US Army Corps
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Little Rock District and Tulsa District

ARKANSAS RIVER NAVIGATION STUDY
NAVIGATION CHANNEL DEPTH

APPENDIX A

HYDROLOGY AND HYDRAULICS REPORT

Navigation Mile 0.0 to 445.0

FEASIBILITY REPORT

30 June 2005

ARKANSAS RIVER NAVIGATION STUDY – NAVIGATION CHANNEL DEPTH

APPENDIX A: HYDROLOGY AND HYDRAULICS

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1. General

The purpose of the Arkansas River Navigation Feasibility Study (Phase II – Navigation Channel Depth) is to develop and evaluate various alternatives that could lead to solutions to provide a dependable project depth of 12-feet for the McClellan-Kerr Arkansas River System (MKARNS). The MKARNS includes four distinct channel segments; the White River Entrance Channel, the Arkansas Post Canal, the Arkansas River, and the Verdigris River. A minimum navigation channel depth of 9 feet is maintained on the entire system. The width of the channel varies from 300 feet in the White River and Arkansas Post Canal, 250 feet on the Arkansas River, and a minimum of 150 feet on the Verdigris River. Channel widths and sharp bends on the White River Entrance Channel are suitable for 1,200-foot tows approximately six months per year or when the water is above elevation 130.0. The existing bank stabilization features and channel alignment on the White River are basic to the layout needed for 1,200-foot tows. The Arkansas River portion of MKARNS was designed to permit navigation by 1200-foot-long tows with widths of 105-feet (3 tows by 35 feet). The present alignment of the Verdigris River portion of the system provides for one-way traffic of 600-foot-long tows with passing lanes at 2-mile intervals. However, 1,200-foot-long tows are using the entire system.

This report presents the hydrology and hydraulics (H&H) investigations of alternatives and the recommended additional studies necessary for the feasibility of the alteration of the MKARNS from its currently maintained 9-foot depth channel to a maintained 12-foot depth channel in the Little Rock and Tulsa Districts, Southwestern Division. A minimum 12-foot channel depth on the MKARNS will make the system more compatible with navigation on the Mississippi River. Though only 9-foot navigation is maintained on the Mississippi River during the low flow season, tows drafting 12-feet can navigate the reach up to Memphis most of the time because of the higher flows and corresponding depths characteristic of the Mississippi River. Typically, water depth a minimum of three feet deeper than the tow draft is available though tows have been known to navigate with as little as one-half to one foot of clearance between the bottom of the tow and the river bed in isolated, short reaches. The MKARNS is operated by the Little Rock District from Navigation Mile (NM) 0.0 to NM 308.6 (Arkansas-Oklahoma State Line) and by the Tulsa District from NM 308.6 to NM 445.0. Each District evaluated the effects of raising navigation pool elevations and channel modifications for their respective reaches of the MKARNS. This study investigated both permanently deepening the existing channel and raising the navigation pools or a combination. Deepening of the channel will require the construction of river training structures (dikes and revetments) to maintain a 12-foot channel depth and a 250-foot channel width with an expected increase in the volume of maintenance dredging. Raising the pools will require modifications to the lock and dams and to structures that span the river. Both may have significant impacts to water surface elevations and require flowage easements.

1.1 Scope of Work

Hydrology and hydraulics investigations were performed to assess the impacts of providing a 12-foot channel depth for the McClellan-Kerr Arkansas River Navigation System. Possible impacts to the existing locks and to the channel stability were investigated. In order to accommodate the funding and schedule limits of this study, the hydrology and hydraulics study approach was scaled back from the typical feasibility level of detail; and thus, this H&H study focuses on conceptual structure designs, a sediment impact assessment and identifying the needed detailed studies to be done during Preconstruction Engineering and Design (PED). Although this study does not meet the typical feasibility level of detail, the proposed conceptual designs should be adequate based on the following: (1) the original channel design was to provide a minimum of 12-feet below the normal pool (Appendix I of Reference PDM 5-3), (2) the project areas for modification comprise only about 10 percent of the entire system, (3) most of the proposed structure modifications are raising them to the original design elevations, and (4) the channel alignment is not changed. Further, with the experience of the system's response over the past 20 years, it is logical to believe that the proposed designs should function as predicted. This conceptual design approach was accomplished using the available original design information, past experience and engineering judgment. In addition, a 2-D numerical sediment transport model was developed for the upper 10 miles (model limits were from NM 33 to 48) of Pool 2. This modeling effort provided a detailed design of the reach from NM 43 to NM 45. It demonstrated that the conceptual structure designs from NM 43 to NM 45 would work as intended. For the additional areas requiring channel deepening, the approach of the study was to extrapolate and correlate the findings from the 2-D modeling to the study areas on the MKARNS. The 2-D modeling results were correlated to results from a HEC-RAS model of Pool 2 then applied to HEC-RAS models of the other project areas in order to size the necessary hydraulic structures for providing a maintenance free 12-foot channel depth. Due to this conceptual design approach, lack of design criteria, and the uncertainty in designing alluvial river systems, it will be necessary to verify the estimated structures (size, location and impacts) with proposed 2-D numerical modeling in the next phase of the project study, Preconstruction Engineering and Design (PED). Additionally, more detailed surveys will be required in order to build these needed models. Also, the deeper drafting barges have unknown impacts to the present lock designs. The present designs do not meet the recommended minimum sill clearance (1.5 times the draft) or the recommended submergence for filling and emptying systems (23 feet submergence). Some of these impacts are assessed later in the report based on prototype tests conducted at Lock 2 in September 2004.

1.2 Methods and Procedures

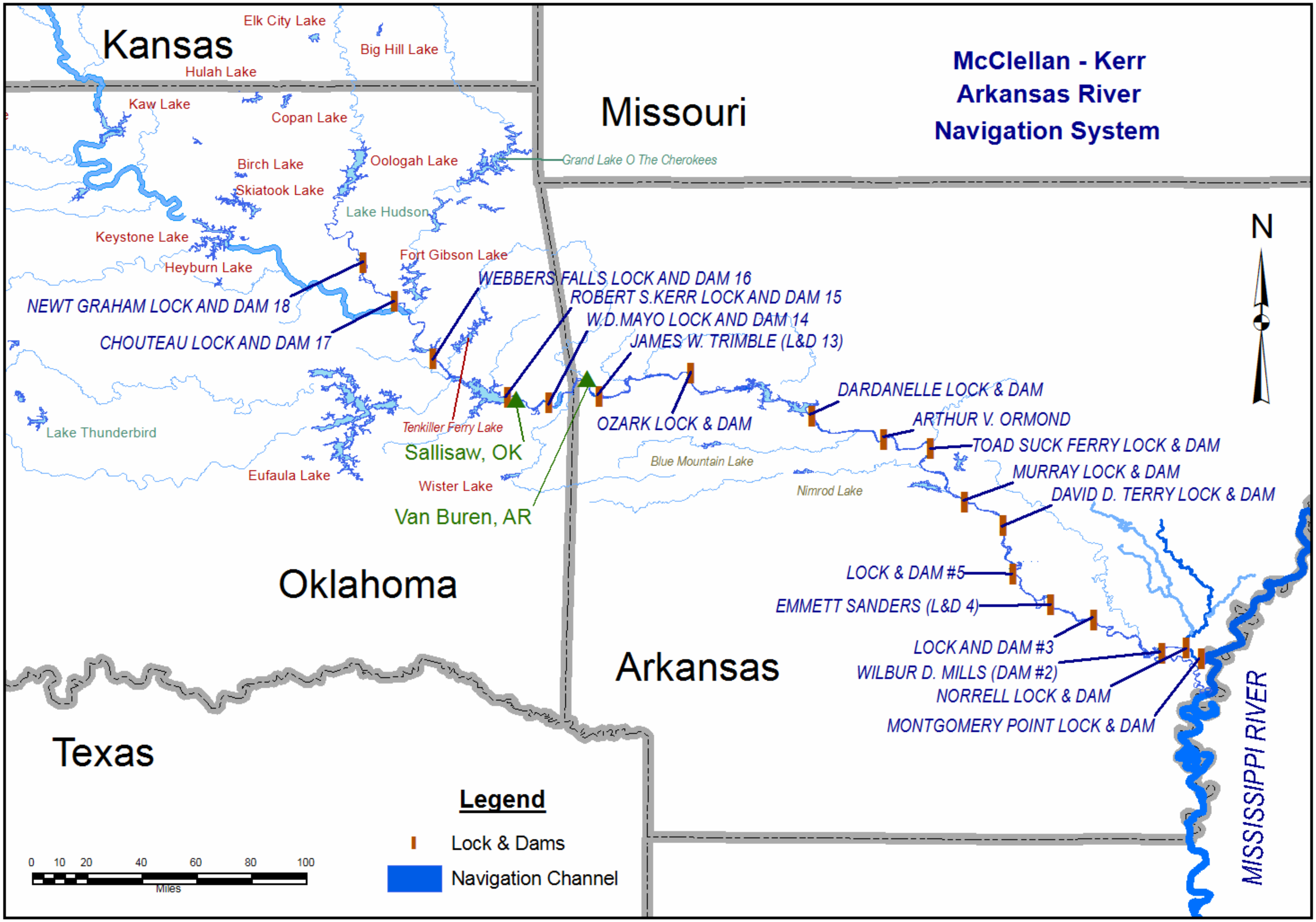
The hydrology and hydraulics procedures used in this study were based on the previous original designs of the Arkansas River navigation system obtained from Design Memorandums, previous model studies that were performed at the Waterways Experiment Station, present-day 2-D (CCHE2D) and HEC-RAS numerical modeling, and past experience and engineering judgment. These tools were used to determine the structure designs for the estimation of rock quantities. Sedimentation issues were not believed to be a major problem due to the limited amount of channel modifications, and therefore, only a qualitative sedimentation assessment was performed.

2. Existing Lock And Dam Operations

2.1 General

Eighteen of the 50 projects in the Arkansas River system are locks and dams constructed to provide navigation from the mouth of the White River to the Arkansas Post Canal, then to the Arkansas River, and then to the Port of Catoosa near Tulsa, Oklahoma. Construction on the

Figure A-1
McClellan – Kerr Arkansas River Navigation System



Arkansas River navigation project began in 1957. Navigation reached Little Rock, Arkansas, in December 1968 and the Port of Catoosa, Oklahoma in December 1970. The lock and dams on the MKARNS are operated for navigation and hydroelectric power production. Hydroelectric plants are currently operated by Corps personnel at the Ozark, Dardanelle, R.S. Kerr and Webbers Falls lock and dams and operated by private/public entities at Lock and Dams 2, 7, 9 and 13 in conjunction with the other authorized system of locks and dams as well as multi-purpose reservoirs in the Arkansas River Basin. Lock and Dam 5 and Dam 2 are also authorized and operated for irrigation purposes. A map of the main channel of the McClellan-Kerr Arkansas River Navigation System and some of the reservoirs is presented on Figure A-1.

2.2 Navigation Pool Operation

The navigation pools are operated within a range or "pool limits" in order to provide a navigable channel from one lock and dam through the next upstream lock and dam. As flows increase on the river, the pool elevation is slowly lowered to the bottom of the pool limit. This lowering of the pool helps in reducing flooding upstream, in reducing maintenance dredging by inducing a scouring action in the navigation channel, and in the smooth transition when raising the tainter gates out of the water in an open river situation. Tables A-1, A-2, and A-3 indicate the pool operating limits for the Little Rock District's projects. These "pool limits" are based on the flow at the lock and dams in Arkansas. The "pool limits" based on Arkansas River flow are Not Applicable (N/A) at Lock and Dam 0 and 1 and Dam 2. Lock and Dam 1 and Lock 2 are located in the Arkansas Post Canal and are not subjected to normal river flows. This canal provides navigation from the Arkansas River to the White River. Lock and Dam 0 (MPLD) is operated to maintain a minimum pool of 115.0 feet, NGVD. Storage pools for the production of hydroelectric power are included in several of the MKARNS projects and are generally used to maintain head for the hydroelectric units and allows for management of releases during low flow periods.

2.3 Flood Control

There is no storage allocated for flood control in the pools above the lock and dams on the MKARNS. During large floods it is possible to slightly reshape the peak of the flood in some of the events by manipulating releases but this can make a minimal change at best.

Table A-1
MKARNS - Lock and Dam Pool Operating Limits in Little Rock District

Inflow (cfs)	0-45,000	45,000-100,000	100,000+	Open River
	POOL LIMITS (feet, NGVD)			Flowrate (cfs)
L&D 13 (Trimble) N.M. 292.8	391.0-392.0	***Based on Tailwater	***Based on Tailwater	135,000
L&D 12 (Ozark/Jetta) N.M. 256.8	370.0-372.5	371.0-372.0	371.0-372.0	360,000
L&D 10 (Dardanelle) N.M. 205.5	336.0-338.2	337.0-338.0	337.0-338.0	600,000
L&D 9 (Ormond) N.M. 176.9	284.0-287.00	284.0-286.0	284.0-286.0	150,000
L&D 8 (Toad Suck) N.M. 155.9	264.8-265.3	264.0-265.0	263.0-265.0	85,000
L$D 7 (Murray) N.M. 125.4	248.8-249.3	248.0-249.0	247.0-249.0	230,000
L&D 6 (Terry) N.M. 108.1	230.8-231.3	230.0-231.0	230.0-231.0	175,000
L&D 5* N.M. 86.3	212.8-213.3	212.0-213.0	211.0-213.0	170,000
L&D 4 (Sanders) N.M. 66.0	195.8-196.3	195.0-196.0	194.0-196.0	150,000
L&D 3 (Hardin) N.M. 50.2	181.8-182.3	181.0-182.0	180.0-182.0	130,000
Dam 2* (Mills) N/A	161.8-162.3	161.0-162.0	160.5-162.0	315,000
Lock 2** N.M. 13.3	N/A	N/A	N/A	N/A
L&D 1 (Norrell)** N.M. 10.3	N/A	N/A	N/A	N/A
L&D 0 (MPLD)** N.M. 0.6	N/A	N/A	N/A	N/A

*Seasonal Pool Limits. See Table A-2.
**L&D 0 has a minimum pool limit of a 115.0 elevation based on the Mississippi River.
**L&D 1 is operated to hold a pool in the canal at approximately a 143.0 elevation.
**Lock 2 does not have a pool limit, as it is dependent on Dam 2's operating pool limit.
*** Pool Limits based on Tailwater. See Table A-3.
Note: As flows decrease the pools are held close to the top of the poll limits.

Table A-2
Lock and Dam 5 and Dam 2 Seasonal Pool Limits
1 May through 30 September

Inflow (cfs)	0-70,000	70,000-100,000	100,000+
	POOL LIMITS (feet, NGVD)		
Lock and Dam 5	213.0-214.0	212.0-213.0	211.0-213.0
Dam 2 (Mills)	162.0-163.0	161.0-162.0	160.5-162.0

Table A-3
Trimble Lock and Dam Pool Limits Based on Tailwater

LOCK AND DAM 13 (TRIMBLE)	
Tailwater (feet, NGVD)	Pool Limit (feet, NGVD)
370.0-379.0	391.0-392.0
379.0-381.0	390.0-391.5
381.0-383.5	389.5-390.5
383.5-385.5	389.0-390.0
385.5-388.3	389.0-389.5

3. Hydrologic Data

The basic hydrologic data used for the frequency and duration analyses was developed using the Arkansas River Basin hydrologic routing model “SUPER”, which was developed by Southwestern Division. The model was calibrated to documented historical events at specific control points. The calibrated model was then used to simulate the 1940-2000 period of record flows. These simulations resulted in continuous 61-year period of record mean daily flows for project conditions at specific control points. The resulting mean daily flow data at the control points located at Van Buren, Dardanelle and Little Rock, Arkansas, were used in this study for the Little Rock reach (NM 10 – NM 308.6). The frequency and duration were computed at the SUPER Model control points and the drainage-area-ratio was done for the lock and dams between control points. The drainage areas between the control points are similar and the amount of uncontrolled areas between control points was about 2 and 3 percent and about equal at each lock and dam at about 1 percent. The use of the drainage-area-ratio was appropriate.
The existing conditions plan is SUPER Model run A01X16. The SUPER Model run, A02X10, was used in this study, as it was the recommended plan of operation in Phase I of the Arkansas River Navigation Study. This plan of operation (A02X10) modifies the existing plan by replacing the 75,000 cfs bench with a 60,000 cfs bench starting 3% lower than the current plan of

operations except June 15-October 1. This Operations Only Plan, SUPER run (A02X10), is almost statistically the same as the No Action Plan (Existing A01X16), except for replacing the 75,000 cfs bench with a 60,000 cfs bench and reducing the system storage for the bench from 18 to 15 percent. This proposed Operations Only Plan accomplishes two goals: Reduces flooding of some agricultural lands in western Arkansas and eastern Oklahoma and enhances commercial navigation operations by reducing the number of days that flows exceed 60,000 cfs at Van Buren. This proposed plan would have an insignificant effect on the basin's flow regime, and therefore, an insignificant effect on the sediment transport capacity of the river.

3.1 Frequency Data

The proposed modification (Operations Only Plan – A02X10) to the existing regulation plan had a negligible effect upon the plotting positions and discharges from the Annual Series and Partial Duration Series Peak Flow Data tables generated by SUPER. Therefore, the discharge frequency curves were the same for the Operations Plan as for the Existing or No Action Plan. Both frequency and duration curves have been calibrated, verified and used for many other studies on the Arkansas River. The mean daily flows resulting from the SUPER model simulations were used to determine annual peak discharges at each control point. These peak discharges were then used in developing the annual series peak discharge-frequency curves. Then peak discharges for the 0.95 through the 0.01-exceedance probability events were determined. The discharge-frequency data developed for the Van Buren control point was used directly for John Paul Hammerschmidt Lake (Pool 13). The drainage-area-ratio method was used to develop discharge frequency data for Ozark Lake (Pool 12) based on the discharge-frequency data developed for the Van Buren and Dardanelle control points. The discharge-frequency data developed for the Dardanelle control point was used directly for Lake Dardanelle (Pool 10). The drainage-area-ratio method was used to develop discharge frequency data for Winthrop Rockefeller Lake (Pool 9) and for Pool 8 based on the discharge-frequency data developed for the Dardanelle and Little Rock control points. The drainage-area-ratio was appropriate due to the minor amount of intervening area between control points where detailed analyses have been performed. The discharge-frequency data developed for the Little Rock control point was used directly for Pool 7 and all remaining downstream pools. Table a-4 lists the discharge-frequency at the Van Buren, Dardanelle and Little Rock control points.

3.2 Duration Data

The mean daily flows from the SUPER model simulations were used to develop flow-duration data at each respective control points for the existing plan of operation (A01X16) and the proposed plan of operation (A02X10). The flow-duration data developed for the Van Buren control point was used directly for John Paul Hammerschmidt Lake. The drainage-area-ratio method was used to develop flow-duration data for Ozark Lake based on the flow-duration data developed for the Van Buren and Dardanelle control points. The flow-duration data developed for the Dardanelle control point was used directly for Lake Dardanelle. The drainage-area-ratio method was used to develop flow-duration data for Winthrop Rockefeller Lake and for Pool 8 based on the flow-duration data developed for the Dardanelle and Little Rock control points. The flow-duration data developed for the Little Rock control point was used for Pool 7 and all remaining downstream pools. The additional drainage area between Dam 2 and Little Rock is less than 2 percent and the river is confined between levees from Little Rock to Dam 2 and would only have a minor impact on the duration. Table A-5 lists the discharge-duration at the Van Buren, Dardanelle and Little Rock control points.

Table A-4
Discharge-Frequency at Control Points
(1000 CFS)

	VAN BUREN	
Frequency	Existing No Action Plan (SUPER A01X16)	Ops Plan (SUPER A02X10)
0.01	500	500
0.02	440	440
0.04	330	330
0.10	250	250
0.20	190	190
0.50	150	150
0.80	95	95
0.95	55	55
	DARDANELLE	
0.01	550	550
0.02	485	485
0.04	355	355
0.10	305	305
0.20	260	260
0.50	190	190
0.80	135	135
0.95	60	60
	LITTLE ROCK	
0.01	505	505
0.02	450	450
0.04	355	355
0.10	295	295
0.20	250	250
0.50	195	195
0.80	155	155
0.95	75	75

Table A-5
Discharge-Duration at Control Points
(1000 CFS)

	VAN BUREN	
Duration (% of Time Equaled or Exceeded)	Existing No Action Plan (SUPER A01X16)	Ops Plan (SUPER A02X10)
0.1	268	269
1	158	158
6	134	135
10	91	97
20	56	54
50	21	21
	DARDANELLE	
0.1	309	310
1	174	175
6	138	140
10	103	107
20	62	58
50	23	23
	LITTLE ROCK	
0.1	320	320
1	198	199
6	151	152
10	121	124
20	72	69
50	28	28

4. Hydraulic Data

Hydraulic data used in this study include results of studies performed in support of the ARNS – Phase I. HEC-RAS backwater models were developed during Phase I of the ARNS using channel sections that were obtained in 1999. These HEC-RAS models were modified with additional cross section data for this study. Representative cross sections, in which proposed structures were to be modified or added, were developed for the river reaches from hydrographic surveys obtained through the Pine Bluff and Russellville Project Offices in January 2004. Overbank portions of the model's cross sections were to be updated form lidar data obtained in 2000 but a useable product was not produced in time for this study (It should be available during the next phase of this study). Therefore, previous 1986 overbank surveys or USGS quadrangle maps were used. The existing dike elevations were based on as-built drawings, ID-IQ contracts and estimated from field inspection notes. Spot surveys were done to verify the dike and revetment structure elevations for the reach of river that was modeled with the 2-D numerical model. The latest existing rating curves were obtained from the Reservoir Control Branch. Lock and dam data were obtained from as-built drawings.

4.1 CCHE2D 2-D Numerical Model

CCHE2D, developed by the National Center for Computational Hydroscience and Engineering at the University of Mississippi, was used to model a study reach in Pool 2. The CCHE2D model is a two-dimensional depth-averaged, unsteady, flow and sediment transport model. The reach limits of the model were from NM 33 to NM 48. However, due to the schedule and funding only detailed investigations were performed in this study from NM 43 to NM 45.

4.2 HEC-RAS Models

The HEC-RAS, developed by the Hydrologic Engineering Center at Davis, California, numerical computer program was used to model Pools 2, 3, 4, 5, 7, 8, 9, Dardanelle and Ozark in the Little Rock District (Pool 6 provides sufficient depths for the 12-foot channel). The models were used to determine the bed shear, sediment transport capacity potential and water surface elevations and are discussed later in this report.

4.3 Water Surface Profiles

Water surface profiles were developed using computer program HEC-RAS version 3.0.1 and updated to version 3.1.2. The models for pools 2, 3, 4, 5, 6, 7, 8, 9, Dardanelle and Ozark were based on year 1999 hydrographic surveys of the channel and 1986 overbank surveys. The models were calibrated to the most current lock and dam tailwater rating curves; USGS gage ratings, and high water marks from the flood of 1990. The calibrated models were then modified adding hydrographic surveyed channel sections with estimated overbank sections in the areas where proposed structures would be needed. These sections were adjusted for the proposed dike modifications and the estimated scour and then used to compute both existing and modified condition water surface profiles. The starting conditions for the backwater models were based on headwater rating curves for each lock and dam. The water surface elevations for the 2-year and 100-year events along with the change in the thalweg for both the Base and Plan (Final modified condition, Mod) conditions are shown in H&H Appendix A-1, Figure A-1-1. The results of the backwater modeling indicate that there are negligible impacts to the 2-year and 100-year water surface elevations. The existing thalweg upstream of the project areas are lower than the estimated dredging and/or scour in the project areas in all pools, except Pool 3, and therefore no significant head-cutting is expected to occur.

5. Existing Channel Conditions in Arkansas

Traditionally, in the Little Rock District there are 13 reaches that dredging and/or pool manipulations (deviations) are required in order to maintain the 9-foot channel depth. In addition, nine of the ten lock approaches require clamming, dredging, and/or pool manipulations as much as two to three times per year in order to maintain the 9-foot channel depth. Through these procedures the 9-foot channel depth is available virtually 100 percent of the time on the MKARNS. Table A-6 lists the traditional shoaling areas that currently require advanced maintenance dredging. Also, over the years there has been a buildup of backlog channel maintenance due to lack of Operation and Maintenance (O&M) funding. These areas will have to be addressed in the future in order to maintain the 9-foot channel depth at the reliability that currently exist. These future problem areas are listed in Table A-7. It will be necessary that these areas be designed and constructed in order to provide a 12-foot channel depth as proposed in this study. Currently about 90 percent of the MKARNS has sufficient depth for a12-foot channel under the authorized operating conditions. The system's remaining 10 percent does not have a 12-foot channel depth available for any significant duration. Table A-8 shows the duration that 9-, 10-, 11-, and 12-foot channel depths are available at several locations in Arkansas. This channel depth availability assumes that no advanced maintenance dredging takes place in the typical shoaling areas for the 10-, 11-, and 12-foot channel depths. The table indicates that there is no reliability that a 12-foot channel depth is available on the MKARNS.

Table A-6
Existing Advanced Maintenance Dredging Locations*
MKARNS in the Little Rock District

Priority**	Location	Project Office	Description
1	NM 43 - 44	PB	Mud Lake
2	NM 50	PB	D/S approach L&D 3
3	NM 66	PB	D/S approach L&D 4
4	NM 79 - 80	PB	Hensley Bar
5	NM 86	PB	D/S approach L&D 5
6	NM 95 - 98	PB	Case Bar
7	NM 108	PB	D/S approach L&D 6
8	NM 125	PB	D/S approach L&D 7
9	NM 127	RV	I-430 Bridge
10	NM 146 - 147	RV	Fourche LaFave
11	NM 156	RV	D/S approach L&D 8
12	NM 169 - 170	RV	Cypress Bend
13	NM 177	RV	D/S approach L&D 9
14	NM 182	RV	Dowdle Bend
15	NM 186	RV	Petit Jean River
16	NM 190	RV	Sweeden Island
17	NM 222	RV	Shoal Bay - Lake Dardanelle
18	NM 241	RV	Six Mile Creek
19	NM 257	RV	D/S approach L&D 12
20	NM 275	RV	Courthouse Slough
21	NM 277-278	RV	Arbuckle Island
22	NM 293	RV	D/S approach L&D 13

*To maintain 9-foot channel depth.
**Priority is based on one dredge availability.

Table A-7
Existing Backlog Maintenance Locations*
MKARNS in the Little Rock District

Location	Description
NM 39.8	Left bank. Raise and tie 1 dike to revetment
NM 42.7-43.4	Right bank. Raise dike and revetment
NM 126.9-127.45	Left bank. Raise dikes and L-heads
NM 186.95-187.05	Right bank. Raise vane dike
NM 189.8-190.5	Left bank. Raise dikes
NM 275.15-275.85	Left and Right banks. Raise dikes

*Future maintenance requirements for 9-foot channel depth necessary to support 12-foot channel .

Table A-8
Flow Required to Provide Channel Depths
Based on Most D/S Shoaling Area in Pool

Location	NM	Flow * Required For	% Time** Available	Flow Required For	% Time Available	Flow Required For	% Time Available	Flow Required For	% Time Available
		9 ft	**9 ft**	**10 ft**	**10 ft**	**11 ft**	**11 ft**	**12 ft**	**12 ft**
Pool 2***	43	1643	100	14800	65	22300	56	29100	46
Pool 4	79	364	100	32500	42	48200	28	61500	21
Pool 5***	96	420	100	62000	22	91700	12	118000	8
Pool 7	146	786	100	18700	60	28200	46	37000	36
Pool 8	169	510	100	19100	60	28700	46	37800	36
Pool 9***	182	615	100	60000	16	89200	8	115300	4
Dardanelle***	222	1123	100	146000	2	215000	0.3	274000	0.1
Ozark***	275	678	100	43500	24	64200	15	82200	9

Navigation depths based on Navigation Pool and no advanced maintenance dredging.
Annual Flow Duration is at Little Rock (Pool 2-8) or Van Buren (Pool 9-Ozark).
*Drought Contingency Plan Sep 1992, Table 4-8, Estimated Evap, Leakage, 24 Lockages/day & infiltration.
**Assumes SOP of advanced maintenance dredging and pool manipulation.
***Duration does not take into account the seasonal pool in Pools 2 and 5, the 3-ft re-regulation storage in Pool 9 or the 2-ft hydropower storage in Dardanelle and Ozark.

6. Channel Conditions in Proposed Project Areas in Arkansas

The channel project areas are those that may require river training structures and/or dredging in order to maintain a 12-foot depth and a 250-foot width channel. Below is the list of the project areas that will need initial dredging, river training structures, and/or maintenance dredging in order to provide and maintain a 12-foot channel depth in the Little Rock District. These areas were identified based on past experience, on 2003 hydrographic surveys and on discussions with project personnel.

Pine Bluff Project Office:

NM 22.5 – 23.7. This is a crossing that will need attention in order to maintain a 12' channel after sustained high flows recede.
NM 27.5 – 29.0. This crossing has depths less than 10 feet at times and will need attention to maintain 12' channel after sustained high flows recede.
NM 31.0 – 32.0. This is a bend and may be a problem to maintain a 12' channel.
NM 32.8 – 33.7. This crossing may be a problem to maintain a 12' channel.
NM 36.0 – 38.2. This crossing may be a problem to maintain a 12' channel.
NM 39.8 – 41.0. This crossing may be a problem to maintain a 12' channel.
NM 42.8 – 45.0. This location has been dredged on a yearly basis to maintain a 9-foot channel. Dikes 63.2L and 63.4L and revetment 64.2L were raised with completion in January 2004. Preliminary surveys have indicated that these improvements may have eliminated future dredging requirements from NM 42.8 to 44.0. Additional dredging will be required from NM 44 to 45 to maintain a 12' channel.
NM 46.0 – 47.0. This crossing has not been dredged since structure improvements in September 1990, but may be a problem to maintain a 12' channel.
NM 48.0 – 49.0. This crossing has not been dredged since structure improvements in November 1990, but will be a problem to maintain a 12' channel.
NM 49.5 – 50.0. D/S lock approach to L&D 3 requires dredging and/or clamming 2-3 times per year and will be required to maintain a 12' channel.
NM 61.0 – NM 62.0. This crossing may be a problem to maintain a 12' channel.
N.M. 65.4 – 65.9. D/S lock approach to Emmett Sanders Lock requires dredging and/or clamming 2-3 times per year and will be required to maintain a 12' channel.
N.M. 79.0 – 80.0. This straight reach will require annual dredging to maintain 12' channel.
N.M. 85.8 – 86.2. D/S lock approach to Lock No. 5 requires annual dredging and will be required to maintain a 12' channel.
N.M. 91.0 – 92.0. This crossing may be a problem to maintain a 12' channel.
N.M. 95.0 – 97.0. This reach will require annual dredging to maintain 12' channel.
N.M. 101.0 – 102.4. This bend and crossing will require annual dredging to maintain 12' channel.
N.M. 107.6 – 107.9. D/S approach to David D. Terry Lock requires annual clamming and will require dredging to maintain 12' channel.
N.M. 124.8 – 125.1. D/S approach to Murray Lock requires bi-annual clamming and will require dredging to maintain 12' channel.

