direction, and describes aggradation on top of the bars as flows and sediment transport decrease over the top of the bar. No statements could be found to support a hypothesis that secondary flow currents during low and intermediate flows, through the conversion of velocity head to static head, raised water surface elevations to exceed elevations at high flow events. And converse to this hypothesis, Smith (1971) states in his summary "Bars formed during the high annual spring discharges are the first to become exposed. Those that escape complete erosion by waning currents are soon overgrown by vegetation to become semipermanent features until destroyed by next year's spring flows."

Comment 14664: *Page 2-38. Plat maps were obviously hand drawn and the 1991 Phelps County Plat Maps still look like that. Middle maps shows water was probably a small part of the area. 1938 photos show that 1904 map did not take into account accretion land and trees that must have been there in 1904. What caused the wide areas in the 1938 photos? Please discuss the problems with comparing different mapping techniques.*

Response: The level of accuracy of the hand drawn maps at this location appears consistent with the other maps. The stippled or tan shaded area of the middle map (USGS topographic map) designates the area of bare sand—that is the area periodically inundated by flow that prevents the growth of vegetation. Although the blue lines give an indication of perennial flow, the stippled area designates the width of the braided river. The river width in the USGS topographic map is similar to the hand drawn maps that come before and after (1860 and 1904). Aerial photos from 1938 indicate this area near Overton was the first reach between Overton and the islands downstream of Kearney to transition from braided to anastomosed.

A note was added to the figure caption in the FEIS to explain that red and yellow bars represent the same distance and location in each photo to aid the comparison.

Comment 14677: *The thickness of the active riverbed layer was not properly computed in the version of the model that I reviewed. It was assumed that the active riverbed layer was a constant thickness throughout the hydrograph routing, and therefore, differential bed scour for different flow magnitudes was not considered. This simplification causes errors in the sediment transport capacity determination and in the overall results of the model.*

Response: In the current version of the model (SEDVEG Gen3) active layer thickness is computed as a function of the sediment transport rate. The active layer thickness can be limited to the thickness of the armor layer.

Comment 14678: *An acceptable and established method for modeling bank erosion or river lateral migration has not been developed. The methodology used in the model is conceptual and it was not possible to calibrate for a lack of suitable data.*

Response: The method used for bank erosion in SEDVEG is described by the ASCE Task Committee on Hydraulics, Bank Mechanics and Modeling of River Width Adjustment (1998) as one of two methods used in the 12 models evaluated. As recommended in this paper, bank erosion for the Platte River SEDVEG Gen3 Model was calibrated using data from 6 repeat cross sections from a habitat study site near RM 226 and RM 227 (Murphy et al., 2006).

Comment 14679: *The lateral distribution of sediment along a transverse cross section is not based on any proven theory. To be acceptable, this routine should be improved and thoroughly verified.*

Response: After 5 years of testing, Reclamation is very satisfied with the results of Dr. Murphy's innovative use of the Rouse parameter first applied in SEDVEG Gen1. Reclamation has concluded that this feature, which allows a 1D model to distribute finer grain sizes to the overbank area (across the second dimension), could be incorporated into a second

Reclamation sediment transport model, GSTAR-1D.

Comment 14680: *The model does not compute both degradation and aggradation on the same cross section at the same time step. Under natural conditions, a riverbed can both scour and aggrade at the same time along a cross section. This limitation of the model is important because changes in riverbed contours affect vegetation establishment or mortality, and cause a change in response throughout the hydrograph routing.*

Response: The model computes aggradation and degradation for 10 different grain sizes at each point in the cross section. Fine material can be eroding while, at the same time, coarse material can be depositing. Also scour can occur in the thalweg while deposition occurs in the overbank area. Erosion can also occur during the rising limb of a hydrograph and deposition in overbank areas during the falling limb of a hydrograph. All of these processes introduce changes in riverbed contours which affect vegetation establishment, growth and mortality.

Comment 14681: *The form of sediment transport is not properly addressed in the model. Transport by macro-forms, or even as dunes, is not considered. This over-simplification has the potential to misrepresent any extrapolation of sediment transport. The miscalculation of bed erosion transfers the errors to the vegetation erosion routine, and consequently causes a chain reaction of imprecision though the entire model routing process.*

Response: Dunes (macroforms) which are large enough to be significant in sediment transport volume calculations, yet small enough to escape detection in cross section spacing of 1.45 miles (see response to Summary Comment 25) have not been detected or measured in the critical habitat reach of the Platte River. JF Sato and Associates (2005) reported that the loss of conveyance at the city of North Platte was due to aggradation with additional factors such as Phragmites, growth of a sandbar, and drainage issues in the overbank area. No large macroforms were detected.

Comment 14682: *The model was incapable of predicting the formation or erosion of sandbars. The dynamics of sandbars along a river channel is an important characteristic for vegetation mortality rate.*

Response: The model does allow some evolution of irregularities in the bed of the modeled cross section. These irregularities and the sideslopes of banks and islands can support vegetation growth and mortality depending on the flow regime. The vegetation then affects sediment transport as intended through bank resistance.

Comment 14683: *The hydraulic routing algorithm uses a simplified method to compute the hydraulic variables. State-of-the-art algorithms available in other models simulate flow routing with better precision. The procedure utilized in the SEDVEG model is based on normal water depth. Although backwater or 2-D models or methods are widely available, they were not used.*

Response: The incorporation of a step-backwater computation of water surface elevation is one of the improvements proposed by Reclamation for the next revision of the SEDVEG code (SEDVEG Gen4). However, the current assumption of normal depth is relatively accurate in most reaches of the Platte River. The water surface varies from normal depth at more locations when the river has: high gradients; large woody debris loads or immoveable boulders; structures that influence flow; and, high sinuosity and sharp bends. Since the Platte River has very few locations with these conditions, there appears to be few locations where an assumption of normal depth hinders the model. The one notable exception is the reach immediately upstream of the Kearney Diversion.

2-D models provide information on secondary flow currents that 1-D models like SEDVEG can not provide. Secondary currents contribute to sandbar formation and contribute to channel widening and deposition. However the computational demand of a 2-D model, and the data required constructing the model, far exceeds computational demand and data requirements of a 1-D model. For these reasons a 2-D model can not be used to analyze the entire 90 miles of the critical habitat reach as a single system. As recommended in the ASCE Task Committee's hierarchal approach (1998), a 1-D model (SEDVEG Gen3) is being used for the initial assessment. A 2-D model is recommended for the analysis of specific sites that may be needed after this Programmatic FEIS.

Comment 14684: *The review of the vegetation parameters available in the Geomorphic Appendix issued November 12, 2003, shows that some of the values are unrealistic. For example, the root growth rate for March to October is set at 0.50 ft/mo for cottonwood, and 0.375 ft/mo for willows. In the model, a positive value means upwards, and a negative value is downwards. These values and sign conventions for the coefficients mean that the roots can grow upwards, out of the ground. The magnitude of root growth with respect to the water table is set to –99 ft for willow. The high band limit for cord grass was set as 99 ft. Both values seem to be outside a reasonable range.*

Response: This typographic error has been corrected in the report *Platte River Sediment Transport and Riparian Vegetation Model* (Murphy et al., 2006). An examination of the input files for the DEIS and the FEIS shows both sets of runs used the correct negative values for root growth rates: -0.50 ft/mo for cottonwood, and -0.375 ft/mo for willows.

The "magnitude of root growth rate" is actually the limit of root growth with respect to the water table or capillary fringe. Willows are highly tolerant of having wet roots so the limit was set by Simons and Associates presumably to avoid limiting growth based on saturated soils. Cord grass is not tolerant of having saturated roots and the limit shown in Murphy et al. (2006) in the input files of the DEIS runs and in the input files of the FEIS runs, is +1 feet.

Comment 14685: *The same Geomorphic Appendix also states that the VEGICE routine was activated to obtain the calibration. The VEGICE routine simulates the removal of vegetation due to the ice dragging effect. The ice routine of the model was very active in removing vegetation, and therefore was a major factor in the dynamic of the model. However, the data used to calibrate the parameters for this routine were very limited. Only one event was used to determine by regression the pertinent coefficients. Unless more data have been used to calibrate these parameters, in my opinion, the results of the VEGICE routine are not reliable and this routine should not be used.*

Response: Under Present Condition, the VEGICE routine in SEDVEG Gen3 accounts for 9 percent of the vegetation mortality which appears reasonable. It is the 4th ranked cause of vegetation mortality out of the 5 causes modeled. Velocity scour, bank failure, and desiccation remove more plants, inundation removes less plants. However a second calibration of the VEGICE subroutine has been added to the list of proposed improvements for the next revision to SEDVEG code.

