Lewis and Clark Lake Sediment Management Study (LCLSMS)
Results of Numerical Modeling of Flushing Scenarios between Fort Randall Dam and Sioux City, IA

Hydroscience and Training Center at Colorado State University

Paul M. Boyd, P.E., Hydraulic Engineer, Omaha District, USACE

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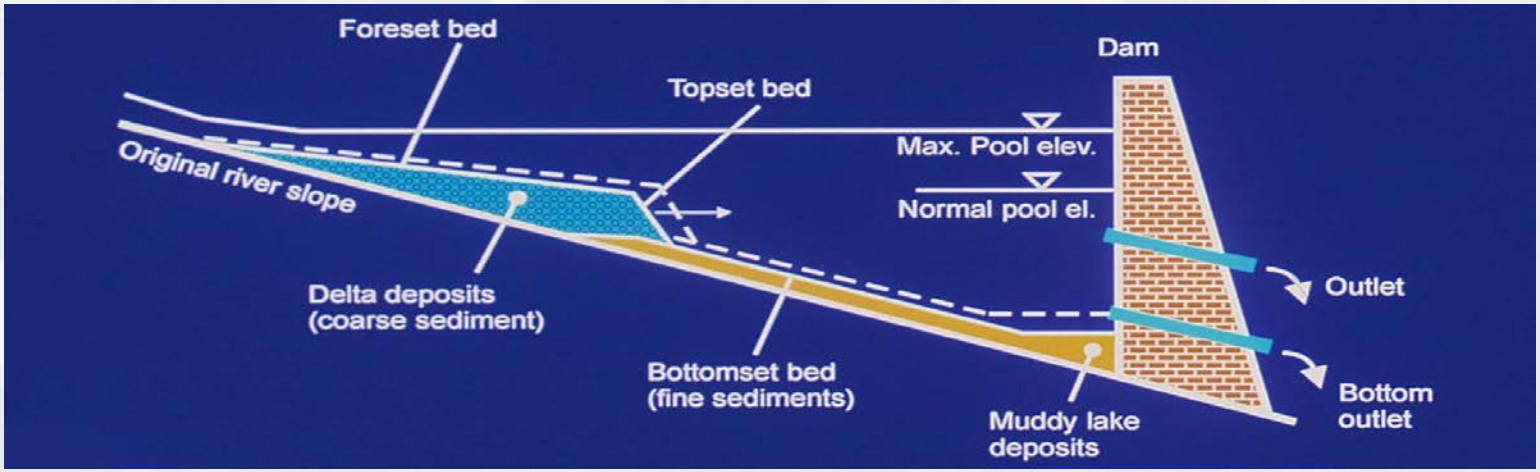
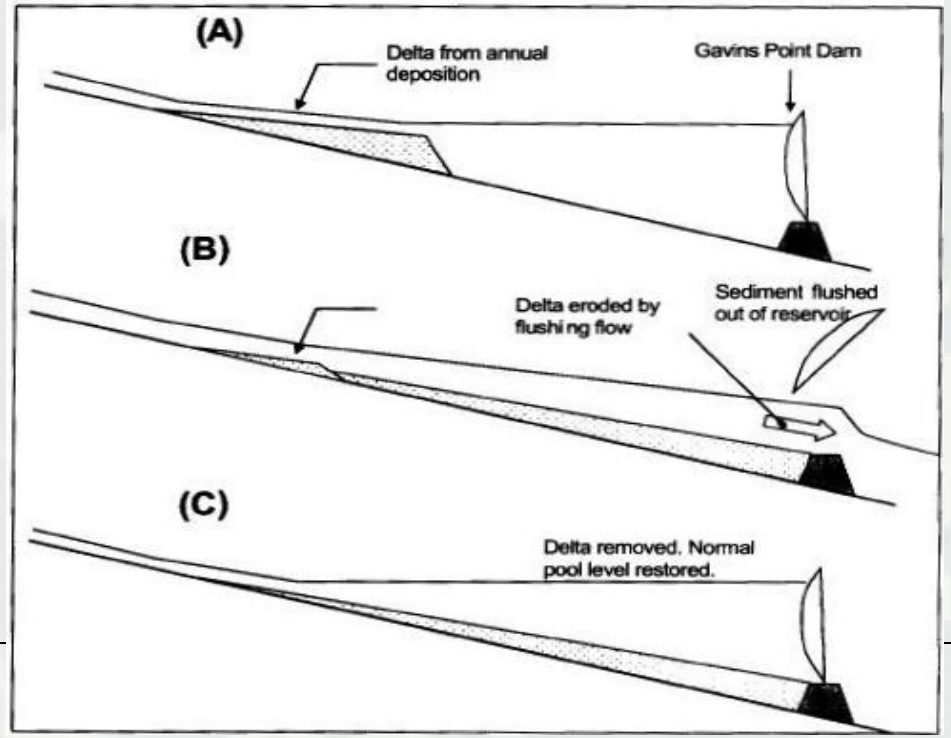
Overview

- LCLSMS
  - Study Background
  - USFWS Biological Opinion
  - Modeling Lewis and Clark Lake
  - Modeling Gavins Point Dam to Sioux City
  - Conclusions
- 2011 Flood Data Collection

Delta Evolution and Flushing





USFWS Biological Opinion (BiOp) Guidance

- Element IV.B.3 2000 BiOp
  - Habitat Restoration/Creation/Acquisition
    - Suggested management techniques for habitat creation include: (1) replenishment or nourishment of river sandbars and islands;
- Element IV.C 2000 BiOp
  - C. Initiation of Sediment Transport/Habitat Studies
    - The Corps shall research and develop a way to restore the dynamic equilibrium of sediment transport and associated turbidity in river reaches downstream of …. Gavins Point Dams (Segment 10), and stop or reverse bed degradation of the river.
    - Because of the large sediment deposition zone at the upper end of Lewis and Clark Lake and its proximity to Gavins Point Dam, Gavins Point may provide the best opportunity for a pilot study.