Russellville Project Office:

NM 126.5. Crossing on right side of channel at I-430 Bridge will require annual dredging to maintain 12' channel.

NM 142.5 - 143.0. Reach will possibly require annual dredging to maintain 12' channel.
NM 145.2 - 145.4. Reach will require annual dredging to maintain 12' channel.
NM 146.2 - 147.0. Fourche La Fave-Routinely clammed and will require frequent dredging to maintain 12' channel.
NM 149.0 - 150.6. Historical "high rock" that was blasted in 1988 appears to be OK.
NM 155.5. D/S lock approach to Toad Suck requires annual clamming and will require dredging to maintain 12'.
NM 164.6 - 164.8. Crossing will require annual dredging to maintain 12'.
NM 169.0 - 170.0. Bend will require annual dredging to maintain 12'.
NM 176.5. D/S approach to Ormond requires clamming 1-2 times/year and will require dredging to maintain 12'.
NM 181.6 - 182.1. Reach will require annual dredging to maintain 12'.
NM 185.0 - 185.8. Crossing will require annual dredging to maintain 12'.
NM 186.7 - 187.2. Area will require initial dredging to provide 12' and annual dredging to maintain 12'.
NM 191.5 - 192.1. Currently marginal at 12' and crossing will require close monitoring to ensure sanctity of 12'.
NM 192.6 - 192.8. Crossing currently marginal at 12' and will require close monitoring.
NM 194.0. Straight reach currently marginal at 12' and will require close monitoring.
NM 195.0. Straight reach currently marginal at 12' and will require close monitoring.
NM 198.8 - 199.0. Long bend currently marginal at 12' and will require close monitoring.
NM 202.8. Currently marginal to provide 12' depth and monitoring and possible occasional dredging will be required to maintain 12' depth.
NM 205.2. D/S approach to Dardanelle Lock will require initial dredging to provide 12' and infrequent dredging may be required to maintain 12' channel.
NM 222.0 - 223.0. Area will require annual dredging to maintain channel width.
NM 227.0. Currently marginal for 12'. Will require annual dredging.
NM 230.1 - 230.4. Currently marginal for 12'. Area will require annual dredging.
NM 236.3. Currently marginal for 12'. Area will require annual dredging.
NM 238.0. Small area will require initial and annual dredging.
NM 239.0. Small area will require initial and annual dredging.
NM 241.0 - 242.1. Crossing area will require initial and frequent dredging to maintain 12' depth.
NM 246.3. Area currently marginal. No problems expected.
NM 249.7. Initial dredging and annual dredging will be required to maintain 12'.
NM 256.5. D/S approach to Ozark Lock. Initial and periodic clamming will be required to maintain 12'.
NM 271.7. Initial and annual dredging will be required to maintain 12'.
NM 272.2. Initial and annual dredging will be required to maintain 12'.
NM 275.5. Crossing is semi-routinely dredged to maintain and routine dredging will be required.
NM 276.9. Currently marginal for 12' and will require some monitoring.
NM 278.7. Crossing currently marginal for 12' and will require some monitoring.
NM 279.5 - 281.1. Crossings semi-routinely dredged to maintain 9' channel and will require routine dredging.
NM 283.6 - 284.1. Crossing will require annual dredging maintain 12'.
NM 285.2 - 286.0. Area is currently marginal for 12' and will require dredging to maintain 12'.
NM 292.3. D/S approach to Trimble Lock routine dredge/clamming will be required.

7. Raise Navigation Pools

One alternative to achieving the additional depth needed for drafting the deeper tows is to raise the navigation pools. Although the pools can be raised about one foot temporarily (during low flow) at all of the lock and dams for emergency and maintenance problems, there are minor problems when this is done. They include water seeping into the inspection gallery and debris and water going over the top of the spillway gates. A permanent increase in the elevation of the navigation pools will cause an encroachment of the navigation clearance criteria (52 feet above the 2% flow line) for overhead structures (bridge and power lines) in all pools in the Little Rock District. In addition, permanent operation of the pools at a higher elevation would increase the elevation-duration and elevation-frequency of lands inundated along the river requiring additional flowage easements. This alternative was eliminated for all the Little Rock pools based on the preliminary cost estimates of modifying structures and for flowage easements in those pools. No H&H analysis for raising the pools is provided in this report.

8. Deepen Navigation Channel

Another alternative to provide the additional depth for drafting deeper tows is to deepen the navigation channel. Presently, about 90 percent of the navigation system has depths and widths that support a 12-foot channel depth with a 250-foot width. For the identified reaches (See paragraph 6.) requiring channel deepening to obtain the 12-foot depth; engineering judgment, experience, original designs, and a correlation of a 2-D sediment transport model to 1-D HEC-RAS models were used to determine conceptual designs for required river training structures. Initially the channel will be dredged in the identified project areas to obtain a 15-foot (3-foot over-dredge) channel depth and a 250-foot channel width. However, this dredged channel will likely fill-in after one or more flood events and require maintenance dredging. Therefore, existing river training structures must be raised and/or extended or new river training structures added to induce scour in these areas to reduce or eliminate maintenance dredging. Currently there is an authorized 3-foot advanced maintenance dredging depth that is documented in the Waterways Experiment Station (WES) Technical Report (TR) H-78-5. And, this over-dredge is still necessary in shoaling locations and is expected to continue to be economically advantageous for the 12-foot channel. The location of new or modified river training structures was determined from hydrographic surveys obtained in April 2003 and meetings with Maintenance Engineering and Project Office personnel in January 2004. The locations and estimated impacts from these proposed structures are included in this report.

9. Downstream Lock Approaches

Shoaling in the downstream lock approach is a typical phenomenon for locks that are located along one bank of a river as on the MKARNS. Sediment moves along the downstream guard wall and is transported into the downstream lock approach where it is deposited as the channel expands at the end of the guard wall. A natural eddy forms in this area augmenting the sediment deposition. Physical model studies examining the shoaling problems in the downstream lock approaches on the Arkansas River were performed at the WES and are documented in TR H-68-8 and H-70-8. Also, the Vicksburg District was consulted regarding the design of the navigation system on the Red River since it is one of the most recently designed systems that has a significant sediment load. Tests and studies done for both of these navigation systems demonstrated that every type of structure examined, that reduced the sediment deposition in the downstream lock approach, was detrimental to navigation. It was concluded that dredging the lock approaches was the best solution based on the current design. On the Red River, future lock and dam designs were modified to reduce the width of the dam structure allowing for better flow patterns that minimized the eddy at the end of the downstream guard wall, thus reducing sediment deposition. The conclusion ensuing from the review of prior model tests and from discussions with designers on the Red River navigation projects was that no satisfactory plan would eliminate or significantly reduce sediment shoaling in the downstream lock approaches without adversely affecting navigation on the MKARNS projects. The studies did indicate that wing dikes, extending downstream from the riverward wall for 400 to 600 feet at about 10 degrees, were the best alternative as the dikes moved the shoaling area downstream from the lock wall. These wing dikes reduced the frequency of deposition and possibly reduced some of the amount of shoaling in the approaches. The wing dikes provided better low flow patterns improving the navigation approach conditions. Wing dikes have been installed at all the lock approaches on the MKARNS. Therefore, no modifications to current wing dike structures are proposed in this study. At the projects where sediment deposition in the downstream lock approach occurs, it is estimated that maintenance dredging will be required an average of two times per year.

10. Channel Model Studies

The Engineer and Research Development Center (ERDC) developed a 2-D numerical sediment transport model in the upper end of Pool 2 (Model limits were from NM 33 to NM 48). However, due to the time and cost constraints in this study, only the river reach from NM 43 to NM 45 were studied in detail. This river reach was modeled because this location has traditionally been a highly dredged reach. Since 1995 this reach has accounted for about 40 percent of the dredging volume in the Little Rock District. The sediment transport model selected for use in this study, CCHE2D, was developed by the National Center for Computational Hydroscience and Engineering at the University of Mississippi. This model was used to verify that the proposed river training structures would produce sufficient scour to maintain a 12-foot deep by 250-foot wide channel from NM 43 to NM 45 while having negligible impacts on water surface elevations and sediment transport. Details of the study are presented in the H&H Appendix A-2. Then for all the river reaches, 1-D HEC-RAS models were used to size and assess the impacts of the proposed river training structures.

11. River Training Structure Design Criteria

The Arkansas River navigation channel consists of dikes and revetments (channel control or river training structures) that help constrict the channel and stabilize riverbanks to prevent them from migrating. The original design (PDM 5-3) estimated the equilibrium bed profile for the 250-foot width navigation channel from Arkansas Post to Dardanelle would provide a minimum of 12-feet below the navigation pools, provided all the river training structures were constructed. This original design accounts for the high percentage of the system that currently provides a 12-foot channel depth. The conceptual design criteria for setting the elevations and lengths of the river training structures was based on the original analytical channel studies and physical model studies that were completed in the late 1950's through the early 1970's. These original studies indicated that the channel trace width (channel bank to bank, dike to dike, or dike to bank) on the Arkansas River should typically range from 1000 to 1500 feet to maintain the required navigation depths and widths. However, in some of the upper reaches of the pools, the trace widths had to be reduced to 600 feet to obtain the needed channel depth. Original design had the river training structures sized to contain flows of 70,000 cfs at the trace width, and to contain flows of 100,000 cfs at the location where the river training structures slope back to the channel bank line. Adopting the original design criteria for this study, it was decided to initially raise existing structures so as to contain at least the 70,000 cfs profile and/or to contract the channel by extending existing structures or adding new structures based on the existing reach's trace width.

12. Channel Forming Discharge

In alluvial river systems it is typical practice to design for what is called the channel forming discharge. The channel forming discharge was assumed to be the 50 percent chance (2-year) event. Therefore, the 2-year flow was used as the design flow.

13. Design Data Correlations

The 2-D model of the river reach, NM 43 to NM 45, was used to validate the HEC-RAS models of the remaining river reaches in need of dredging. A correlation of the bed shear;

$$\tau_b = \gamma * [n/1.49]^2 * V^2 / R^{1/3}$$

where, τ_b=bed shear, γ=specific weight of water, **n**=manning's value, **V**=channel velocity, and **R**=channel hydraulic radius, to the amount of channel scour was used based on the 2-year event being the design flow. Proposed river training structures were input as typical for a reach in the HEC-RAS models to determine the percent increase in bed shear for that reach. Once the percent change in bed shear was similar to the percent change in bed shear experienced in the 2-D model, the river training structure design was considered good. See Table A-9 for percent change in bed shear between the Base (existing) and Plan (modified training structures) conditions for the 2-D model and the HEC-RAS models. Once the percent change in bed shear was determined to be sufficient to induce scour in the reach, the HEC-RAS channel sections were increased in area to reflect the amount of scour observed in the 2-D modeling for the different percent change in bed shear values. For the percent change in bed shear from 20 to 40 percent, the channel area was increased by about 2600 sq. ft.; and for changes in bed shear from 10 to 20 percent, the channel area was increased by about 1250 sq. ft. The maximum proposed dredging for this project is to a 15-foot depth and in some areas results in a channel area increase of up to about 1,600 sq. ft. In addition to increasing the channel area, the thalweg was lowered 5 feet and 3 feet, respectively, based on the 2-D modeling results. This correlation of bed shear versus bed scour is based on the assumption that the gradations of the materials from the bed sediment samples taken by the USGS in September, October, and November of 2003 are similar. This was the case as the sediment sample analyses showed that the average bed materials were classified as a medium sand for Pools 2, 3, 4, 5, 6 and 7. The D50 particles ranged from about 0.35 mm to 0.50 mm for Pools 2, 3, 4, 5, 6, and 7. Most of the locations upstream from Pool 7 had mixtures of medium and course sand and thus the correlation of the 2-D model results may be over estimating the scour. However, since the correlation is based on a percent change from the existing channel bed scour and the current structures are similar to the lower river reaches, the correlation is not unrealistic. Locations at NM 90 and NM 281 indicated that the bed material was very coarse sand. At NM 249.6 and NM 249.8 the sediment was classified as very fine gravel. The bed sediment samples locations and analyses are shown in H&H Appendix A-4.

Table A-9
Percent Change in Bed Shear
HEC-RAS and 2-D (CCHE2D)

	Base				Plan				HEC-RAS	2-D Model
NM	Comp n	Chnl Vel	Hyd Rad.	Shear	Comp n	Chnl Vel	Hyd Rad.	Shear	% Change	% Change
Pool 2										
44.41	0.0223	5.64	23.72	0.155	0.0238	5.60	23.43	0.174	12.76	
44.00	0.0222	5.37	22.43	0.142	0.0236	5.34	22.26	0.159	12.03	5.56
43.60	0.0251	4.76	17.42	0.155	0.0241	5.43	15.11	0.195	25.80	31.25
43.31	0.0254	5.28	20.14	0.186	0.0232	6.55	16.16	0.257	38.16	40.00
39.73	0.0275	6.27	16.84	0.326	0.0263	6.93	15.29	0.376	15.39	
36.17	0.0234	5.53	20.69	0.171	0.0229	6.27	18.15	0.220	28.61	
34.97	0.0241	5.52	17.47	0.192	0.0247	5.91	16.20	0.237	23.48	
Pool 3										
61.53	0.0312	5.60	22.89	0.302	0.0310	5.90	21.95	0.331	9.70	
61.12	0.0304	4.75	22.79	0.207	0.0300	5.05	21.44	0.238	15.35	
Pool 4										
79.28	0.0258	5.82	23.90	0.220	0.0268	6.27	21.94	0.283	28.86	
Pool 5										
102.40	0.0318	5.29	24.21	0.275	0.0312	5.71	22.97	0.314	14.14	
101.59	0.0322	4.44	19.03	0.215	0.0315	4.89	17.78	0.256	18.74	
97.10	0.0306	4.50	21.34	0.192	0.0310	4.86	18.44	0.241	25.68	
96.42	0.0298	7.8	21.17	0.549	0.0302	8.50	19.18	0.692	26.04	
Pool 7										
146.71	0.0306	4.43	24.67	0.177	0.0306	4.87	22.08	0.222	25.40	
145.78	0.0308	5.62	24.29	0.291	0.0309	6.40	21.28	0.397	36.41	
145.00	0.0297	5.39	27.18	0.240	0.0299	5.69	25.50	0.276	15.38	
142.87	0.0349	3.91	23.48	0.183	0.0358	4.03	22.69	0.207	13.06	
127.45	0.0311	4.10	20.15	0.168	0.0297	4.96	23.92	0.212	26.05	
127.39	0.0311	4.05	20.24	0.164	0.0297	4.89	24.03	0.205	25.56	
127.21	0.0311	3.76	21.37	0.138	0.0297	4.48	24.43	0.171	23.82	
126.85	0.0301	3.68	20.48	0.126	0.0297	4.16	24.21	0.148	17.67	
Pool 8										
169.50	0.036	3.99	23.76	0.201	0.0360	4.41	21.39	0.255	26.52	
164.70	0.033	3.34	23.12	0.119	0.0330	3.47	22.10	0.131	9.57	
Pool 9										
187.40	0.0442	3.33	18.16	0.232	0.0442	3.65	16.67	0.286	23.62	
184.82	0.038	3.61	21.92	0.189	0.0387	3.74	21.15	0.213	12.66	
181.77	0.0349	4.61	23.18	0.255	0.0372	5.02	21.25	0.354	38.68	
181.60	0.0324	4.23	19.45	0.196	0.0323	4.64	17.68	0.242	23.45	
Dardanelle										
241.82	0.03	4.81	18.97	0.219	0.0300	5.26	17.10	0.272	23.80	
239.62	0.03	4.41	13.96	0.204	0.0300	4.63	13.22	0.229	12.25	
236.41	0.0404	4.63	13.83	0.410	0.0410	4.88	13.06	0.478	16.62	
Ozark										
285.11	0.0314	5.55	24.33	0.295	0.0312	5.67	23.70	0.306	3.95	
284.34	0.0359	4.47	25.07	0.247	0.0372	4.48	24.02	0.271	9.40	
280.16	0.0357	4.37	19.75	0.253	0.0369	4.58	18.43	0.304	20.09	
275.78	0.0355	5.30	16.22	0.393	0.0355	5.98	15.26	0.511	29.92	

14. Proposed River Training Structures

Table A-10 is the list of structures (dikes, revetments and bendway weirs) for Reach 1 through Reach 4, that have been conceptually designed based on past experience, engineering judgment, and the correlation of data from the 2-D modeling. These structures are needed in order to provide a minimum of a 12-foot deep by 250-foot wide navigation channel from NM 0.0 to NM 308.6. Dikes and revetments have been used successfully as river training structures on the Arkansas River for many years, but in the bend at NM 101 the use of bendway weirs appears to be the best type of structure to maintain the channel depth and width through the reach. This is the only location found to lend itself to the use of bendway weirs, as there is sufficient depth and width for their construction at this location. During PED it is planned to have experienced bendway weir designers (St. Louis District or ERDC) assist in the actual bendway weir locations, angles and spacing design. Plate A-1 shows the typical sections for the different type of river training structures to be used on this project. The location of the proposed new and modified structures in Arkansas and Oklahoma are shown on the maps in Appendix E.

For reaches 5 and 6 located in the Tulsa District, several areas were identified in this study, which have been continuing dredging problems. Since the deepening of the channel will result in an increased cross sectional area thus decreasing velocities more dredging may result. To keep current velocities at or near the same, finger dikes were designed that jut out from the bank to reduce the cross sectional area and restore the velocities to current or near current conditions. The top of the dike's elevation was set at the 60,000 cfs water surface profile at each location. The model HECRAS was utilized to compute the dike lengths needed for the various depths. Appendix C (Engineering), Table C4, list the locations of the finger dikes in the Tulsa District.

14.1 Impacts to Water Surface Elevations and Sediment Transport Capacity

Appendix A-1 includes the HEC-RAS modeling results for each pool as they pertain to the impacts of the proposed project. The modeling results indicate a negligible change in the 2-year and 100-year water surface elevations with the proposed project and are shown in Table A-1-1. The impacts or change to the sediment transport capacity potential are shown in Table A-19 of Appendix A-1. The HEC-RAS modeling results indicate that the MKARNS system will have approximately the same sediment transport capacity potential with the proposed project.

14.2 Impacts to Channel Stability and Tributaries

The proposed river training structures and dredging activities are expected to have minimal impacts on the main channel stability and the major tributaries. The river training structures and dredging are projected to lower the channel thalweg in localized reaches as much as three to six feet in order to maintain a 12-foot channel depth. The HEC-RAS models show negligible impacts to elevations and velocities (See Appendix A-1) between the pre- and post-project condition. The thalweg lowering will be localized in the navigation channel and typically close to the river training structures. Also, the channel degradation and/or dredging will usually take place several hundred feet from either channel bank line. The channel modifications will affect about 300 to 400 feet in a river that has a trace width of about 1000 to 1500 feet and a typical top bank width of 2000 to 3000 feet. The proposed project locations are part of a channel that currently scours and deposits during a typical flood event. Although the proposed design is intended to maintain the lower thalweg permanently, head-cutting on the main stem will not migrate very far upstream due to already existing deeper thalweg elevations that exist upstream.

Table A-10
Structures to be Raised, Extended, or Added in Arkansas
To Support a 12-Foot Navigation Channel

Navigation Mile	Structure Number	Existing Type (*1)	Construction Activity	Typical Section (*2) (Type #) Description	Existing Ground Elevation FT-NGVD	Existing Top Elevation FT-NGVD	Proposed Top Elevation FT-NGVD	Delta Length FT
POOL 2 – REACH 1								
24.2-24.7	47.3L	R	Raise	(1) Dike	146.0	163.0	164.0	0
28.1-28.5	50.2L	R	Extend	(2) Pile Dike	148.0	156.4	166.0	750
27.9	49.8R	D	Raise	(1) Dike	147.0	162.0	166.0	0
28.2	50.1R	D	Raise	(1) Dike	155.0	162.0	166.0	0
28.6	50.5R	D	Raise	(1) Dike	154.0	159.0	166.0	0
31.8-33.2	53.7-54.7L	R	Raise	(1) Dike	158.0	163.0	167.0	0
33.2	54.7L	D	Raise	(1) Dike	157.0	162.5	167.0	0
36.15	57.4L	D	Extend	(1) Dike	155/145	164.0	168.5	100
36.3	57.6L	D	Extend	(2) Pile Dike	155/145	160.0	168.5	100
36.5	57.7L	D	Extend	(2) Pile Dike	155/145	160.0	168.5	100
37.4-38.45	58.85-59.5L	D	Raise	(1) Dike	148.0	153.0	169.0	0
39.15-39.55	60.7L	R	Raise	(1) Dike	155.0	163.5	169.5	0
39.55-39.8	60.9L	R	Raise	(1) Dike	155.0	165.0	169.5	0
39.8	60.9L	D	Raise	(1) Dike	155.0	165.0	169.5	0
39.8-40.25	60.9R	R	Raise	(4) Trench Fill Revt.	155.0	165.0	169.5	0
42.7-43.05	62.93R	R	Raise	(1) Dike	160.0	165.0	171.0	0
43.1-43.4	62.97-63.62R	D	Raise	(1) Dike	160.0	165.0	171.5	0
43.65	63.50R	D	Extend	(1) Dike	160.0	160.0	172.0	250
43.8	63.62R	D	Extend	(1) Dike	160.0	160.0	172.0	300
44	NEW-R	D	NEW	(3) New Dike Const.	160.0	N/A	165.0	460
44.2	NEW-R	D	NEW	(3) New Dike Const.	160.0	N/A	165.0	460
44.4	NEW-R	D	NEW	(3) New Dike Const.	160.0	N/A	165.0	520
44.6	NEW-R	D	NEW	(3) New Dike Const.	160.0	N/A	165.0	600
46.25	68.8R	D	Extend	(1) Dike	155.0	155.0	173.0	225
46.35	69.8R	R	Extend	(1) Dike	150.0	150.0	173.0	365
46.6	68.6L	D	Extend	(1) Dike	155.0	155.0	173.0	275
46.9	68.8L	D	Extend	(1) Dike	155.0	155.0	173.0	300
48.2-48.8	72.0L	R	Extend	(4) Trench Fill Revt.	158.0	172.0	173.5	300
48.7	70.78R	D	Extend	(1) Dike	155.0	155.0	173.5	200
48.8	70.91R	D	Extend	(1) Dike	155.0	155.0	173.5	200
48.9	71.03R	D	Extend	(1) Dike	155.0	155.0	173.5	200
49	71.17R	D	Extend	(1) Dike	155.0	155.0	173.5	200
49.15	71.37R	D	Extend	(1) Dike	155.0	155.0	173.5	50
POOL 3 – REACH 1								
61.18	83.06L	D	Raise	(1) Dike	170.0	180.0	185.4	0

*1 D-Dike; R-Revetment; D/P-Pile Dike; LH-L Head; BW-Bendway Weir.
*2 See Plate 1 “Typical Sections of River Training Structures” for details (Type #).

Table A-10 (Continued)
Structures to be Raised, Extended, or Added in Arkansas
To Support a 12-Foot Navigation Channel

Navigation Mile	Structure Number	Existing Type (*1)	Construction Activity	Typical Section (*2) (Type #) Description	Existing Ground Elevation FT-NGVD	Existing Top Elevation FT-NGVD	Proposed Top Elevation FT-NGVD	Delta Length FT
POOL 4 – REACH 2								
79.3	NEW-L	D	NEW	(3) New Dike Const.	180.0	N/A	200.0	250
79.49	NEW-L	D	NEW	(3) New Dike Const.	180.0	N/A	200.0	250
79.68	NEW-L	D	NEW	(3) New Dike Const.	180.0	N/A	200.0	250
79.87	NEW-L	D	NEW	(3) New Dike Const.	180.0	N/A	200.0	250
POOL 5 – REACH 2								
96.2 - 98.4	NEW-R	R	NEW	(5) Dumped Stone	205.0	N/A	219.0	11900
96	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
96.1	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
96.2	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
96.3	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
96.4	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
96.5	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
96.6	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
96.7	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
96.8	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
96.9	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
97	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
97.1	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
97.2	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
97.3	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
97.4	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
97.5	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
97.6	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
97.7	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
97.8	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
97.9	NEW-R	D	NEW	(3) New Dike Const.	205.0	N/A	215.5	350
100.76	NEW-R	BW	NEW	(6) Bendway Weir	185.0	N/A	195.0	300
100.85	NEW-R	BW	NEW	(6) Bendway Weir	185.0	N/A	195.0	300
100.95	NEW-R	BW	NEW	(6) Bendway Weir	185.0	N/A	195.0	300
101.4	NEW-R	BW	NEW	(6) Bendway Weir	188.0	N/A	195.0	300
101.14	NEW-R	BW	NEW	(6) Bendway Weir	190.0	N/A	195.0	300
101.23	NEW-R	BW	NEW	(6) Bendway Weir	190.0	N/A	195.0	200
101.7	148.1L	LH	Raise	(1) Dike	193.0	212.0	217.8	0
101.9	148.3L	LH	Raise	(1) Dike	194.0	208.5	217.8	0
102.1	148.4L	LH	Raise	(1) Dike	190.0	204.5	217.8	0
102.4	148.7L	LH	Raise	(1) Dike	191.6	209.3	217.9	0

*1 D-Dike; R-Revetment; D/P-Pile Dike; LH-L Head; BW-Bendway Weir.
*2 See Plate 1 "Typical Sections of River Training Structures" for details (Type #).

Table A-10 (Continued)
Structures to be Raised, Extended, or Added in Arkansas
To Support a 12-Foot Navigation Channel

Navigation Mile	Structure Number	Existing Type (*1)	Construction Activity	Typical Section (*2) (Type #) Description	Existing Ground Elevation FT-NGVD	Existing Top Elevation FT-NGVD	Proposed Top Elevation FT-NGVD	Delta Length FT
POOL 7 – REACH 3								
126.9	173.2L	D	Extend	(1) Dike	235.2	242.9	251.0	150
127.1	173.4L	LH	Raise	(1) Dike	214.8	239.3	251.0	0
127.3	173.6L	LH	Raise	(1) Dike	206.3	236.3	251.0	0
127.45	173.7L	LH	Raise	(1) Dike	220.6	236.3	251.0	0
142.51	188.0R	LH	Raise	(1) Dike	239.3	251.4	254.3	0
142.51	188.0R	D	Extend	(1) Dike	239.3	245.4	254.3	50
142.69	NEW-R	D	NEW	(3) New Dike Const.	238.0	N/A	256.2	500
142.9	188.4R	D	Extend	(1) Dike	229.0	252.9	254.6	400
143.05	188.6R	D	Extend	(1) Dike	229.3	252.6	254.6	300
143.2	188.7R	D	Extend	(1) Dike	241.6	250.0	254.6	200
145.09	NEW-L	D	NEW	(3) New Dike Const.	240.0	N/A	255.3	375
145.25	NEW-L	D	NEW	(3) New Dike Const.	240.0	N/A	255.3	375
145.4	NEW-L	D	NEW	(3) New Dike Const.	240.0	N/A	255.3	400
145.55	NEW-L	D	NEW	(3) New Dike Const.	240.0	N/A	255.3	400
145.7	191.2L	D	Extend	(1) Dike	240.5	252.7	255.5	200
145.9	191.4L	D	Extend	(1) Dike	241.5	251.2	255.6	200
146.2	191.7L	D	Extend	(1) Dike	239.6	251.7	256.0	300
146.52	191.9L	D	Extend	(1) Dike	229.7	252.7	256.0	300
146.88	192.3L	D	Extend	(1) Dike	239.8	245.7	256.0	300
147.1	192.6L	D	Extend	(1) Dike	240.7	244.7	256.0	200
147.28	192.8L	D	Extend	(1) Dike	239.6	244.7	256.1	200
147.52	193.0L	D	Extend	(1) Dike	239.7	245.7	256.2	200
POOL 8 – REACH 3								
164.6	209.4L	D	Raise	(1) Dike	255.8	266.5	270.0	0
164.9	209.7L	LH	Raise	(1) Dike	230.1	250.1	270.0	0
169.27	217.3L	D	Extend	(1) Dike	253.8	260.8	273.0	100
169.4	217.4L	D	Extend	(1) Dike	250.8	260.8	273.0	100
169.5	217.5L	D	Extend	(1) Dike	257.9	260.9	273.0	50
169.6	217.6L	D	Extend	(1) Dike	256.9	260.9	273.0	150
169.8	217.7L	D	Extend	(1) Dike	260.0	271.9	273.0	250
170.1	218.1L	D/P	Extend	(2) Pile Dike	260.4	268.4	273.0	250

*1 D-Dike; R-Revetment; D/P-Pile Dike; LH-L Head; BW-Bendway Weir.
*2 See Plate 1 “Typical Sections of River Training Structures” for details (Type #).

Table A-10 (Continued)
Structures to be Raised, Extended, or Added in Arkansas
To Support a 12-Foot Navigation Channel

Navigation Mile	Structure Number	Existing Type (*1)	Construction Activity	Typical Section (*2) (Type #) Description	Existing Ground Elevation FT-NGVD	Existing Top Elevation FT-NGVD	Proposed Top Elevation FT-NGVD	Delta Length FT
POOL 9 – REACH 3								
181.5	229.4R	D	Extend	(1) Dike	266.7	284.4	288.0	150
181.8	229.7R	D	Extend	(1) Dike	265.5	283.5	288.0	150
182.2	230.0R	D	Extend	(1) Dike	273.0	282.0	288.0	150
184.6	232.1R	D	Extend	(1) Dike	278.3	282.3	288.0	100
184.9	232.4R	D/P	Extend	(2) Pile Dike	270.8	284.3	288.0	100
185.2	232.7R	D/P	Extend	(2) Pile Dike	273.8	284.3	288.0	100
185.3	232.8R	D/P	Extend	(2) Pile Dike	261.3	282.1	288.0	100
186.95 - 187.05	234.5R	VD	Raise	(1) Dike	275.0	286.0	289.0	0
187.3	234.9R	D	Raise	(1) Dike	272.6	286.0	289.0	0
189.8 - 190.5	237.9L	R	Raise	(1) Dike	279.0	287.0	290.2	0
DARDANELLE – REACH 4								
236.3	288.4R	D	Extend	(1) Dike	330.3	338.7	340.0	100
236.75 - 237.42	290.0R	R	Raise	(4) Trench Fill Revet.	317.4	339.0	340.0	0
238.95	291.3L	D	Raise	(1) Dike	326.0	336.3	340.0	0
239.28	291.6L	D	Extend	(1) Dike	329.3	336.5	340.0	50
239.8	292.3L	D	Extend	(1) Dike	329.6	338.3	340.0	50
240.15	292.5L	D	Extend	(1) Dike	321.4	335.0	340.0	100
240.46	292.9L	D	Extend	(1) Dike	333.0	339.0	340.0	100
240.78	293.1L	D	Extend	(1) Dike	335.6	337.9	340.3	100
241.05	293.4L	D	Extend	(1) Dike	327.6	337.3	340.5	100
241.05 - 241.5	293.7L	R	Extend	(4) Trench Fill Revet.	325.5	335.5	340.5	100
241.5	293.7R	D	Extend	(1) Dike	328.6	337.0	340.5	100
241.73	293.9R	D	Extend	(1) Dike	327.5	340.8	342.0	200
242	294.1R	D	Extend	(1) Dike	330.9	337.8	342.0	200
242.12	294.3R	D	Extend	(1) Dike	330.0	339.8	342.0	200
242.28	294.4R	D	Extend	(1) Dike	330.8	342.5	342.0	200

*1 D-Dike; R-Revetment; D/P-Pile Dike; LH-L Head; BW-Bendway Weir, VD-Vain Dike.
*2 See Plate 1 “Typical Sections of River Training Structures” for details (Type #).