Comment 14688: *Page 2-37. The DEIS emphasizes narrowing of a small portion of the river in recent decades (that may actually have been caused by upstream clearing operations) while not reporting other reaches that have consistently widened during the same period (Johnson 1997). Also, the South Platte River narrowed earlier than the Platte nearly a century ago; more recently channel widths have increased or remained stable, contrary to that stated on 2-37, 38.*

Response: Figure 2-14 on page 2-37 of the DEIS shows measures of width from North Platte to Chapman, so the reader can observe trends. This figure shows very substantial narrowing throughout this lengthy river reach. This is the major focus of the analysis. References to river narrowing have been revised to reflect that most narrowing had occurred by the 1960s.

Discussion of width changes on the South Platte River have been removed since the information was no longer pertinent.

Comment 14747: *P.5-53 The DEIS does not describe the limitations/offsetting impacts of channel widening. For example, as the channel is widened the stage change from increased flow is reduced. Yet increased stage change is stated as a desired outcome. The DEIS must specify the critical widths and tradeoffs and how they were developed. In addition, it must analyze how well the wider channel can be maintained as velocities will also be reduced.*

Response: The sediment transport model, SEDVEG Gen3, is used to provide these types of analysis. Please see indicators in the “River Geomorphology” section of FEIS chapter 5 such as sandbar height potential, width to depth ratio, and length of braided or wide river resulting from mechanical plans.

Comment 14758: *The SedVeg model should not be used to describe impacts, set performance standards or impact thresholds, or to make comparisons among alternatives. Given the uncertainties in the knowledge, a more qualitative assessment is needed with the understanding that the final Program would be structured to monitor actual effects and make adjustments through Program Adaptive Management to offset negative impacts as appropriate using proven habitat management methods.*

Response: Comment noted. The preferred alternative proposes that the methods for restoring channel habitat be tested and monitored over a 3-year period at a small scale and, if successful, increased in scale with continuous monitoring. Also see response to Summary Comment 23.

Comment 14926: *The occurrence of the China syndrome was frequent during SED model development, testing, and calibration, and I am not aware that it has been resolved. Establishing an arbitrary depth limit for the scour of the riverbed to control the China syndrome is not a scientifically valid procedure and cannot be acceptable in any sediment model. This actually negates the usefulness of the model.*

Response: In the earliest versions of the program there was a code error referred to as China syndrome, but this error was corrected prior to the Parsons review in 2003, and prior to addition of the transverse slope parameter. As stated by Parsons (2003), “Discussions with the USBR indicated that this approach may not be needed in the future as a result of other changes that have been made in other portions of the model.” No arbitrary depth limit for scour of the riverbed is incorporated into the SEDVEG Gen3 Model.

Comment 14933: *No data is provided in the DEIS showing that the prescribed flow relationships and the magnitude and duration of flow recommendation and SedVeg modeling will result in the scouring of vegetation. It is equally likely that the hypothesized processes for vegetation removal will have the opposite effect by in fact distributing seedlings with a short term pulse and growth (and narrowing of the channel) through late summer irrigation via release of so called forage fish flows.*

Response: See Summary Comment 28 (in the “Summary Comments and Responses” section of this document) with respect to the magnitude and duration of flow recommendations. Based on recommendations from Dr. Hsieh Shen during the National Research Council’s review of SEDVEG, vegetation removal by scour in the FEIS SEDVEG Gen3 Model is dependent on flow velocity rather than shear or active layer scour. The velocity at which vegetation scour occurs are specified parameters input to the model as reported in Murphy et al., (2006). Flow velocities are computed at each point in the section, at each time step, based on an assumption of normal depth and the geometry of the area at the point. The velocity parameters were initially set by the contractors Simons and Associates who wrote and calibrated the vegetation subroutines, and the parameters are within reasonable ranges. Also see response to Comment 13778.

Comment 14935: *The SEDVEG team has my plant demography data base, but there is no indication from the DEIS that it was used in the testing of SEDVEG. Aspects of SEDVEG are not satisfying to a wetland plant ecologist. For SEDVEG to ultimately be useful as a management tool, the model team needs to be broadened to include a riparian plant ecologist and to be more thoroughly tested under field conditions. The DEIS provides no corroboration from disinterested scientists that the SEDVEG model ""is successful at predicting general spatial and temporal trends in channel width…."*

Response: Although there are always improvements that can be made, SEDVEG Gen3 currently reflects dynamic bank resistance effects resulting from vegetation establishment and growth. This is a capability not found in most sediment transport models (see response to Comment 14590). And, the EIS team includes a wetland plant ecologist.

Comment 14937: *The DEIS alleges that high flows transport the majority of sediment in the Platte. This incorrect hypothesis has prevailed from USDOI's 2001 DRAFT White Paper to the present. Several investigators including the USGS (1983) assessed the frequency and duration of transport by these high flow events and contrasted them with the frequency, duration and transport capacity of all other flow rates. Even Reclamation's analysis of the full range of flows disproves this hypothesis. The question of which flows transport the most sediment cannot be resolved by looking only at the sediment amount transported by short-duration, high flow rates. The agreement of scientific literature on this point is undeniable. Though much has been learned about the effective flow rates in the river (the rates that shape the channel), the DEIS disregards significantly-relevant work by the USGS (1983), Smith (1970 and 1971), and Parsons (2003a) in assessing the role of frequent flows in the channel-formative and maintenance processes.*

The DEIS assumes that the Platte is geomorphologically "episodic," which in simple terms is a theory that its channel is shaped and maintained by infrequent, high flows. No other publication uses this term to describe this river, and the USGS study (1983), Smith (1970, 1971) and Parsons' A3 and A4 reports (2003a) prove that the flows that are effective in shaping and maintaining the river's form are the daily "workhorse" flows.

Response: One advantage to sediment transport models is it has large computational capabilities, eliminating the need to select or focus on a specific flow rate for sediment transport estimates. SEDVEG Gen3 computes sediment transport every day throughout the hydrologic record, ensuring consideration of the entire range of flow events.

Comment 14938: *The erroneous DEIS comparison of one 10,000 cfs event with ten 1,000 cfs events is used to illustrate their assumption that the instantaneous flow rate which moves sediment at the highest rate must logically move the most sediment. No scientific writing allows such a conclusion. All studies and references on this subject acknowledge the physical work that can be done in moving sediment with a range of lower flows having longer durations than the rare, short-duration high flows.*

Response: The commenter's example derives from a commonly noted relation that sand transport is often a function of flow to the second power, $Q_s = f(Q^2)$ (Julien, 1995). The DEIS example should read "three 1,000 cfs events," rather than ten. That error has been corrected in the FEIS. Also see response to Comment 14937.

Comment 14939: *The claim that historical "high" flows transported the "large sediment excesses" arriving in the South Platte to the Central Platte habitat reach has never been substantiated. Even a conservative estimate of events having a 10-day duration would not move sediment more than a few dozen miles. If the sediment was eventually getting to the habitat area in the past, these high flows couldn't have been delivering it, and it was most likely being* *transported in the form of macroforms by daily "workhorse" flows that had sufficient duration and frequency to carry the sediment that far.*

Response: Regardless of rate of delivery, the habitat reach received substantial bedload (sand) from upstream reaches in a sustainable cycle that produced a relatively stable (in dynamic equilibrium) river.

Comment 14941: *Murphy et. Al (2004) state that the stabilizing effects of vegetation prevented the high flood flows of 1973, 1983, and 1984 from widening the channel. Some of the bars must have had new vegetation, which evidently was not impacted by these floods, refuting the allegation that pulse flows (at rates lower than these floods) will provide a means of widening or maintaining the width of the river.*

Response: The authors do not agree with this interpretation of Murphy et al., (2004). As made clear in the DEIS and FEIS, the Program relies on mechanical means to widen the river, not high flows.

Comment 14943: *The Platte River, in both its present and former (pre-development) states, has a narrow vertical range of deviation of stage with flow rate (it is currently only 2.8 ft between drought level and flood level and was probably less for the braided stream). As a result, and assuming the DEIS theories are true, then high, dry, and unvegetated sandbars could not have been a characteristic feature of the Central Platte's channel.*

Response: See response to Comment 14602 in this section and Summary Comment 30 in the "Summary Comments and Responses" section of this document. What the DEIS and FEIS describe as historical conditions are numerous sandbars, reworked on a nearly annual basis and so remaining free of vegetation, and built high enough by annual peak flows so as to remain free of inundation after tern and plover nesting has occurred.