- Conservation Recommendations – Pallid Sturgeon: 2003 Amended BiOp
  - The most significant benefit of increased sediment transport and availability would be expressed in the Lower Missouri River below Gavins Point Dam and in the Middle Mississippi River.
  - Based on the Corps' 2002 Conceptual Analysis of Sedimentation Issues on the Niobrara and Missouri River, there appears to be a feasible alternative to manage reservoir sediment (e.g., reservoir flushing). We strongly encourage the Corps to heed the advice of the contractor that prepared the report and proceed to a Feasibility Study

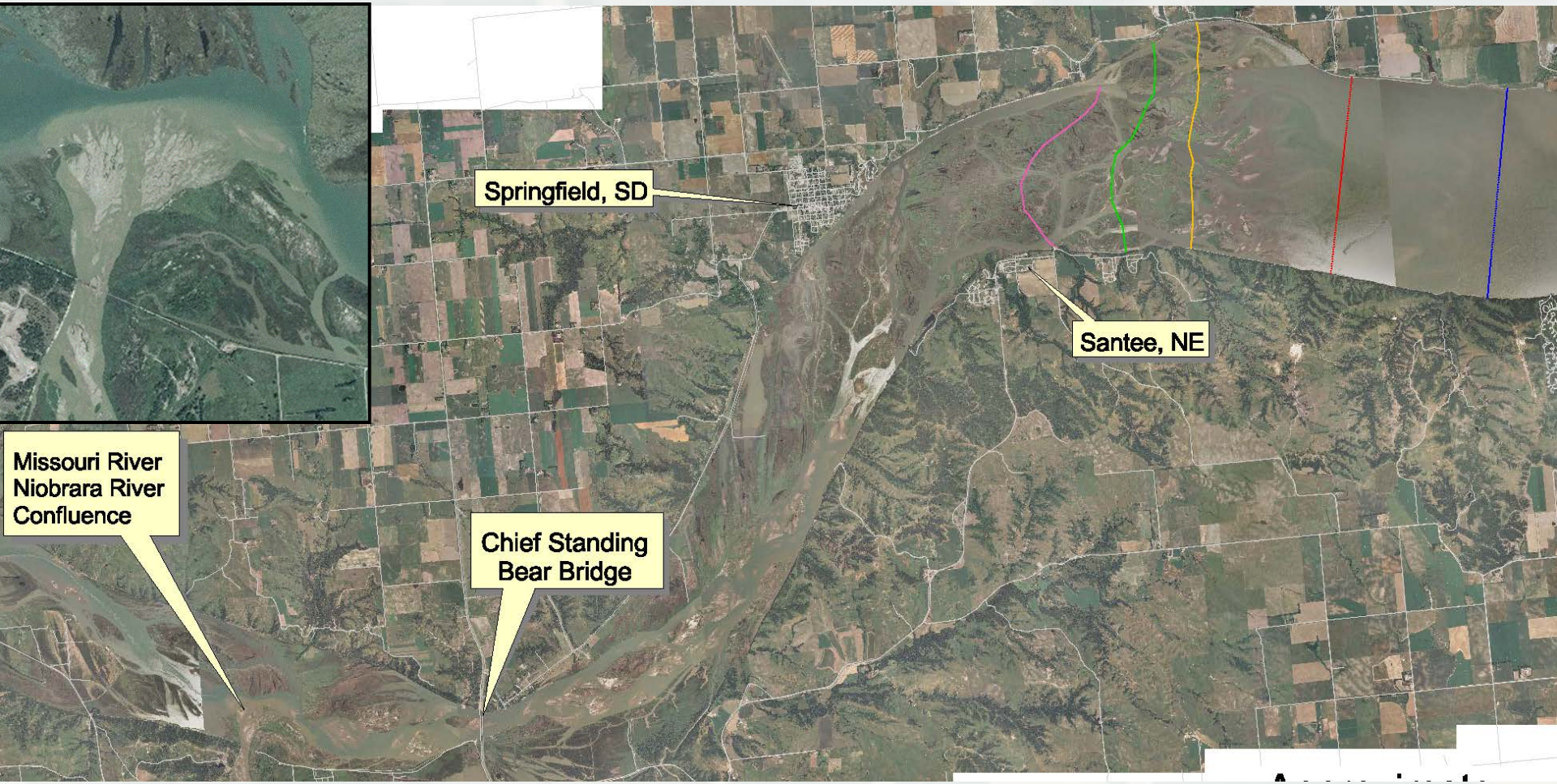
Conceptual Analysis of Sedimentation Issues Report (2002)

- Reconnaissance/Conceptual look at the possible effectiveness of flushing
- What makes flushing work
  - Low outlets
  - Exposed delta by lowering reservoir level
  - High flows
  - Easily moveable sediment
- Recommended feasibility level look at flushing with existing and modified dam outlets, and provided discharge and duration guidance

Lewis and Clark Lake Facts

- Authorized Project Purposes:
  - Reregulation of Flows for Navigation
  - Hydropower Generation
  - Flood Control
  - Recreation
  - Water supply
  - Fish and Wildlife (endangered species)
  - Water quality
  - Irrigation
- Original open lake = 25 miles Current open lake = 17 miles
- 2,400 ac-ft of sediment deposited annually below elevation 1210 ft
- 55-60% of sediment load from Niobrara River
- Navigation and Hydropower impacted in 125-175 years, other purposes sooner
- As of 2007, 21.7% of storage below 1210 ft lost
- Visible face of delta moved significantly during 2011 flood

Delta Locations



Study Formulation

- Scoping charrette in 2005 including USACE, USGS, Univ. of Iowa IHR, USBR concluded that the GSTARS modeling suite was best suited to flushing modeling at Gavins Point dam
- USACE Contracted with Dr. C.T. Yang at Colorado State University to build a hybrid model that would meet the needs of the study. (Dr. Yang is the original author of the GSTARS model while with US Bureau of Reclamation)
- USACE Omaha to provide downstream sediment transport model to assess impacts below Gavins Point Dam

LCLSMS Project Goals

- Evaluate the engineering viability of using varying discharges and stages through/in Lewis and Clark Lake to transport currently deposited sediments in the lake to/through Gavins Point Dam
- Develop modeling tools that will allow for analysis of most upstream and downstream flow and sediment transport scenarios
- Design a test flow that would verify the model (there is no physical test as part of this study)
- Draw conclusions about the viability of the flow alternatives modeled

Flow Scenarios Modeled

(guidance from 2002 Conceptual Analysis Report and Public Input)

Scenario no.	spillway	Days of main flushing	Gavins Point Dam Discharge (cubic feet per second)
1	Existing	8	176,000
2	Existing	10	88,000
3	Existing	Until 2,600 ac-ft of sediment flushed	88,000
4	Modified	8	176,000
5	Modified	Until 2,600 ac-ft of sediment flushed	88,000