Table A-10 (Continued)
Structures to be Raised, Extended, or Added in Arkansas
To Support a 12-Foot Navigation Channel

Navigation Mile	Structure Number	Existing Type (*1)	Construction Activity	Typical Section (*2) (Type #) Description	Existing Ground Elevation FT-NGVD	Existing Top Elevation FT-NGVD	Proposed Top Elevation FT-NGVD	Delta Length FT
OZARK – REACH 4								
275.15	327.6L	D	Raise	(1) Dike	361.3	373.3	374.5	0
275.25	327.7R	D	Raise	(1) Dike	354.8	364.2	374.5	0
275.3	327.9L	D	Raise	(1) Dike	356.0	357.0	374.5	0
275.49	328.0L	D/R	Raise	(1) Dike	355.8	364.8	374.5	0
275.55	328.0R	D	Raise	(1) Dike	362.7	366.8	374.6	0
275.85	328.4R	D	Raise	(1) Dike	356.8	357.0	374.8	0
276.2	328.7R	D	Raise	(1) Dike	356.8	369.0	375.0	0
279.58	333.6R	D	Extend	(1) Dike	352.8	373.3	376.0	200
279.8	333.8R	D	Extend	(1) Dike	361.8	373.2	376.3	200
280.05	333.9R	D	Extend	(1) Dike	357.8	373.8	376.8	200
278.9 - 280.25	334.0L	R	Raise	(1) Dike	362.1	371.8	376.5	0
280.2	334.0R	D	Extend	(1) Dike	358.8	373.6	376.6	100
280.3 - 280.6	334.3R	R	Extend	(4) Trench Fill Revet.	361.3	374.0	376.7	400
280.48	334.3L	D	Extend	(1) Dike	356.8	372.2	376.7	100
280.67	NEW-L	D	NEW	(3) New Dike Const.	365.0	N/A	376.9	700
280.86	NEW-L	D	NEW	(3) New Dike Const.	365.0	N/A	377.0	450
283.76	NEW-R	D	NEW	(3) New Dike Const.	365.0	N/A	378.3	100
283.35 - 283.8	337.5L	R	Raise	(1) Dike	359.6	374.0	378.3	0
283.95	NEW-R	D	NEW	(3) New Dike Const.	365.0	N/A	378.5	100
284.1	NEW-R	D	NEW	(3) New Dike Const.	365.0	N/A	378.5	100
285.4	339.4R	LH	Raise	(1) Dike	360.6	375.2	381.0	0
285.4	NEW-L	D	NEW	(3) New Dike Const.	365.0	N/A	379.0	400
285.65	339.5L	D	Raise	(1) Dike	357.5	374.6	379.1	0
285.9	339.7L	D	Raise	(1) Dike	359.5	373.0	379.2	0

*1 D-Dike; R-Revetment; D/P-Pile Dike; LH-L Head; BW-Bendway Weir.
*2 See Plate 1 “Typical Sections of River Training Structures” for details (Type #).

In the event of the worst case, the channel degradation could only migrate to the grade control structures, the lock and dams. Degradation from 2 to 10 feet has occurred at every lock and dam over the previous 30+ years, as was anticipated in the original design of the lock and dams. Consequently, this makes available a 12-foot channel depth at these locations. The degradation that has taken place has had minimum impacts to the current channel stability. Also, there are no known impacts to any of the major tributaries. For the major tributaries, degradation in the Arkansas River has not caused any known head-cutting problems to-date. All localized main channel thalweg lowering will be far enough removed from the tributary mouths, the tributaries will be emptying into a stable pool or flow profile that has not significantly changed, and the mouths of the tributaries are mostly separated from the main river by river training structures, that induced head-cutting in the tributaries will not occur.

15. Navigation Locks

There are 18 locks on the MKARNS with all having the same usable lock chamber dimensions of 110 feet wide by 600 feet long. Potential impacts of deeper barge drafts on the existing locks and structures include insufficient lock sill clearance, excessive turbulence during lock filling and emptying, entrance and exit safety due to out draft currents and barge impacts to the approach walls. To reduce costs for modifying existing structures, the study addressed possible solutions such as, changes in towboat operation, i.e., entering and exiting speeds, and changes to the filling and emptying procedures.

15.1 Lock Sill Depths

On the MKARNS, 15 locks have a minimum depth at the downstream (d/s) sill of 14 feet below the navigation pool (MPLD d/s sill depth is 15.5 feet based on the design guidance in 1992. Norrell d/s sill depth is 18 feet based on the MPLD project that maintains a minimum pool elevation of 115 feet. Ozark d/s sill depth is 15 feet for unknown reason). And at the upstream sills the minimum sill depth is 15 feet at five of the locks, under typical project operations. EM 1110-2-1604, Hydraulic Design of Navigation Locks, states, “A sill depth less than 1.5 times the tow draft (1.5d), except for very–low-lift (0-10 ft) locks, should not be considered due to safety reasons.” This criterion is exceeded at all locks for the 8.5-foot draft (1.5x8.5 = 12.75 ft). The proposed 11.5-foot draft does not meet this design criteria (1.5x11.5 = 17.25 ft) for the clearance over the upstream or downstream lock sills at any of the locks except the upstream sill at Ormond (#9) and the downstream sill at Norrell (#1). Based on the 1.5d criterion, the minimum sill depth would need to be 17.25 feet. Additional design guidance, EP 1110-2-14 states, "Ideally, depth over the sill of twice the tow design draft (example: 18-ft depth over the sill for a 9-ft draft) should be available 95 percent of the time, and minimum clearance of 1.7 times the draft should be available 100 percent of the time." With the proposed 11.5-foot draft, the minimum sill clearance is reduced to 2.5 feet at most of the downstream sills and provides a depth to draft ratio of 1.22 (14/11.5). Table A-11, Lock Sill and Chamber Data for the MKARNS, shows the draft ratios (Sd/Draft) for each lock. Disregard to the 1.5d guidance increases the risk of a barge or tow striking and damaging a lock sill. On the MKARNS this risk will increase as the minimum depth at several locks occurs a significant amount of time during the low flow season. Table A-12, Percent Time Minimum Navigation Depths at Downstream Sills, indicates that, for hourly readings examined, during the low flow season, August through October for 1999-2003, there was a significant duration that this minimum depth (14 feet) occurred at the downstream lock sills at Lock 4 (12%), Lock 5 (31%) and Lock 7 (14%).

15.2 Tow Squat

Tow squat is the vertical drop of the tow due to motion, measured from the still water level. There are four mechanisms for producing tow squat that have been acknowledged: (1) Displacement squat, (2) Piston squat, (3) Propeller squat, and (4) Moment squat. It is this squat phenomenon that necessitates the existing sill depth guidance (EM 1110-2-1604) of 1.5d for safe sill clearance. WES Technical Report HL-87-3, Safe Navigation Speeds and Clearance at Lower Sill, Temporary Lock 52, Ohio River, investigated this squat issue. Tow squat is reduced for entering and exiting tows when the valves to the discharge culvert remain open. Publication ERDC/CHL TR-00-13 states, "Based on these model and prototype experiences, clearance beneath the design vessel should be 0.61-0.91 m (2-3 ft) to prevent the tow from striking the sill." However, most of the observations tests were with 9-foot drafts and with the model tests the maximum draft was 10 feet. Discussions with lockmasters on the Mississippi, Tennessee, Illinois and Ohio Rivers and the GIWW were conducted in December 2003. The lockmasters were asked about the allowable draft at the minimum sill depth or clearance at their projects. The lockmaster at Peoria Lock stated that most drafts were 9-foot with a 12-foot minimum depth and that he would not want less than a 3-foot clearance. In addition, at a 14-foot depth (5-foot clearance) safety measures are required for the tows entering the lock. Lockmaster at Old River Lock (GIWW) stated most drafts are 9 to 10 feet with a minimum depth at 16 feet, but suggested that 14-foot should be the minimum for 9 to 10-foot drafts. Lockmaster at McAlpine Lock said, "We do not have any problems with drafts at 10 feet for the minimum 14-foot depth, but I don't know if that would be the case at a 12-foot depth." The electrician at Kentucky Lock stated that drafts of 10 and 10.5 feet are typical and drafts up to 11 and 11.5 feet occur. There have been tows that have drug the sill but no damage reported. Lockmaster at Lock 52 stated that the sill has been damaged at least three (3) times. The last incident was in 2001 when the Daytona was drafting 10 feet with a water depth of 12 feet (2 feet of clearance). The Daytona struck the lower sill when exiting the lock. The Daytona was damaged as it lost its propeller on the steel plated sill. No significant damage was done to the sill due to the sill's steel-plate cap modification. This modification to the concrete sill was installed after a previous incident did significant damage to the sill, which kept the lock out of service for 6 months. Lock 52 has a draft limit of 9 feet and 3 inches when water depth falls to 12 feet (2.75 feet of clearance).

15.3 Filling and Emptying Systems

EM 1110-2-1604 states that for low-lift designs (10-30/40 ft), "For Side Port (SP) locks, acceptable chamber performance is obtained during hydraulic feature design for a specific filling time and specific commercial traffic (9-ft draft tows) because of tested relationships between lift, chamber dimensions, submergence, port dimensions, baffles, and valving. An 8-min operation time is a common goal for lifts near midrange, 25 ft." The side port design at sixteen (16) of the locks on the MKARNS was based on model tests as documented in WES TR No. 2-743, "Filling and Emptying Systems Low Lift Locks Arkansas River Projects". From the results of these tests it was recommended that the design of sidewall port systems for 110- by 600-foot locks on the Arkansas River to have: (1) Port-to-culvert area ratio of about 0.95, (2) Ports should be spaced 28 feet on centers, (3) Port manifold should cover at least 50 percent of chamber length, (4) Port manifold should be approximately centered in the lock chamber, (5) Triangular recesses/deflectors should be installed in front of the upstream one-third of the ports, (6) Ports with throat areas in the 9- to 10-square-foot range should be used in low-lift projects with

Table A-11
Lock Sill and Chamber Data
McClellan-Kerr Arkansas River Navigation System

LOCK	No.	U/S Navigation Pool (HW)	U/S* Minimum Pool (HW)	U/S Sill	U/S Sd	U/S Sd/Draft	D/S Navigation Pool (TW)	Chamber Floor	Cd**	D/S Sill	D/S Sill Height	D/S*** Sd	D/S Sd/Draft	D/S Sd/Draft
		Elevation	Elevation	Elevation	Feet	11.5’	Elevation	Elevation	Feet	Elevation	Feet	Feet	8.5’	11.5’
MPLD	0	115	115	99.5	15.5	1.35	95	77.5	17.5	79.5	2	15.5	1.82	1.35
Norrell	1	142+	142	126	16	1.39	115	20	20	97	2	18	2.12	1.57
No. 2	2	162++	161	144	17	1.48	142+	15	15	128	1	14	1.65	1.22
Joe Hardin	3	182	180	164	16	1.39	162+	15	15	148	1	14	1.65	1.22
Emmett Sanders	4	196	194	178	16	1.39	182	17	17	168	3	14	1.65	1.22
No. 5	5	213++	211	195	16	1.39	196	17	17	182	3	14	1.65	1.22
David D. Terry	6	231	230	213	17	1.48	213+	17	17	199	3	14	1.65	1.22
Murray	7	249	247	231	16	1.39	231	29	29	217	17	14	1.65	1.22
Toad Suck Ferry	8	265	263	247	16	1.39	249	17	17	235	4	14	1.65	1.22
Arthur V. Ormond	9	284	284	266	18	1.56	265	18	18	251	4	14	1.65	1.22
Dardanelle	10	336	336	321	15	1.30	284	21	21	270	7	14	1.65	1.22
Ozark-Jeta Taylor	12	370	370	354	16	1.39	336	27	27	321	2	15	1.76	1.30
James W. Trimble	13	391	389	374	15	1.30	370	17	17	356	4	14	1.65	1.22
W. D. Mayo	14	412	412	397	15	1.30	391	18	18	377	4	14	1.65	1.22
Robert S. Kerr	15	458	458	442	16	1.39	412	15	15	398	1	14	1.65	1.22
Webbers Falls	16	487	487	471	16	1.39	458	21	21	444	7	14	1.65	1.22
Chouteau	17	511	511	496	15	1.30	487	25	25	473	5	14	1.65	1.22
Newt Graham	18	532	532	517	15	1.30	511	18	18	497	4	14	1.65	1.22

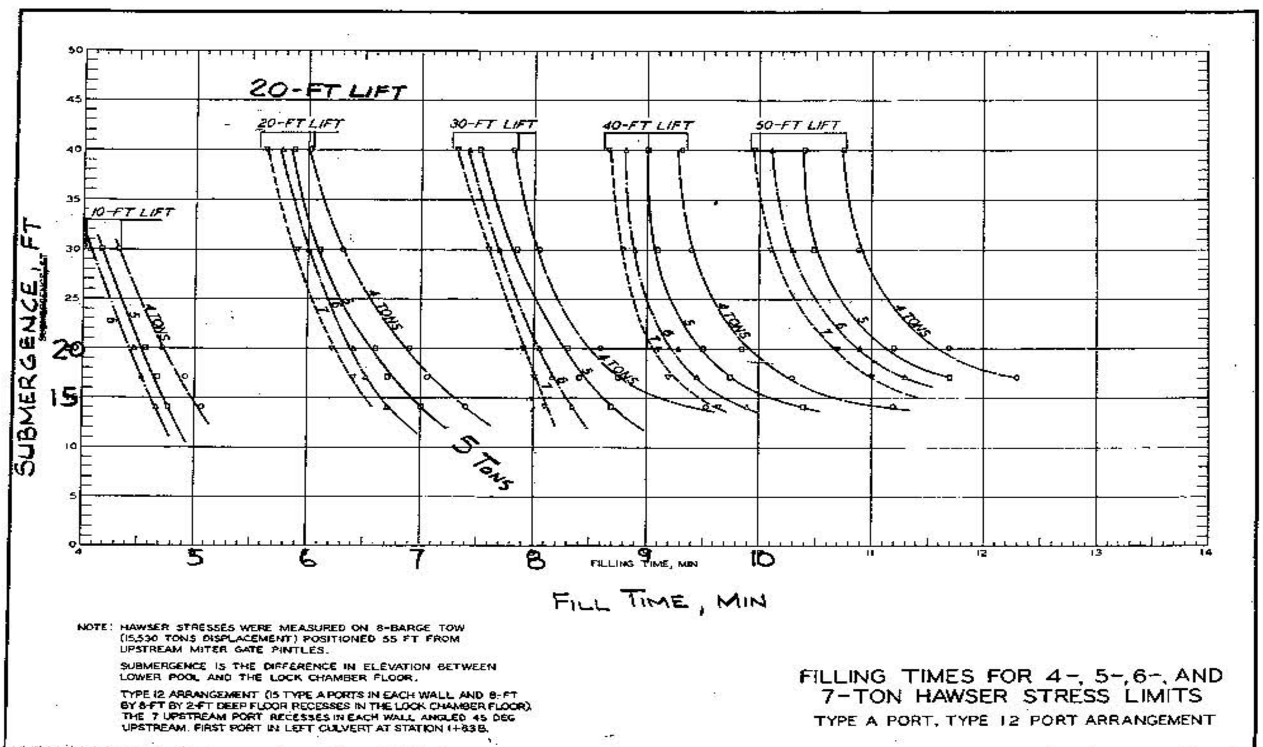
+ Canal pool elevation raised to 143.0 with a weir extension.
++ Pool 2 and Pool 5 have seasonal (May-Sep) pools of 163.0 and 214.0, respectively.
* Minimum Pool based on normal operation in the Little Rock District for flows exceeding 100,000 cfs (See Table A-1)
** Cd – Chamber depth or submergence
*** Sd – Minimum sill depth (Norrell Sd based on MPLD minimum headwater at 115.0)

Table A-12
Percent Time Minimum Navigation Depths Occur at Downstream Sills

Location	Lower Sill	Nav Pool	Percent Time Navigation Depth is Equal or Less Than				
Lock Approach	ELEV	ELEV	14.0	14.1	14.5	15.0	Comments
	NGVD	NGVD	FT	FT	FT	FT	
LD13	356	370	0	1	2	7	Daily MN (POR ’70-’03) Ozark power pool: 370-372
OZA	321	336	0	0	0	0	Daily MN (POR ’71-’03) Dar power pool: 336-338
DAR	270	284	0	0	1	4	Daily MN (POR ’70-03) Pool 9 re-reg pool: 284-287
LD09	251	265	5	8	20	29	Daily MN (POR ’70-’03)
			4	10	60	80	1-hr data for AUG-OCT, 1999-2003
LD08	235	249	1	1	7	16	Daily MN (POR ’70-’03)
			1	2	8	18	6-hr data (POR ’70-’03)
			3	4	24	49	1-hr data for AUG-OCT, 1999-2003
LD07	217	231	5	9	35	51	Daily MN (POR ’70-’03)
			14	28	86	99	1-hr data for AUG-OCT, 1999-2003
LD06	199	213	5	8	19	32	Daily MN (POR ’69-’03) Pool 5 seasonal pool May-Sep (214)
			8	12	41	76	1-hr for AUG-OCT, 1999-2003
LD05	182	196	7	12	27	38	Daily MN (POR ’69-’03)
			31	52	85	96	1-hr data for AUG-OCT, 1999-2003
LD04	168	182	4	7	24	39	Daily MN (POR ’69-’03)
			4	8	25	39	6-hr data (POR ’69-’03)
			12	22	74	95	1-hr data for AUG-OCT, 1999-2003
LD03	148	162	2	3	9	17	Daily MN (POR ’69-’03) Pool 2 seasonal pool May-Sep (163)
			2	3	10	20	1-hour data (POR ’96-’03)
			4	6	22	51	1-hr data for AUG-OCT, 1999-2003

submergences of at least 15 feet. The proposed 11.5-foot barge drafts do not meet the current design criteria for the clearance above the filling and emptying side ports in the locks. The proposed 11.5-foot drafts would reduce the minimum design clearance from 5 feet to 2 feet at most of the locks, and could cause the hawser forces to exceed the stress limit guidance of 5-tons. See Figure A-2, Hawser Forces versus Fill Times, for original modeling design data. Although changes in gate valve operations would reduce hawser force impacts, these impacts due to the deeper drafts are unknown. A December 2003 telephone survey with the electrician at Kentucky Lock revealed that barges drafting up to 11 and 11.5 feet create a problem with hawsers breaking. The current filling and emptying times at all the locks, except Dardanelle and Ozark, have a maximum time, when occupied, of about 8 minutes with no problems with hawsers breaking. For Dardanelle and Ozark the maximum time is a little more than 10 minutes. The Dardanelle and RS Kerr Locks are high-lift designs and have bottom lateral filling systems, which are designed to produce very uniformly distributed flows during lock filling and emptying and no increase in hawser forces from hydraulic flow conditions are anticipated.

Figure A-2
Hawser Forces versus Fill Times



15.4 Upstream Lock Approaches

Increasing the draft of the barges will affect the maneuverability of the tow as it enters or exits upstream because the ports or openings in the guard wall will not have the recommended clearance of 4 to 6 feet as recommended in EM 1110-2-1611, “Layout and Design of Shallow-Draft Waterways”. See Table A-13, Lock Chamber Ports, Guard Wall Openings and Manifold

Openings Data, for the clearances at each lock. This reduced clearance could alter the out draft and draw, and thus, entering barges could strike the upper guard walls more often and exiting tows could get pinned against the walls. The increase in draft to 11.5 feet will increase the barge mass by about 35 (11.5/8.5) percent and this translates to higher impact forces to the semi-gravity approach walls.

ERDC conducted an evaluation of all the upstream lock approaches. This evaluation was based on guidance in EM 1110-2-1611 and the results of recently completed Lock Approach Guidance research, ERDC/CHL TR-04-4. Based on this review, ERDC recommends that the projects having the highest potential for approach problems be evaluated with the use of a physical model. This evaluation may require only a single model study, but possibly as many as four model studies may be needed to answer the effects of the deeper draft vessels on navigation conditions in the upper lock approaches.

15.5 Entry and Exit Speeds and Transit Times

Presently the regulations for the MKARNS allow tow speeds up to 200 feet per minute (3.33 feet per second) when entering and exiting the locks unless the lockmaster deems conditions warrant slower speeds. Example: At Dardanelle Lock, prevailing winds and guard wall alignment have made it necessary for the standard locking procedure of down bound tows to come to a complete stop at the upstream guard wall before proceeding into the lock. However, the speed of a tow is naturally limited when navigating in a confined area such as a canal or lock. Therefore, the relationship of the sill to the bottom of the tow will limit the speed of entering and exiting tows. A method for computing “limiting speed” in canals was presented by Jansen and Schijf. Although their method cannot be used to quantify speeds in a lock, their concept is valid and WES Technical Report HL-87-3 (Figure 5) shows that the limiting speed for tows moving in a canal to be 3.3 feet per second at an 8.5-foot draft with a 14-foot depth. Extrapolation of this figure indicates that the “limiting speed” of a tow would drop to about 1.25 feet per second for an 11.5-foot draft with a 14-foot depth. ERDC/CHL TR-00-13 presents the work of Kooman who utilized the “limiting speed” concept to compute lock entry and exit times based on the relationship of the tow draft to the lock sill/lock chamber area or the blockage factor (BF). Table A-14, Effects of Lock Sill and Chamber Depth on Transit Time, shows the relative increase in transit times at each lock between an 8.5-foot and 11.5-foot draft tow.

Table A-13
Lock Chamber Ports, Guard Wall Openings and Manifold Openings Data
McClellan-Kerr Arkansas River Navigation System

LOCK	Lock	Minimum Navigation Pool	Min TW	Lock Chamber Top of Ports	Lock Chamber Port Clearance	U/S Guard Wall Top of Opening	U/S Guard Wall Opening Clearance	Top of U/S Intake Manifold	U/S Intake Manifold Clearance	Top of D/S Discharge Manifold	D/S Discharge Manifold Clearance
	No.	Elev.	Elev.	Elev.	11.5-ft Draft	Elev.	11.5-ft Draft	Elev.	11.5-ft Draft	Elev.	11.5-ft Draft
MPLD	0	115	95	81.0	2.5	Varies	1.5	102	1.5	82	1.5
Norrell	1	143	115	96.5	7	135	-3.5	127	4.5	100	3.5
No. 2	2	161	143	128.5	3	157	-7.5	145	4.5	132	-0.5
Joe Hardin	3	180	162	148.5	2	168	0.5	165	3.5	152	-1.5
Emmett Sanders	4	194	182	168.5	2	182	0.5	177	5.5	172	-1.5
No. 5	5	211	196	182.5	2	200	-0.5	196	3.5	186	-1.5
David D. Terry	6	230	213	199.5	2	217	1.5	214	4.5	203	-1.5
Murray	7	247	231	205.5	14	234	1.5	231	4.5	209	10.5
Toad Suck Ferry	8	263	249	235.5	2	251	0.5	248	3.5	239	-1.5
Arthur V. Ormond	9	284	265	251.5	2	272	0.5	267	5.5	255.08	-1.6
Dardanelle	10	336	284	263	9.5	328	-3.5	NA	NA	NA	NA
Ozark-Jeta Taylor	12	370	336	319.5	5	357	1.5	346	12.5	NA	NA
James W. Trimble	13	389	370	356.5	2	378	-0.5	374	3.5	360	-1.5
W. D. Mayo	14	412	391	377.5	2	402	-1.5	400	0.5	381	-1.5
Robert S. Kerr	15	458	412	389	11.5	445	1.5	436	10.5	NA	NA
Webbers Falls	16	487	458	440.5	6	474	1.5	472	3.5	NA	NA
Chouteau	17	511	487	473.5	2	500	-0.5	496	3.5	477	-1.5
Newt Graham	18	532	511	497.5	2	522	-1.5	517	3.5	NA	NA

Note: The filling and emptying ports at Lock 10 and the emptying ports at Locks 12, 15, 16, and 18 are located outside of the lock approaches.
(-) Negative number indicates that 11.5-ft draft barge extends below the opening.

Table A-14
Effects of Lock Sill and Chamber Depth on Transit Time

LOCK	No.	Lock Sill Area	Lock Chamber Area	LCA/LSA	Blocking Factor (BF)	Blocking Factor (BF)	Entry Time	Entry Time	Entry Time	Exit Time	Exit Time	Exit Time
		sq ft	sq ft	R <= 1.3*	8.5’	11.5’	8.5’	11.5’	Incr. In Min	8.5’	11.5’	Incr. In Min
MPLD	0	1705	1925	1.1	0.50	0.68	9.0	13.2	**4.2**	6.3	8.2	**1.9**
Norrell	1	1980	2200	1.1	0.43	0.59	7.8	10.9	**3.1**	5.7	7.2	**1.5**
No. 2	2	1540	1650	1.1	0.57	0.77	10.4	16.0	**5.6**	6.9	9.4	**2.4**
Joe Hardin	3	1540	1650	1.1	0.57	0.77	10.4	16.0	**5.6**	6.9	9.4	**2.4**
Emmett Sanders	4	1540	1870	1.2	0.54	0.73	9.8	14.8	**5.0**	6.7	8.9	**2.2**
No. 5	5	1540	1870	1.2	0.54	0.73	9.8	14.8	**5.0**	6.7	8.9	**2.2**
David D. Terry	6	1540	1870	1.2	0.54	0.73	9.8	14.8	**5.0**	6.7	8.9	**2.2**
Murray	7	1540	3410	**2.2**	0.53	0.71	9.5	14.2	**4.7**	6.5	8.7	**2.1**
Toad Suck Ferry	8	1540	1870	1.2	0.54	0.73	9.8	14.8	**5.0**	6.7	8.9	**2.2**
Arthur V Ormond	9	1540	1980	1.3	0.53	0.72	9.6	14.3	**4.8**	6.6	8.7	**2.1**
Dardanelle	10	1540	2310	**1.5**	0.53	0.71	9.5	14.2	**4.7**	6.5	8.7	**2.1**
Ozark-Jeta Taylor	12	1650	2970	**1.8**	0.49	0.67	8.8	12.9	**4.0**	6.2	8.1	**1.9**
James W. Trimble	13	1540	1870	1.2	0.54	0.73	9.8	14.8	**5.0**	6.7	8.9	**2.2**
W. D. Mayo	14	1540	1980	1.3	0.53	0.72	9.6	14.3	**4.8**	6.6	8.7	**2.1**
Robert S. Kerr	15	1540	1650	1.1	0.57	0.77	10.4	16.0	**5.6**	6.9	9.4	**2.4**
Webbers Falls	16	1540	2310	**1.5**	0.53	0.71	9.5	14.2	**4.7**	6.5	8.7	**2.1**
Chouteau	17	1540	2750	**1.8**	0.53	0.71	9.5	14.2	**4.7**	6.5	8.7	**2.1**
Newt Graham	18	1540	1980	1.3	0.53	0.72	9.6	14.3	**4.8**	6.6	8.7	**2.1**

Based on ERDC/CHL TR-00-13: Eq. 5 – Entry Time: Te=6.11exp(2.16BF)/2: Eq 6 – Exit Time: Te=5.90exp(1.51BF)/2
Equation 5 and 6 were divided by 2 to convert from the 1200’ length barge data to 600’ barges
*Kooman’s data limited to 1.3 ratio
Blocking Factor (BF) = (Beam)(Draft)/{(Lock Chamber Area + 2*Lock Sill Area)/3}
Lock Width = 110 ft; Beam = 105 ft; Barge Draft = 8.5 ft & 11.5 ft
Data based on tow approach speed of 1 m/s (2.24 mph)
Existing Regulations on MKARNS allow entry and exit speeds of 200 ft/m (1.0 m/s)

15.6 Prototype Tests by ERDC at Lock 2

Sill clearance and lock filling and emptying issues are typically addressed with physical models. For this study, prototype tests at Lock 2, located in the canal at N.M. 13.3, were conducted by ERDC from 7 September through 22 September 2004 in order to determine how the 11.5-foot drafting barges would react to various obstacles while navigating the locks on the MKARNS. These field tests address the issues as presented in paragraphs 15.1, 15.2, 15.3, and 15.5 and determine whether the proposed 11.5-foot draft barges can be successfully and safely used with the existing lock structures and operations. The field tests included 15 barges drafting 11.5 feet, a crew, and a towboat to evaluate the potential following impacts: (1) for a barge to strike the end sill at the minimum navigation depth of 14.0 feet, (2) for a sill strike with the surge problem at Lock 2, (3) on filling and emptying times, (4) on increases in hawser forces, and (5) on transit times for tows through the lock. The report on the field tests is included in Appendix A-3.

The findings based on these prototype tests for barges that draft 11.5 feet include: (1) There will be a negligible chance of the barges striking the downstream lock sill when the minimum expected tailwater depth of 14 feet occurs at the MKARNS projects. (2) It is highly unlikely that the barges will strike the downstream lock sill at Lock 2 due to surging in the canal. (3) Some operational changes at Lock 2 will be required in order to reduce the chance of a barge striking the upstream miter gate. (4) The current filling and emptying operations will be satisfactory for all the side port system locks, except the Ozark and Webbers Falls projects due to the greater lifts of 34 and 30 feet, respectively. ERDC recommends using the numerical models HAWSER and LOCKSIM to determine the impacts to hawser forces and lock filling and emptying times for these projects. (5) The results of the tests on the barges moored downstream of the lock discharge are shown in Table 11 of Appendix A-3.