Comment 14978: *The latest White Paper (Murphy et. Al 2004) does not explain or document the presumed relationship between active channel width and unvegetated width, but instead uses them interchangeably throughout. It has been established by all investigations that the unvegetated widths have decreased, but no report by the EIS Team or others has proven that the active channels have narrowed. Active channels are known to pass through vegetated areas, and their widths cannot be established by examining aerial photos or GLO maps.*

An analysis of effective discharge proves that active channel widths would return at least to their 1938 widths if vegetation could be mechanically removed or if the expansion process could be reversed. This means that the Present Condition alternative will be effective to the extent that vegetation can be eradicated.

Response: See National Research Council (2005) for a historical discussion of the inter-related effects of changes in flow on sediment transport, vegetation and channel morphology, which espouses reductions in active channel width in response to flow reductions. See chapters 2 and 4 of the FEIS for a view of historical channel changes, through consideration of plan form that includes, in addition to factors of flow and sediment, aspects of topography in the historic flood plain. This process based approach also recognizes the reductions in active channel width resulting from reductions in flow and the changing plan form.

Comment 14979: *The long-standing assumption regarding the between-banks precision of the original 1860's GLO surveys is disproved by Parsons (A3 chapter). The GLO maps were surveys of property outside the meander lines or of high-value islands inside the lines, and did not record the numerous other islands and bars or the extent of vegetative growth between the meander lines.*

Response: Even accepting these opinions does not eliminate the substantive reductions of "between bank" widths of the river over time. The National Research Council (2005) discussion focuses on woodland expansion since 1938 (excludes GLO plat maps from 1860s and USGS topographic maps from 1896 to 1902) and arrives at similar conclusions of substantive width reductions by the 1960s.

Comment 14980: *Detailed data discovered by Parsons at Kearney (A3 chapter) support the hypothesis that, other than some vegetation expansion, there has been no morphologic change at Kearney. Islands, bars, and other features in 1870 and 1998 at Kearney are exceptionally similar. Substantial vegetation existed in 1870, and changes over time in the width of the corridor occupied by the effective discharge are minor.*

Response: Reclamation could not reach the same conclusions. Also, see the National Research Council (2005) report.

Comment 14981: *The data presented in several chapters of the Parsons report disproves the long-standing hypothesis that there has been a significant loss of morphologically-relevant channel width. The only scientific conclusions that can be made from the 1860's General Land Office surveys and aerial photographs is that vegetation has expanded into greater areas between the original meander lines (although the meander lines have not significantly changed), and that some reaches have converted to an anabranched form. The channels are still there, and have been encroached but not eliminated by vegetation expansion. They are still active in conveying both sediment and water.*

Response: See responses to Comments 14978, 14979, and 14980. The comment seems to dismiss the importance of vegetation expansion into the formerly unvegetated river channel. This expansion results in the loss of more than 90 percent of the channel habitat. Perhaps this suggests that "morphologically – relevant channel width," as defined by the commenter, is not particularly relevant to the habitat used by the species.

Comment 14986: *If the expansion of vegetation is regarded as a geomorphic effect, as alleged in the DEIS (this is strongly disputed by the Parsons study), then the scientific method requires that it must also be concluded that it is driven by climate. If it is not geomorphic, (as strongly proven) then the unvegetated width cannot be equated with "active" channel or any other morphologic measure. This is because the preponderance of literature shows that the primary geomorphic driving force in the Platte is climate. The far-ranging vegetation expansion in the river that has taken place in the past 100 years is best explained, scientifically, as a response to climate changes. Spatially-limited effects of storage and diversion have been documented, but the extent of impacts of these facilities does not allow inference that the far-reaching expansion of vegetation is the result of these projects.*

Response: See Murphy et. al., (2004) in volume 3 of the FEIS and the National Research Council report (2005) for the roles of climate and anthropogenic influences on Platte River morphology, historically and in the present. Also see response to Comment 14598.

Comment 15014: *SEDVEG is alleged to be able to predict that Kingsley Dam can affect river morphology throughout over 150 miles of river. No precedent for a single dam of this size having geomorphic impacts this far downstream is cited in the DEIS, and for that matter, none exists. The limited downstream degradation effects of Kingsley have been studied, documented and published in peer-reviewed journals, and cannot possibly extend this far downstream.*

Response: Data in the form of repeat surveyed cross sections (Holburn et al., 2006), basic geomorphic theory, and SEDVEG Gen3, predict (and quantify) that the volume of Johnson-2 clear water return flows from the Tri-County Canal causes degradation for at least 15 miles directly downstream of the canal return. Basic geomorphic theory and the SEDVEG Model also predict that a continuation of this imposed sediment imbalance will impact river reaches further downstream in the future. The most direct impact of Kingsley Dam on channel morphology in the critical Habitat Area is the altered flow regime imposed by the reservoir. The altered flow regime is an input to the SEDVEG Gen3 Model so that flow effects can be incorporated into the analysis of channel morphology in the critical Habitat Area.

Comment 15016: *The Parsons report (2003a) proved that elevations of the base channel calculated in SEDVEG simulations of time periods between available sets of transect measurements are in very poor agreement with elevations of the actual channel base surveyed along the actual transects.*

Response: The evaluation by Parsons (2003), *Results of Investigation B3 – Evaluation of Predictive Capabilities of SEDVEG Model*, was of little value since it assessed 2-D modeling capabilities of a 1-D model. The evaluation is also not applicable to SEDVEG Gen3 due to two revisions to the original code and two revisions to the structure of the Platte River SEDVEG Model since the original review. Also see response to Comment 14926.

Comment 15017: *Variation in channel shape and incision depths at a single cross-section during several months of measurements at different flow rates was shown in the Parsons report (2003a) to be greater than the variation in long-term bed elevation predicted in the DEIS.*

Response: This is consistent with the differences in short-term and long-term variations to be measured in the field. This speaks to the importance of the repeated surveys of numerous river cross sections carried out by Reclamation over the last 25 years.

Comment 15020: *The DIES does not address the adverse channel capacity effects of, and remedies for, the recent expansion of Phragmites in this reach. This is an invasive, 10- to 12-ft tall reed that over the past 15 years has covered the river banks and bars for several miles upstream and downstream of North Platte, and has now extended to virtually every square foot of sand as far as can be seen in both directions from the Highway 30 and Highway 81 bridges. Some observers report that it is appearing at many locations downstream to and beyond Grand Island.*

Response: See the "Land Use Types", "Invasive Plant Species" section of chapter 5 of the FEIS.

Comment 15021: *A foundational assumption of the DEIS and supporting documents is that "a larger grain size is generally associated with a more deep and narrow channel section" (DEIS 2004). The scientific resource used to make this generalization is not provided. Proportional relationships as straightforward as Yang's equation (see p. 94 in the 2004 White Paper) prove that when all other factors are constant, an increase in grain size results in a decrease (not an increase) in the product of the channel width and depth. Alleging that an increase in depth and decrease in width will occur is speculative and not consistent with these fundamental proportional relationships that are well-documented in scientific literature.*

Response: The process of degradation and erosion of finer materials from the bed creates an association between larger grain size and smaller width to depth ratio in the Central Platte River, but this is not "a foundational assumption" of the FEIS.

Comment 15022: *The repeated allegations in the DEIS that the bed material classifies as "coarse sand" is disproved by Parsons (2003a) and not consistent with published classifications of sand sizes. The bed sediment gradations of the 1930's and earlier classify the bed as a medium sand, and subsequent gradations still classify by all standard classification methods as a medium sand. The DEIS should not consider any change from one type of medium sand to another medium sand as a basis for developing a new, controversial theory about coarsening, and then treating the hypothesis as a fact in developing conclusions and action plans.*

Response: The median grain size in the river reach between Overton and Grand Island was approximately 0.35 to 0.40 millimeter in 1931 (USACE, 1935), and 0.60 to 1.05 millimeter in 1989 (Murphy, et. al, 2004). Rouse (1950) lists coarse sand as 0.5 to 1.0 millimeter, Perloff and Baron (1976) list coarse sand as 2.0 to 0.42 millimeter; Julian (1995) lists coarse sand as 0.5 millimeter to 1.0 millimeter. These three examples all encompass the median grain sizes measured in 1989. However descriptions in the FEIS of “coarser sand” are intended to imply a change in size rather than a sediment classification.