Building the current conditions model in GSTARS4

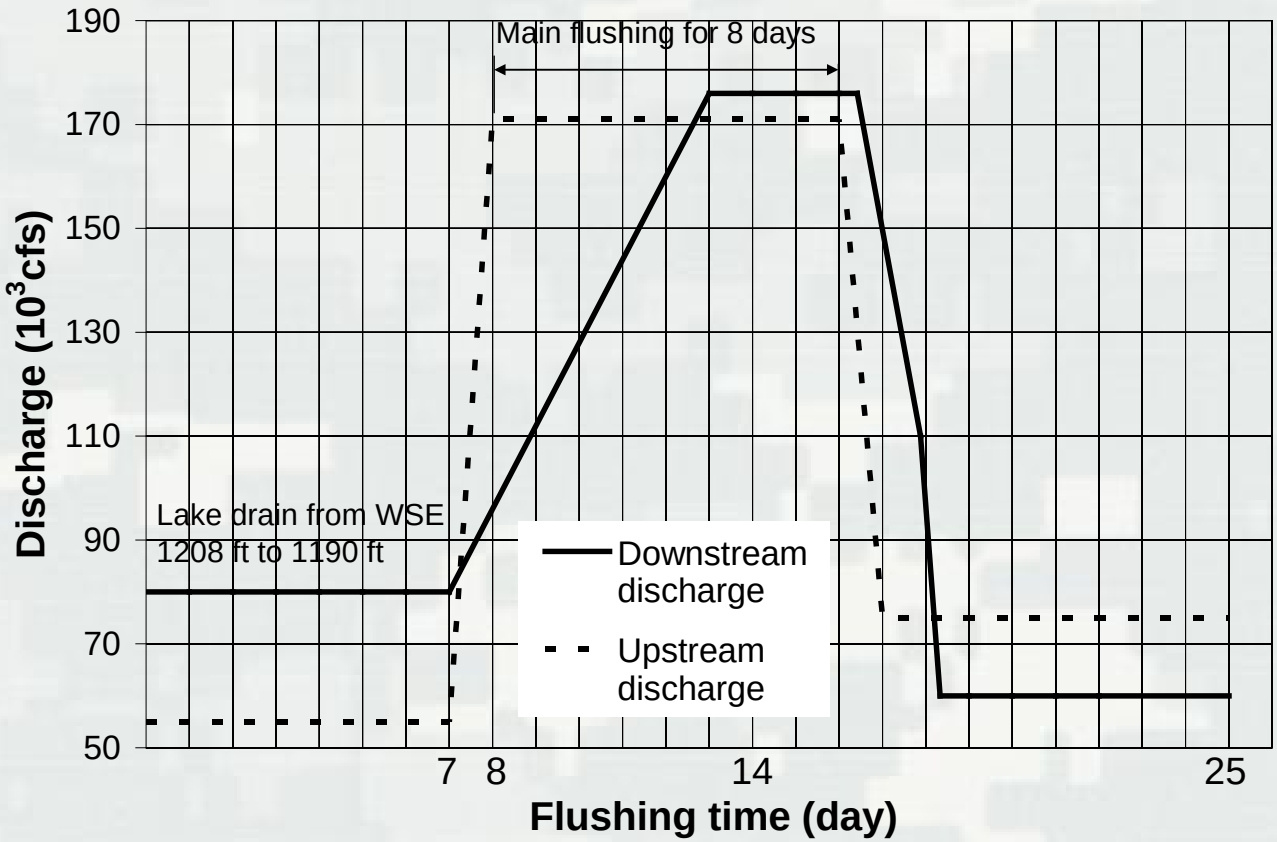
- 2007 Survey and Sediment Data was used to develop the current conditions geometry
- Transport function and recovery factor guidance from 1975-1995 model
- Hydrograph flows for draining and refilling had to be determined by trial and error.
- Modified Spillway geometry and rating curve developed

Discharge Staging

- Each scenario requires:
  - Reservoir drawdown (gate controlled discharge)
  - Spillway gate opening
  - Peak flushing flow (stage controlled discharge)
  - Reservoir refilling (gate controlled discharge)
- Timing by T&E due to varying peak travel time