16. Dredging History

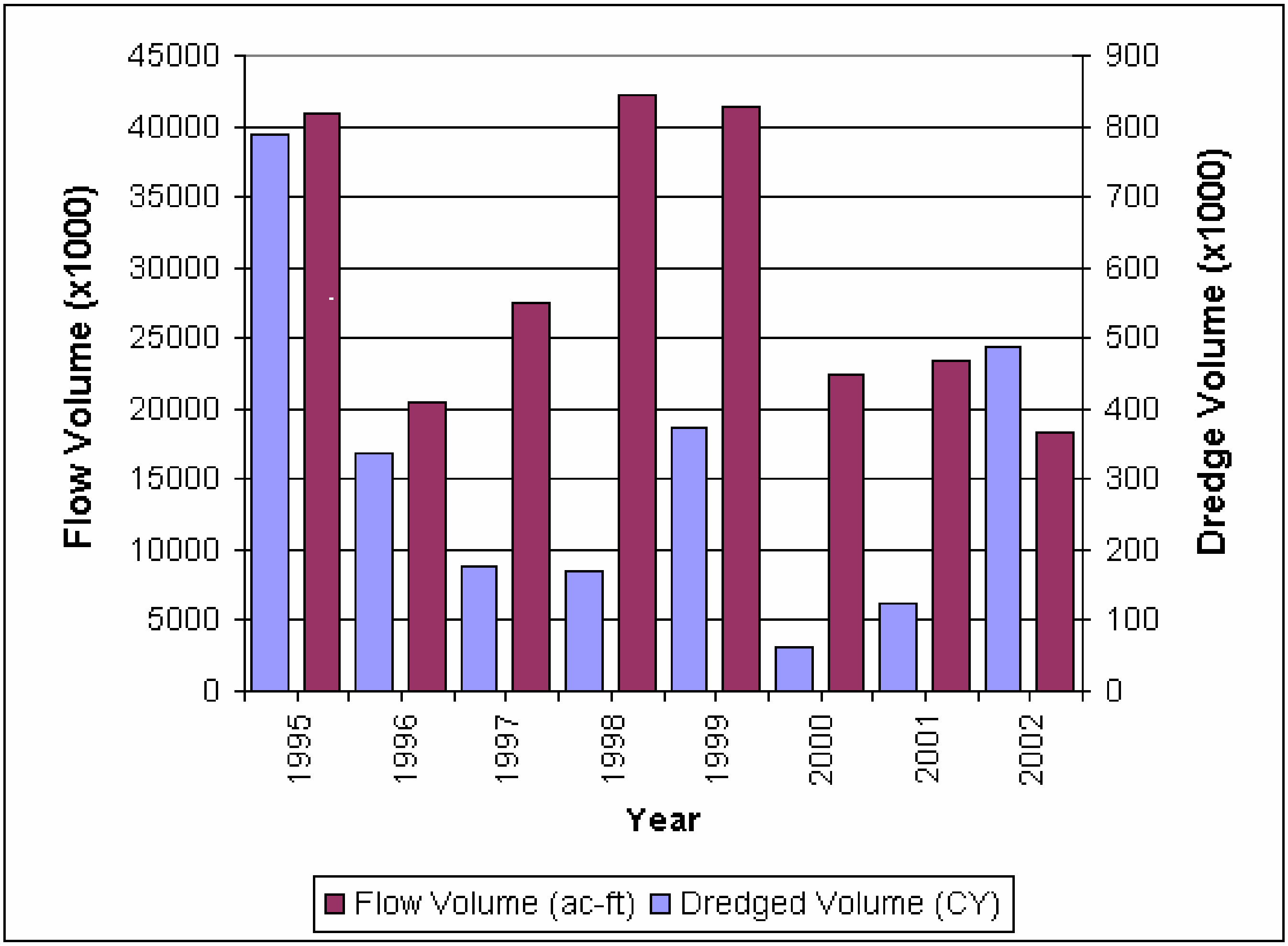
Dredging records for the MKARNS were available from 1995 through 2002 and are shown in Table A-15. Also, the Arkansas River dredging history from 1969 through 1994 was documented in a 1995 paper written by Tasso Schmidgall of Southwestern Division. This paper was titled “Twenty-Six Years of Dredging on the Arkansas River”. From these sources, dredging volumes averaged 3.5 million cubic yards (MCY) for 1971-1978, 1.3 MCY for 1979-1986, 1.2 MCY for 1987-1994, and 0.3 MCY for 1995-2002. The average flow volumes at Little Rock for these periods were 33.5, 33.0, 40.3, and 35.2 million acre-feet, respectively. These numbers reflect a continued decrease in the amount of sediment that is being transported and deposited in the navigation channel of the MKARNS. Figure A-3 shows the yearly dredge volumes and flow volumes for the period 1995-2002. Dredging and flow data for the period 1970 through 1994 is shown in Appendix A-1, Table 20. The Corps has not collected Arkansas River suspended sediment samples since 1981. The average sediment load for 1972-1981 was estimated (Tasso Schmidgall) at 7.8 million tons per year (MT/Y). Also, the sediment load at Little Rock was computed in the Arkansas-White River Cutoff Project Feasibility Study (1999) and estimated from 4.6 MT/Y to 13.3 MT/Y. However, three suspended sediment samples were collected and analyzed by the USGS during this study with all showing a decrease in the concentration of suspended sediments. The suspended sediment load curve based on these USGS measurements (Appendix A-4) and the estimated suspended sediment concentration used in the sediment transport 2-D modeling is shown on Figure A-4 (upper curve). It indicates a downward shift in the sediment load concentrations from the pre-1981 data. With this latest estimated sediment load concentration and using the flow duration of the proposed regulation plan (SUPER RUN A02X10), the sediment load is 2.8 MT/Y as shown in Table A-16.

Table A-15
Arkansas River Dredging History from 1995-2002

LOCATION	1995	1996	1997	1998	1999	2000	2001	2002	Total CY	CY/YR
	C.Y.	C.Y.	C.Y.	C.Y.	C.Y.	C.Y.	C.Y.	C.Y.	C.Y.	C.Y.
Pool 2	222,756	101,758	18,960		105,555	55,336	37,936	96,615	638,916	79,864
Lock 3	78,486	54,561	44,977	36,948	21,019		10,093		246,084	30,761
Pool 3		24,434							24,434	3,054
Lock 4			5,689	19,772	16,261		4,425		46,147	5,768
Lock 5		5,305	3,263	8,061	10,179		3,755		30,563	3,820
Pool 5				40,568					40,568	5,071
Lock 6							6,990		6,990	874
Pool 7					26,060		19,046	26,233	71,340	8,917
Pool 8	37,703								37,703	4,713
Lock 10				29,385					29,385	3,673
Pool 10	122,300			35,637		8,096		41,811	207,844	25,981
Pool 12	95,343						61,605	82,472	239,420	29,927
Pool 13								23,425	23,425	2,928
Lock 14					19,445				19,445	2,431
Pool 14	62,214								62,214	7,777
Pool 16	75,486	147,988	102,894		82,530			151,606	560,503	70,063
Pool 17	50,171	3,328							53,499	6,687
Lock 18					91,404			91,404	182,807	22,851
Pool 18	42,777								42,777	5,347
YEAR TOTAL	787,237	337,374	175,783	170,372	372,453	63,432	143,850	513,566	2,564,065	320,508

Note: To convert from Cubic Yards to Tons multiply by 1.3.

Figure A-3
Yearly Flow Volumes and Dredge Volumes
1995-2002



Note: Yearly-dredging volumes may not necessarily be attributed to yearly flow.

Figure A-4
Current and Previous Suspended Sediment Concentration at Little Rock

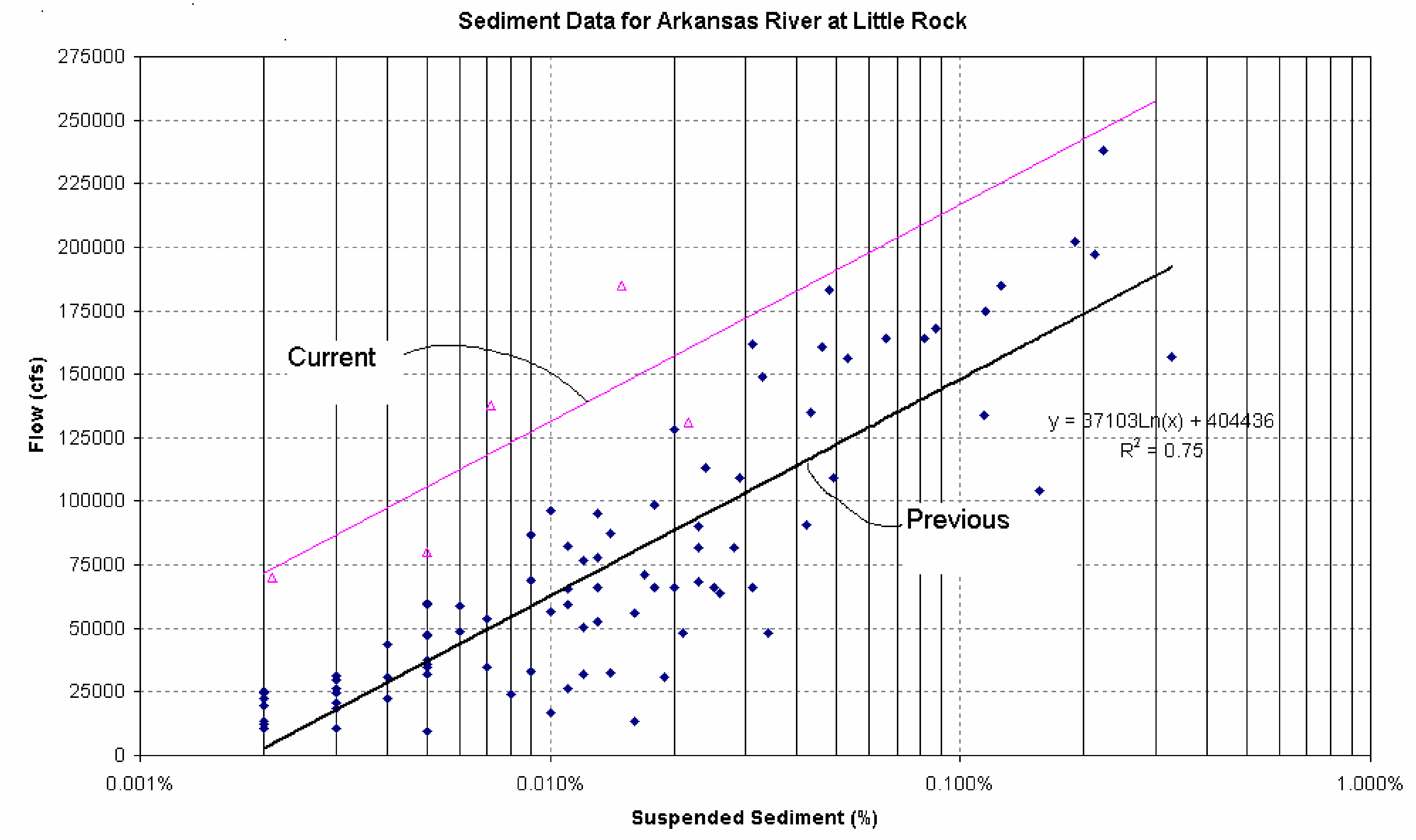


Table A-16
Estimated Annual Average Suspended Sediment Load for Arkansas River at Little Rock

Percent of Time Flow is Equal or Exceeded	Flow	Suspended Sediment from Regression Equation	Increm.	No. of	Volume of Water	Weight of Water	Weight of Sediment
	CFS	# Sed / # Water	Percent	Days / Yr	Cu. Ft.	Tons	Tons
100%	652	0.000007	5%	18.25	1.03E+09	3.21E+07	2.14E+02
95%	3539	0.000007	5%	18.25	5.58E+09	1.74E+08	1.23E+03
90%	5143	0.000007	5%	18.25	8.11E+09	2.53E+08	1.84E+03
85%	6339	0.000007	5%	18.25	1.00E+10	3.12E+08	2.33E+03
80%	8530	0.000008	5%	18.25	1.35E+10	4.20E+08	3.28E+03
75%	10359	0.000008	5%	18.25	1.63E+10	5.10E+08	4.13E+03
70%	12748	0.000009	5%	18.25	2.01E+10	6.27E+08	5.33E+03
65%	16313	0.000009	5%	18.25	2.57E+10	8.03E+08	7.33E+03
60%	19878	0.000010	5%	18.25	3.13E+10	9.78E+08	9.61E+03
55%	23613	0.000011	5%	18.25	3.72E+10	1.16E+09	1.23E+04
50%	27884	0.000012	5%	18.25	4.40E+10	1.37E+09	1.58E+04
45%	32639	0.000013	5%	18.25	5.15E+10	1.61E+09	2.04E+04
40%	37395	0.000014	5%	18.25	5.90E+10	1.84E+09	2.57E+04
35%	43719	0.000016	5%	18.25	6.89E+10	2.15E+09	3.42E+04
30%	50043	0.000018	5%	18.25	7.89E+10	2.46E+09	4.45E+04
25%	58583	0.000021	5%	18.25	9.24E+10	2.88E+09	6.19E+04
20%	68336	0.000026	5%	18.25	1.08E+11	3.36E+09	8.79E+04
15%	84852	0.000037	5%	18.25	1.34E+11	4.17E+09	1.52E+05
10%	120763	0.000075	5%	18.25	1.90E+11	5.94E+09	4.48E+05
5%	157455	0.000158	4%	14.60	1.99E+11	6.20E+09	9.82E+05
1%	207252	0.000434	1%	3.65	6.54E+10	2.04E+09	8.84E+05
TOTALS			100%	365.			2.81E+06

Based on flow duration (SUPER RUN A02X10–POR 1940-2000) and regression of suspended sediment with flow (6.572E-6 * EXP(2.021E-5*Flow).

17. Maintenance Dredging

Based on the MKARNS dredging history, river stability and minimal channel modifications, it is estimated that maintenance dredging for the proposed 12-foot channel depth will be necessary two times a year at the lock approaches and every other year at the reaches originally dredged but with no structures modified. The future maintenance dredge volumes were based on the original dredge volumes computed from the 2003 hydrographic survey needed to obtain the 12-foot channel depth (plus the 3 feet authorized advanced maintenance dredging) and were assumed to be 200 percent (100 percent twice per year) for the lock approaches, 50 percent at areas that no structures were modified and 10 percent at the areas that had modified structures. This assumption is based on what the past experience has been on shoaling locations and frequency of shoaling and that little change would occur based on the proposed project. It is assumed that the current survey is of a system at equilibrium and that it will try to return to that state after dredging occurs. Therefore, from an economic perspective, in areas where no training structures are proposed, it is expected that the 3-foot of over-depth advanced maintenance dredging will provide navigation depths for 2 years before re-dredging is necessary. At the areas where structures are added or modified it was estimated that 10 percent is a reasonable volume based on the results of the 2-D model's success in scouring potential. The estimated increase in maintenance dredging for sustaining a 12-foot channel depth on the MKARNS is about 0.58 MCY per year in the Little Rock District. See Table A-17 for maintenance dredging volumes. In the Tulsa District it was assumed that annual dredging would be about 0.24 MCY per year. This is an estimated total volume of about 0.82 MCY per year.

This total annual volume is assumed to be a reasonable amount based on the sediment studies that were conducted for the original design. The original studies predicted that approximately 2.2 MCY per year would be the required dredging to provide a 12-foot channel (9-foot navigation and 3-foot over-dredge). The actual 25-year average (1970-1994) was 2.0 MCY per year. The estimated sediment load for the period of 1972 through 1981 was 7.8 MT/Y as per Tasso Schmidgall. Assuming that the latest estimated sediment load of 2.8 MT/Y is truly representative of a reduction in the sediment load and the proposed structures function successfully, then the estimated annual dredging to provide a 12-foot channel would be 0.79 MCY per year (2.2 MCY per year times 2.8/7.8 MT/Y).

Table A-17
Maintenance Dredging Volume Increases Per Year with Proposed Project

Navigation Pool	Navigation Mile	10' Channel	11' Channel	12' Channel
		Cubic Yards	Cubic Yards	Cubic Yards
2	NM 22.5 -23.7	70	348	1,143
2	NM 27.5 -29.0	10	272	1,473
2	NM 31.0 - 32.0	369	1,232	2,698
2	NM 32.8 - 33.7	1,545	3,560	6,766
2	NM 36.0 - 38.2	5,090	10,619	18,757
2	NM 39.8 - 41.0	5,564	9,042	13,301
2	NM 46.0 - 47.0	1,553	3,498	6,784
2	NM 48.0 - 49.0	2,063	4,030	6,981
2	**NM 49.5 - 50.0***	6,464	13,566	23,052
3	NM 61.0 – 62.0	36	500	2,064
3	**NM 65.4 – 65.9***	2,840	5,796	10,206
Reach 1 Subtotal		25,603	52,465	93,224
4	NM 79.0 - 80.0	227	1,312	4,070
4	**NM 85.8 - 86.2***	6,228	11,372	18,362
5	NM 91.0 - 92.0	609	1,827	3,741
5	NM 95.0 - 97.0	7,931	15,566	26,859
5	NM 101.0 - 102.4	482	2,759	8,267
5	**NM 107.6 - 107.9***	6,646	10,368	14,880
Reach 2 Subtotal		22,123	43,204	76,179
6	**NM 124.8 - 125.1***	10,156	17,654	27,078
7	NM 126.6 - 126.8	1,100	610	1,430
7	NM 142.2 - 142.3	0	0	660
7	NM 142.5 - 143.2	0	1,540	7,810
7	NM 143.4 - 143.4	0	0	550
7	NM 144.0 - 144.1	0	440	770
7	NM 144.5 - 144.8	0	660	2,200
7	NM 145.0 - 145.5	1,320	4,180	5,500
7	NM 146.1 - 146.3	660	770	1,210
7	NM 146.3 - 147.1	1,320	3,080	5,280
7	**NM 155.4 - 155.5***	0	6,600	13,200
8	NM 164.7 - 165.1	0	1,210	2,420
8	NM 168.4 - 169.1	1,320	1,430	3,300
8	NM 169.2 - 169.5	0	1,210	1,320
8	NM 174.0 - 174.3	1,320	1,430	1,540
8	NM 174.9 - 175.2	1,760	1,870	1,980
8	**NM 176.4 - 176.5***	0	0	4,400
9	NM 186.1 - 187.4	5,390	5,720	7,700
9	NM 191.3 - 192.4	0	440	6,380
9	NM 199.1 - 199.8	1,320	2,530	3,850
9	**NM 204.5 - 205.0***	0	15,400	44,000
Reach 3 Subtotal		25,666	66,774	142,578

Table A-17 (Continued)
Maintenance Dredging Volume Increases Per Year with Proposed Project

Navigation Pool	Navigation Mile	10' Channel Cubic Yards	11' Channel Cubic Yards	12' Channel Cubic Yards
10	**NM 221.5 - 221.9****	14,300	14,850	19,250
10	**NM 225.2 - 225.4****	0	6,600	8,800
10	**NM 226.7 - 226.9****	0	0	6,600
10	**NM 229.5 - 230.1****	0	0	17,050
10	NM 232.8 - 233.4	0	0	3,520
10	NM 233.5 - 233.9	0	0	2,200
10	NM 235.9 - 236.4	3,300	6,600	11,000
10	NM 237.3 - 239.1	4,400	7,370	13,200
10	NM 241.6 - 242.1	0	1,760	3,300
10	NM 249.5 - 249.9	1,320	2,640	3,300
10	**NM 256.2 - 256.2***	0	0	6,600
12	**NM 271.4 - 271.9****	15,400	17,600	19,250
12	**NM 272.0 - 273.0****	0	26,400	35,750
12	NM 274.9 - 275.3	880	1,210	2,420
12	NM 275.4 - 276.0	2,200	2,420	4,070
12	NM 277.5 - 278.4	1,760	1,980	5,830
12	NM 279.2 - 281.0	8,800	15,620	19,580
12	NM 281.9 - 282.9	3,520	3,630	5,940
12	NM 283.6 - 284.5	2,200	3,080	6,050
12	NM 285.2 - 285.4	0	0	1,540
12	NM 289.0 - 289.4	0	1,760	2,860
12	**NM 291.8 - 292.4***	44,000	46,200	70,400
Reach 4 Subtotal		102,080	159,720	268,510
Reach 1 - 4 Total		**175,472**	**322,163**	**580,491**

Assumed 10% of initial dredging quantity in areas where structures were modified
***Assumed 100% initial dredging in lock approach twice per year**
****Assumed 50% of initial dredging quantity in areas where there are no structures**

18. Sedimentation Assessment Studies

Detailed sedimentation studies were not performed, as it was believed that the proposed project would have only localized effects on the sediment transport capacity. The 2-D sediment transport model results supported this belief as sediment was observed to scour in the channel in both depth and width in the areas of the proposed structures, while the navigation channel downstream of the proposed changes remained relatively stable with indications that additional deposition would occur mostly in the dike fields. See H&H Appendix A-2, Sediment Transport Model Study 2-D Numerical Model CCH2ED. Although, some deposition was seen in the channel downstream it was minor and would be expected to self-clean as the system re-adjusts towards a state of equilibrium that presently exists. Table A-18 shows the results of the 2-D modeling for the 2-year design flow on the sediment transport capacity change from the existing (Base) condition, with structures (Plan) condition, and structures with channel modification (Mod) condition. The Plan condition initially induces a localized significant change in sediment transport capacity but once the channel is dredged and/or scours, the Mod condition, the modified reach indicates channel stability, as the sediment transport capacity is similar to the existing conditions. A comparison of the change in the sediment transport capacity potential for all river reaches was made using the Hydraulic Design module of HEC-RAS. Although this sediment transport capacity potential does not take into account the suspended sediment load, effects can be assessed qualitatively by comparing the percent change. The comparison of the percent change in sediment transport capacity potential from the existing (Base) condition, with structures (Plan) condition, and structures and channel modification (Mod) condition is shown for each pool in Table A-19 located in the H&H Appendix A-1. The data shows that the proposed structures (Plan) have a significant effect (to produce scour) on the sediment transport through the reach, but once the channel has stabilized to the estimated depth and width (Mod), there is only a minor change in the current system's sediment transport capacity (Base). This sediment transport capacity potential change was compared to the 2-D and SIAM (see next paragraph) model results and the assessment is there would be minimal expected aggradation or degradation problems due to the change in the river reaches sediment transport capacity. Sediment transport capacity is expected to remain similar to the existing conditions, but it is predicted that there will be minor changes in the location of sediment deposition in the proposed project areas. Sediments will be moved downstream a short distance with most deposition occurring in the dike fields.

In addition, long-term impacts on channel stability for Pool 7 were evaluated using the Sediment Impact Assessment Model (SIAM) and the methods recommended in USACE EM 1110-2-1418, "Channel Stability Analyses for Flood Control Projects". Pool 7 was selected for analysis because of the impacts of the project on shear stress, and the presence of gravel bars (and potential project impacts). An annual average sediment budget analysis showed no significant project impacts. Sensitivity runs were performed and showed no significant increase in project impacts for reasonable modifications of data inputs. The study results suggest that the hydraulic impacts of the navigation project are unlikely to cause long-term channel stability impacts. Details of this analysis are provided in Appendix C.8 of the EIS.

Table A-18
Sediment Transport Capacity
2-D Model Results (2-Year Flow)

NM	Base	Plan	% Change	Mod	% Change
	Tons/Day	Tons/Day		Tons/Day	
44.00	66250	66677	0.6	61249	-8.2
43.80	57505	65191	13.4	59421	3.2
43.60	64080	90815	41.7	65999	2.9
43.40	52850	77046	45.8	51989	-1.7
43.31	47302	66993	41.6	52256	9.5
43.00	55868	70771	26.7	57184	2.3
42.65	55528	63155	13.7	58214	4.6

19. Studies during Preconstruction, Engineering and Design

Additional 2-D numerical sediment transport modeling during the Preconstruction, Engineering and Design (PED) Phase will need to be performed to verify and finalize the proposed conceptual structure designs and the impacts to the river and to navigation. Ten river reaches on the system have been identified that will need to be modeled for detailed design and impacts.

In the Little Rock District the reaches are:

NM 33-49
NM 94-104
NM 139-151
NM 163-174
NM 180-192
NM 270-290

In the Tulsa District the reaches are:

NM 308-319
NM 351-361
NM 391-401
NM 440-445

It is estimated that each of these models will take approximately six (three years total modeling time) months to complete.

Although the sediment assessment for Pool 7 indicated that there is no expected significant impact to sediment transport capacity, it is recommended that a sediment assessment of the entire system be performed with the Sediment Impact Assessment Model (SIAM) and that the sediment transport model, HEC-6, be done for a minimum of one and up to five pools to verify the SIAM results in order to quantify sedimentation amounts in problem areas and to better predict the estimated annual maintenance dredging.

ERDC recommends using the numerical models LOCKSIM and HAWSER to determine the impacts to emptying and filling of the side port systems at the Ozark and Webbers Falls projects due to the 34 and 30 foot lifts that are significantly greater than the 20-foot lift at Lock 2 where the prototype tests were performed without problems.

ERDC recommends the use of a physical model (maybe only one model but as many as four models) to evaluate the effects on navigation conditions in the upper lock approaches. Hardin Lock and Dam (#3) has been selected to model the outdraft impacts and Newt Graham Lock and Dam (#18) has been selected to model the draw impacts.

Table A-21 is the proposed schedule for design modeling to be performed during Pre-Construction Engineering and Design (PED).

Table A-21
Proposed Numerical and Physical Modeling during Pre-Construction Engineering and Design
Arkansas River Navigation Study (ARNS)

TASK	SCHEDULE	FY05	FY06	FY07	FY08	TOTALS
VERIFY STRUCTURE DESIGN & IMPACTS						
2-D Numerical Model NM 33-49 Pool2	6 months: 7-1-05/12-31-05*	$75,000	$78,750			$153,750
2-D Numerical Model NM 139-151 Pool 7	6 months: 7-1-05/12-31-05	$75,000	$78,750			$153,750
2-D Numerical Model NM 391-401 Pool 16	6 months: 1-1-06/6-30-06		$157,500			$157,500
2-D Numerical Model NM 94-104 Pool 5	6 months: 1-1-06/6-30-06		$157,500			$157,500
2-D Numerical Model NM 163-174 Pool 8	6 months: 7-1-06/12-31-06		$78,750	$82,750		$161,500
2-D Numerical Model NM 180-192 Pool 9	6 months: 7-1-06/12-31-06		$78,750	$82,750		$161,500
2-D Numerical Model NM 270-290 Pool 12	6 months: 1-1-07/6-30-07			$165,500		$165,500
2-D Numerical Model NM 308-319 Pool 13	6 months: 1-1-07/6-30-07			$165,500		$165,500
2-D Numerical Model NM 351-361 Pool 14	6 months: 7-1-07/12-31-07			$82,750	$87,000	$169,750
2-D Numerical Model NM 440-445 Pool 15	6 months: 7-1-07/12-31-07			$82,750	$87,000	$169,750
ASSESS IMPACTS TO SEDIMENT REGIME						
SIAM models	6 months: 7-1-05/12-31-05	$75,000	$50,000			$125,000
HEC-6 - Verify SIAM model	3 months: 10-1-05/12-31-05	$30,000	$45,000			$75,000
HEC-6 Additional HEC-6 models may be required. Assume 4 additional models.	3 months/model 1-1-06/6-30-06**		$225,000			$225,000
OPERATIONAL PROCEDURES						
HAWSER/LOCKSIM (Determine Filling & Emptying times to minimize hawser forces)	6 months: 7-1-05/12-31-05	$84,000	$80,000			$164,000
NAVIGATION CONDITIONS						
Physical Model - Upstream approach for outdraft (Lock 3) & draw (Lock 18)	12 months: 7-1-05/6-30-06	$250,000	$750,000			$1,000,000
LOCK STRUCTURE BARGE COLLISION						
Barge Impacts-Lock Component and Risk & Uncertainty Anal.	6 months: 7-1-05/12-31-05	$50,000	$76,000			$126,000
TOTALS		**$639,000**	**$1,856,000**	**$662,000**	**$174,000**	**$3,331,000**

*Two 2-D Numerical models assumed to be developed concurrently.
**In-house capabilities used concurrently with contract to reduce costs.
District PED costs for design, review, meetings and coordination not included.

20. References

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Project Design Memorandum No. 4, Navigation Dams - Criteria, July 1960
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Technical Report 2-746, Navigation Conditions at Lock and Dam No. 4, October 1966
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"Stabilization Plan for the Arkansas River", by Edward B. Madden, U.S. Army Engineer District, Little Rock, Arkansas, ASCE Convention 7-11 March 1960

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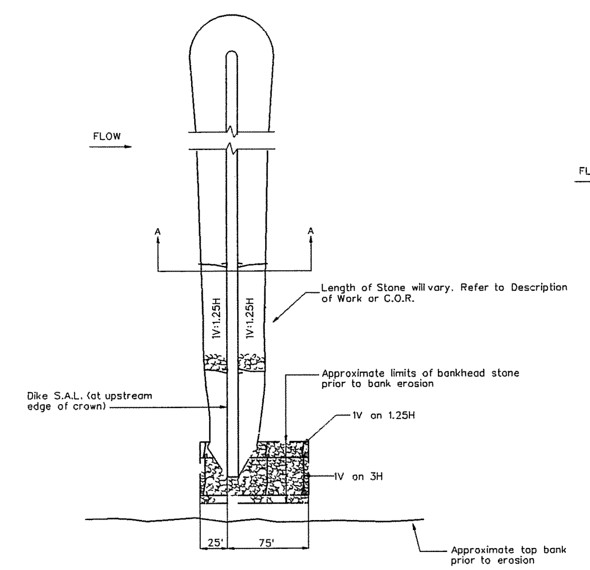
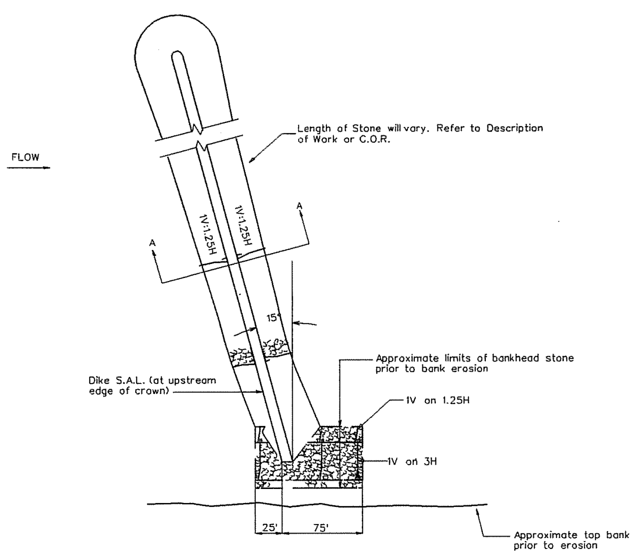
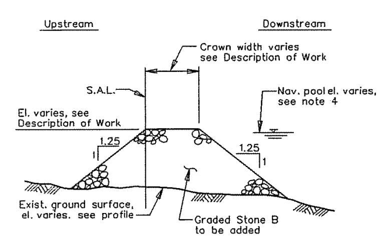


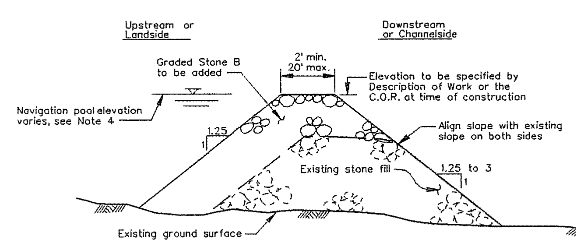
TYPE 3
TYPICAL DIKE WITH BANKHEAD



TYPE 6
TYPICAL BENDWAY WIER WITH BANKHEAD



SECTION A:A



TYPE 1
TYPICAL FOR RAISING TOP ELEVATION OF DIKES

TABLE NO. 1

Navigation System Information

LOCK AND DAM NAME	NAVIGATION MILE	UPPER POOL ELEVATION
Norrell, (No. 1)	10.3	142
Wilbur Mills, (No. 2)	13.3	162
Joe Hardin, (No. 3)	50.2	182
Emmett Sanders, (No. 4)	66.0	196
No. 5	86.3	213
David D. Terry, (No. 6)	108.1	231
Murray, (No. 7)	125.4	249
Todd Suck Ferry, (No. 8)	155.9	265
Arthur V. Ormond, (No. 9)	176.9	284
Dardanelle	205.5	*336 - 338
Ozark-Jeta Taylor	256.8	**370 - 372
James W. Trimble, (No. 13)	292.8	391

*Use 337.0 water surface for construction
**Use 372.0 water surface for construction

TABLE NO. 2

Bankhead/Trench-fill Revetment Crown Width Criteria

MAXIMUM WATER DEPTH BELOW POOL	BANKHEAD/TRENCH-FILL REVETMENT CROWN WIDTH
8.00' or shallower	5'
10.25'	6'
12.50'	7'
14.75'	8'
17.00'	9'
19.25'	10'
21.50'	11'
23.75'	12'
26.00'	13'
28.25'	14'
30.50'	15'
32.75'	16'
35.00'	17'
37.25'	18'
39.50'	19'
41.75' or deeper	20'

NOTES:

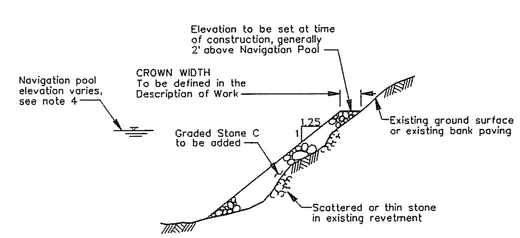
1. The crown widths shown for the typical sections shall be used unless a different crown width is specified by the Description of Work or by the C.O.R.