Appendix C – Basis of River Flows

The USGS measures the stage and estimates the flow rate at a number of gaging stations along this reach of the river at intervals of 15 to 60 minutes. Early data collection was not as frequent, but daily flow rate values have been observed for over a century in Nebraska. Daily average flow rates and monthly average flow rates are calculated by the USGS and reported in Water Supply Papers and Water Resources Data reports. These data provide the historic record of flow along the Platte River. The state of Nebraska also manages and reports data from several stream gages on the North, South, and Platte Rivers.

Historic Flow Records

The earliest data on flow rates in the Platte River and its tributaries in Nebraska began in 1895. Daily flow rates for the North Platte River at North Platte, NE (USGS No. 06693000) and for the Platte River at Duncan, NE (USGS No. 06774000) were observed beginning in 1895. However, river ice prevented the collection of flow rates during the winter months. Additional gaging stations, for the measurement of river flow, began operating at the locations and times listed below:

- No. 06764000: South Platte at Julesburg, Colorado in 1902,
- No. 06765500: South Platte River at North Platte, Nebraska in 1914,
- No. 06766000: Platte River at Brady, Nebraska in 1938,
- No. 06766500: Platte River near Cozad, Nebraska in 1940.
- No. 06767000: Platte River near Lexington, Nebraska in 1902,
- No. 06768000: Platte River near Overton, Nebraska in 1918, and
- No. 06770500: Platte River near Grand Island, Nebraska in 1934.

Flow measurements from the gaging stations on the North and South Platte Rivers at North Platte, NE and from the gaging stations on the Platte River near Cozad, Overton, and Grand Island, NE are the basis of flows used in the different SedVeg models. Flows used in the SedVeg Gen1 Historic Platte River Model are USGS gage flows described in more detail in Appendix E. Flows used in the SedVeg Gen1, Gen2 and Gen3 Platte River Models for present and future conditions (Present Conditions flows) are adjusted USGS gage flows.

Adjusted River Flows (Present Condition flows)

Because the effects of human controls have varied significantly during the historic record, the most recent flow record and operations in the basin (1980s and 1990s) have been used to develop a monthly model of the Present Condition baseline hydrology influenced by a constant set of controls. This baseline hydrology represents what the historic monthly flows would have been if the present-day level of water resource development (and its current operating strategy) had been in place during the entire historic period of interest.

Present Condition hydrology is based on historic flow data from 1947 to 1994, including both the drought period of the1950's and the spillway-flood release from Kingsley Dam in 1983. The historic flows are adjusted using the OpStudy hydrologic model (Stroup and Anderson, 2006) that analyses monthly flow volumes. To develop the model run, the hydrology model was adjusted to address several significant water management-related trends that occurred within the Platte River basin and to portray these trends in a normalized manner reflecting current conditions over the modeled period. If an item is included in the EIS hydrology study, it is operated as if it had existed for the entire period. For example, construction of Glendo Reservoir was completed in 1958, but the reservoir is included in the OpStudy North Platte Model beginning in 1947. Other items are not as easy to visualize because they involve changes in the physical environment that have occurred (e.g., changes in irrigation demand, adjusted river gains, or increased trans-mountain diversions) or changes in how existing facilities are operated (e.g., non-irrigation season release of water from Lake McConaughy).

A result of combining these elements is a set of simulated data that represent the Platte River system as if the current level of development had existed in 1947. The data demonstrate the flow produced from the combination of the current operating procedure and historic hydrology, and is used as Present Condition flows to provide a reference point. The runs for other alternatives are compared against this reference point to measure the incremental effects due to each alternative.

Daily-Flow Data Sets

Sediment transport rates tend to increase at an exponential rate with increases in river flow. Because the daily pattern of river flow within a month can be highly variable, the SedVeg code uses mean-daily flow rates to accurately compute monthly-sediment transport loads. The daily-flow data set used in the SedVeg Gen1 Platte River Model was originally generated from the OpStudy monthly flow volumes using a conversion model (DayFlow, undocumented), but by 2003, daily-flow data sets were derived from monthly flow volumes by the OpStudy model itself. Sections 3.11.2 and 4.3 of the OpStudy documentation describe the procedures used by the model to estimate daily flows at multiple stream gage locations. Daily flows at intermediate locations used by the SedVeg Gen2 and Gen3 models ("bridge segments") were then calculated by temporally and spatially distributing the gains and losses occurring between corresponding gages.

The OpStudy model provides flows at 17 bridge segments including one location each on the North Platte River and South Platte River, and 15 locations on the Platte River beginning at North Platte, Nebraska. These 17 sets of daily flow were input directly to the SedVeg Gen2 model. Because the SedVeg Gen3 model begins downstream of North Platte, Nebraska, at the Johnson-2 Return between Lexington, Nebraska and Overton, Nebraska (Figure 1.1), only 11 of the 17 OpStudy data sets are input to the SedVeg Gen3 model. OpStudy does not output the daily flows for the south channel of Jeffreys Island, so the south channel flow set for Jeffreys Island is computed. Daily flows at RM 250.5, upstream of Jeffreys Island, are subtracted from OpStudy daily flows at RM 244. OpStudy flows at RM 244 are the combined flows of the north and south channels of Jeffreys Island. The difference between RM 250.5 and RM 244 OpStudy flows are the flows in the south channel of Jeffreys Island, the first set of daily flows input to SedVeg Gen3. At cross section 239.9 (Table 5.17), the RM 238 set of daily flows from OpStudy are input followed by the remaining 9 sets of daily-flow data. This brings the total number of flow-input sets in SedVeg Gen3, to 11.

Appendix D – Basis of Vegetation Subroutines

Modeling vegetation growth within a sediment transport model is an approach that began to emerge in the 1980s and the 1990s. The advantages to incorporating vegetation growth in sediment transport analysis of the Platte River is twofold: (1) vegetation effects on sediment transport through bank resistance can be computed, and (2) the presence of vegetation in the flood plain can be tracked as an important habitat characteristic for the Whooping Crane, Piping Plover, and Least Tern. Modeling the interrelated processes associated with vegetation growth aids understanding of sediment transport and the response of the Platte River to historic change and future management actions.

Background of Vegetation Modeling

A review at the time of development of SedVeg Gen1 revealed that few sediment transport modeling efforts included calibration and verification of various aspects of sediment modeling. Two fairly complete calibration and verification efforts that included comparing hydraulics, sediment transport, and measured and computed bed elevation changes were discussed in Simons *et al.* (2000) on the Otomona and Ajkwa River system in Irian Jaya, Indonesia and for the Skokomish River in Washington (Simons and Simons, 1996; 1997). These modeling efforts were able to demonstrate reasonably good comparisons, thereby demonstrating the accuracy and reliability of the models in providing a satisfactory degree of confidence in model predictions. The models were then utilized to evaluate various alternative strategies in controlling or improving channel morphology issues.

One of the first vegetation modeling studies was conducted on the Platte River in the 1980s by Simons & Associates (1990) as part of the Federal Energy Regulatory Commission (FERC) relicensing process for Kingsley Dam. The model was calibrated utilizing cross sections surveyed during the 1920s and historic flow data from about that same time through the mid 1980's. Based on the channel geometry and flow data, the model first computed hydraulic conditions and then corresponding vegetation response year by year. Processes included in the model focused on establishment of vegetation during the seed germination season and subsequent growth or removal of vegetation from scour using flow-based criteria. After testing to demonstrate that the model was functioning properly on a conceptual basis, the calibration of the model showed that the model could successfully reproduce the response of vegetation at cross sections on the North, South, and Platte Rivers. In other words, the computed expansion of vegetation reasonably matched the actual expansion of vegetation as measured from a series of aerial photographs that were taken over time from the late 1930s to the 1980s. When a model, based on key governing physical processes and utilizing actual data describing the channel and flow, can reproduce results obtained in the field, a reasonable degree of confidence is gained in the model as an analytical and predictive tool. The measured data from aerial photographs compare well with the results computed by the model considering the dominant period of expansion of vegetation as well as the removal of some vegetation due to the high flows of 1983.

Subsequent to this initial work, vegetation modeling was conducted on a reach of the Snake River in Idaho from Swan Falls Dam to the Idaho/Oregon border, as well as another short reach at

Dolman Rapids. Portions of this work were published, demonstrating the results of the work (Johnson, *et al.*, 1995); however, no site-specific calibration of the model was conducted for these studies.