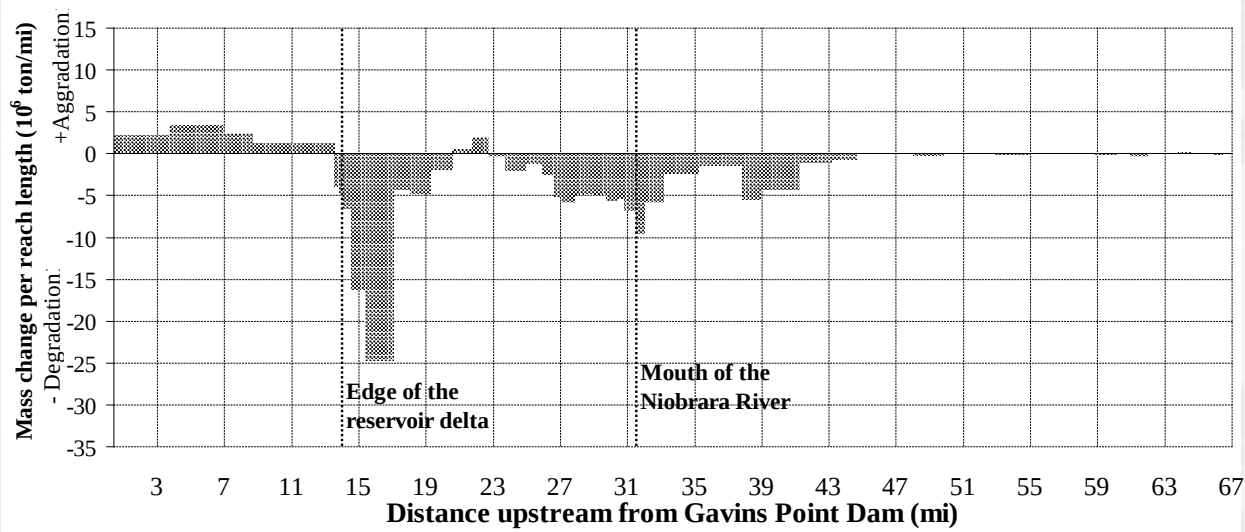
Flow Scenario 1 & 4

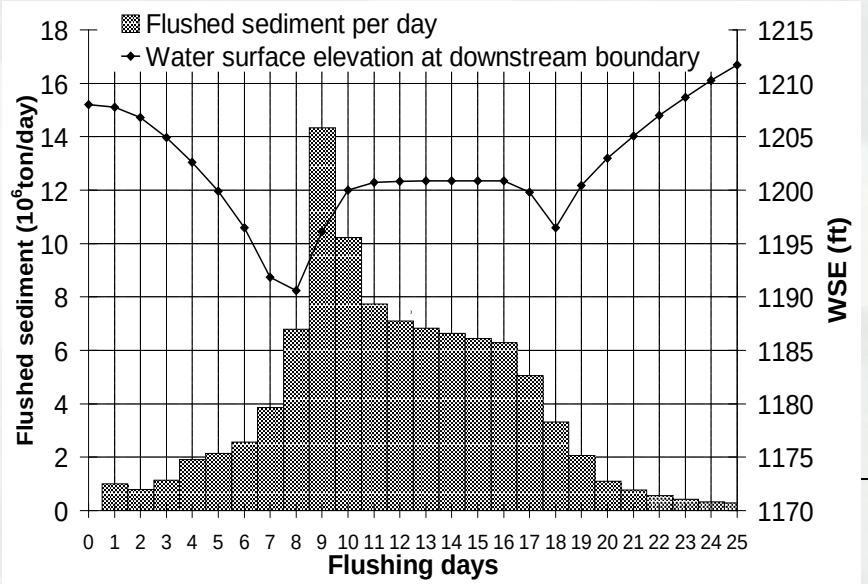
- 176,000 cfs for 8 days (current & modified spillway)



GSTARS4 Model Output

- Scenario 1 – 176,000 cfs for 8 days





•Reservoir water surface elevation approx. 1200 ft during flush

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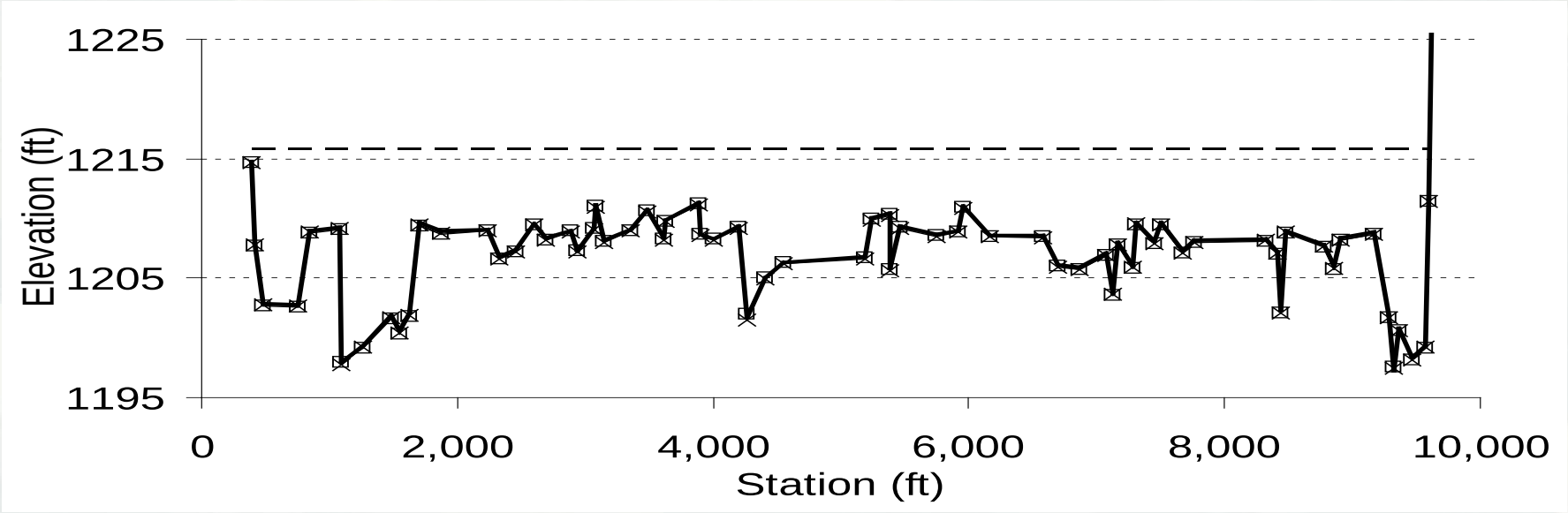
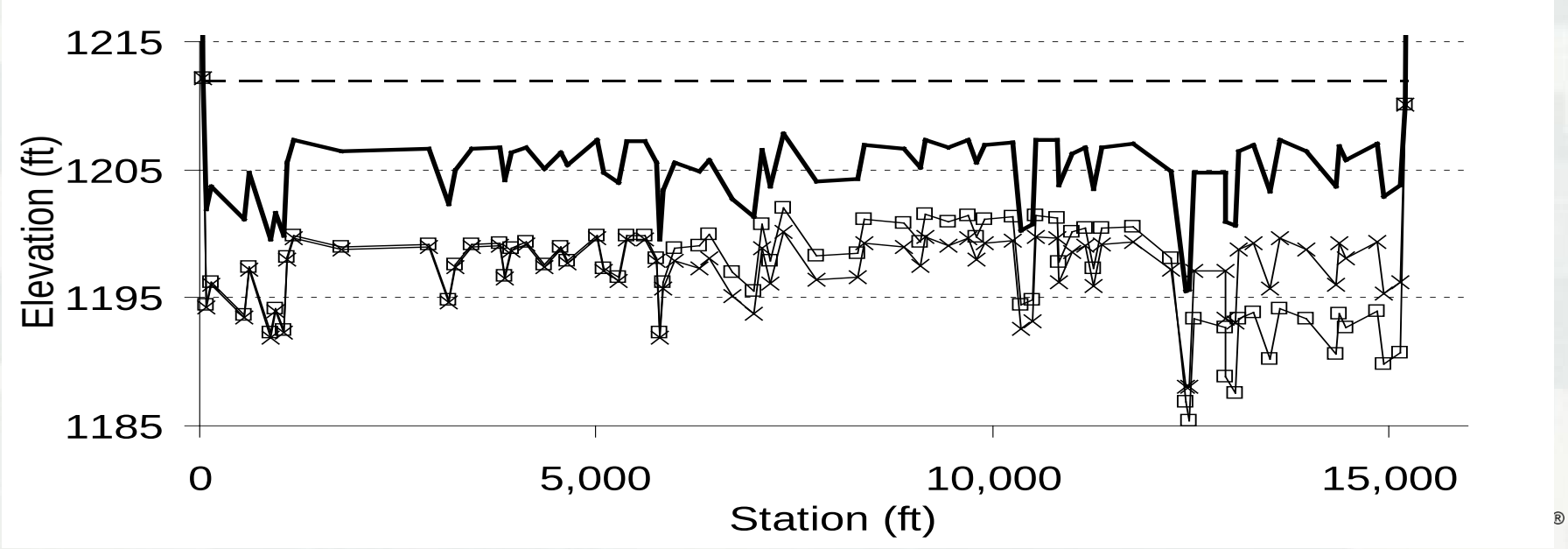
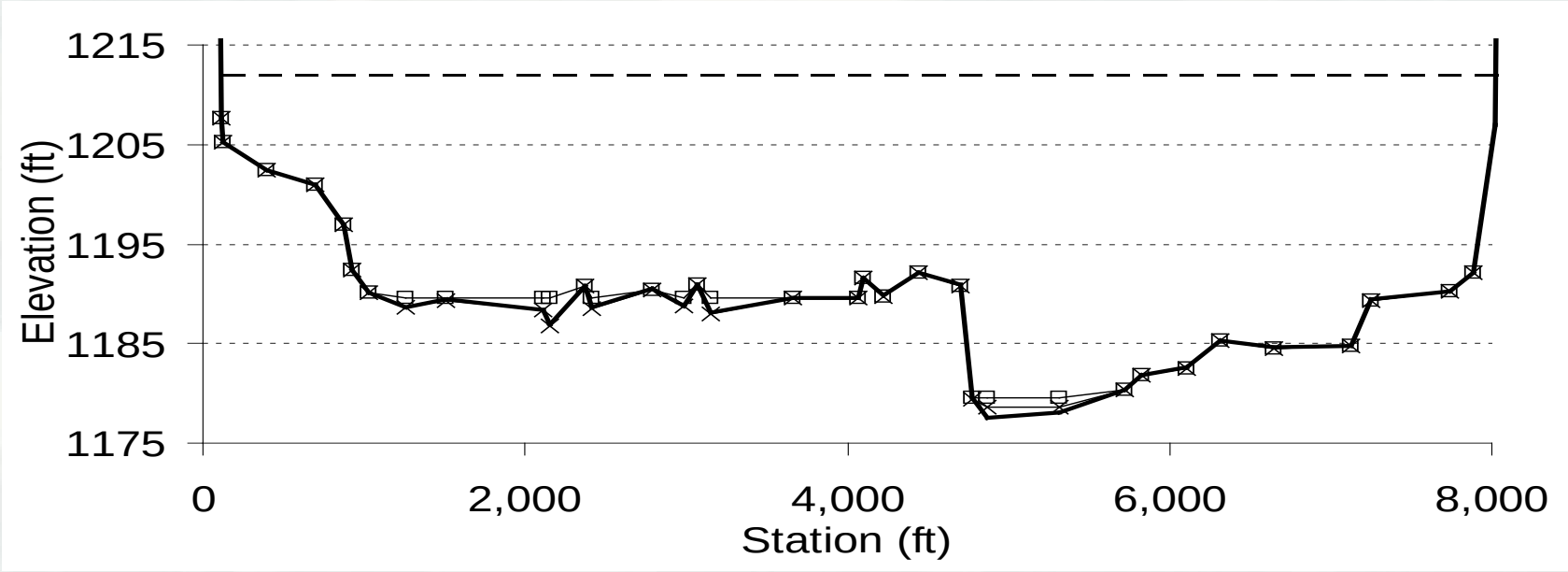