2. The S.A.L. for Type 4 Trench Fill Revetment will be specified by the Description of Work or by the C.O.R.

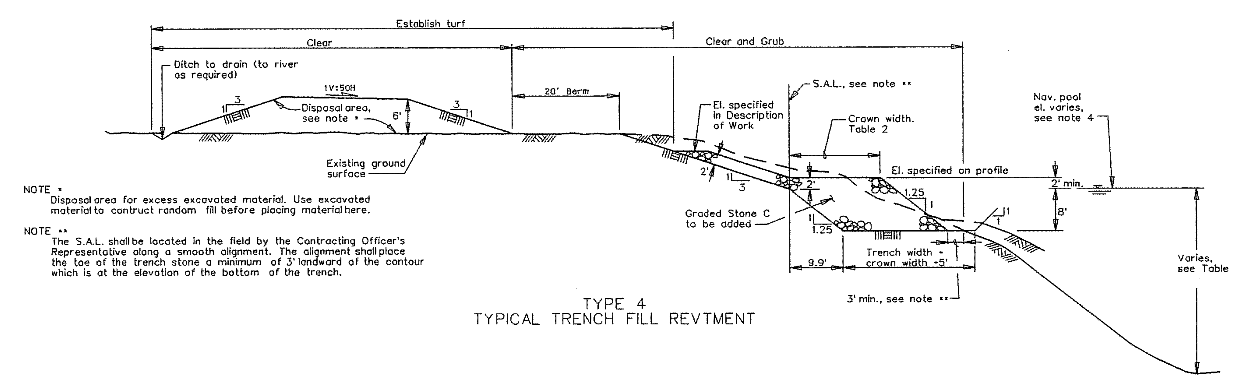
3. For single pile revetments and dikes, the S.A.L. is located on the channelward or upstream surface of piles. For multi-clump revetments and dikes, the S.A.L. is located along the center of the channelward or upstream row of clumps.

4. See Table No. 1 for navigation pool elevations.

5. The Description of Work included in the Task Order may change shown dimensions and will define the scope of work.



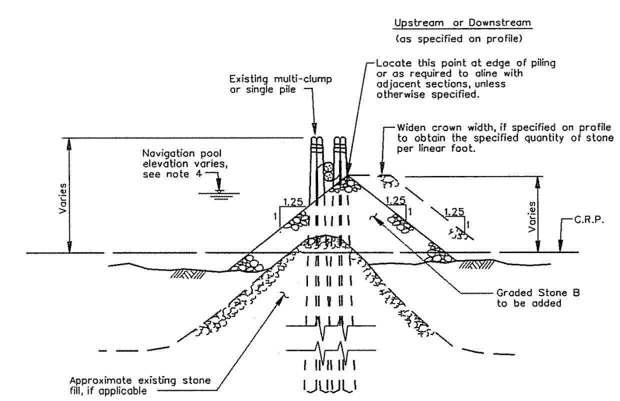
TYPE 5
TYPICAL BANKHEAD



NOTE *
Disposal area for excess excavated material. Use excavated material to contruct random fill before placing material here.

NOTE **
The S.A.L. shall be located in the field by the Contracting Officer's Representative along a smooth alignment. The alignment shall place the toe of the trench stone a minimum of 3' landward of the contour which is at the elevation of the bottom of the trench.

TYPE 4
TYPICAL TRENCH FILL REVTMENT



TYPE 2

US Army Corps of Engineers
Little Rock District

Symbol	Description	Date	Appr.	Description	Date	Appr.

(HARD COPY ORIGINAL SIGNED)

Designed by: GPK	Date: JUNE 2004	
Drawn by: GPK	Solicitation No.: XXXXXX-XX-X-XXXX	
Reviewed by: HHH	Contract No.: XXXXXX-XX-X-XXXX	

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS

Submitted by:

Chief, Hydraulics and Hydrology Section
(HARD COPY ORIGINAL SIGNED)

MCCLELLAN-KERR ARKANSAS RIVER NAVIGATION SYSTEM
ARNS PHASE II
STANDARD DETAILS

TYPICAL SECTIONS OF IMPROVEMENTS

Drawing Code/ Serial No.
10700-115/5417

Drawing Ref. Number
1

APPENDIX A-1

Water Surface Elevations, Thalweg Profiles, and Sediment Transport Potential for Base and Plan (Mod) Using HEC-RAS; and MKARNS Dredging History

Pools 2, 3, 4, 5, 6, 7, 8, 9, Dardanelle, and Ozark

APPENDIX A-1

Water Surface Elevations, Thalweg Profiles, and Sediment Transport Potential for Base and Plan (Mod) Using HEC-RAS; and MKARNS Dredging History

TABLE OF CONTENTS

Table A-1-1
Water Surface Elevation Impacts for the 2- and 100-year Events

POOL 2 - Water Surface Elevations						
	2-YEAR			100-YEAR		
NM	**Base**	**Plan**	**Delta**	**Base**	**Plan**	**Delta**
50	182.26	182.23	**-0.03**	193.09	193.13	**0.04**
49.6	182.1	182.07	**-0.03**	192.83	192.88	**0.05**
48.43	181.67	181.63	**-0.04**	192.31	192.36	**0.05**
47.15	181.22	181.18	**-0.04**	191.9	191.96	**0.06**
45.63	180.64	180.61	**-0.03**	191.41	191.47	**0.06**
44.91	180.01	179.97	**-0.04**	190.58	190.65	**0.07**
44.77	179.9	179.86	**-0.04**	190.42	190.49	**0.07**
44.41	179.77	179.74	**-0.03**	189.79	189.92	**0.13**
44	179.56	179.54	**-0.02**	189.6	189.71	**0.11**
43.6	179.36	179.3	**-0.06**	189.42	189.42	**0.00**
43.31	179.06	178.87	**-0.19**	189.23	189.18	**-0.05**
41.86	177.92	177.85	**-0.07**	187.49	187.59	**0.10**
40.36	176.95	176.83	**-0.12**	186.19	186.08	**-0.11**
39.73	176.35	176.29	**-0.06**	185.92	185.91	**-0.01**
39.43	176.45	176.39	**-0.06**	185.92	185.82	**-0.10**
36.17	174.68	174.52	**-0.16**	183.37	183.32	**-0.05**
34.97	173.89	173.83	**-0.06**	182.8	182.79	**-0.01**
33.47	173.28	173.28	**0**	182.02	182.02	**0**
31.99	171.78	171.78	**0**	181.27	181.27	**0**
30.26	169.91	169.91	**0**	179.28	179.28	**0**
27.67	168.5	168.5	**0**	177.7	177.7	**0**
26	167.4	167.4	**0**	176.63	176.63	**0**
22.99	166.41	166.41	**0**	175.97	175.97	**0**
22.67	165.25	165.25	**0**	174.18	174.18	**0**
22.55	165.2	165.2	**0**	173.55	173.55	**0**
22.47	165.15	165.15	**0**	173.4	173.4	**0**
22.27	165.08	165.08	**0**	173.47	173.47	**0**
20.83	164.4	164.4	**0**	172.42	172.42	**0**
19.83	163.9	163.9	**0**	171.93	171.93	**0**
19.21	163.58	163.58	**0**	171.45	171.45	**0**
17.78	162.75	162.75	**0**	170.32	170.32	**0**
17	162	162	**0**	168.7	168.7	**0**

Table A-1-1 (Continued)
Water Surface Elevation Impacts for the 2- and 100-year Events

POOL 3 - Water Surface Elevations						
	2-YEAR			100-YEAR		
NM	**Base**	**Plan**	**Delta**	**Base**	**Plan**	**Delta**
65.63	196.25	196.25	**0**	207.21	207.22	**0.01**
65.22	195.85	195.85	**0**	206.82	206.84	**0.02**
64.46	195.34	195.34	**0**	206.48	206.49	**0.01**
64.13	194.95	194.95	**0**	206.21	206.22	**0.01**
63.7	194.48	194.48	**0**	205.73	205.75	**0.02**
62.93	193.9	193.9	**0**	205.1	205.12	**0.02**
62.13	193.3	193.3	**0**	204.13	204.15	**0.02**
61.53	192.62	192.6	**-0.02**	203.32	203.29	**-0.03**
61.12	192.34	192.35	**0.01**	202.99	203	**0.01**
59.93	191.65	191.65	**0**	202.37	202.37	**0**
59.3	190.74	190.74	**0**	201.28	201.28	**0**
58.69	190.24	190.24	**0**	200.94	200.94	**0**
58.46	189.95	189.95	**0**	200.62	200.62	**0**
57.39	188.64	188.64	**0**	199.5	199.5	**0**
56.37	187.87	187.87	**0**	198.94	198.94	**0**
55.85	187.59	187.59	**0**	198.68	198.68	**0**
55.54	187.45	187.45	**0**	198.54	198.54	**0**
55.23	187.26	187.26	**0**	198.28	198.28	**0**
54.92	187.06	187.06	**0**	197.85	197.85	**0**
53.69	186.32	186.32	**0**	196.97	196.97	**0**
52.97	185.68	185.67	**-0.01**	196.34	196.34	**0**
52.35	185.08	185.08	**0**	195.94	195.94	**0**
51.18	183.8	183.8	**0**	195.1	195.1	**0**

Table A-1-1 (Continued)
Water Surface Elevation Impacts for the 2- and 100-year Events

POOL 4 - Water Surface Elevations						
	2-YEAR			100-YEAR		
NM	**Base**	**Plan**	**Delta**	**Base**	**Plan**	**Delta**
86.04	210.68	210.73	**0.05**	222.8	222.86	**0.06**
85.63	210.51	210.56	**0.05**	223.03	223.09	**0.06**
84.87	210	210.06	**0.06**	222.6	222.67	**0.07**
84.36	209.62	209.67	**0.05**	222.04	222.1	**0.06**
83.9	209.45	209.51	**0.06**	221.91	221.98	**0.07**
83.37	209.22	209.27	**0.05**	221.61	221.69	**0.08**
82.84	208.99	209.05	**0.06**	221.1	221.18	**0.08**
81.78	208.55	208.61	**0.06**	220.69	220.77	**0.08**
81.2	208.21	208.27	**0.06**	220.5	220.58	**0.08**
80.48	207.58	207.65	**0.07**	219.92	220.01	**0.09**
79.28	206.61	206.66	**0.05**	219.46	219.58	**0.12**
78.34	205.56	205.56	**0**	216.77	216.77	**0**
77.07	204.35	204.35	**0**	215.97	215.97	**0**
76.02	203.41	203.41	**0**	215.04	215.04	**0**
75.04	202.58	202.58	**0**	214.36	214.36	**0**
74.82	202.39	202.39	**0**	213.52	213.52	**0**
74.79	202.34	202.34	**0**	213.4	213.4	**0**
74.76	202.31	202.31	**0**	213.58	213.58	**0**
74.18	202.05	202.05	**0**	213.38	213.38	**0**
73.35	201.33	201.33	**0**	211.64	211.64	**0**
72.62	200.8	200.8	**0**	210.56	210.56	**0**
71.28	200.47	200.47	**0**	210.84	210.84	**0**
70.23	199.85	199.85	**0**	210.28	210.28	**0**
69.39	199.36	199.36	**0**	209.88	209.88	**0**
68.2	198.91	198.91	**0**	209.5	209.5	**0**
67.8	198.32	198.32	**0**	208.85	208.85	**0**
67.39	197.88	197.88	**0**	207.08	207.08	**0**
67.33	197.69	197.69	**0**	206.44	206.44	**0**
67.13	197.68	197.68	**0**	206.79	206.79	**0**
66.72	197.39	197.39	**0**	206.43	206.43	**0**
66.15	196.6	196.6	**0**	206.1	206.1	**0**

Table A-1-1 (Continued)
Water Surface Elevation Impacts for the 2- and 100-year Events

POOL 5 - Water Surface Elevations						
	2-YEAR			100-YEAR		
NM	**Base**	**Plan**	**Delta**	**Base**	**Plan**	**Delta**
107.85	230.41	230.43	**0.02**	240.54	240.56	**0.02**
107.2	230.12	230.14	**0.02**	240.3	240.31	**0.01**
106.4	229.65	229.67	**0.02**	239.94	239.95	**0.01**
105.36	228.73	228.76	**0.03**	239.14	239.16	**0.02**
104.4	227.86	227.89	**0.03**	238.05	238.07	**0.02**
103.8	227.34	227.37	**0.03**	237.81	237.83	**0.02**
102.98	226.88	226.92	**0.04**	237.64	237.66	**0.02**
102.4	226.24	226.26	**0.02**	236.66	236.62	**-0.04**
101.59	225.76	225.68	**-0.08**	236.36	236.33	**-0.03**
100.29	224	224	**0.00**	234.76	234.84	**0.08**
98.92	222.85	222.84	**-0.01**	234.23	234.34	**0.11**
98.15	221.91	221.88	**-0.03**	233.76	233.87	**0.11**
97.1	220.97	220.88	**-0.09**	232.87	232.89	**0.02**
96.42	219.35	219.34	**-0.01**	232.02	232.05	**0.03**
95.43	218.93	218.93	**0**	231.85	231.85	**0**
95	218.69	218.69	**0**	231.8	231.8	**0**
94.37	218.39	218.39	**0**	231.66	231.66	**0**
93.08	217.32	217.32	**0**	230.94	230.94	**0**
92.14	216.93	216.93	**0**	230.29	230.29	**0**
91.6	216.73	216.73	**0**	230.36	230.36	**0**
90.9	216.38	216.38	**0**	230.28	230.28	**0**
90.37	215.43	215.43	**0**	227.99	227.99	**0**
89.26	215.11	215.11	**0**	228.38	228.38	**0**
88.5	214.65	214.65	**0**	228.09	228.09	**0**
87.37	214	214	**0**	227.29	227.29	**0**
86.5	213.2	213.2	**0**	225.6	225.6	**0**

Table A-1-1 (Continued)
Water Surface Elevation Impacts for the 2- and 100-year Events

POOL 7 - Water Surface Elevations						
	2-YEAR			100-YEAR		
NM	Base	Plan	Delta	Base	Plan	Delta
155.65	271.6	271.64	**0.04**	285.19	285.29	**0.10**
154.87	271.22	271.26	**0.04**	284.82	284.91	**0.09**
153.59	270.61	270.65	**0.04**	284.16	284.26	**0.10**
152.44	270.1	270.14	**0.04**	283.57	283.68	**0.11**
151.53	269.58	269.63	**0.05**	282.93	283.05	**0.12**
150.53	269.11	269.17	**0.06**	282.36	282.49	**0.13**
150.13	268.65	268.71	**0.06**	281.89	282.03	**0.14**
149.63	268.28	268.34	**0.06**	281.61	281.75	**0.14**
149.48	267.97	268.04	**0.07**	281.22	281.37	**0.15**
148.53	267.34	267.41	**0.07**	280.3	280.46	**0.16**
147.68	266.95	267.02	**0.07**	279.95	280.12	**0.17**
146.71	266.41	266.44	**0.03**	279.37	279.51	**0.14**
145.78	265.51	265.45	**-0.06**	278.16	278.18	**0.02**
145	264.89	264.88	**-0.01**	276.66	276.71	**0.05**
143.52	264.04	264.05	**0.01**	275.05	275.09	**0.04**
142.87	263.73	263.74	**0.01**	274.68	274.71	**0.03**
141.83	262.63	262.63	**0**	273.38	273.38	**0**
141.55	262.06	262.06	**0**	272.46	272.45	**-0.01**
140.43	260.7	260.7	**0**	272.01	272.01	**0**
139.79	260.05	260.05	**0**	271.58	271.58	**0**
139.14	259.55	259.56	**0.01**	271.01	271.01	**0**
138.5	258.93	258.94	**0.01**	270.19	270.19	**0**
137.58	258.78	258.78	**0**	270.07	270.06	**-0.01**
136.7	258	258	**0**	269.1	269.1	**0**
135.75	256.36	256.37	**0.01**	268.43	268.43	**0**
134.43	255.51	255.52	**0.01**	267.74	267.73	**-0.01**
133.21	254.81	254.82	**0.01**	267.31	267.31	**0**
132.36	254.28	254.29	**0.01**	266.78	266.78	**0**
132.3	254.25	254.25	**0**	266.73	266.72	**-0.01**
131.78	253.92	253.93	**0.01**	266.16	266.16	**0**
131.6	253.81	253.82	**0.01**	266.03	266.03	**0**
131.54	253.76	253.77	**0.01**	265.99	265.98	**-0.01**
130.05	252.51	252.52	**0.01**	264.84	264.84	**0**
129.3	251.91	251.92	**0.01**	264.4	264.39	**-0.01**
127.86	251.03	251.04	**0.01**	263.78	263.78	**0**
127.45	250.77	250.71	**-0.06**	263.5	263.42	**-0.08**
127.39	250.74	250.68	**-0.06**	263.45	263.37	**-0.08**
127.21	250.66	250.61	**-0.05**	263.3	263.23	**-0.07**
126.85	250.49	250.47	**-0.02**	263.14	262.98	**-0.16**
126.79	250.47	250.47	**0**	263.12	263	**-0.12**
126.58	250.39	250.39	**0**	263.03	262.91	**-0.12**
126.56	250.37	250.37	**0**	262.96	262.84	**-0.12**
126.18	249.56	249.56	**0**	262.31	262.17	**-0.14**
125.45	249	249	**0**	261.9	261.9	**0**

Table A-1-1 (Continued)
Water Surface Elevation Impacts for the 2- and 100-year Events

POOL 8 - Water Surface Elevations						
	2-YEAR			100-YEAR		
NM	**Base**	**Plan**	**Delta**	**Base**	**Plan**	**Delta**
176.65	288.12	288.15	**0.03**	300.94	300.96	**0.02**
176.19	287.85	287.88	**0.03**	300.72	300.75	**0.02**
175.13	287.33	287.36	**0.03**	300.5	300.53	**0.03**
174.36	286.82	286.85	**0.03**	299.9	299.93	**0.02**
173.77	286.29	286.33	**0.04**	298.76	298.79	**0.02**
173.23	285.8	285.84	**0.04**	297.89	297.92	**0.03**
173.02	285.58	285.61	**0.03**	297.21	297.24	**0.02**
172.96	285.53	285.57	**0.04**	297.07	297.1	**0.03**
172.79	285.42	285.45	**0.03**	297.07	297.1	**0.02**
172.22	285.13	285.17	**0.04**	296.91	296.94	**0.03**
171.35	284.7	284.74	**0.04**	296.77	296.8	**0.03**
170.21	284.1	284.15	**0.05**	296.2	296.24	**0.03**
169.5	283.56	283.56	**0.00**	295.81	295.81	**0**
168.85	283	283.02	**0.02**	294.8	294.8	**0**
167.23	281.61	281.64	**0.03**	293.35	293.36	**0**
165.89	280.77	280.8	**0.03**	293.3	293.31	**0**
164.7	280.24	280.24	**0**	292.95	292.94	**0**
164.27	279.75	279.75	**0**	292.96	292.96	**0**
163.1	278.96	278.96	**0**	292.38	292.38	**0**
162.05	278.02	278.02	**0**	291.61	291.61	**0**
160.79	276.8	276.8	**0**	290.14	290.14	**0**
160.16	275.95	275.95	**0**	289.28	289.28	**0**
160.07	275.92	275.92	**0**	289.13	289.13	**0**
158.99	275.06	275.06	**0**	288.64	288.64	**0**
157.76	274.06	274.06	**0**	287.76	287.76	**0**
156.98	273.6	273.6	**0**	287.08	287.08	**0**
156.05	273	273	**0**	286.5	286.5	**0**

Table A-1-1 (Continued)
Water Surface Elevation Impacts for the 2- and 100-year Events

POOL 9 - Water Surface Elevations						
	2-YEAR			100-YEAR		
NM	**Base**	**Plan**	**Delta**	**Base**	**Plan**	**Delta**
205.25	309.86	309.95	**0.09**	326.42	326.45	**0.03**
205.04	309.82	309.91	**0.09**	326.33	326.36	**0.03**
204.71	309.63	309.73	**0.10**	325.85	325.88	**0.03**
204.39	309.47	309.57	**0.10**	325.42	325.45	**0.03**
204	309.18	309.27	**0.09**	324.73	324.77	**0.04**
203.86	309.11	309.21	**0.10**	324.67	324.7	**0.03**
203.47	308.93	309.03	**0.10**	324.47	324.51	**0.04**
203.38	308.86	308.96	**0.10**	324.23	324.27	**0.04**
203.1	308.64	308.74	**0.10**	323.98	324.02	**0.04**
202.61	308.28	308.39	**0.11**	323.69	323.73	**0.04**
202.09	307.68	307.8	**0.12**	323.01	323.05	**0.04**
201.31	307.09	307.22	**0.13**	322.56	322.64	**0.08**
200.43	306.44	306.58	**0.14**	321.8	321.89	**0.09**
199	305.66	305.81	**0.15**	321.05	321.14	**0.09**
198.22	304.97	305.13	**0.16**	320.24	320.35	**0.11**
197.52	304.74	304.9	**0.16**	320.32	320.42	**0.10**
196.72	304.25	304.43	**0.18**	319.39	319.5	**0.11**
195.71	303.54	303.73	**0.19**	318.2	318.32	**0.12**
195.09	303.13	303.32	**0.19**	317.84	317.96	**0.12**
194.16	302.8	303	**0.2**	317.63	317.75	**0.12**
193.41	302.24	302.46	**0.22**	316.89	317.03	**0.14**
192.9	302	302.22	**0.22**	316.45	316.59	**0.14**
192.41	301.62	301.85	**0.23**	315.99	316.13	**0.14**
191.68	301.13	301.37	**0.24**	315.57	315.72	**0.15**
190.71	300.43	300.69	**0.26**	315.17	315.33	**0.16**
189.51	299.67	299.92	**0.25**	314.87	315.01	**0.14**
188.44	298.78	299.06	**0.28**	314.2	314.36	**0.16**
187.4	297.99	298.16	**0.17**	313.76	313.88	**0.12**
186.38	297.14	297.27	**0.13**	312.73	312.84	**0.11**
185.54	296.07	296.22	**0.15**	310.98	311.11	**0.13**
184.82	295.66	295.77	**0.11**	310.96	311.05	**0.09**
184.21	295.25	295.35	**0.1**	310.69	310.76	**0.07**
183.61	294.75	294.86	**0.11**	310.26	310.34	**0.08**
182.64	293.42	293.56	**0.14**	309.53	309.61	**0.08**
181.77	292.35	292.34	**-0.01**	308.69	308.73	**0.04**
181.6	292.24	292.22	**-0.02**	308.69	308.68	**-0.01**
180.58	291.71	291.71	**0**	308.22	308.22	**0**
179.47	290.99	290.99	**0**	307.53	307.53	**0**
178.75	290.61	290.61	**0**	307.63	307.63	**0**
177.03	289.1	289.1	**0**	306.2	306.2	**0**

Table A-1-1 (Continued)
Water Surface Elevation Impacts for the 2- and 100-year Events

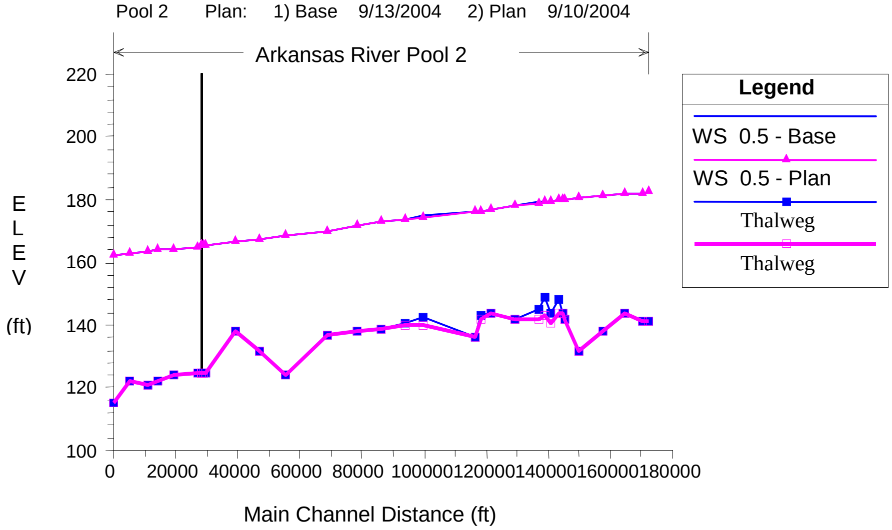
Dardanelle Pool - Water Surface Elevations						
	2-YEAR			100-YEAR		
NM	Base	Plan	Delta	Base	Plan	Delta
256.43	359.9	359.91	**0.01**	375.48	375.5	**0.02**
255.91	359.45	359.46	**0.01**	374.62	374.65	**0.03**
255.03	358.83	358.84	**0.01**	373.85	373.87	**0.02**
254.17	358.23	358.24	**0.01**	373.07	373.11	**0.04**
253.29	357.48	357.49	**0.01**	371.83	371.86	**0.03**
252.1	356.47	356.48	**0.01**	371.16	371.2	**0.04**
251	355.24	355.26	**0.02**	368.63	368.68	**0.05**
249.96	354.66	354.67	**0.01**	367.41	367.47	**0.06**
249.18	354.37	354.38	**0.01**	367.24	367.3	**0.06**
248.3	353.91	353.92	**0.01**	366.8	366.86	**0.06**
247.64	353.58	353.59	**0.01**	366.33	366.4	**0.07**
246.95	353.03	353.05	**0.02**	365.5	365.57	**0.07**
245.99	352.29	352.31	**0.02**	364.3	364.39	**0.09**
245.37	351.89	351.91	**0.02**	363.82	363.91	**0.09**
244.55	351.43	351.45	**0.02**	363.44	363.53	**0.09**
243.71	351.03	351.05	**0.02**	362.96	363.06	**0.10**
242.83	350.42	350.44	**0.02**	362.22	362.32	**0.10**
241.82	349.57	349.57	**0.00**	360.97	361.04	**0.07**
241	348.68	348.71	**0.03**	359.9	359.96	**0.06**
239.62	347.04	347.13	**0.09**	357.46	357.49	**0.03**
238.65	346.75	346.86	**0.11**	356.29	356.36	**0.07**
237.31	346.27	346.39	**0.12**	355.41	355.49	**0.08**
236.41	345.37	345.45	**0.08**	354.49	354.54	**0.05**
235.04	343.38	343.38	**0**	352.62	352.62	**0**
234.76	343.08	343.08	**0**	352.28	352.28	**0**
234.64	343.07	343.07	**0**	352.25	352.25	**0**
234.41	342.83	342.83	**0**	351.99	351.99	**0**
233	342.22	342.22	**0**	351.03	351.03	**0**
231.28	341.38	341.38	**0**	349.43	349.43	**0**
229.28	340.7	340.7	**0**	348.02	348.02	**0**
228.15	340.45	340.44	**-0.01**	347.5	347.5	**0**
226.9	340.16	340.16	**0**	346.98	346.97	**-0.01**
224.45	339.53	339.53	**0**	345.61	345.61	**0**
222.3	339.26	339.26	**0**	345.03	345.03	**0**
221.58	339.19	339.19	**0**	344.87	344.87	**0**
220.23	338.95	338.95	**0**	343.85	343.85	**0**
219.6	338.85	338.85	**0**	343.43	343.43	**0**
216.77	338.59	338.59	**0**	341.9	341.9	**0**
213.69	338.43	338.43	**0**	341.05	341.04	**-0.01**
210.11	338.3	338.3	**0**	340.32	340.32	**0**
207.08	338.09	338.09	**0**	338.78	338.78	**0**
205.6	338	338	**0**	338	338	**0**

Table A-1-1 (Continued)
Water Surface Elevation Impacts for the 2- and 100-year Events