A vegetation model was developed and is being utilized by Canadian researchers to evaluate the effects of historic and alternative future reservoir operation plans for various portions of the Columbia River system in Canada for BCHydro. Discussion of this model with those that are developing and applying it indicates that the model basically includes the processes of germination and inundation, and it shows the spatial expansion and contraction of vegetation along reservoir shorelines in response to variations in hydrology and reservoir operation.

In 2001, a much more detailed vegetation modeling analysis was being conducted on the Hells Canyon reach of the Snake River. Some of the significant improvements in vegetation modeling came about as a collaborative process with Drs. Stewart Rood and Jeff Braatne. Mahoney and Rood (1998) described what is called the recruitment box concept that provides a process-based and quantitative relationship between flow and water surface fluctuations and the response of riparian vegetation. For this analysis, on the order of 100 vegetation transects were established in both riverine and reservoir shoreline areas of the Snake River. Within each transect, vegetation data were collected at quadrants from the water line (at relatively low flow and water level) up to the upland vegetation zone. The data included vegetation species composition and density, substrate characteristics, and a survey of the geometry of each transect. The model was run using the transect geometry and substrate as input along with the historic hydrology providing water-surface fluctuations over time on a mean daily basis. Transects were set with an initial condition of no vegetation, and the model was run over a period of several decades to allow it to produce a pattern of vegetation. Six types of vegetation were accounted for in the modeling process. The computed pattern of vegetation was compared with the pattern of vegetation observed in the field at vegetation transects. The work demonstrated that the vegetation model could successfully reproduce historic patterns of vegetation.

The combination of processes governing the response of the Platte River and the previous success of sediment and vegetation modeling led the authors to the development and application of a river hydraulic, sediment transport, and vegetation model for the Platte River. This approach provides a quantitative means to evaluate current trends and the effects of alternative flow, sediment, and vegetation management strategies. The interaction between the geomorphology of a river and riparian vegetation involves several processes. These processes include the exposure or inundation of suitable substrates based on variations in flow and riverine hydraulics, root and stem growth, sediment transport, and scour and deposition of sediment. These processes are highly complex phenomena. As with most other issues, an appropriate balance was sought between model complexity and feasibility of obtaining a sufficiently reliable solution.

The vegetation subroutines are a component of the SedVeg model prepared in cooperation between Reclamation and Simons and Associates, specifically for the Platte River EIS. Vegetation subroutines were written by Simons & Associates, Inc for SedVeg Gen1 in 2000. Based on the contract which governed this effort (dated 9/15/99), Reclamation can not use or apply the vegetation subroutines except for the Platte River EIS. As part of the contract with Reclamation, Simons and Associates also calibrated the vegetation components of the model. Provided below is a summary description of the calibration process.

Fixed Bed Calibration of Vegetation Subroutines in SedVeg Gen1

The vegetation subroutines in SedVeg Gen1 were calibrated using the entire time period from 1865 to 1994 (SedVeg Gen1 Historic Platte River Model, see Appendix E). This calibration was initially conducted using a fixed-bed simulation (where the initial cross-section geometry remains constant with time) and the allowable velocity scour criteria. The model also included ice scour, depending on the age of vegetation. The active channel width for this analysis was defined as the portion of the channel that remained free of vegetation. This relatively simple definition, however, had to be clarified. Based on interpretation of aerial photographs and field observations, it was noted that areas that appeared to be un-vegetated in an aerial photograph may have been, in fact, quite densely vegetated with young vegetation that was too small to be observed from the photographs. Based on previous experience, a three-year age criteria for vegetation was adopted in which vegetation identified on the photographs was assumed to have been at least three-years of age. Therefore, the portion of channel considered active was anything that remained un-vegetated or had vegetation that was less than three-years old. The SedVeg Gen1 model produced output that computed active channel based on a range of cutoff ages of vegetation, which allowed comparisons based on a range of criteria.

At the time of this calibration, the computation of active channel width focused only on the channel and floodplain surface and did not consider the width of the vegetation canopy. The results of the run were considered in terms of the active channel width as it varied over time, and was compared to data points of active channel width measured from aerial photographs by FWS. The portion of the channel defined as active for an initial condition baseline was established based on the historic information developed by Reclamation, and may or may not have included all portions of potential channel as shown on the cross sections.

Model results showed reasonable agreement with the measured data. The active channel remained close to its maximum channel width for about 10 years (1865 to 1875) before losing about 20 percent of its active width and remaining in a state of dynamic equilibrium for almost 40 years (1876 to 1916). This is consistent with the concept that pre-development flows (as estimated) maintained the channel in a predominantly un-vegetated condition, but not in a completely un-vegetated state, with some vegetation occurring on riverbanks, bars, and islands. During the early part of the 1900s, the model showed the initial response to reduced flow as the active channel began to reduce incrementally from its previous 40 years of dynamic equilibrium. As the flow reduced significantly due to the effect of the 1930s drought and continued water resources development, the model produces an abrupt drop in active channel width to less than 500 ft at this location. The active channel remained fairly steady at this width until some higher flows occurred after 1969 (particularly 1983). Some widening and subsequent narrowing of the active channel occurred after this time in response to wetter and drier periods in the recent past. The amount of widening associated with the 1983 event may or may not have been realistic since no data were readily available to calibrate the vegetation removal parameters for the relatively few high-flow events. However, the model does show an increase in the active channel width during such events. The previous modeling effort (Simons & Associates, 1990) compared the locations of widening during the high flows of 1983 with the locations predicted by the model. The comparison indicated that the model matched these responses reasonable well.

Two exceptions to the comparison by Simons and Associates (1990) were also described. The input parameters remain the same for all cross sections. At one cross section there was a reasonable comparison between measured and computed active widths, but the channel did not remain predominantly un-vegetated in the pre-development state. At a second cross section, the same parameters did not provide a reasonable match between measured and computed data over time, except for the convergence that occurs at the end of the time period modeled. Initial indications for these discrepancies relate back to the development of the cross-section geometry for input. A sensitivity analysis was also carried out at a later time partially instigated by the performance of these sections.

Active Bed Calibration of Vegetation Subroutines in SedVeg Gen1

The model was also run with the sediment transport portion activated resulting in scour, deposition, and changes in cross-section geometry. Allowing the channel bed to respond through sediment transport processes did not substantially change the results of the active width computations. The lack of major difference is probably due to the fact that the channel geometry did not change considerably over time for those sections evaluated.

Given the fact that the model used cross-section data estimated for 1865 conditions and estimated pre-development river flows, it was able to provide some quite reasonable comparisons with measured data. This process also provided insights regarding channel geometry issues as well as minor model refinements that were included in additional sensitivity analyses and verification studies.

Appendix E – Calibration and Verification of SedVeg Gen1, including the Historic Platte River Model

Simons and Simons (1996) and the ASCE Task Committee on Hydraulics, Bank Mechanics, and Modeling of River Width Adjustment (1998) suggest the use of the three-level approach to compare qualitative geomorphic analysis and quantitative engineering and geomorphic analyses with computer modeling, as a means of independent verification of the model results. These concepts are discussed further in Simons *et al.* (2000). Model calibration and verification are defined as follows:

Model calibration is the process of adjusting the dimensions of simplified geometrical elements and the values of empirical hydraulic coefficients so that flow events simulated on the model will reproduce as faithfully as possible the comparable natural events, (Cunge et al., 1980). The verification process involves running the model with calibrated parameters and comparing the results to a set of data other than that which was used in the calibration phase. In sediment transport modeling (as with other types of modeling), there are a number of parameters or coefficients that must be set or quantified in such a way that the model can compute answers that match, to a reasonable degree, the data collected in the field that describe the flow characteristics, sediment movement, and resulting erosion or deposition exhibited by the actual body of water. Processes of model calibration and verification provide information necessary to evaluate the accuracy and reliability of the predictive results generated by a model.

The SedVeg Gen1 Historic Platte River model was constructed for calibration studies of the SedVeg Gen1 Platte River Model. Calibration and verification studies of the SedVeg Gen1 model, including a description of the Historic Platte River Model, are presented here. The vegetation subroutines of SedVeg Gen1 were calibrated by Simons and Associates, under contract to Reclamation. A summary of the vegetation calibration by Simons and Associates can be found in Appendix D.