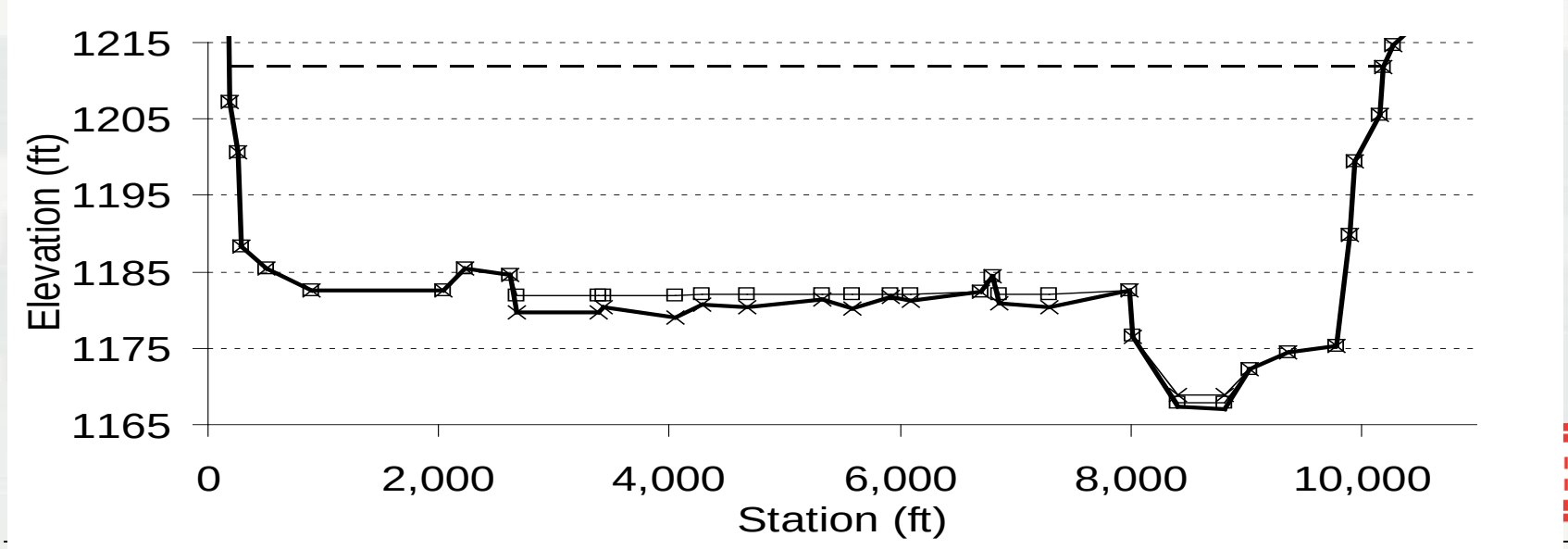
21.1 mi above GPD (near Springfield, SD)



16 mi above GPD (just below visible delta face)