Ozark Pool - Water Surface Elevations						
	2-YEAR			100-YEAR		
NM	**Base**	**Plan**	**Delta**	**Base**	**Plan**	**Delta**
292.5	392.32	392.36	**0.04**	404.54	404.57	**0.03**
291.4	391.41	391.45	**0.04**	403.62	403.65	**0.03**
290.04	390.67	390.71	**0.04**	402.68	402.73	**0.05**
289.08	390.03	390.08	**0.05**	401.41	401.46	**0.05**
288.13	389.42	389.47	**0.05**	400.36	400.41	**0.05**
287.21	388.82	388.88	**0.06**	399.51	399.57	**0.06**
286.16	388.18	388.24	**0.06**	398.91	398.98	**0.07**
285.11	386.98	387.1	**0.12**	398.3	398.38	**0.08**
284.34	386.44	386.58	**0.14**	397.73	397.84	**0.11**
283.52	385.55	385.68	**0.13**	396.17	396.25	**0.08**
282.42	384.91	385.05	**0.14**	395.36	395.45	**0.09**
281.25	383.95	384.11	**0.16**	393.6	393.73	**0.13**
280.16	383.09	383.18	**0.09**	392.24	392.3	**0.06**
279.3	382.36	382.41	**0.05**	391.36	391.37	**0.01**
278.12	381.83	381.89	**0.06**	390.53	390.54	**0.01**
276.92	381.2	381.26	**0.06**	389.81	389.82	**0.01**
275.78	380.06	380.04	**-0.02**	389.28	389.28	**0**
274.55	378.96	378.96	**0**	388.35	388.35	**0**
273.4	378.53	378.53	**0**	387.97	387.97	**0**
271.28	377.31	377.31	**0**	386.42	386.42	**0**
270.31	376.88	376.88	**0**	385.34	385.34	**0**
268.62	376.13	376.13	**0**	384.46	384.46	**0**
267.7	375.7	375.7	**0**	383.57	383.57	**0**
266.38	375.19	375.19	**0**	382.67	382.67	**0**
265.58	374.91	374.91	**0**	381.82	381.82	**0**
264.7	374.61	374.61	**0**	380.83	380.83	**0**
263.84	374.33	374.33	**0**	380.09	380.09	**0**
263.19	374.13	374.13	**0**	379.79	379.79	**0**
262.33	373.84	373.84	**0**	379.06	379.06	**0**
260.83	373.46	373.46	**0**	378.19	378.19	**0**
260.19	373.26	373.26	**0**	377.66	377.66	**0**
259.59	373.08	373.08	**0**	377.12	377.12	**0**
258.88	372.9	372.9	**0**	376.67	376.67	**0**
258.28	372.66	372.66	**0**	375.55	375.55	**0**
258.23	372.65	372.65	**0**	375.49	375.49	**0**
258.18	372.59	372.59	**0**	374.94	374.94	**0**
258.07	372.55	372.55	**0**	374.79	374.79	**0**
256.9	372	372	**0**	372	372	**0**

Figure A-1-1
Water Surface and Thalweg Profiles

Pool 2
2 year



Pool 2
100 year

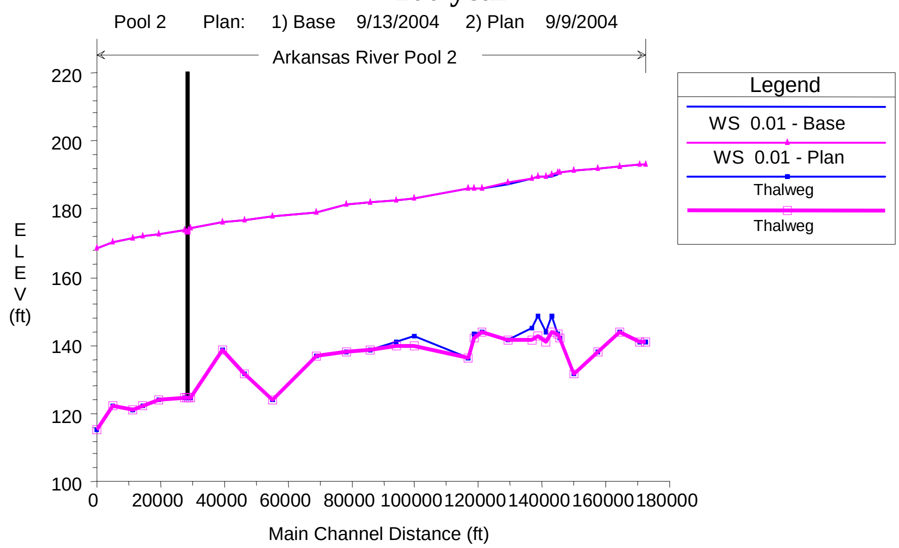
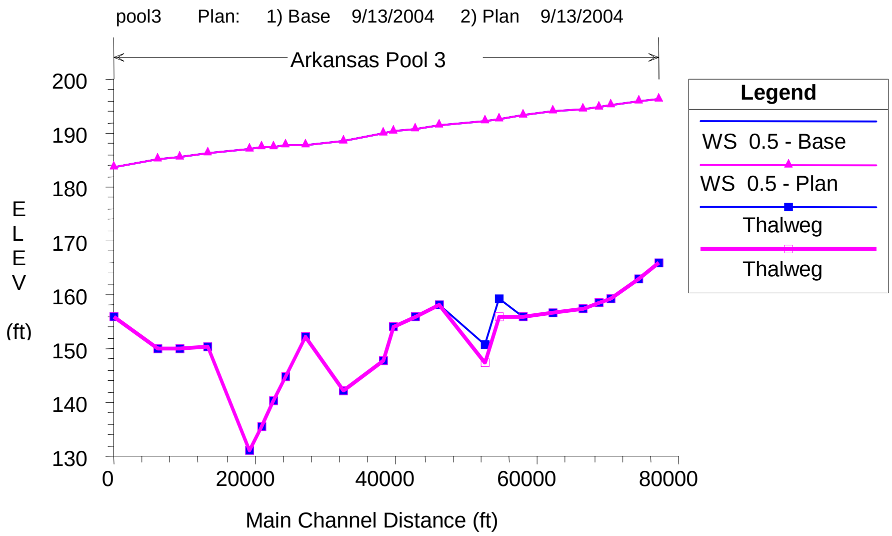


Figure A-1-1 (Continued)
Water Surface and Thalweg Profiles

Pool 3
2 year



Pool 3
100 year

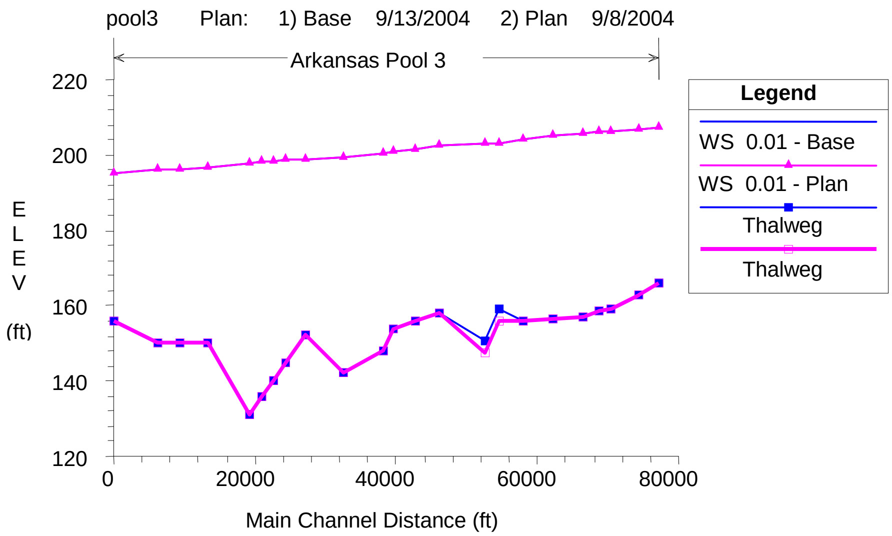
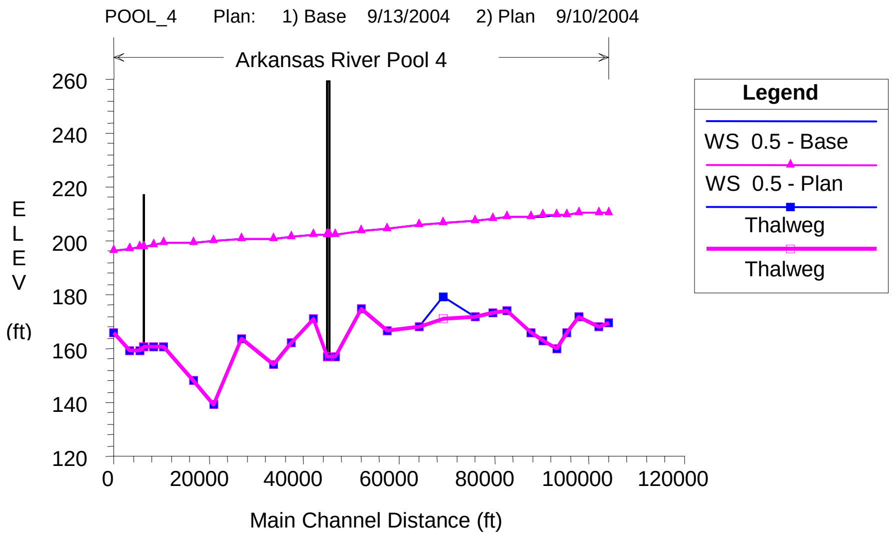


Figure A-1-1 (Continued)
Water Surface and Thalweg Profiles

Pool 4
2 year



Pool 4
100 year

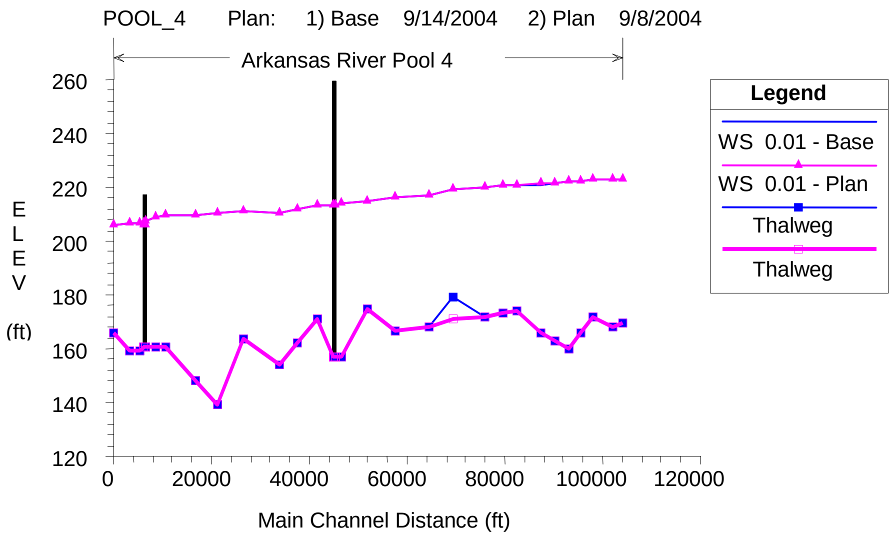
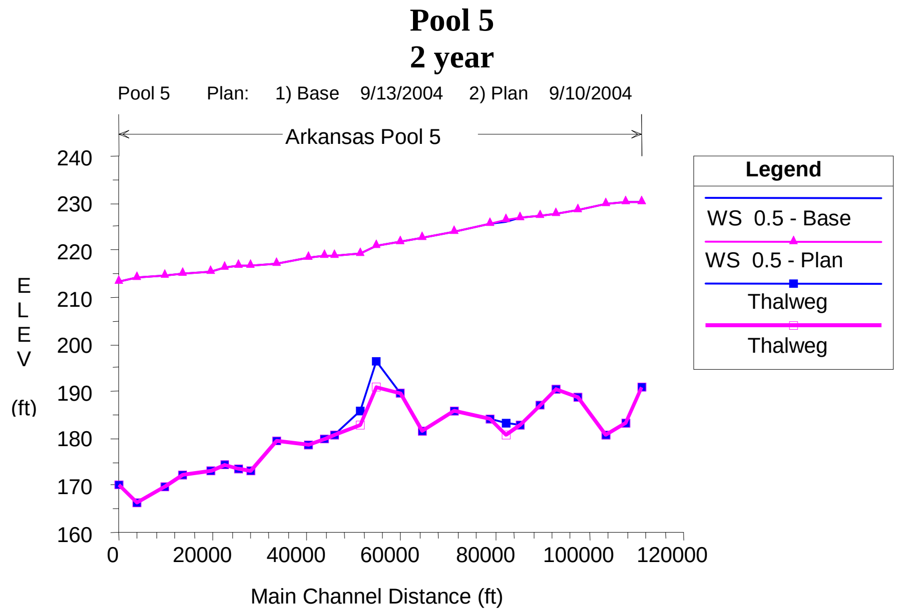


Figure A-1-1 (Continued)
Water Surface and Thalweg Profiles



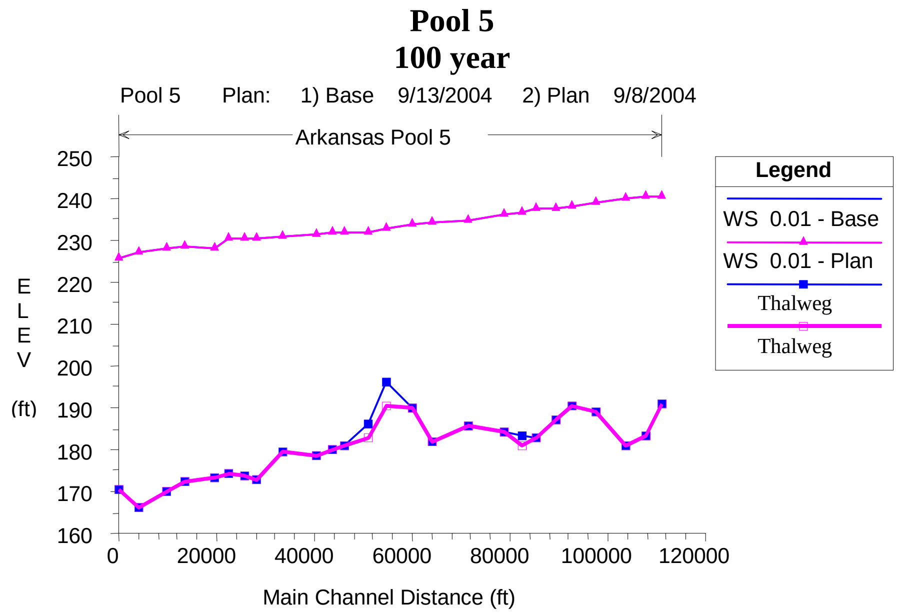
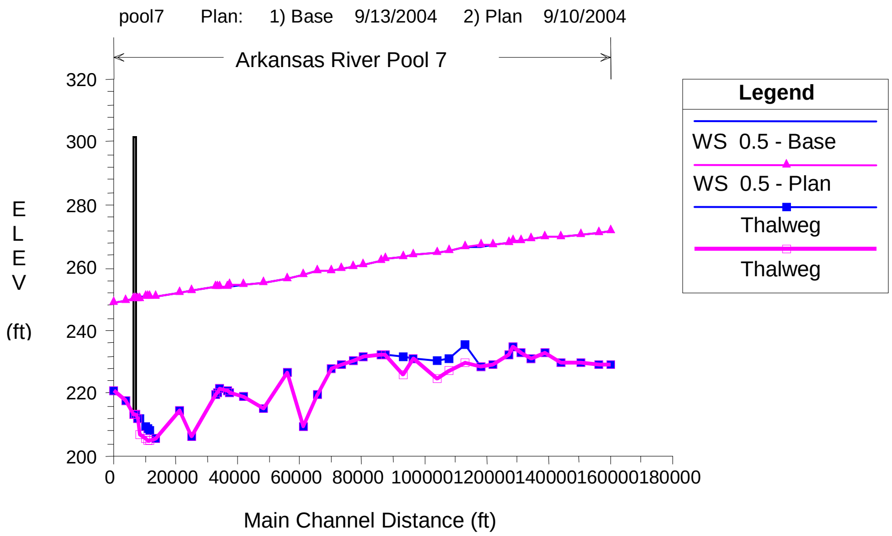


Figure A-1-1 (Continued)
Water Surface and Thalweg Profiles

Pool 7
2 year



Pool 7
100 year

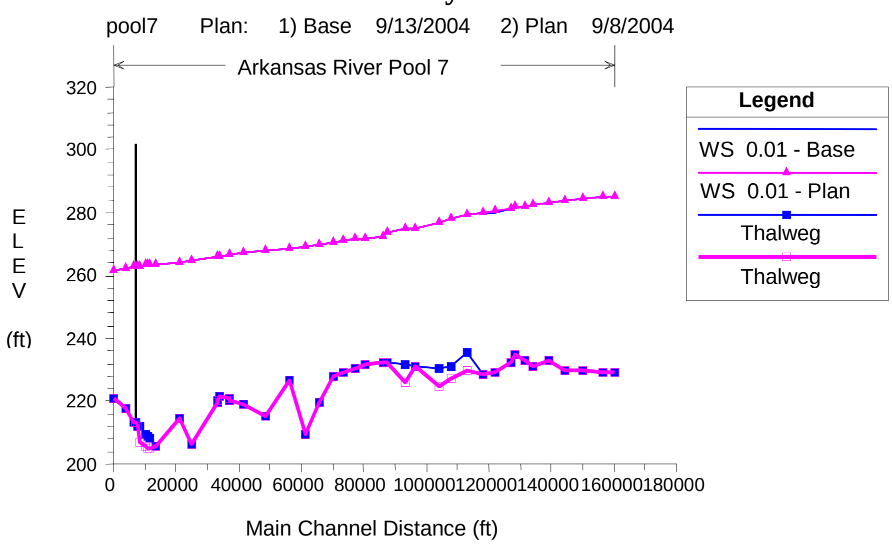
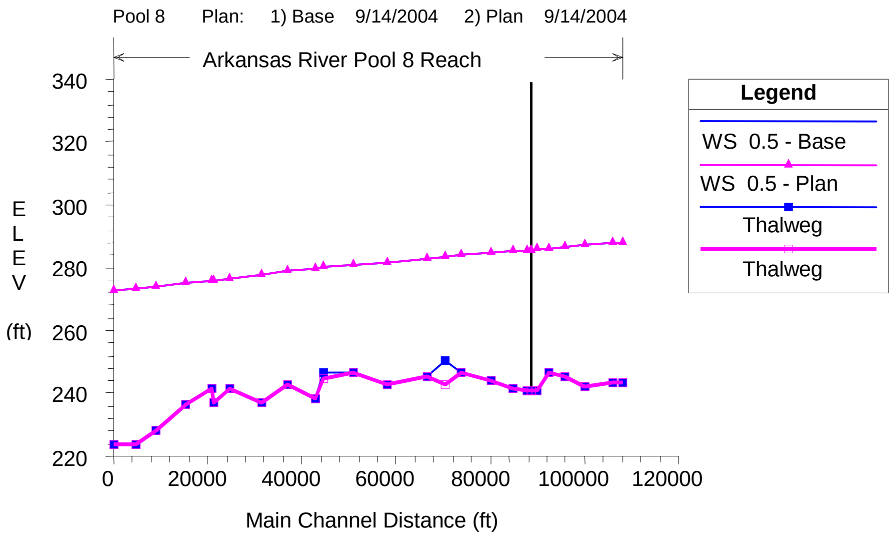


Figure A-1-1 (Continued)
Water Surface and Thalweg Profiles

Pool 8
2 year



Pool 8
100 year

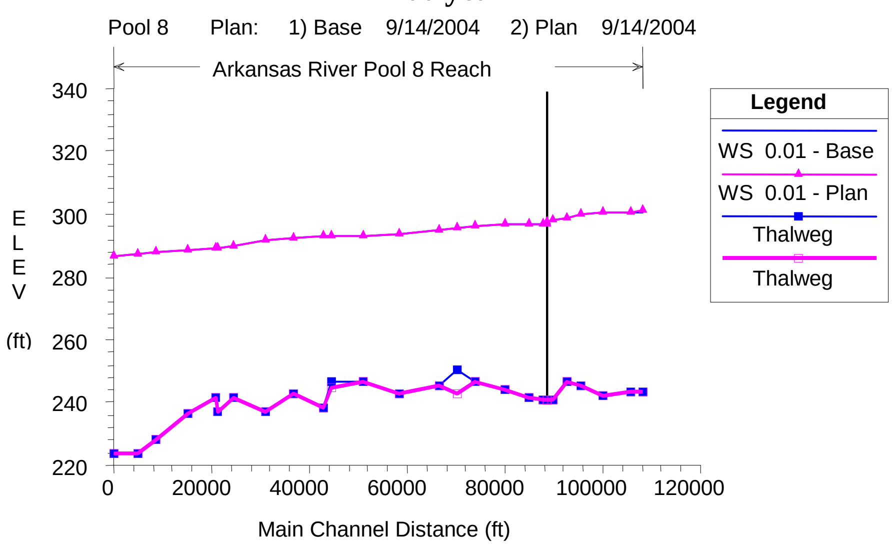
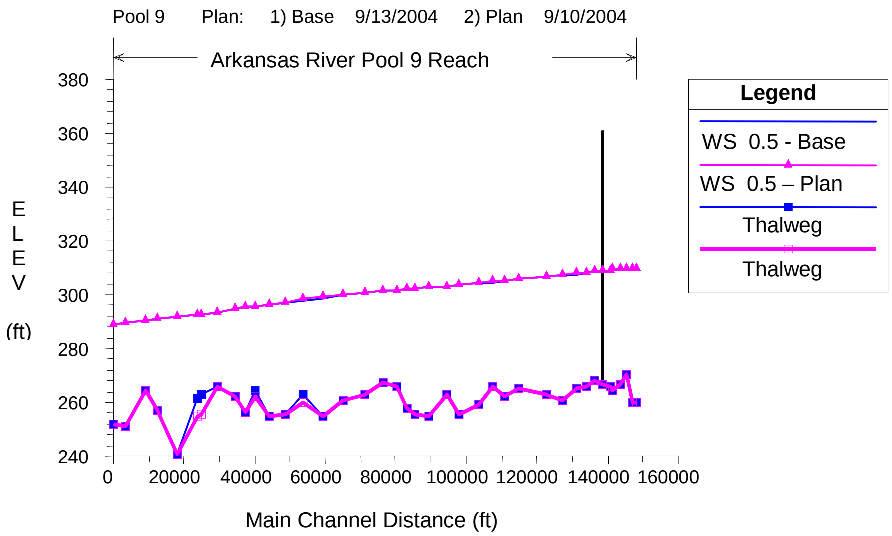


Figure A-1-1 (Continued)
Water Surface and Thalweg Profiles

Pool 9
2 year



Pool 9
100 year

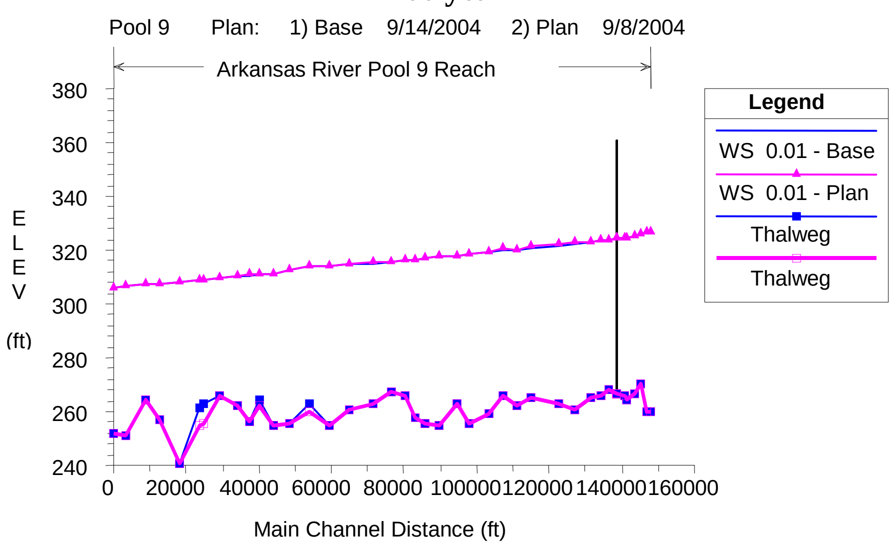
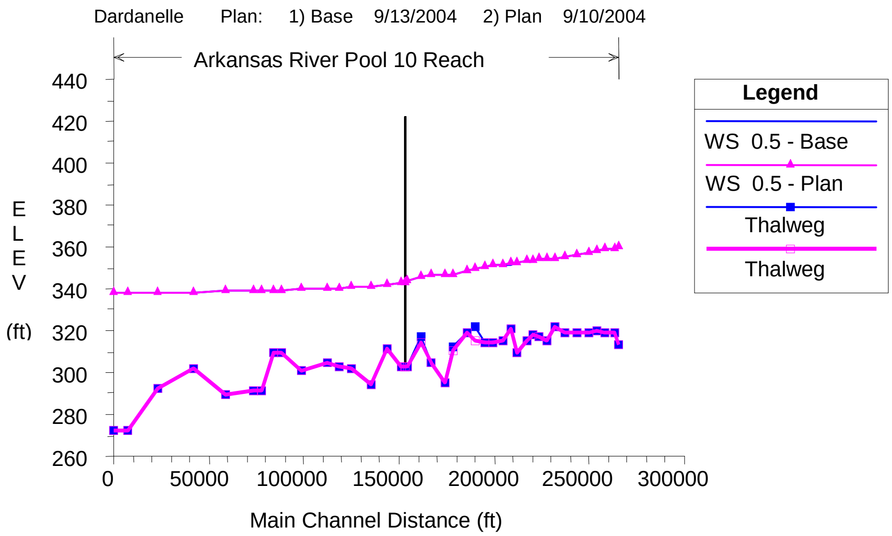


Figure A-1-1 (Continued)
Water Surface and Thalweg Profiles

Dardanelle
2 year



Dardanelle
100 year

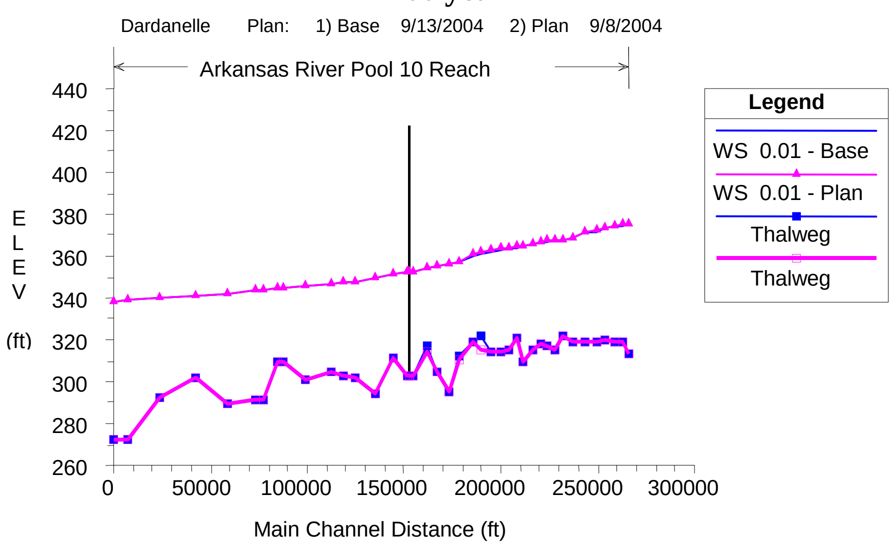
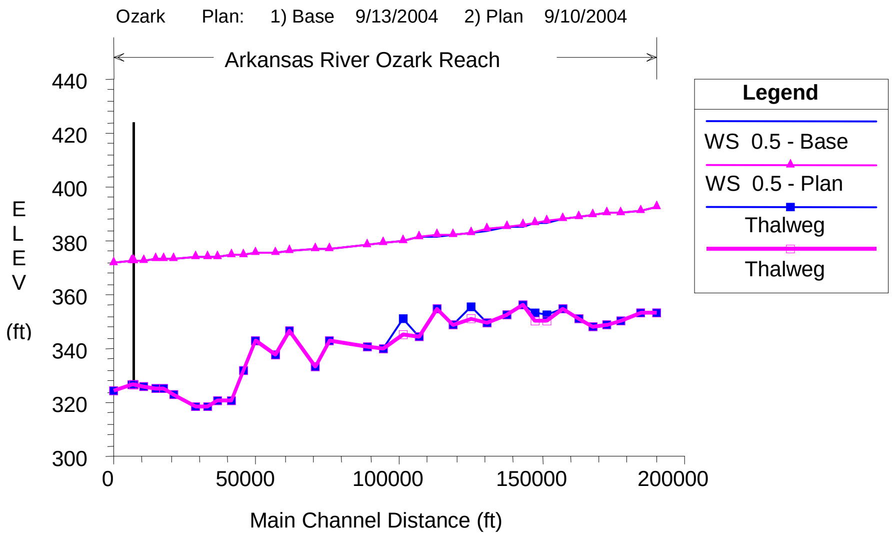


Figure A-1-1 (Continued)
Water Surface and Thalweg Profiles

Ozark
2 year



Ozark
100 year

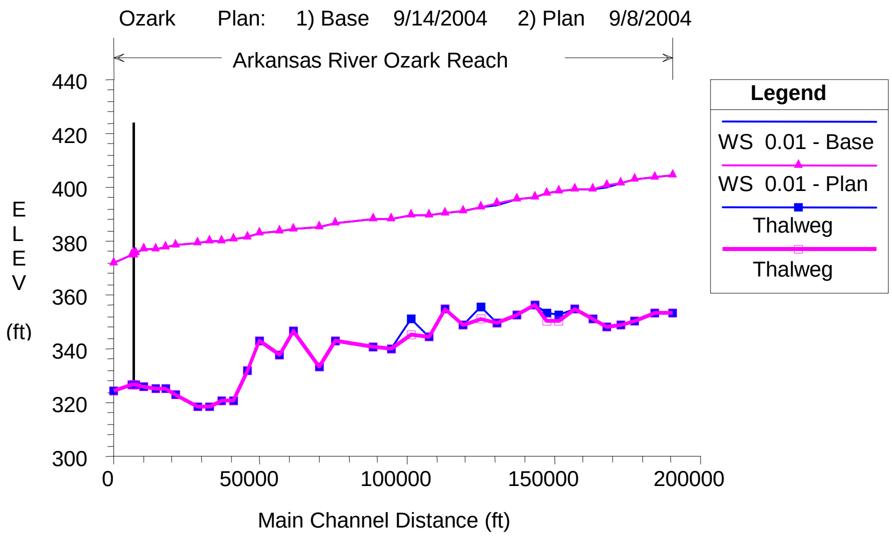


Table A-19
Sediment Transport Capacity Potential
HEC-RAS Model HD Results (2-Year Flow)