Time Periods

Maps of the river channel, created from Government Land Office surveys during the 1860s, made 1865 a desired starting date for the pre-development part of the river's history (Murphy *et al.*, 2004). Although water was directly diverted from the Platte River and its tributaries during the late 1800s, the first large storage dam, Pathfinder, was not built until 1909 (Simons, 2000). Although water diversions would have reduced river flows during the irrigation season, there were no large storage reservoirs to significantly reduce annual flood peaks. Therefore, the year 1909 was considered the end of the pre-development period. Glendo Dam, the last large storage dam on the Platte River system, was built in 1957, and irrigation changes continued through 1969. Therefore, 1969 was considered the end of the transition period.

Calibration and verification of the SedVeg Gen1 Platte River Model were completed through comparison of model results with equilibrium conditions before water-resources development (1865-1909), comparison of model results with the transition (caused by water resource developments) to recent developed-river conditions (1910-1969), and comparison of model results with recent developed-river conditions (1970-1999). The pre-development period was simulated to demonstrate that the model is capable of reaching equilibrium under conditions of a wide, shallow channel, high annual peak flows, and where vegetation offers a smaller relative effect on bank resistance values. A verification test was completed by comparing model results to sets of cross sections measured in 1998 and 2000 (selected cross sections, Murphy *et al.*, 2004; all cross sections, Holburn *et al.*, 2006).

Flow Data

Historic flow data from USGS gage stations were used whenever possible. When flow data were unavailable, flow rates were estimated based on correlations with data from other gaging stations. No river flow data were available before 1895.

Pre-development Period (1865 to 1909)

Calibration model-input data for the hydrology of the pre-development period (1865 to 1909, inclusive) are based on the five USGS gaging stations and their periods of record:

- No. 06693000: North Platte River at North Platte, Nebraska, 1895-1994,
- No. 06765500: South Platte River at North Platte, Nebraska, 1917-1994,
- No. 06766500: Platte River near Cozad, 1938-1991,
- No. 06768000: Platte River near Overton, 1914-1994, and
- No. 06770500: Platte River near Grand Island, 1933-1999.

Either water surface gage heights or daily average flow rates calculated from the staff gage heights by the USGS are reported in USGS Annual Reports (13, 18, 20), Bulletins (131, 140) and Water Supply Papers (11, 15, 27, 36, 37, 49, 50, 66, 84, 99, 130, 172, 208, 246, 266).

The historic data from these records were extended twice, first to cover the 1895-1909 period with good estimates of the missing data and then to cover the 1865-1894 period with the best available estimates. The principal additional data used to provide good estimates of the 1895-1909 periods were the records of the USGS gaging stations:

- No. 06774000: Platte River near Duncan (aka near Columbus), 1895-1999; and
- No. 06764000: South Platte at Julesburg, CO, 1902-1999.

Daily flow rates for the North Platte River at North Platte, NE and for the Platte River at Duncan were observed, although ice prevented data collection in the winter months. Monthly flow records were also reported. The flow rate on the Platte River near Duncan was shifted to compensate for the travel time between that site and the North Platte River at North Platte, NE, and the difference between those flow rates was used to estimate flow on the South Platte River at North Platte, NE between 1895 and 1902. The flow rate on the South Platte at Julesburg was shifted to compensate for the travel time between that site and North Platte, NE and was used to estimate flow on the South Platte River at North Platte, NE between 1902 and 1909. The correlations between the estimates obtained applying these data extension processes to the period after 1917 when there were data from the gaging station, South Platte River at North Platte, NE, indicated that this extension process was valid. This general process was then also used to estimate the flow rates at Cozad, Overton, and Grand Island on the Platte River. Because there were no historic data during the 1865-1894, the correlation method cannot be applied during that period.

Instead, the fifteen years of 1895-1909 data were copied twice onto the 1865-79 and 1880-1894.

Transition Period (1910-1969)

Calibration model-input data for the hydrology of the transition period (1910 to 1969, inclusive) are the daily average flow rates from five USGS gaging stations. The periods of record used in the input file are:

- No. 06693000: North Platte River at North Platte, NE, 1895-1994;
- No. 06765500: South Platte River at North Platte, NE, 1917-1994;
- No. 06766500: Platte River near Cozad, 1938-1991;
- No. 06768000: Platte River near Overton, 1914-1994; and
- No. 06770500: Platte River near Grand Island, 1933-1999.

Either water surface gage heights or daily average flow rates calculated from the staff gage heights by the USGS are reported in USGS Water Supply Papers (286, 306, 326, 356, 386, 406, 436, 456, 476, 506, 526, 546, 566, 586, 606, 626, 646, 666, 686, 701, 716, 731, 746, 761, 786, 806, 826, 856, 876, 896, 926, 956, 976, 1006, 1036, 1056, 1086, 1116, 1146, 1176, 1210 1240, 1280, 1340, 1390, 1440, 1510, 1630 1710,1918, and 2118). Additional data are reported in three Nebraska Department of Public Works, Bureau of Irrigation, Water Power and Drainage Special Survey Reports to the Governor.

The hydrology of the pre-development period was included in the transition period file so that the transition period would begin with the fully-developed vegetation, and the riverbed would evolve during the pre-development period. The hydrology of the developed-river period was also included in the transition period file so that the transition period would extend into a time when more cross section and sediment data were collected.

Recent Period (1970-1994)

Calibration model-input data for the hydrology of the developed river (1970 to 1994, inclusive) are the daily average flow rates from five USGS gaging stations. The gaging stations and their corresponding periods of record used in the input file are:

- No. 06693000: North Platte River at North Platte, NE, 1895-1994;
- No. 06765500: South Platte River at North Platte, NE, 1917-1994;
- No. 06766500: Platte River near Cozad, 1938-1991;
- No. 06768000: Platte River near Overton, 1914-1994; and
- No. 06770500: Platte River near Grand Island, 1933-1999.

Either water surface gage heights or daily average flow rates calculated from the staff gage heights by the USGS are reported in USGS Water Supply Papers and Water Resources Data - Nebraska Reports.

Cross Section Data

Pre-development Period (1865 to 1909)

Seventeen cross sections were used for the calibration model-input data of the pre-development period (1865 to 1909, inclusive, calipast\input18.dat file). The earliest cross section data found were five surveyed bridge cross sections from 1920s. These cross sections are near Brady, Overton, and Gibbon on the Platte River and near Hershey on the North and South Platte Rivers. The data from these cross sections describe the early state of the seventeen cross sections used in the SedVeg Gen1 Platte River Model. The detailed points of the five cross sections were superimposed on the general location of the seventeen sections as measured from USGS topographic maps dated 1951.

The widths and some elevations of the seventeen cross sections were adjusted as part of the calibration process to approximately match the widths of the survey data from the 1860s Government Land Office surveys. The widths were also adjusted to obtain a near-equilibrium geomorphic condition. The 1920s cross section at Overton was used most frequently. Cross sections are identified by the approximate river miles (+/- 0.1 mile) between the individual sections and the mouth of the Platte River (where it joins the Missouri River). The overbank channels carried water only after the flood plains were overtopped.

Rating curves of depth versus flow rate at the USGS gaging stations show the shallow nature of the North, South and Platte Rivers. For example, the maximum depths of the North Platte River gage at North Platte, NE and the Platte River gage near Lexington, NE are 3.4 ft and 3.6 ft, respectively, for a river flow of 10,000 ft^3/s.

Transition Period (1910-1969)

Calibration model-input data for the 17 cross sections of the transition period (1910 to 1969, inclusive) are the same seventeen, composite, pre-development cross sections. The time of the transition period hydrology file includes the pre-development period. Width data during the transition period are available from aerial photographs, including years 1938 and 1957, of the Platte River channel. The model was adjusted so that the widths calculated by the model approximated the widths indicated in the photographs.

Recent Period (1970-1994)

Calibration data for the cross sections from the developed-river period (1970-1994, inclusive) are based on survey data collected by the Bureau of Reclamation in 1989 (Holburn *et al.*, 2006). Width data for years during the developed-river period were available from aerial photographs taken of the Platte River channel, including year 1983.

The shallow nature of the Platte River is true in both the pre-development and the present day periods. Although the channel has narrowed, rating curves of depth versus flow rate at the USGS gaging stations still show this shallow nature. The maximum depth of the Platte River at Odessa, Nebraska is 4.4 ft for a river flow of 10,000 ft^3/s.

Sediment Data

The riverbed material presently in the central Platte River between Lexington and Grand Island is mainly sand, with small fractions of coarser material (gravel) and small fractions of finer material (silt and clay). Ten sediment grain sizes, from clay to gravel, were used to describe the river bed material in the top surface layer, and in the underlying bed layer, at each point in the cross sections.