7.5 mi above GPD



1.0 mi above GPD

Particle Size Distribution of Flushed Sediments

Time (hour)	Water discharge (cfs)	Sediment discharge (ton/hour)	Gradation (%)				
			Silt and Finer	Very Fine and Fine Sand	Medium Sand	Coarse and Very Coarse Sand	Gravels and Larger
			0.001 - 0.0625 mm	0.0625 - 0.250 mm	0.250 - 0.500 mm	0.500 - 2.00 mm	2.00 + mm
1	78756	41475	**100.00**	0.00	0.00	0.00	0.00
86	77704	82882	**100.00**	0.00	0.00	0.00	0.00
120	77120	94530	**100.00**	0.00	0.00	0.00	0.00
136	76662	107617	**100.00**	0.00	0.00	0.00	0.00
168	74445	214347	**100.00**	0.00	0.00	0.00	0.00
192	63137	360596	**100.00**	0.00	0.00	0.00	0.00
250	171072	326398	**100.00**	0.00	0.00	0.00	0.00
300	175935	284977	**100.00**	0.00	0.00	0.00	0.00
380	176010	260571	**100.00**	0.00	0.00	0.00	0.00
400	171851	199779	**100.00**	0.00	0.00	0.00	0.00
429	117812	138968	**100.00**	0.00	0.00	0.00	0.00
440	66086	101127	**100.00**	0.00	0.00	0.00	0.00
600	61501	10818	**100.00**	0.00	0.00	0.00	0.00

Discharge PSD for Scenario 1

Time (hour)	Water discharge (cfs)	Sediment discharge (ton/hour)	Gradation (%)				
			Silt and Finer	Very Fine and Fine Sand	Medium Sand	Coarse and Very Coarse Sand	Gravels and Larger
			0.001 - 0.0625 mm	0.0625 - 0.250 mm	0.250 - 0.500 mm	0.500 - 2.00 mm	2.00 + mm
1	78756	41475	**100.00**	0.00	0.00	0.00	0.00
80	77800	76049	**100.00**	0.00	0.00	0.00	0.00
135	76697	106567	**100.00**	0.00	0.00	0.00	0.00
188	68919	518533	**99.95**	**0.05**	0.00	0.00	0.00
212	62265	776438	**99.93**	**0.06**	0.00	0.00	0.00
265	172765	571188	**99.99**	**0.01**	0.00	0.00	0.00
330	175753	490813	**99.99**	**0.01**	0.00	0.00	0.00
400	175715	454700	**99.99**	**0.01**	0.00	0.00	0.00
420	171110	371526	**99.99**	**0.01**	0.00	0.00	0.00
450	110449	303626	**99.99**	**0.01**	0.00	0.00	0.00
460	69662	209722	**100.00**	0.00	0.00	0.00	0.00
500	62658	79171	**100.00**	0.00	0.00	0.00	0.00
600	61740	18188	**100.00**	0.00	0.00	0.00	0.00

Discharge PSD for Scenario 4 (mod spillway)

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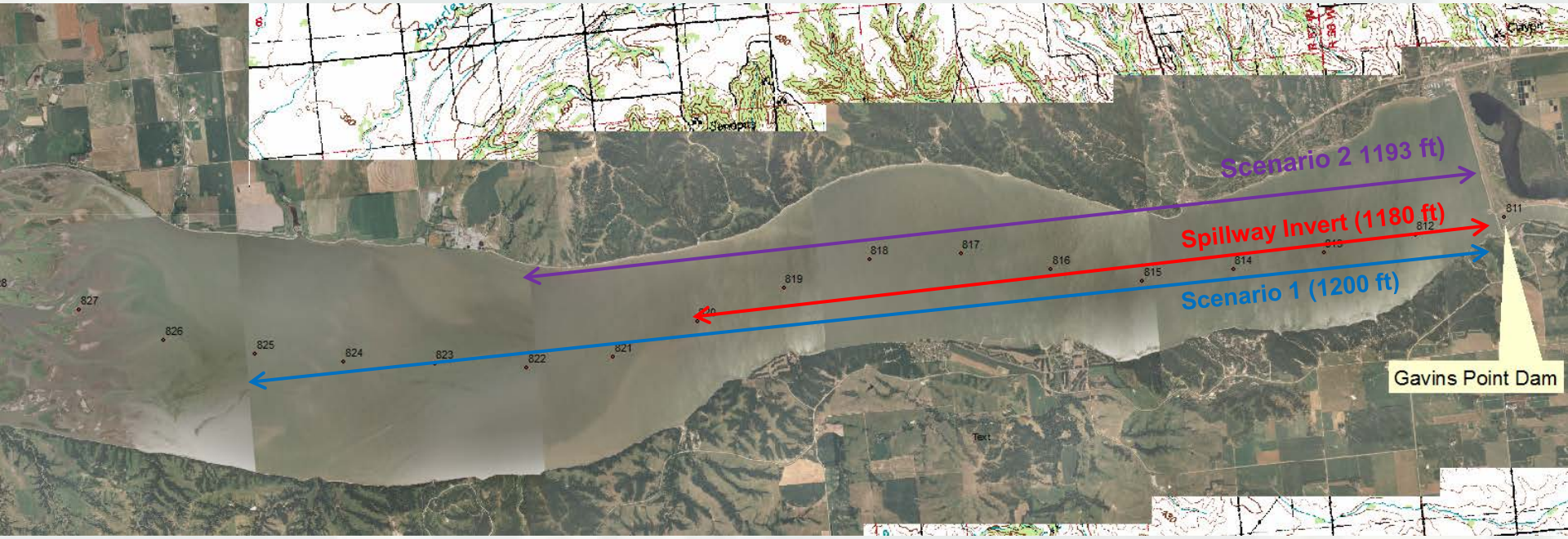
Effective Length of Reservoir during flushing

- The elevation of the spillway gates prevents the reservoir from fully draining. Gavins Point Dam was not constructed with low level outlets for sediment management.
- Spillway Invert 1180 ft – 15,000 ac-ft
- Scenario 1 1200 ft – 215,000 ac-ft
- Scenario 2 1193 ft – 105,000 ac-ft
- Scenario 3 & 5 1200 ft
- Scenario 4 1195 ft