Sed Reach	NM	Sediment Transport Function	BASE	PLAN	% Delta	MOD	% Delta
			Tons/Day	Tons/Day		Tons/Day	
pool 2	50.00	Laursen (Copeland)	42480	39130	-8	42730	1
pool 2	49.60	Laursen (Copeland)	59410	54350	-9	59790	1
pool 2	48.43	Laursen (Copeland)	59930	53640	-10	60410	1
pool 2	47.15	Laursen (Copeland)	21530	18700	-13	21750	1
pool 2	45.63	Laursen (Copeland)	11190	9693	-13	11310	1
pool 2	44.91	Laursen (Copeland)	74250	62140	-16	75200	1
pool 2	44.77	Laursen (Copeland)	64030	52970	-17	64900	1
pool 2	44.41	Laursen (Copeland)	73430	73430	0	66170	-10
pool 2	44.00	Laursen (Copeland)	58000	54790	-6	45260	-22
pool 2	43.60	Laursen (Copeland)	62870	93230	48	62390	-1
pool 2	43.31	Laursen (Copeland)	37550	61120	63	47890	28
pool 2	41.86	Laursen (Copeland)	142200	130400	-8	145100	2
pool 2	40.36	Laursen (Copeland)	67720	60570	-11	70180	4
pool 2	39.73	Laursen (Copeland)	276500	335700	21	213600	-23
pool 2	39.43	Laursen (Copeland)	15090	13790	-9	15380	2
pool 2	36.17	Laursen (Copeland)	112300	178200	59	147100	31
pool 2	34.97	Laursen (Copeland)	101500	125200	23	80490	-21
pool 2	33.47	Laursen (Copeland)	14390	14390	0	14390	0
pool 2	31.99	Laursen (Copeland)	333600	333600	0	333600	0
pool 2	30.26	Laursen (Copeland)	107800	107800	0	107800	0
pool 2	27.67	Laursen (Copeland)	31460	31460	0	31460	0
pool 2	26.00	Laursen (Copeland)	84890	84890	0	84890	0
pool 2	24.58	Laursen (Copeland)	47920	47920	0	47920	0
pool 2	22.67	Laursen (Copeland)	50780	50780	0	50780	0
pool 2	22.55	Laursen (Copeland)	51220	51220	0	51220	0
pool 2	22.47	Laursen (Copeland)	51670	51670	0	51670	0
pool 2	22.27	Laursen (Copeland)	52410	52410	0	52410	0
pool 2	20.83	Laursen (Copeland)	74140	74140	0	74140	0
pool 2	19.83	Laursen (Copeland)	66540	66540	0	66540	0
pool 2	19.21	Laursen (Copeland)	50330	50330	0	50330	0
pool 2	17.78	Laursen (Copeland)	58960	58960	0	58960	0
pool 2	17.00	Laursen (Copeland)	93660	93660	0	93660	0
pool3	65.63	Laursen (Copeland)	83780	81010	-3	83770	0
pool3	65.22	Laursen (Copeland)	45830	44290	-3	45820	0
pool3	64.46	Laursen (Copeland)	33770	32590	-3	33770	0
pool3	64.13	Laursen (Copeland)	77640	74590	-4	77630	0
pool3	63.70	Laursen (Copeland)	57780	55370	-4	57770	0

Table A-19 (Continued)
Sediment Transport Capacity Potential
HEC-RAS Model HD Results (2-Year Flow)

Sed Reach	NM	Sediment Transport Function	BASE	PLAN	% Delta	MOD	% Delta
			Tons/Day	Tons/Day		Tons/Day	
Pool3	62.93	Laursen (Copeland)	34250	32890	-4	34240	0
pool3	62.13	Laursen (Copeland)	56110	53440	-5	56100	0
pool3	61.53	Laursen (Copeland)	125700	148200	18	119700	-5
pool3	61.12	Laursen (Copeland)	61940	77950	26	50340	-19
pool3	59.93	Laursen (Copeland)	33820	33820	0	33820	0
pool3	59.30	Laursen (Copeland)	193700	193700	0	193700	0
pool3	58.69	Laursen (Copeland)	81250	81250	0	81250	0
pool3	58.46	Laursen (Copeland)	80750	80750	0	80750	0
pool3	57.39	Laursen (Copeland)	122700	122700	0	122700	0
pool3	56.37	Laursen (Copeland)	58590	58590	0	58590	0
pool3	55.85	Laursen (Copeland)	32510	32510	0	32510	0
pool3	55.54	Laursen (Copeland)	23480	23480	0	23480	0
pool3	55.23	Laursen (Copeland)	24120	24120	0	24120	0
pool3	54.92	Laursen (Copeland)	25280	25280	0	25280	0
pool3	53.69	Laursen (Copeland)	65480	65480	0	65480	0
pool3	52.97	Laursen (Copeland)	63360	63360	0	63360	0
pool3	52.35	Laursen (Copeland)	64280	64280	0	64280	0
pool3	51.18	Laursen (Copeland)	85130	85130	0	85130	0
pool 4	86.04	Laursen (Copeland)	266700	257700	-3	264200	-1
pool 4	85.63	Laursen (Copeland)	177100	170300	-4	175200	-1
pool 4	84.87	Laursen (Copeland)	133100	128600	-3	131900	-1
pool 4	84.36	Laursen (Copeland)	209200	201300	-4	206900	-1
pool 4	83.90	Laursen (Copeland)	75320	71740	-5	74320	-1
pool 4	83.37	Laursen (Copeland)	108200	104400	-4	107100	-1
pool 4	82.84	Laursen (Copeland)	107100	103300	-4	106000	-1
pool 4	81.78	Laursen (Copeland)	137800	130700	-5	135800	-1
pool 4	81.20	Laursen (Copeland)	144000	135000	-6	141500	-2
pool 4	80.48	Laursen (Copeland)	209300	196500	-6	205700	-2
pool 4	79.28	Laursen (Copeland)	272000	383400	41	234500	-14
pool 4	78.34	Laursen (Copeland)	408200	408200	0	408200	0
pool 4	77.07	Laursen (Copeland)	451900	451900	0	451900	0
pool 4	76.02	Laursen (Copeland)	348000	348000	0	348000	0
pool 4	75.04	Laursen (Copeland)	192200	192200	0	192200	0
pool 4	74.82	Laursen (Copeland)	90250	90250	0	90250	0
pool 4	74.79	Laursen (Copeland)	91440	91440	0	91440	0
pool 4	74.76	Laursen (Copeland)	218300	218300	0	218300	0
pool 4	74.18	Laursen (Copeland)	99740	99740	0	99740	0

Table A-19 (Continued)
Sediment Transport Capacity Potential
HEC-RAS Model HD Results (2-Year Flow)

Sed Reach	NM	Sediment Transport Function	BASE	PLAN	% Delta	MOD	% Delta
			Tons/Day	Tons/Day		Tons/Day	
pool 4	73.35	Laursen (Copeland)	195500	195500	0	195500	0
pool 4	72.62	Laursen (Copeland)	198100	198100	0	198100	0
pool 4	71.28	Laursen (Copeland)	23570	23570	0	23570	0
pool 4	70.23	Laursen (Copeland)	65210	65210	0	65210	0
pool 4	69.39	Laursen (Copeland)	49890	49890	0	49890	0
pool 4	68.20	Laursen (Copeland)	25320	25320	0	25320	0
pool 4	67.80	Laursen (Copeland)	138800	138800	0	138800	0
pool 4	67.39	Laursen (Copeland)	347600	347600	0	347600	0
pool 4	67.33	Laursen (Copeland)	368100	368100	0	368100	0
pool 4	67.13	Laursen (Copeland)	80510	80510	0	80510	0
pool 4	66.72	Laursen (Copeland)	85720	85720	0	85720	0
pool 4	66.15	Laursen (Copeland)	306900	306900	0	306900	0
pool 5	107.85	Laursen (Copeland)	21670	22140	2	21940	1
pool 5	107.20	Laursen (Copeland)	15720	16040	2	15910	1
pool 5	106.40	Laursen (Copeland)	27670	28310	2	28040	1
pool 5	105.36	Laursen (Copeland)	65190	67130	3	66310	2
pool 5	104.40	Laursen (Copeland)	49160	50430	3	49930	2
pool 5	103.80	Laursen (Copeland)	63040	64770	3	64040	2
pool 5	102.98	Laursen (Copeland)	33110	34570	4	33950	3
pool 5	102.40	Laursen (Copeland)	66930	103500	55	61300	-8
pool 5	101.59	Laursen (Copeland)	41940	74960	79	45630	9
pool 5	100.29	Laursen (Copeland)	467800	177800	-62	472400	1
pool 5	98.92	Laursen (Copeland)	42130	38810	-8	42610	1
pool 5	98.15	Laursen (Copeland)	197100	176100	-11	218700	11
pool 5	97.10	Laursen (Copeland)	43420	56240	30	49960	15
pool 5	96.42	Laursen (Copeland)	94680	107200	13	80620	-15
pool 5	95.43	Laursen (Copeland)	142300	194900	37	108600	-24
pool 5	95.00	Laursen (Copeland)	30080	30080	0	30080	0
pool 5	94.37	Laursen (Copeland)	26720	26720	0	26720	0
pool 5	93.08	Laursen (Copeland)	99790	99790	0	99790	0
pool 5	92.14	Laursen (Copeland)	27310	27310	0	27310	0
pool 5	91.60	Laursen (Copeland)	25560	25570	0	25570	0
pool 5	90.90	Laursen (Copeland)	29410	29410	0	29410	0
pool 5	90.37	Laursen (Copeland)	195800	195800	0	195800	0
pool 5	89.26	Laursen (Copeland)	24040	24040	0	24040	0
pool 5	88.50	Laursen (Copeland)	40950	40950	0	40950	0
pool 5	87.37	Laursen (Copeland)	36490	36490	0	36490	0

Table A-19 (Continued)
Sediment Transport Capacity Potential
HEC-RAS Model HD Results (2-Year Flow)

Sed Reach	NM	Sediment Transport Function	BASE	PLAN	% Delta	MOD	% Delta
			Tons/Day	Tons/Day		Tons/Day	
pool 5	86.50	Laursen (Copeland)	99610	99610	0	99610	0
pool 7	155.65	Laursen (Copeland)	59280	55900	-6	58910	-1
pool 7	154.87	Laursen (Copeland)	57440	53770	-6	57040	-1
pool 7	153.59	Laursen (Copeland)	73730	67030	-9	72990	-1
pool 7	152.44	Laursen (Copeland)	30310	27280	-10	29970	-1
pool 7	151.53	Laursen (Copeland)	45230	40240	-11	44670	-1
pool 7	150.53	Laursen (Copeland)	42880	37850	-12	42260	-1
pool 7	150.13	Laursen (Copeland)	92010	80080	-13	90620	-2
pool 7	149.63	Laursen (Copeland)	78110	67790	-13	76810	-2
pool 7	149.48	Laursen (Copeland)	89090	81300	-9	87820	-1
pool 7	148.53	Laursen (Copeland)	73120	65380	-11	72220	-1
pool 7	147.68	Laursen (Copeland)	58650	50260	-14	57650	-2
pool 7	146.71	Laursen (Copeland)	55510	112600	103	76010	37
pool 7	145.78	Laursen (Copeland)	129700	225100	74	144500	11
pool 7	145.00	Laursen (Copeland)	107800	135100	25	88530	-18
pool 7	143.52	Laursen (Copeland)	66370	64950	-2	66290	0
pool 7	142.87	Laursen (Copeland)	46920	53550	14	38910	-17
pool 7	141.83	Laursen (Copeland)	45430	45350	0	45420	0
pool 7	141.55	Laursen (Copeland)	332900	331400	0	332800	0
pool 7	140.43	Laursen (Copeland)	42780	42420	-1	42740	0
pool 7	139.79	Laursen (Copeland)	116500	115700	-1	116400	0
pool 7	139.14	Laursen (Copeland)	70950	70380	-1	70890	0
pool 7	138.50	Laursen (Copeland)	104900	103900	-1	104800	0
pool 7	137.58	Laursen (Copeland)	6431	6382	-1	6425	0
pool 7	136.70	Laursen (Copeland)	177800	178600	0	182500	3
pool 7	135.75	Laursen (Copeland)	103300	101700	-2	103100	0
pool 7	134.43	Laursen (Copeland)	21610	21190	-2	21560	0
pool 7	133.21	Laursen (Copeland)	32740	32140	-2	32660	0
pool 7	132.36	Laursen (Copeland)	63080	62080	-2	62950	0
pool 7	132.30	Laursen (Copeland)	63480	62420	-2	63290	0
pool 7	131.78	Laursen (Copeland)	62160	61170	-2	62030	0
pool 7	131.60	Laursen (Copeland)	62610	61470	-2	62460	0
pool 7	131.54	Laursen (Copeland)	65000	63810	-2	64850	0
pool 7	130.05	Laursen (Copeland)	135800	132600	-2	135300	0
pool 7	129.30	Laursen (Copeland)	68860	66940	-3	68610	0
pool 7	127.86	Laursen (Copeland)	126300	104100	-18	123100	-3
pool 7	127.45	Laursen (Copeland)	46860	83950	79	53710	15
pool 7	127.39	Laursen (Copeland)	44150	78570	78	50600	15

Table A-19 (Continued)
Sediment Transport Capacity Potential
HEC-RAS Model HD Results (2-Year Flow)

Sed Reach	NM	Sediment Transport Function	BASE	PLAN	% Delta	MOD	% Delta
			Tons/Day	Tons/Day		Tons/Day	
pool 7	127.21	Laursen (Copeland)	30460	56580	86	37930	25
pool 7	126.85	Laursen (Copeland)	31370	45380	45	30740	-2
pool 7	126.79	Laursen (Copeland)	27070	27070	0	27070	0
pool 7	126.58	Laursen (Copeland)	25000	25000	0	25000	0
pool 7	126.56	Laursen (Copeland)	25170	25170	0	25170	0
pool 7	126.18	Laursen (Copeland)	223700	223700	0	223700	0
pool 7	125.45	Laursen (Copeland)	55570	55570	0	55570	0
pool 8	176.65	Laursen (Copeland)	39180	38530	-2	39010	0
pool 8	176.19	Laursen (Copeland)	38580	37890	-2	38400	0
pool 8	175.13	Laursen (Copeland)	20470	19910	-3	20320	-1
pool 8	174.36	Laursen (Copeland)	25780	25120	-3	25600	-1
pool 8	173.77	Laursen (Copeland)	33910	33150	-2	33710	-1
pool 8	173.23	Laursen (Copeland)	50570	49470	-2	50280	-1
pool 8	173.02	Laursen (Copeland)	59990	58710	-2	59650	-1
pool 8	172.96	Laursen (Copeland)	60400	59100	-2	60060	-1
pool 8	172.79	Laursen (Copeland)	54330	53090	-2	53990	-1
pool 8	172.22	Laursen (Copeland)	22470	21740	-3	22280	-1
pool 8	171.35	Laursen (Copeland)	22770	21990	-3	22570	-1
pool 8	170.21	Laursen (Copeland)	21150	20380	-4	20940	-1
pool 8	169.50	Laursen (Copeland)	22280	33520	50	22840	3
pool 8	168.85	Laursen (Copeland)	34220	33930	-1	34080	0
pool 8	167.23	Laursen (Copeland)	44290	43980	-1	44140	0
pool 8	165.89	Laursen (Copeland)	32500	32200	-1	32350	0
pool 8	164.70	Laursen (Copeland)	23820	29010	22	25470	7
pool 8	164.27	Laursen (Copeland)	50050	50050	0	50050	0
pool 8	163.10	Laursen (Copeland)	24550	24550	0	24550	0
pool 8	162.05	Laursen (Copeland)	49880	49880	0	49880	0
pool 8	160.79	Laursen (Copeland)	35830	35830	0	35830	0
pool 8	160.16	Laursen (Copeland)	84250	84250	0	84250	0
pool 8	160.07	Laursen (Copeland)	48490	48490	0	48490	0
pool 8	158.99	Laursen (Copeland)	23330	23330	0	23330	0
pool 8	157.76	Laursen (Copeland)	37510	37510	0	37510	0
pool 8	156.98	Laursen (Copeland)	34740	34740	0	34740	0
pool 8	156.05	Laursen (Copeland)	38320	38320	0	38320	0
pool 9	205.25	Laursen (Copeland)	1428	1402	-2	1411	-1
pool 9	205.04	Laursen (Copeland)	2413	2362	-2	2380	-1

Table A-19 (Continued)
Sediment Transport Capacity Potential
HEC-RAS Model HD Results (2-Year Flow)

Sed Reach	NM	Sediment Transport Function	BASE	PLAN	% Delta	MOD	% Delta
			Tons/Day	Tons/Day		Tons/Day	
pool 9	204.71	Laursen (Copeland)	14180	13840	-2	13960	-2
pool 9	204.39	Laursen (Copeland)	17610	17240	-2	17370	-1
pool 9	204.00	Laursen (Copeland)	34770	34020	-2	34290	-1
pool 9	203.86	Laursen (Copeland)	35020	34250	-2	34520	-1
pool 9	203.47	Laursen (Copeland)	34500	33660	-2	33950	-2
pool 9	203.38	Laursen (Copeland)	34900	34040	-2	34340	-2
pool 9	203.10	Laursen (Copeland)	41720	40690	-2	41050	-2
pool 9	202.61	Laursen (Copeland)	59450	57690	-3	58310	-2
pool 9	202.09	Laursen (Copeland)	75390	73090	-3	73890	-2
pool 9	201.31	Laursen (Copeland)	47260	45790	-3	46300	-2
pool 9	200.43	Laursen (Copeland)	34800	33590	-3	34010	-2
pool 9	199.00	Laursen (Copeland)	44130	42360	-4	42970	-3
pool 9	198.22	Laursen (Copeland)	75280	72600	-4	73410	-2
pool 9	197.52	Laursen (Copeland)	29400	28010	-5	28490	-3
pool 9	196.72	Laursen (Copeland)	47450	45030	-5	45850	-3
pool 9	195.71	Laursen (Copeland)	50760	48380	-5	49200	-3
pool 9	195.09	Laursen (Copeland)	57710	54620	-5	55680	-4
pool 9	194.16	Laursen (Copeland)	20680	18290	-12	19080	-8
pool 9	193.41	Laursen (Copeland)	53540	50620	-5	51620	-4
pool 9	192.90	Laursen (Copeland)	37740	35700	-5	36390	-4
pool 9	192.41	Laursen (Copeland)	58350	54650	-6	55900	-4
pool 9	191.68	Laursen (Copeland)	59450	55340	-7	56730	-5
pool 9	190.71	Laursen (Copeland)	45220	40790	-10	42240	-7
pool 9	189.51	Laursen (Copeland)	43090	43560	1	45630	6
pool 9	188.44	Laursen (Copeland)	36140	30040	-17	32270	-11
pool 9	187.40	Laursen (Copeland)	38710	56250	45	49210	27
pool 9	186.38	Laursen (Copeland)	27210	25700	-6	26540	-2
pool 9	185.54	Laursen (Copeland)	73920	68910	-7	71680	-3
pool 9	184.82	Laursen (Copeland)	27510	31300	14	27940	2
pool 9	184.21	Laursen (Copeland)	20460	19480	-5	20090	-2
pool 9	183.61	Laursen (Copeland)	28300	26310	-7	27550	-3
pool 9	182.64	Laursen (Copeland)	94730	85500	-10	91100	-4
pool 9	181.77	Laursen (Copeland)	58200	87460	50	58030	0
pool 9	181.60	Laursen (Copeland)	43530	59690	37	39850	-8
pool 9	180.58	Laursen (Copeland)	16930	16930	0	16930	0
pool 9	179.47	Laursen (Copeland)	52560	52560	0	52560	0
pool 9	178.75	Laursen (Copeland)	26360	26360	0	26360	0
pool 9	177.68	Laursen (Copeland)	68530	68530	0	68530	0

Table A-19 (Continued)
Sediment Transport Capacity Potential
HEC-RAS Model HD Results (2-Year Flow)

Sed Reach	NM	Sediment Transport Function	BASE	PLAN	% Delta	MOD	% Delta
			Tons/Day	Tons/Day		Tons/Day	
pool 9	177.03	Laursen (Copeland)	60500	60500	0	60500	0
dard	256.43	Laursen (Copeland)	76020	74780	-2	75930	0
dard	255.91	Laursen (Copeland)	229900	225200	-2	229500	0
dard	255.03	Laursen (Copeland)	252600	247400	-2	252300	0
dard	254.17	Laursen (Copeland)	242500	235900	-3	242000	0
dard	253.29	Laursen (Copeland)	348600	338600	-3	347800	0
dard	252.10	Laursen (Copeland)	219100	534000	144	218600	0
dard	251.00	Laursen (Copeland)	293300	284200	-3	292600	0
dard	249.96	Laursen (Copeland)	184400	177500	-4	183900	0
dard	249.18	Laursen (Copeland)	88110	85310	-3	87890	0
dard	248.30	Laursen (Copeland)	173500	165500	-5	172900	0
dard	247.64	Laursen (Copeland)	68120	64640	-5	67860	0
dard	246.95	Laursen (Copeland)	104100	97350	-6	103600	0
dard	245.99	Laursen (Copeland)	207100	193700	-6	206300	0
dard	245.37	Laursen (Copeland)	157600	143800	-9	156700	-1
dard	244.55	Laursen (Copeland)	118700	107600	-9	117900	-1
dard	243.71	Laursen (Copeland)	43020	38420	-11	42690	-1
dard	242.83	Laursen (Copeland)	124100	110300	-11	123100	-1
dard	241.82	Laursen (Copeland)	261000	365700	40	242400	-7
dard	241.00	Laursen (Copeland)	265600	249500	-6	263800	-1
dard	239.62	Laursen (Copeland)	178900	186400	4	173200	-3
dard	238.65	Laursen (Copeland)	16040	14790	-8	15260	-5
dard	237.31	Laursen (Copeland)	73220	68390	-7	70400	-4
dard	236.41	Laursen (Copeland)	393800	500700	27	414600	5
dard	235.04	Laursen (Copeland)	24030	24030	0	24030	0
dard	234.76	Laursen (Copeland)	26560	26560	0	26560	0
dard	234.64	Laursen (Copeland)	26740	26740	0	26740	0
dard	234.41	Laursen (Copeland)	28540	28540	0	28540	0
dard	233.00	Laursen (Copeland)	15460	15460	0	15460	0
dard	231.28	Laursen (Copeland)	102100	102100	0	102100	0
dard	229.28	Laursen (Copeland)	49010	49020	0	49020	0
dard	228.15	Laursen (Copeland)	45070	45070	0	45070	0
dard	226.90	Laursen (Copeland)	24920	24920	0	24920	0
dard	224.45	Laursen (Copeland)	7577	7578	0	7578	0
dard	222.30	Laursen (Copeland)	4663	4663	0	4663	0
dard	221.58	Laursen (Copeland)	4799	4799	0	4799	0
dard	220.23	Laursen (Copeland)	13870	13870	0	13870	0
dard	219.60	Laursen (Copeland)	14180	14180	0	14180	0

Table A-19 (Continued)
Sediment Transport Capacity Potential
HEC-RAS Model HD Results (2-Year Flow)

Sed Reach	NM	Sediment Transport Function	BASE	PLAN	% Delta	MOD	% Delta
			Tons/Day	Tons/Day		Tons/Day	
dard	216.77	Laursen (Copeland)	8797	8797	0	8797	0
dard	213.69	Laursen (Copeland)	2814	2814	0	2814	0
dard	210.11	Laursen (Copeland)	511	511	0	511	0
dard	207.08	Laursen (Copeland)	5045	5040	0	5040	0
dard	205.60	Laursen (Copeland)	5110	5110	0	5110	0
ozark	292.50	Laursen (Copeland)	51510	49100	-5	50790	-1
ozark	291.40	Laursen (Copeland)	78790	99200	26	77910	-1
ozark	290.04	Laursen (Copeland)	25210	23510	-7	24860	-1
ozark	289.08	Laursen (Copeland)	98000	92250	-6	96790	-1
ozark	288.13	Laursen (Copeland)	55420	52870	-5	54980	-1
ozark	287.21	Laursen (Copeland)	64870	61880	-5	64270	-1
ozark	286.16	Laursen (Copeland)	79660	71830	-10	78060	-2
ozark	285.11	Laursen (Copeland)	276700	292300	6	236700	-14
ozark	284.34	Laursen (Copeland)	73090	75280	3	66420	-9
ozark	283.52	Laursen (Copeland)	198900	184300	-7	191800	-4
ozark	282.42	Laursen (Copeland)	50850	47240	-7	49080	-3
ozark	281.25	Laursen (Copeland)	119700	109100	-9	114400	-4
ozark	280.16	Laursen (Copeland)	80330	98520	23	87030	8
ozark	279.30	Laursen (Copeland)	88360	84980	-4	87440	-1
ozark	278.12	Laursen (Copeland)	25290	24420	-3	25040	-1
ozark	276.92	Laursen (Copeland)	11670	10330	-11	11320	-3
ozark	275.78	Laursen (Copeland)	132800	183600	38	126200	-5
ozark	274.55	Laursen (Copeland)	54750	54750	0	54750	0
ozark	273.40	Laursen (Copeland)	76580	76580	0	76580	0
ozark	271.28	Laursen (Copeland)	46630	46630	0	46630	0
ozark	270.31	Laursen (Copeland)	55930	55930	0	55930	0
ozark	268.62	Laursen (Copeland)	62010	62010	0	62010	0
ozark	267.70	Laursen (Copeland)	50920	50920	0	50920	0
ozark	266.38	Laursen (Copeland)	50120	50120	0	50120	0
ozark	265.58	Laursen (Copeland)	34780	34780	0	34780	0
ozark	264.70	Laursen (Copeland)	36400	36400	0	36400	0
ozark	263.84	Laursen (Copeland)	37980	37980	0	37980	0
ozark	263.19	Laursen (Copeland)	26110	26110	0	26110	0
ozark	262.33	Laursen (Copeland)	27430	27430	0	27430	0
ozark	260.83	Laursen (Copeland)	25570	25570	0	25570	0
ozark	260.19	Laursen (Copeland)	32840	32840	0	32840	0
ozark	259.59	Laursen (Copeland)	33970	33970	0	33970	0

Table A-19 (Continued)
Sediment Transport Capacity Potential
HEC-RAS Model HD Results (2-Year Flow)

Sed Reach	NM	Sediment Transport Function	BASE	PLAN	% Delta	MOD	% Delta
			Tons/Day	Tons/Day		Tons/Day	
ozark	258.88	Laursen (Copeland)	19400	19400	0	19400	0
ozark	258.28	Laursen (Copeland)	36290	36290	0	36290	0
ozark	258.23	Laursen (Copeland)	36380	36380	0	36380	0
ozark	258.18	Laursen (Copeland)	36740	36740	0	36740	0
ozark	258.07	Laursen (Copeland)	36970	36970	0	36970	0
ozark	256.90	Laursen (Copeland)	60880	60880	0	60880	0

Table A-20
McClellan-Kerr Arkansas River Navigation System
History of Dredging and Flow Data
1971-2002

POOL NO.	PROJECT NAME	VOLUME OF MATERIALS DREDGED FROM EACH POOL PER CALENDAR YEAR OF PROJECT OPERATION: In Thousands of Cubic Yards							
		1971	1972	1973	1974	1975	1976	1977	1978
1	Norrell L&D	0	0	0	0	0	0	0	0
2	W.D. Mills L&D	226	484	1,493	1,557	571	588	557	594
3	Lock & Dam No. 3	0	11	64	17	49	19	0	0
4	E. Sanders L&D	5	25	43	37	16	0	0	0
5	Lock & Dam No. 5	307	7	101	112	17	24	107	32
6	D.D. Terry L&D	61	36	47	0	0	0	0	0
7	Murray L&D	154	476	803	639	258	232	96	14
8	Toad Suck Ferry LD	95	612	775	749	176	102	39	0
9	A.V. Ormand L&D	50	162	220	313	81	49	0	39
10	Dardanelle L&D	700	488	164	32	0	43	67	29
12	Ozark-J Taylor L&D	126	162	456	598	289	285	107	99
13	J.W. Trimble L&D	0	77	0	43	0	0	0	0
13	J.W. Trimble L&D	0	2,575	2,530	3,195	351	541	0	193
14	W.D. Mayo L&D	0	0	48	0	0	0	0	0
15	R.S. Kerr L&D	0	619	0	0	11	0	117	0
16	Webbers Falls L&D	0	65	0	82	17	0	0	0
17	Chouteau Lock	0	0	0	0	235	0	42	0
18	Newt Graham L&D	0	575	0	0	79	0	100	0
YEARLY DREDGING VOLUME- In Million Cubic Yards:		1.1	6.4	6.7	7.4	2.2	1.9	1.2	1.0
TOTAL VOLUME OF ARKANSAS RIVER FLOWS PER CALENDAR YEAR: In Millions of Acre-Feet									
AT NEWT GRAHAM L&D, VEDIGRIS		2.4	2.1	8.4	8.5	4.7	2.2	3.4	3.1
AT WEBBERS FALLS L&D, ARKANSAS		10.5	9.2	43.4	31.3	20.5	8.8	11.9	11.8
AT VAN BUREN GAGE, ARKANSAS		16.9	14.1	61.1	44.5	33.9	14.3	15.1	16.6
AT LITTLE ROCK GAGE, ARKANSAS		21.5	18.7	75.1	52.1	41.5	17.2	20.0	21.6
PEAK DISCHARGE OF ARKANSAS RIVER PER CALENDAR YEAR: In Thousands of Cubic Feet per Second									
AT NEWT GRAHAM L&D, VEDIGRIS		28	22	33	63	25	28	29	24
AT WEBBERS FALLS L&D, ARKANSAS		91	80	152	184	89	96	75	84
AT VAN BUREN GAGE, ARKANSAS		161	115	249	209	145	162	106	101
AT LITTLE ROCK GAGE, ARKANSAS		237	161	322	236	221	144	203	149

Table A-20 (Continued)
McClellan-Kerr Arkansas River Navigation System
History of Dredging and Flow Data
1971-2002

POOL NO.	PROJECT NAME	VOLUME OF MATERIALS DREDGED FROM EACH POOL PER CALENDAR YEAR OF PROJECT OPERATION: In Thousands of Cubic Yards							
		1979	1980	1981	1982	1983	1984	1985	1986
1	Norrell L&D	0	0	0	0	0	0	0	0
2	W.D. Mills L&D	376	22	0	513	867	745	848	2,044
3	Lock & Dam No. 3	9	0	0	97	21	6	92	90
4	E. Sanders L&D	0	0	0	0	13	0	154	0
5	Lock & Dam No. 5	138	0	0	118	0	0	0	53
6	D.D. Terry L&D	0	0	0	0	0	0	0	0
7	Murray L&D	153	0	0	205	238	51	339	285
8	Toad Suck Ferry LD	0	0	0	0	0	0	0	0
9	A.V. Ormand L&D	108	0	0	81	0	48	0	94
10	Dardanelle L&D	0	0	0	0	77	53	40	13
12	Ozark-J Taylor L&D	43	0	0	0	0	57	114	284
13	J.W. Trimble L&D	0	0	0	0	0	0	0	0
13	J.W. Trimble L&D	186	0	0	0	0	0	0	0
14	W.D. Mayo L&D	0	0	0	0	0	0	0	0
15	R.S. Kerr L&D	332	0	0	0	0	0	0	0
16	Webbers Falls L&D	222	374	0	90	142	0	82	33
17	Chouteau Lock	87	0	0	67	0	0	41	101
18	Newt Graham L&D	0	0	0	145	0	0	0	0
YEARLY DREDGING VOLUME- In Million Cubic Yards:		1.6	0.4	0.0	1.3	1.3	1.0	1.7	3.0
TOTAL VOLUME OF ARKANSAS RIVER FLOWS PER CALENDAR YEAR: In Millions of Acre-Feet									
AT NEWT GRAHAM L&D, VEDIGRIS		2.5	1.8	0.9	3.4	4.4	4.7	9.1	7.7
AT WEBBERS FALLS L&D, ARKANSAS		12.2	9.0	6.6	17.4	19.9	18.2	36.7	29.1
AT VAN BUREN GAGE, ARKANSAS		20.0	11.6	9.7	24.8	25.7	25.8	52.1	40.0
AT LITTLE ROCK GAGE, ARKANSAS		30.7	14.3	13.6	33.2	32.4	37.1	57.8	45.0
PEAK DISCHARGE OF ARKANSAS RIVER PER CALENDAR YEAR: In Thousands of Cubic Feet per Second									
AT NEWT GRAHAM L&D, VEDIGRIS		20	25	16	27	33	31	53	107
AT WEBBERS FALLS L&D, ARKANSAS		65	73	51	109	110	130	136	343
AT VAN BUREN GAGE, ARKANSAS		107	80	49	154	132	133	191	350
AT LITTLE ROCK GAGE, ARKANSAS		173	75	70	271	169	165	218	308