Pre-development Period (1865 to 1909)

One sediment gradation based on the North Platte calibration data was used for the initial input in the Historic Platte River Model. Model-input data for the riverbed sediments of the pre-development period (1865 to 1909, inclusive) are input to the model.

For calibration of this run, the earliest riverbed sediment samples found of the Platte River bed material were collected by the U.S. Army Corps of Engineers (COE). COE collected the samples in 1931 along the Platte River and the North Platte River, and reported the particle size distribution (by weight) for the samples in 1934 (COE, 1934). Three Platte River sediment gradations are from the bridges for State Route 47 near Gothenburg, State Route 44 near Kearney, and State Route 2 near Grand Island, and the riverbed sediment samples found for the North Platte River were for 10 grain sizes from a bridge cross section (COE, 1934) for U.S. Route 30 near North Platte, NE. The earliest riverbed sediment samples found for the South Platte River were for 10 grain sizes from a bridge cross section for U.S. Route 83 near North Platte, NE.

Transition Period (1910-1969)

The bed-material sediment samples for the pre-development period were also used for the transition period. The time of the transition period hydrology file included the pre-development period so that the transition period would begin with the fully-developed vegetation and riverbed produced during the pre-development period. No other riverbed sediment data are available for years during the transition period. However, the model was adjusted to data from the recent period.

Recent Period (1970-1994)

Model-input data for the riverbed sediments of the recent period (1970 to 1994, inclusive) are displayed in the five columns for the Platte River and North and South Platte Rivers entered in the sed.dat file. Input data are from bed-material sediment samples (for 10 grain sizes) collected and reported by Kircher (1983) of the USGS, in 1979-80 from three bridge cross sections on the Platte River and at North Platte, NE on the North and South Platte Rivers. The three cross sections on the Platte are at the bridges near Cozad, Overton, and Grand Island, NE. More recent samples of the bed material, providing data for verification, were collected and the particle size distribution measured by Reclamation in 1989, 1998, and 2000. The data collected by Reclamation in 1989 are reported in Holburn *et al.*, 2006. Data collected in 1998 and 2000 are reported by DJ&A, (1998), and DJ&A, P.C. (2000).

A few measurements of sediment transport have been made along the North, South, and Platte Rivers during the recent period. Data for the concentrations of sediment moving in suspension were obtained by Kircher (1983) and by Lyons and Randle (1988). Sediment rating curves by Kircher (1983) and Lyons and Randle (1988) are available in Randle and Samad (2003). In a comparison of data and rating curves, the sediment concentration clearly tends to increase with increasing flow rate but there is substantial scatter in the data.

Vegetation Data

Pre-development Period (1865 to 1909)

The extent of river channel coverage by the four indicator plant types and bare sand were estimated based on historical accounts of the vegetation seen during the westward migration of miners and settlers during the mid- to late-1800s. The widths used may overestimate the active channel width of the river at some locations, if maps from this period only represent large islands and neglect small vegetated islands assumed to have low property value.

Transition Period

The extent of coverage of the four indicator plant types was part of the definition of river width and was measured from aerial photographs during this period including years 1938 and 1957. No data on the vegetation of the transition period, other than the aerial photographs, were available. Channel narrowing by vegetation encroachment is indicated by the time series of photographs during the transition period.

Recent Period (1970-1994)

The extent of coverage for some of the four indicator plant types was estimated from field inspections and aerial photographs (Johnson, 1997). This investigation indicated that channel narrowing by vegetation encroachment did not continue during the developed-river period.

Calibration and Verification

Calibration and verification of SedVeg Gen1 has been performed by the simulation of three separate time periods using the Historic Platte River Model:

- The period 1865 to 1909 was used to represent pre-development conditions (prior to substantial water resource development). Model parameters were calibrated, within a reasonable range, to produce equilibrium sediment conditions (i.e., the amount of sediment being transported out of the 150-mile reach matched the amount being supplied at the upstream end).
- The period 1910 to 1969 was used to represent the transition period of substantial water resource development. The same model parameters that were calibrated for the pre-development period (1865-1909) were also used (without adjustment) to simulate the period 1865 to 1998. Model results for the active channel width (vegetation-free width) were then compared with measured average conditions (based on aerial photograph analysis) in 1939, 1959, 1983, and 1998.
- The period 1970 to 1998 was used to represent the most recent period of water resource development. The same model parameters that were calibrated for the pre-development period (1865-1909) were also used (without adjustment) to simulate the period 1970 to 1998. However, in this model simulation, data from the 1989 channel surveys were used to represent the initial cross section geometries. The initial bed material data were based on measurements from 1979 and 1980. Verification was performed by comparing the computer model prediction of the Platte River cross sections and bed material for 1998 and 2000, with survey data (Holburn *et al.*, 2006) and bed material samples collected in those years. Bed material samples were also collected by Reclamation in 2000.

The availability of data, particularly in the pre-development and transition periods and also to some extent in the recent period, dictate what can be accomplished in calibrating and verifying the model. Obviously, in the first two periods, data for sediment transport and vegetation modeling are relatively scarce and there is a greater supply of available data in the recent period. However, substantial changes and interesting channel responses transpired during the transition period when considerable changes in flow, sediment transport, and vegetation occurred, which provided useful information on model performance versus actual river response under fairly dynamic conditions. Also useful for calibration is the pre-development period, where historic accounts suggest that the river was in a state of dynamic equilibrium (Murphy *et al.*, 2004). The SedVeg Gen1 model was tested under each of these conditions to see if such conditions could be reasonably simulated by the model.

Pre-development Period (1865-1909)

The amount of sediment transport, erosion, and deposition in the model was calibrated by adjusting the upstream sediment supply and the parameter, k, in the Rouse number computation. The Rouse [1937] equation for the vertical distribution of concentration:

Rouse Equation: $c = c_0\left(\frac{h}{D-h}\right)^{w/k\nu_*}$, for $D-h > 0.1$;

$c = c_0(19.0)^{w/k\nu_*}$, for $D-h < 0.1$.

These parameters were calibrated such that total mass of sediment entering the upstream end of the modeled reach would equal the total mass of sediment leaving at the downstream end of the reach. Adjustments in the upstream sediment supply affect the amount of sediment deposition or erosion at the upstream cross sections. Adjustments in the *k* parameter affect the vertical distribution of suspended-sediment particles in the water column. A higher value of *k* will cause a given grain size to be suspended at a higher elevation in the water column. A properly calibrated *k* parameter can result in fine sediment being deposited, during high flows, on high-elevation portions of the channel while coarse sediment is eroded from the channel bottom. As a result of testing, the Rouse *k* parameter used in SedVeg Gen2 and SedVeg Gen3 is 0.80.

The model calibration for the pre-development period reproduces the wide, shallow cross sections in a near equilibrium condition (with a slight aggradational trend). Vegetation grew and occupied all high-elevation portions of the channel that were not frequently inundated. Vegetation grew at the fastest rate during low-flow periods. Some cross sections aggraded while others degraded, but no cross sections changed vertically by more than a few feet.

The overall sediment transport rates along the Platte River from North Platte to Chapman, NE varied only slightly in the downstream direction. Over this period of 45 years, about 400 million tons of sand traveled past North Platte, NE and continued all the way downstream to Chapman, NE. The deposition and erosion at individual cross sections was only a few percent of the transport through the reach.

Sand grain sizes constituted the vast majority of the moving sediment. The running average is computed, for each grain size, by summing all the transport values from the beginning of the simulation and then dividing by the number of days simulated. At first, the average fluctuates because few years are accounted for in the averaging process. After about 10 years, the running averages (for each grain size) become nearly constant through the end of the pre-development period (until 1910). The computed average transport rates for the end of the simulation period are listed in Table E.1.

Table E.1. Average sand transport rates over the pre-development period (1865 to 1909) for the North and South Platte Rivers at North Platte, Nebraska.

Sand Size	Size Range (mm)	Average sediment transport rates (tons per day)	
		North Platte River	South Platte River
Very fine sand	0.062 to 0.125	5,700	140
Find sand	0.125 to 0.25	5,700	600
Medium sand	0.25 to 0.5	5,700	1,300
Coarse sand	0.5 to 1.0	2,700	900
Very coarse sand	1.0 to 2.0	1,300	450

Based on modeling, the South Platte River during the pre-development period, contributes much less sediment than the North Platte River. The outflow of sediment past Chapman, NE at this downstream location equals the inflow of sediment at the upstream end to within a few percent. The three finer sediment sizes (very fine, fine and medium sand), deposit 8, 19, and 9 million tons of, respectively. In contrast, the two coarsest sediment sizes (coarse and very coarse), erode 31 and 4 million tons. The net change in the grain-size distribution for the overall riverbed is slightly finer.