Summary of Sediment Transport

Scenario no.	Total operation days	Cumulative water past Gavins Point Dam		Cumulative sediment transport past Gavins Point Dam		Ratio of discharged sediment / water
		Billion cu-ft	Million ac-ft	Million tons	(1,000 ac-ft)*	
1	25	229	5.26**	99.7	95.4	0.018
2	25	116	2.66**	72.0	68.8	0.026
3 & 5	8	27	0.62	3.9	3.8	0.0062
4	25	230	5.28**	178.4	170.6	0.032

*Density of 48 lb/ft^3 due to silt and clay, **transport may vary up to 50%** due to model variables

**Base flow of 30,000 cfs would require 1.49 Million ac-ft

- All scenarios predict the discharge of sediment past Gavins Point Dam
- Scenario 2 uses ½ the volume of water of Scenario 1, discharges ¾ the volume of sediment

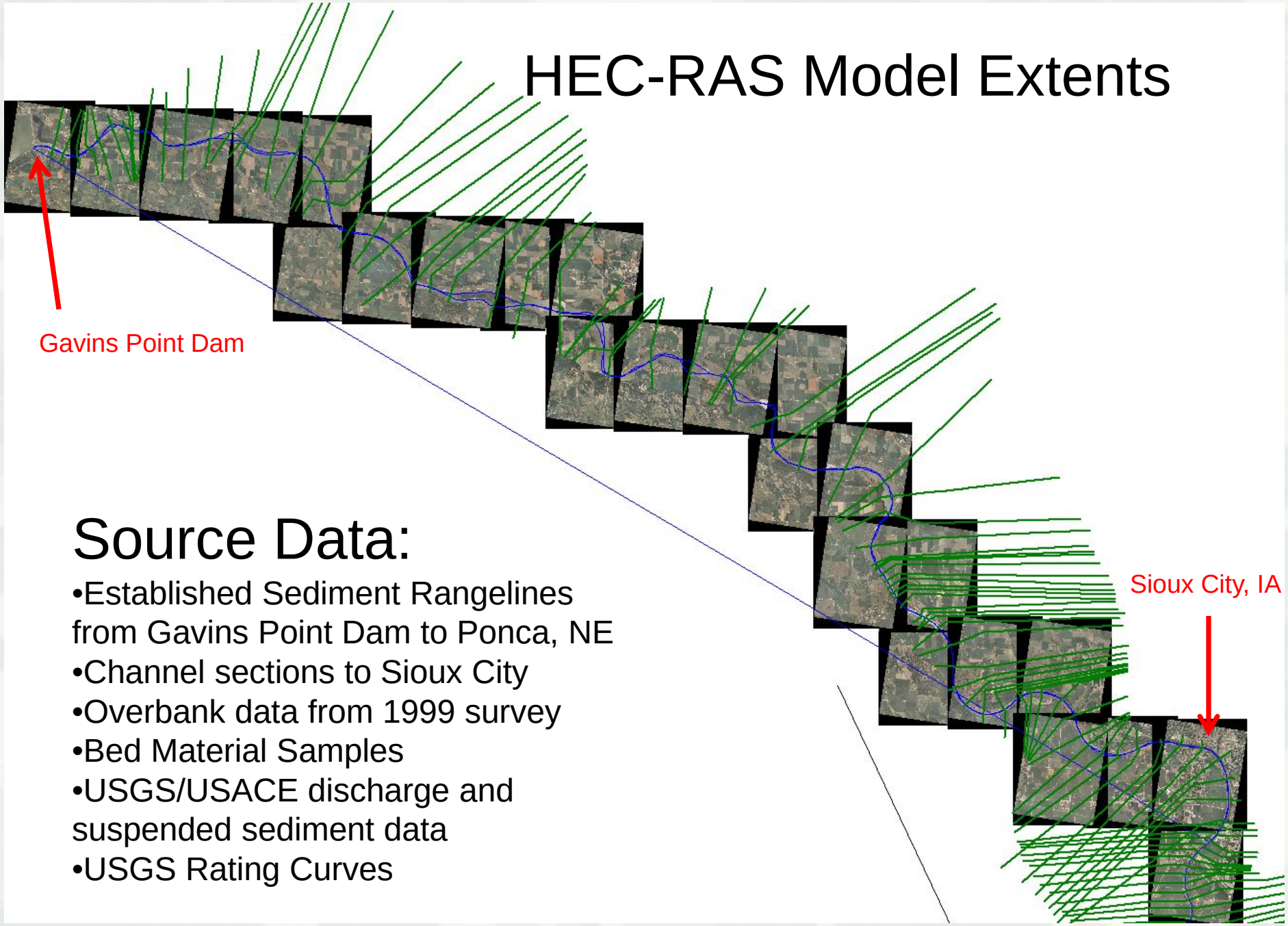
GSTARS4 Modeling Conclusions

- The GTARS4 model predicts that all scenarios would discharge scoured sediments at the Gavins Point Dam spillway
- Bed changes within =/- one foot should be considered within the error of the model
- The sediment is comprised of only silt and clay sized particles
- Lake elevation is a critical factor when evaluating flushing efficiency, while the highest flows move the most sediment, they may not be the most efficient
- Sand size sediments are deposited in the deeper lake behind the dam
- Repeated flushing would continue to fill the deeper lake, but longer travel distance may reduce efficiency
- Availability of fine sediment may affect future effectiveness

Building a HEC-RAS model to assess downstream impacts

- 1-dimensional hydraulic model with sediment transport
- Hydrologic Engineering Center – River Analysis System v.4.1
- Established model required calibration, but does not require testing of model functionality

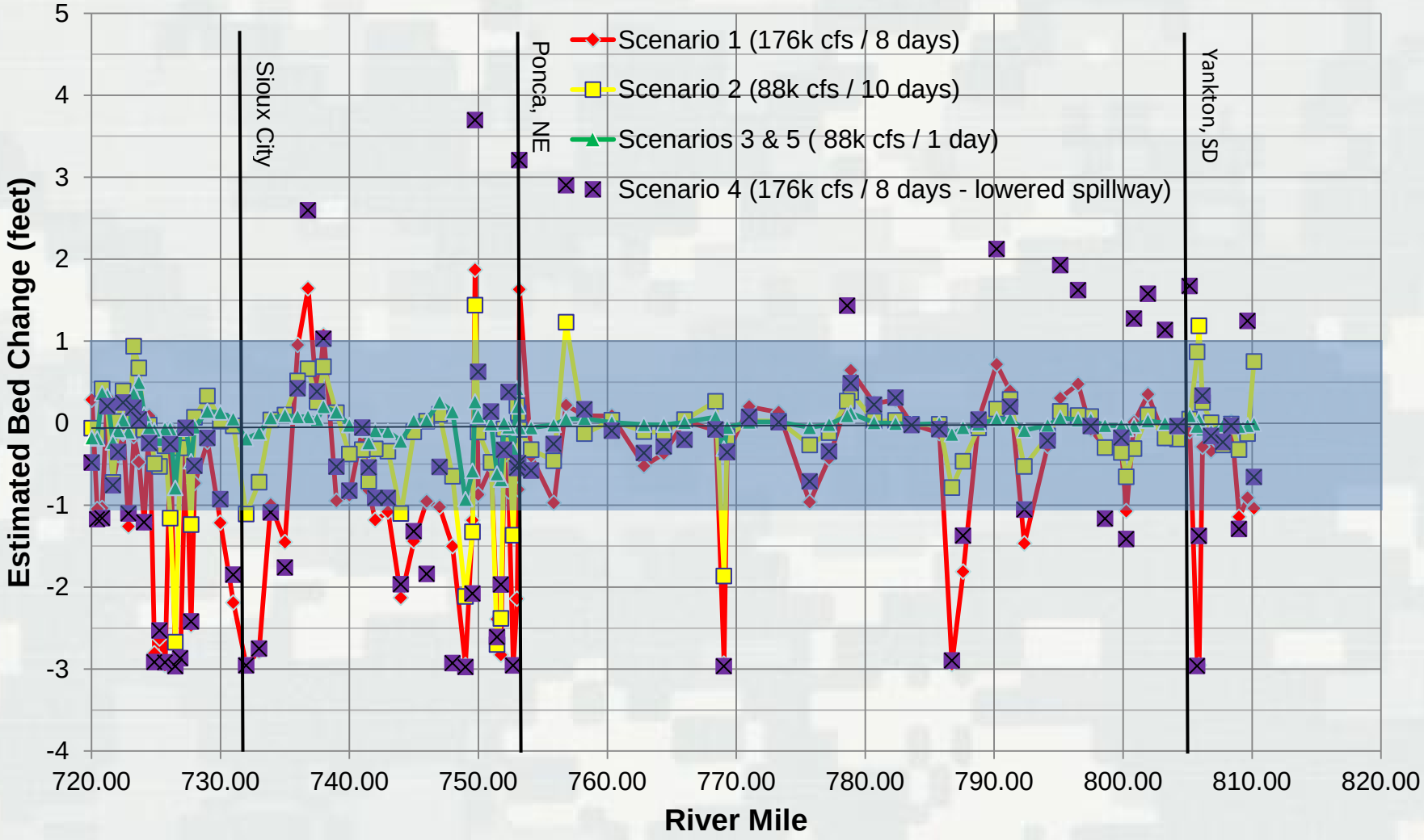
HEC-RAS Model Extents



Source Data:

- Established Sediment Rangelines from Gavins Point Dam to Ponca, NE
- Channel sections to Sioux City
- Overbank data from 1999 survey
- Bed Material Samples
- USGS/USACE discharge and suspended sediment data
- USGS Rating Curves

Predicted Bed Change Gavins Point Dam to Sioux City, IA



- Yang transport function

HEC-RAS Modeling Conclusions

- Only scenario 4 resulted in aggradation rates in excess of one foot.
- Changes in aggradation of less than one foot should be considered within the error of the model.
- Channel degradation would be expected at the start of the navigation structures near Ponca, NE and in narrow, bank stabilized sections of the river
- Sediment that reaches the Navigation Channel at Sioux City appears to continue down the river as suspended load for all scenarios.

LCLSMS Modeling Conclusions

- It is possible to undertake hydraulic flushing of delta sediments
- Majority of sediment moved from Niobrara and Missouri River delta faces
- With the deep lake area right behind the dam, most if not all the sand re-deposits and only silts and clays are transported below the dam
- Dewatering of Lewis and Clark Lake is necessary for effective flushing
- Physical limitations of the infrastructure reduce effectiveness
- Higher discharge flushes = higher sediment transport, but not highest efficiency with existing infrastructure
- Sediment flushed below Gavins Point Dam generally transports through the reach and moves to the navigation channel
- Flows would likely cause mild to major flooding depending on location
- Flushed sediment is not highly suitable to ESH & SWH needs: silts and clays
- Only large, single event flushing flows were modeled
- Environmental, social, political, economic impacts WERE NOT considered in this study

Project Completion

- Complete downstream modeling report by February 2012
- Provide MRRP with guidance on parameters for a model verification flush
  - If any test were to be implemented, the full NEPA process would be incorporated, with all alternatives analyzed and impacts identified
- Report, fact sheets, presentation are available on the Missouri River Recovery Program website: Moriverrecovery.org
- MRRP considering ‘Phase II’ to examine other scenarios and incorporate 2011 flood data

USGS/USACE Data Collection During 2011 Flood (NWO)

- Suspended and Bed Material Samples, approx 10 per site, June through October
  - Washburn, ND
  - Bismarck, ND
  - Maskell, NE
  - Sioux City, IA
  - Omaha, NE
  - Neb City, NE
- Water Surface Profiles (above 150k cfs):
  - Garrison to Lake Oahe
  - Ft. Randall to L&C Lake
  - Gavins Point to Rulo

Missouri USGS Efforts

- Streamflow measurement at St. Joseph, Waverly, and Boonville weekly from June through October.
- In support of the Missouri River Bed Degradation study, measured river velocity at 37 locations between river miles 290 and 493, July through October.
- Five time-sequenced multi-beam echo sounder scans and ADCP at both St. Joseph and Kansas City between September and December. Measured discharge, turbidity, and collected suspended sediment and bed load samples.
- Installed turbidity, specific conductance, and temperature gage at Randolph, (just downstream from KC gage).

USACE Post Flood Data Collection

- Hydrosurveys:
  - Fort Randall to Sioux City (Nov 2011),
  - Nav Channel, Sioux City to Rulo (Aug 2012)
- LiDAR data and Imagery:
  - Fort Randall to Rulo (Dec 2011)
  - Lake Oahe to Garrison Dam (Ice out, 2012)
- Bed Material Samples:
  - Fort Randall to Sioux City (Apr 2012)

Products that Include 2011 Data

- Gavins Agg & Deg Reports
- Updated Area-Capacity for Lewis and Clark Lake
- USGS Sediment Samples Report
- Bank Recession Report for ESH (Garrison and Gavins reaches)
- LCLSMS Phase II modeling

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