Transition Period (1910-1969)

The model parameters that were calibrated for the pre-development period were held constant during the simulation of the transition period. The cross sections did not aggrade or degrade more than a few feet but they did narrow significantly due to encroachment by vegetation. For cross sections that aggraded, the amount of vegetation encroachment was due to the reduction in peak flows. For the cross sections that degraded over a portion of the channel, the amount of vegetation encroachment was even greater. This is because the degrading portions of the channel convey more of the total flow over a narrower width, and a larger flow than before is needed to overtop and mobilize the sediments of the channel portions that were not degraded. When high flows occur less frequently, vegetation has an easier time of growing to maturity on the higher portions of the channel because they are being inundated and mobilized less frequently.

Model results indicate that the total mass of sand transported along the Platte River, from 1865 through 1939, did not vary significantly with distance downstream, except that there was significant deposition between river miles 258 and 229. From 1910 through 1939, the average transport rates decreased gradually due to a decrease in mean flows and peak flows from the operation of major dams in Wyoming. Some of the reduction, depending on the location, may have also been due to sediment trapped by upstream reservoirs. The running averages for each grain size drop steadily until 1940.

Table E.2. During the transition period, average sand transport rates from 1910 to 1939 for the North and South Platte Rivers at North Platte, NE

Sand Size	Size Range (mm)	Average sediment transport rates (tons per day)	
		North Platte River	South Platte River
Very fine sand	0.062 to 0.125	4,700	130
Find sand	0.125 to 0.25	4,700	600
Medium sand	0.25 to 0.5	4,700	1,300
Coarse sand	0.5 to 1.0	2,200	900
Very coarse sand	1.0 to 2.0	1,000	450

In the South Platte River from 1910 through 1939, the running averages for most grain sizes at first increase and then decrease until 1940. During this part of the transition period, the South Platte River is still delivering sand at a much smaller rate than the North Platte River (Table E.2). The outflow of sand past Chapman, NE, at this downstream location, is less than the inflow of sand at North Platte, Nebraska, indicating a net aggradation of sand along the river bed.

The net changes from 1910 through 1939 are deposition of 8, 15, 20, 1, and 2 million tons for the increasing sand sizes. The grain size of the overall riverbed material becomes slightly finer. From 1865 to 1939, the three finer sand sizes (very fine, fine, and medium sand), deposit 16, 34, and 29 million tons respectively, while the two coarser sizes (coarse and very coarse sand) erode 30 and 2 million tons.

The total mass of sand transported along the Platte River, from 1940 through 1969, did not vary significantly with distance downstream, except for significant deposition at river miles 310 (immediately downstream from the Tri-County Diversion Dam).

The running-average, daily-transport rates for the sand sizes being supplied from the North Platte River from 1940 through 1969, and then continuing on until 1994 was considered. The running average is restarted in 1940 because Kingsley Dam suddenly and substantially changed the downstream flow rates on the North Platte River. The running averages for each grain size attain a new, nearly constant set of values by 1950. These values are then roughly constant during the relatively low-flow decades of the 1950s and 1960s (see Table E.3).

Table E.3. Average sand transport rates over the transition period for the North and South Platte Rivers at North Platte, NE

Sand Size	Size Range (mm)	Average sand transport rates (tons per day)	
		North Platte River (1940 to 1969)	South Platte River (1940 to 1969)
Very fine sand	0.062 to 0.125	300	240
Find sand	0.125 to 0.25	270	1,000
Medium sand	0.25 to 0.5	270	2,300
Coarse sand	0.5 to 1.0	120	1,600
Very coarse sand	1.0 to 2.0	60	800

When considering the running-average, daily-transport rates for the sand supplied by the South Platte River from 1940 through 1969, and then continuing on until 1994, the running averages for all grain sizes increase suddenly and substantially in 1942 and then become nearly steady by 1969. During this part of the transition period, the South Platte River rapidly becomes a much larger source of moving sediment than the North Platte River (Table 5-3), presumably due to operation of the Sutherland Supply Canal diverting North Platte River flows to the South Platte River upstream of North Platte, NE, and construction of the Kingsley Dam at Lake McConnaughy in 1941.

The increase in sediment load from the South Platte River, in comparison to sediment loads from the North Platte River appear overly large. The sediment loads computed by Randle and Samad (2003) from rating curves by Kircher (1983) and Simons and Associates, Inc. (2000) give different ratios. South Platte River sediment loads are only 65 to 75 percent of North Platte River sediment loads during the transition period, and the sediment contributions from the two rivers in the recent period, based on rating curves, are approximately even.

The outflow of sediment past Chapman, NE, at this downstream location, is less than the inflow of sediment at the upstream end of the modeled reach, indicating net aggradation along the river bed. The net changes from 1940 through 1969 are depositions of 2, 11, 23, 13, and 7 million tons for the increasing sand sizes. The grain size of the overall riverbed material becomes slightly finer. During both the predevelopment period and the transition period, from 1865 to 1969, the three finer sediment sizes, very fine, fine and medium sand, deposit 18, 45, and 52 million tons, respectively, while coarse sand erodes 17 million tons and very coarse sand deposits 5 million tons.

Recent Period (1970-1994)

Model parameters that were calibrated for the pre-development period were held constant during the simulation of the recent period. The model results for the recent period (1970 to 1994) indicate he Platte River sediment transport rates at North Platte, NE and Chapman, NE did not vary substantially during this period.

The running averages for each grain size were also nearly steady through the rest of the recent period (until 1994). Considering the running-average, daily-transport rates for the sand transported by the Platte River, the outflow of sand past Chapman, NE, at this downstream location, is in balance with the inflow at the upstream end.

Verification – Input for Present Conditions Model (1970 to 1998)

The 1989 cross sections and the 1979-1980 sediment grain-size distributions were used in the Present Conditions analysis. Only the daily-flow input values were different from the Recent Period calibration data (see Appendix C for a discussion of differences between USGS gage flows and Present Condition flows). The calibrated model and Present Condition flows were used to simulate the period 1970 to 1998. Model results were compared with cross-section data that were measured during 1998, and there was general agreement between the model predictions and the measured data.

The change in channel morphology for both cases showed that, overall, the channel was near equilibrium with only a few feet of aggradation or degradation (vertical deposition or erosion) at the cross sections. However, there was a spatial pattern to the channel changes. Model results predict aggradation in the reach between the towns of North Platte and Cozad, NE. The reach between the towns of Cozad and Overton, NE degraded. The reach between the towns of Overton and Grand Island, NE also degraded but only slightly, less than 1 foot.

For both analyses, the net change in sediment transport for the entire reach (during the 28-year simulation period) indicated a small net outflow (erosion) of sediment. These model results were checked by comparison with sediment mass balance calculated using the sediment-discharge rating curves reported by Simons and Associates (2000), and also by comparison with an analysis using the Army Corps of Engineers sediment model, HEC-6. The three independent calculations produced approximately the same results

The history of the net change in sediment transport, between the inflow at North Platte, Nebraska and the outflow at Grand Island, Nebraska, indicates that a slow, but nearly steady, erosion of sediment is occurring, except during flood flows. During periods of high river flow, sediment is transported through the reach between North Platte, Nebraska and the Johnson-2 Return, and river flows are high relative to the canal return flow. During periods of low river flow, the inflow of sediment from the river is limited, and the clear-water return flows from the canals are relatively high and sediment free. The sediment outflow in the reach between the towns of Overton and Grand Island, NE is higher because this reach includes the flows from the Johnson-2 Return. The flow rates in the river passing the gaging stations near Overton and Grand Island, NE are nearly identical with only a 2-day lag time (the time it takes for discharge waves to travel between the gaging stations). The flow and sediment transport rates in the reach between North Platte, Nebraska and the Johnson-2 Return are much lower than in the downstream reach between the towns of Overton and Grand Island, Nebraska.

The model only predicts a large amount of sediment deposition for one cross section at river mile 310.2. At this location, the model over-predicts the deposition there by a factor of two. For all other locations, both the measured and predicted cross-section geometry show relatively little changes (1 or 2 ft of local vertical change) from the initial conditions. The measured cross-section data do show generally larger differences from the initial bed than do the model predictions. The measured data also show more bank erosion than does the model.