Table A-20 (Continued)
McClellan-Kerr Arkansas River Navigation System
History of Dredging and Flow Data
1971-2002

POOL NO.	PROJECT NAME	VOLUME OF MATERIALS DREDGED FROM EACH POOL PER CALENDAR YEAR OF PROJECT OPERATION: In Thousands of Cubic Yards							
		1987	1988	1989	1990	1991	1992	1993	1994
1	Norrell L&D	0	0	0	0	0	0	0	0
2	W.D. Mills L&D	1,173	1,114	518	1,338	379	257	980	618
3	Lock & Dam No. 3	34	47	0	166	13	19	140	23
4	E. Sanders L&D	58	0	0	28	0	32	32	0
5	Lock & Dam No. 5	41	0	0	0	51	0	0	0
6	D.D. Terry L&D	0	0	0	139	3	0	21	0
7	Murray L&D	67	0	262	677	81	0	0	0
8	Toad Suck Ferry LD	40	0	0	154	0	0	0	0
9	A.V. Ormand L&D	0	0	0	90	0	83	95	45
10	Dardanelle L&D	59	0	103	77	0	0	99	42
12	Ozark-J Taylor L&D	145	0	45	171	155	22	0	77
13	J.W. Trimble L&D	0	0	0	5	0	0	0	0
13	J.W. Trimble L&D	0	0	1	1	230	0	64	0
14	W.D. Mayo L&D	0	0	0	0	0	0	0	0
15	R.S. Kerr L&D	0	0	0	0	0	0	0	0
16	Webbers Falls L&D	0	0	0	2	0	0	0	20
17	Chouteau Lock	0	0	0	0	0	0	48	0
18	Newt Graham L&D	0	0	37	0	0	0	0	0
YEARLY DREDGING VOLUME- In Million Cubic Yards		1.6	1.2	1.0	2.8	1.0	0.4	1.5	0.8
TOTAL VOLUME OF ARKANSAS RIVER FLOWS PER CALENDAR YEAR: In Millions of Acre-Feet									
AT NEWT GRAHAM L&D, VEDIGRIS		5.1	4.2	3.8	5.1	1.6	4.8	7.5	4.8
AT WEBBERS FALLS L&D, ARKANSAS		26.5	18.2	13.9	21.6	6.7	20.7	39.2	18.1
AT VAN BUREN GAGE, ARKANSAS		36.3	25.1	25.7	42.7	18.0	36.0	56.5	27.9
AT LITTLE ROCK GAGE, ARKANSAS		41.4	30.5	31.4	52.0	26.8	39.6	65.1	35.2
PEAK DISCHARGE OF ARKANSAS RIVER PER CALENDAR YEAR: In Thousands of Cubic Feet per Second									
AT NEWT GRAHAM L&D, VEDIGRIS		33	31	29	44	28	36	51	34
AT WEBBERS FALLS L&D, ARKANSAS		124	141	79	152	73	128	200	138
AT VAN BUREN GAGE, ARKANSAS		186	160	138	397	130	206	265	149
AT LITTLE ROCK GAGE, ARKANSAS		262	182	209	404	159	225	246	181

Table A-20 (Continued)
McClellan-Kerr Arkansas River Navigation System
History of Dredging and Flow Data
1971-2002

POOL NO.	PROJECT NAME	VOLUME OF MATERIALS DREDGED FROM EACH POOL PER CALENDAR YEAR OF PROJECT OPERATION: In Thousands of Cubic Yards							
		1995	1996	1997	1998	1999	2000	2001	2002
1	Norrell L&D	0	0	0	0	0	0	0	0
2	W.D. Mills L&D	301	156	64	37	127	55	48	97
3	Lock & Dam No. 3	0	24	6	20	16	0	4	0
4	E. Sanders L&D	0	5	3	8	10	0	4	0
5	Lock & Dam No. 5	0	0	0	41	0	0	7	0
6	D.D. Terry L&D	0	0	0	0	0	0	0	0
7	Murray L&D	0	0	0	0	26	0	19	26
8	Toad Suck Ferry LD	38	0	0	0	0	0	0	0
9	A.V. Ormand L&D	0	0	0	29	0	0	0	0
10	Dardanelle L&D	122	0	0	36	0	8	0	42
12	Ozark-J Taylor L&D	95	0	0	0	0	0	62	82
13	J.W. Trimble L&D	0	0	0	0	0	0	0	0
13	J.W. Trimble L&D	0	0	0	0	19	0	0	23
14	W.D. Mayo L&D	62	0	0	0	0	0	0	0
15	R.S. Kerr L&D	0	0	0	0	0	0	0	0
16	Webbers Falls L&D	75	148	103	0	83	0	0	151
17	Chouteau Lock	50	3	0	0	91	0	0	91
18	Newt Graham L&D	43	0	0	0	0	0	0	0
YEARLY DREDGING VOLUME- In Million Cubic Yards		0.7	0.3	0.2	0.2	0.4	0.1	0.1	0.5
TOTAL VOLUME OF ARKANSAS RIVER FLOWS PER CALENDAR YEAR: In Millions of Acre-Feet									
AT NEWT GRAHAM L&D, VEDIGRIS		6.6	1.8	3.6	6.7	7.0	3.8	2.9	2.1
AT WEBBERS FALLS L&D, ARKANSAS		29.7	11.0	18.4	31.1	32.5	15.3	12.7	10.5
AT VAN BUREN GAGE, ARKANSAS		40.9	20.5	27.5	42.2	41.4	22.4	23.4	18.3
AT LITTLE ROCK GAGE, ARKANSAS		45.8	26.2	32.1	49.6	47.9	25.9	29.3	24.7
PEAK DISCHARGE OF ARKANSAS RIVER PER CALENDAR YEAR: In Thousands of Cubic Feet per Second									
AT NEWT GRAHAM L&D, VEDIGRIS		41	33	30	37	51	30	27	19
AT WEBBERS FALLS L&D, ARKANSAS		261	82	114	147	149	107	87	116
AT VAN BUREN GAGE, ARKANSAS		268	175	155	191	172	164	157	152
AT LITTLE ROCK GAGE, ARKANSAS		253	218	195	226	184	186	208	225

APPENDIX A-2

Sediment Transport Model Study
2-D Numerical Model CCH2ED
By ERDC

Feasibility Study: Inducing Channel Scour by Elevating Existing Dikes and Revetments in Pool 2 of the Arkansas River

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Prepared for the Little Rock District, Corps of Engineers
September 23, 2004

METRIC TO ENGLISH CONVERSION TABLE

Variable	Multiply	By	To Obtain
Distance	Meters	3.28	Feet
Velocity	Meters per Second	3.28	Feet per second
Specific Discharge	Square Meters per Second	10.76	Square Feet Per Second
Bed Shear Stress	Pascals	0.02089	Pounds per Square Foot

Feasibility Study: Inducing Channel Scour by Elevating Existing Dikes and Revetments in Pool 2 of the Arkansas River

INTRODUCTION

Currently, a nine-foot channel is maintained in Pool 2 of the Arkansas River to support navigation. This minimum depth requirement is referenced to a pool elevation of 162.0 feet mean sea level (msl). Studies are currently underway to evaluate the feasibility of maintaining a 12-foot channel by raising the elevation of existing channel training structures (dikes and revetments) to further confine flows and subsequently induce scour and deepen the channel. This would be a less costly alternative to continuous dredging to maintain a navigable depth.

The study described in this report was conducted to evaluate the effectiveness of raising revetment and adjacent dike elevations in a relatively short reach (2500 ft) of Pool 2 to induce scour. Additionally, four new dikes were evaluated in the model upstream of this reach to reduce sedimentation in the navigation channel that periodically occurs. A two-dimensional finite element sediment transport model was utilized to evaluate channel hydrodynamic and morphological response due to planned changes. A number of steady - state flow events were evaluated, as well as two long-term events (127 days). The impact on the channel was evaluated through change in hydrodynamic variables such as flow velocity, bed shear stress magnitude, and specific discharge magnitude, as well as sediment transport characteristics such as transport capacity and potential for scour.

APPROACH

A fifteen-mile reach of Pool 2 was selected as the study reach (NM 48 – NM 33). A numerical model grid was constructed for this reach (Figure 1), including numerous dikes and revetment (Figure 2). Model boundaries included the dike fields as well as over banks up to about a 180 ft msl elevation where possible. The hydrodynamics were calibrated using USGS flow measurements for a 70,000 cfs flow event (Appendix F). There were no sediment discharge data available for Pool 2 to calibrate the sediment model. Because of this, predictions of hydrodynamic and sediment transport change were made based on the change in existing and planned channel simulations. Two model grids were constructed. A base condition grid contained structures at existing elevations. The plan condition grid contained structures with elevation changes designed to further confine the flows. The base condition was simulated and bed change computed. Then the plan condition was simulated. The difference in the plan and base bed change was evaluated as the scour potential due to changes in the revetment and dike elevations. Table 1 lists the planned changes to revetment and dikes in the existing channel.

FLOW AND SEDIMENT BOUNDARY CONDITIONS

The numerical model hydrodynamic simulations require upstream discharge and downstream stage boundary data. The stage boundary data at NM 33 for the selected flows were obtained from HECRAS simulations conducted by the Little Rock District. For the sediment transport model, inflowing suspended sediment concentrations and bed load rate are required. Because no sediment discharge data were available for Pool 2, sediment boundary conditions were estimated for the simulations. It is an iterative process for which sediment boundary conditions are assumed, the sediment model is run, and the upstream inflowing boundary stability is evaluated. When the upstream model boundary is relatively stable (no excessive deposition or scour) then the inflowing sediment concentration is assumed to be adequate.

Flow Boundary Conditions

Four ten-day steady-state flow events were evaluated representing flows from 80,000 – 185,000 cfs (Table 2). A log-pearson analysis of 10 years of Arkansas River flow data indicate that 185,000 cfs is the two year return flow event, which is considered to be the bank full or channel forming discharge. Under existing conditions, flows overtop much of the revetment at approximately 70,000 cfs. To simulate a long term flow event, ten years of discharge records for the Arkansas River were analyzed (1993 – 2003). Discharges of 50,000 cfs and below are considered clear water discharges for which little if any sediment is mobilized. Therefore, only discharges greater than 50,000 cfs were considered for the long-term simulation. The return frequency of flows for the ten-year record are shown in Figure 3. Based on this return frequency, the average number of days per year for each 10,000 cfs flow interval was computed (Table 3), and an idealized symmetrical hydrograph was constructed that represents the total days per year that flows are above 50,000 cfs (Figure 4). This should be considered a worst-case hydrograph for which the bed is progressively subjected to channel forming flows.

Sediment Boundary Conditions

A number of sediment simulations were conducted to find a range of inflowing sediment concentrations for which the model boundary was stable. The final concentration range was from 50 to 150 mg/l for flows ranging from 80,000 to 185,000 cfs.

Bed Sediment Description

A comprehensive set of bed sediment samples were taken along the 15-mile study reach. Figure 5 presents an overview of the size characteristics of the bed sediments in terms of the coarse sediment fraction (D_{90}), median size fraction (D_{50}), and fine sediment fraction (D_{10}). The bed sediments were very uniform over the study reach therefore a uniform bed was assumed throughout the model. Based on analysis of the sample data, the bed was assumed to consist of 89 percent medium sand (0.354 mm) and 11 percent fine sand (0.177 mm).

MODEL SIMULATIONS

Three types of simulations were conducted during this study. The initial simulations were conducted to verify the hydrodynamic model to USGS field measurements for a 70,000 cfs flow event. The sediment transport simulations were performed in two parts. Initially, a hydrodynamic simulation is computed until the model reaches steady state. The results of the hydrodynamic simulations were then used to begin the sediment simulations.

Verification Simulations

The first set of model simulations were conducted to verify the model velocity flow field within the specific reach under study (NM 45 – NM 42). The results of the verification are in Appendix G. A number of simulations were conducted to determine the best method for representing roughness of the channel bed. A number of options are available in the model, including assigning a Manning n, using the Van Rijn method (Van Rijn 1984b), or using the Wu method (Wu 1999). The Van Rijn and Wu methods determine the bed roughness based on bed forms, and are the most representative for large alluvial rivers. The verification simulations revealed that using a constant Manning n resulted in too high a flow distribution in the channel thalweg. The Wu function was found to be the most representative, with the flow results most closely matching the USGS data. This function was also used for all the hydrodynamic model simulations during the study. Figures 1g – 4g in Appendix G indicate good agreement between the simulated and measured velocities.

Hydrodynamic Steady State Simulations

For the hydrodynamic steady state simulations, the Wu function was used as the bed roughness predictor. The mixing length turbulence model was used for all the simulations. The model was run for 20,000 seconds to a steady state condition using a time step of 20 seconds. The results of these simulations provide the initial flow conditions for the sediment transport simulations.

Sediment Transport Simulations

The sediment transport simulations were run in a quasi-steady mode. This assumes that the hydrograph is relatively gradual, and that steady state conditions can be assumed for each day of simulation. The model computes sediment transport and bed change over an initial time step and assumes that it is steady for the duration of the time step. The model then updates the hydrodynamics through a number of iterations and repeats the process for the next time step. In reality, sediment transport is unsteady in nature, however, the quasi-steady approach results in a significant savings of computational time, and should be representative for evaluating the change between base and plan conditions. The Wu and Wang sediment transport function (Wu 2000) was used for all the sediment transport simulations. This function has been thoroughly researched and validated through numerous laboratory and field tests (Jia 2001).

SIMULATION RESULTS

Modeling results are presented in terms of changes in both hydrodynamic and sediment transport characteristics. The 120,000 cfs steady-state simulation is presented as an example, showing the impact of the proposed changes on flow velocity, bed shear stress, specific discharge, and bed elevation change for the reach bounded by NM 44 – NM 43. Additionally, bed elevation change is computed for crossections above and below the affected reach to evaluate the impacts of the planned changes on adjacent channel stability and sediment fate. The results from four steady-state 10 day duration simulations are presented, as well as two long term simulations, one of which evaluates scour potential due to the addition of four new right bank dikes (NM 44.6 – NM 44.0).

Results: Hydrodynamic and Sediment Simulations for the 120,000 cfs Event

The planned changes in the Pool 2 reach bounded by NM 44 – NM 43 result in conditions conducive to scour. Figure 6 shows the velocity field for the base and plan condition for the 120,000 cfs event. The velocity is depicted in terms of color contours and velocity vectors. In the base condition, flow inundates the dike fields just below NM 44, reducing the flow and velocity magnitude in the navigation channel. This effect has resulted in shoaling that requires periodic dredging. The plan condition run shows the confinement of the flows within this reach due to the higher revetment and dikes, as well as an increase in velocity in the navigation channel. The potential impact on sediment transport and sediment transport capacity is shown in Figures 7 and 8. The bed shear stress has increased, as well as the specific discharge in the channel, thus inferring an increase in sediment transport capacity in the navigation channel. The hydrodynamic response of the planned changes results in scour in the channel (Figure 9).

Results: Sediment Transport Simulations NM 44.77 – NM 39.77

Eight transects were evaluated for bed change for five sediment transport simulations; four steady state runs and a long-term simulation (127 days for flows over 50,000 cfs). These transects range from NM 44.77 to NM 39.77 (Figure 10). The transects above and below the reach in question (NM 44 – NM 43) were included to determine the response of other areas of the channel and the potential fate of any scoured sediments.

Appendices A – E contain plots of the change in bed elevation for each of the five simulations. As described above, the scour potential is determined by the difference in the change in bed elevation between the base and plan simulations. Two crossection profiles are found on each plot. The crossections are presented with an upstream view. One profile is the initial bed elevation and the other is the same profile minus the change in bed elevation from the base and plan comparison. This provides an indication of not only the magnitude of change, but also the spatial change. The model results indicate 1.0 to 3.0 feet of scour potential over the 80,000 – 185,000 cfs simulations in the areas of concern (NM 43.6 and NM 43.31), and that the change is primarily in the channel thalweg. The one-year model simulation indicates up to 5.0 feet of scour potential, with a tendency of the channel to widen.   For all flows, transects above NM 44.0 and below NM 44.31 remain relatively stable.

Figure 11 presents a summary plot of bed elevation change for all four steady state flows at NM 43.6, while three simulations are presented in figure 12 to examine the maximum scour potential.   The simulations presented in figure 12 represent higher flows that will potentially form the channel. Two steady-state simulations at a bank full discharge (185,000 cfs at 10 and 20 day durations respectively) and the one-year simulation are presented.   The results show a tendency for the channel to widen for the higher flow events.

The simulations do not reveal a significant increase in shoaling in the navigation channel downstream of the study reach.   The base condition simulations tended to deposit more sediment in the left bank dike fields of the affected reach, whereas the plan simulations resulted in larger sediment deposits in the left bank dike fields below the affected reach (NM 43 – NM 42). The one year simulation indicates that channel scour of 0.5 to 1.0 feet will potentially occur in the channel above the affected reach (NM 45 – NM 44) due to the planned changes.

Results: Addition of Right Bank Dikes: NM 44.6 – NM 44.0

Historically, the channel reach from NM 44.6 to NM 44.0 has been depositional. Four right bank dikes were included in the model to constrict the channel in this reach and thus increase sediment transport capacity. The location of these dikes is presented on the model roughness map (Figure 13). The one-year model simulation was re-run, with potential crossection scour presented from NM 44.0 to NM 43.31 (Appendix F). The addition of the right bank dikes results in 2.0 to 3.0 ft of scour in the reach from NM 44.6 to NM 44.0, with additional scour in the one-mile reach where the left bank revetment and dike elevations were raised (NM 44.0 to NM 43.31).

Results: Limited Sediment Transport Model Validation

During the conduct of this study, a 120,000 cfs flow event occurred in Pool 2 lasting approximately 10 days. The study reach was surveyed immediately after the event, and bed elevation change computed using a previous survey as the initial bed condition. The results are found in Figures 14 and 15 for crossections NM 43.6 and NM 43.31, along with a comparison to model results.   The predicted and measured maximum scour depths for NM 43.6 were 2.5 and 5.0 feet respectively. The model and survey results were in good agreement on scour location, with the model predicting a wider area of scour. For NM 43.31, which is in a crossing, the model was in good agreement with the location of the side channel scour, however, the model under-predicted scour potential in the vicinity of the channel thalweg.

CONCLUSIONS AND RECOMMENDATIONS

Modeling results indicate that the planned increases in revetment and dike elevations in the reach bounded by NM 44 and NM 43 will increase the sediment transport capacity and subsequently scour the bed. Results from the bank full discharge and one year simulations indicate that the bed in this reach has the potential to scour from 3.0 to 5.0 feet, with the one-year simulation showing an increase in channel width as well as depth.

The addition of right bank dikes has the potential to scour the affected reach (NM 44.6 – NM 44.0) 2.0 to 3.0 feet.

The navigation channel downstream of the proposed changes is relatively stable for all simulations. However, the plan simulations do indicate that more sediment will potentially deposit in the dike fields below the affected reach. The long-term simulation indicates bed scour on the order of 0.5 to 1.0 feet occurring upstream of the affected reach (NM 45 to NM 44). The model results indicate that the relative change in transport capacity is primarily confined to the affected reach and will not result in regional instabilities that will result in excessive increases in system sedimentation. However, it must be noted that the 127-day simulation may not be completely representative of long-term morphology change in the reach.

Comparison of model results to surveyed bed changes for the 120,000 cfs event indicates that the model is adequate at predicting scour locations but under predicts scour potential. However, it must be noted that the model simulations compared base to plan simulations at the same flows, thus the model results best reflect the impact of the proposed changes in reference to the original channel condition.

It is recommended that additional surveys be taken throughout this reach (NM 44 – NM 43) for future flow events greater than 120,000 cfs. This data can be used to further validate and refine the sediment model, as well as develop useful statistical relationships that will potentially enable the prediction of bed response to sediment transport capacity change resulting from future channel alterations.

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Wu, W., and Wang, S.S.Y. (1999), “Movable Bed Roughness in Alluvial Rivers”, Journal of Hydraulic Engineering, ASCE, Vol. 125, No. 12, pp. 1309-1312.

Wu, W., Wang, S.S.Y., and Jia, Y. (2000), “Non-uniform Sediment Transport in Alluvial Rivers”, Journal of Hydraulic Research, IAHR, Vol. 38, No. 6.

Jia, Y., and Want, S.S.Y. (2001), "CCHE2D Verification and Validation Test Documentation", Technical Report No. NCCHE-TR-2001-2, August 2001.

TABLES

Table 1. Proposed changes to Pool 2 dikes and revetments

ARKANSAS RIVER NAVIGATION STUDY - PHASE II
POOL 2 - PROPOSED MODIFICATIONS TO STRUCTURES FOR 2-D MODEL

NM	Dike/Revt	Source	Exist Elev stone average ele	Exist Elev pile	Prop Elev stone 70K cfs Profile	Est. Ground elevation avg gr ele 5' min	Exist Length stone	Prop Length stone	Proposed Structure Modification Raise to 70,000 cfs profile unless noted
36.15	D57.4L	63-79	164		168.5	**155/145**	500	**600**	Raise LT Dike to elev 168.5 and ext 100 ft
36.3	D57.6L	63-79,66-52	160	168	168.5	**155/145**	300	**400**	Raise LT Dike to elev 168.5 and ext 100 ft
36.5	D57.7L	63-79,66-52	160	169	168.5	**155/145**	200	**300**	Raise LT Dike to elev 168.5 and ext 100 ft
36.6	D57.8L	63-79	155	169	168.5	150	450	450	Raise LT Dike to elev 168.5 and ext 100 ft
37.4-38.45	D58.85-59.5L	68B-0045	153		169	148	2950	2950	Raise LT Dike All L-Heads to elev 169
38.45	D59.6L	90B-0079	163.5	170	169	155	500	500	Raise LT Dike to elev 169
38.6-38.95	R60.01L	63-37	163.5	170	169.5	155	1780	1780	Raise LT Revt to elev 169.5
38.95	D60.01L	76B-0041	163.5	170	169.5	155	500	500	Raise LT Revt to elev 169.5 from bank to revt
39.15-39.8	R60.7L	63-37	163.5		169.5	155	2250	2250	Raise LT Revt to 169.5
	R60.9L	67B-0058	165		169.5	155	1500	1500	Raise LT Revt to 169.5
39.8-40.25	R60.9R	73B-0091	165		169.5	155	1600	1600	Raise Kicker Dike on RT to elev 169.5
42.7-43.05	R62.93R	73B-0011	165		171	160	1880	1880	Raise Rt Revt to elev 171
43.1-43.4	D62.97-63.62R	73B-0011	165		171.5	160	1030	1030	Raise 3 L-Heads 380', 350', 300'
43.65	D63.50R	63-32	160		171.5	160	0	250	Tie & Extend from Bank 250' at El 171.5
43.8	D63.62R	63-32	160		172	160	0	300	Tie & Extend from Bank 300' at El 172
43.4-43.9	D63.2L		165*		171-178*				Exist Structure raised July 2003
	D63.4L				171-178*				Exist Structure raised July 2003
	R63.4L		166*		171-172*		2500	2500	Exist Structure raised July 2003
46.25	D68.8R	90B-0037	155		173	155	1820	**2045**	Extend 225' Dike on Rt as Originally planned
46.35	R69.8R	90B-0037	150		173	150	1820	**2185**	Extend 365' Revetment on Rt as Originally planned
46.6	D68.5L	77B-0036	155		173	155	0	**275**	Tie & Extend from Bank 275' at El 173
46.9	D68.6L	67B-0016	155		173	155	0	**300**	Tie & Extend from Bank 300' at El 173

* Structures were constructed in July 2003. For 2-D model base condition they were modeled based on the plans and specs elevations and then the as builts elevations were input for the proposed plan.

NOTES:

1) Dike / revetment could not be included in the model due to resulting instabilities NM 46.25, NM 46.35, NM 36.6, NM 36.5

Table 2. – Flow boundary conditions for the steady state simulations

Discharge - cfs	WSE at NM 33
80,000	166.6
120,000	168.2
150,000	169.5
185,000	170.6

Table 3. Average number of days per discharge range

Discharge Range - cfs	Average Number of Days per Year
50,000 – 60,000	18
60,000 – 70,000	17
70,000 – 80,000	13
80,000 – 90,000	13
90,000 – 100,000	9
100,000 – 110,000	7
110,000 – 120,000	6
120,000 – 130,000	6
130,000 – 140,000	7
140,000 – 150,000	8
150,000 – 160,000	8
160,000 – 170,000	8
170,000 – 180,000	5
180,000 – 190,000	2

FIGURES

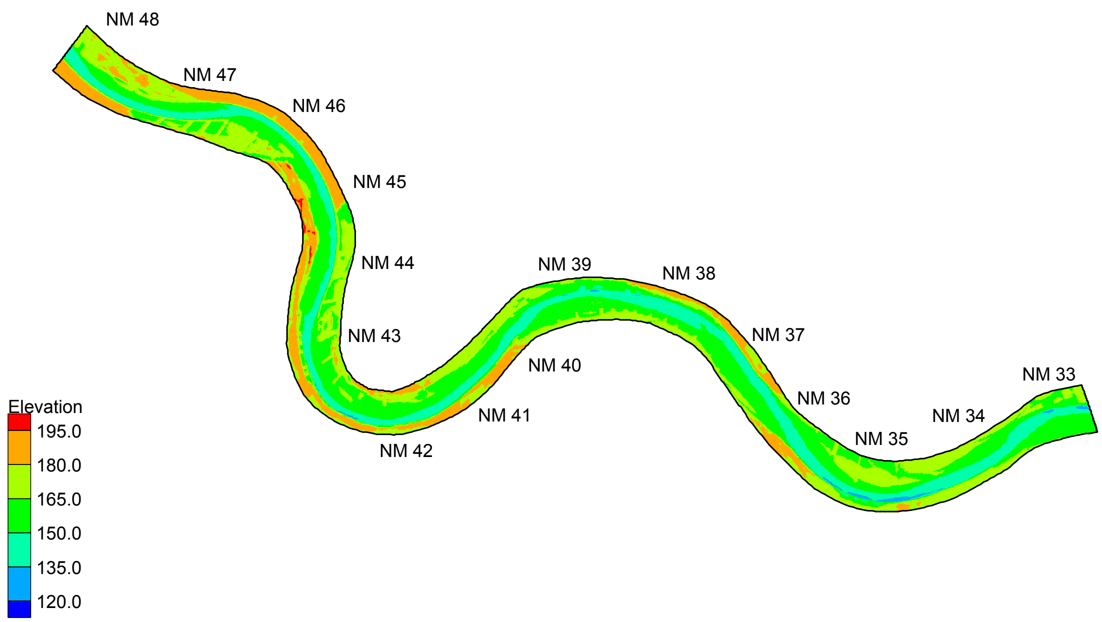


Figure 1. Pool 2 model limits – NM 33 to NM 48

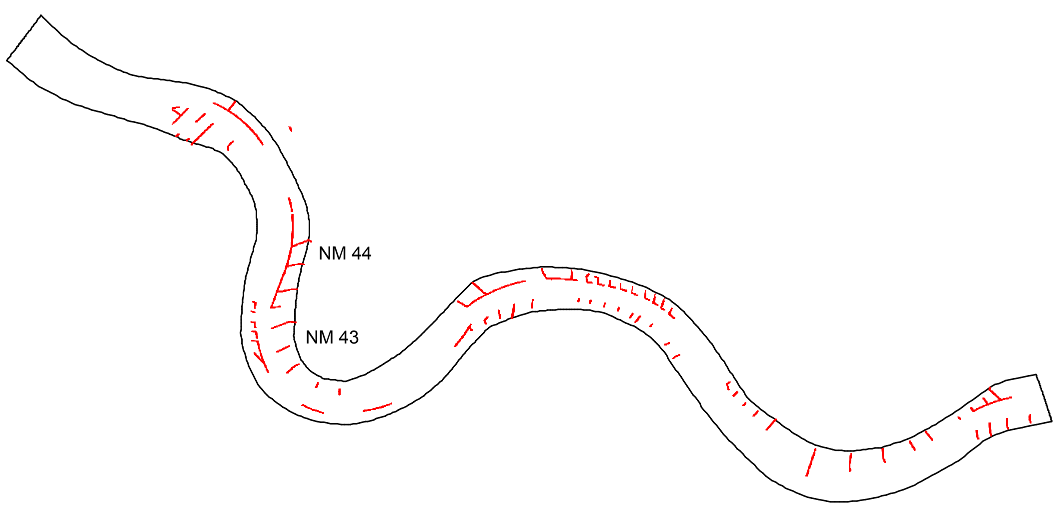


Figure 2. Dike and revetment locations in study reach

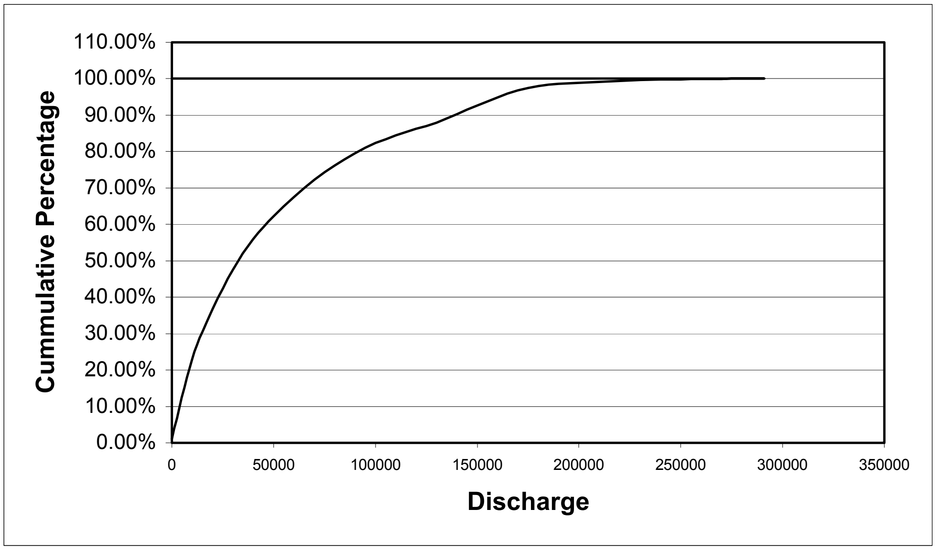


Figure 3. Frequency of annual return flows – 1993 through 2003

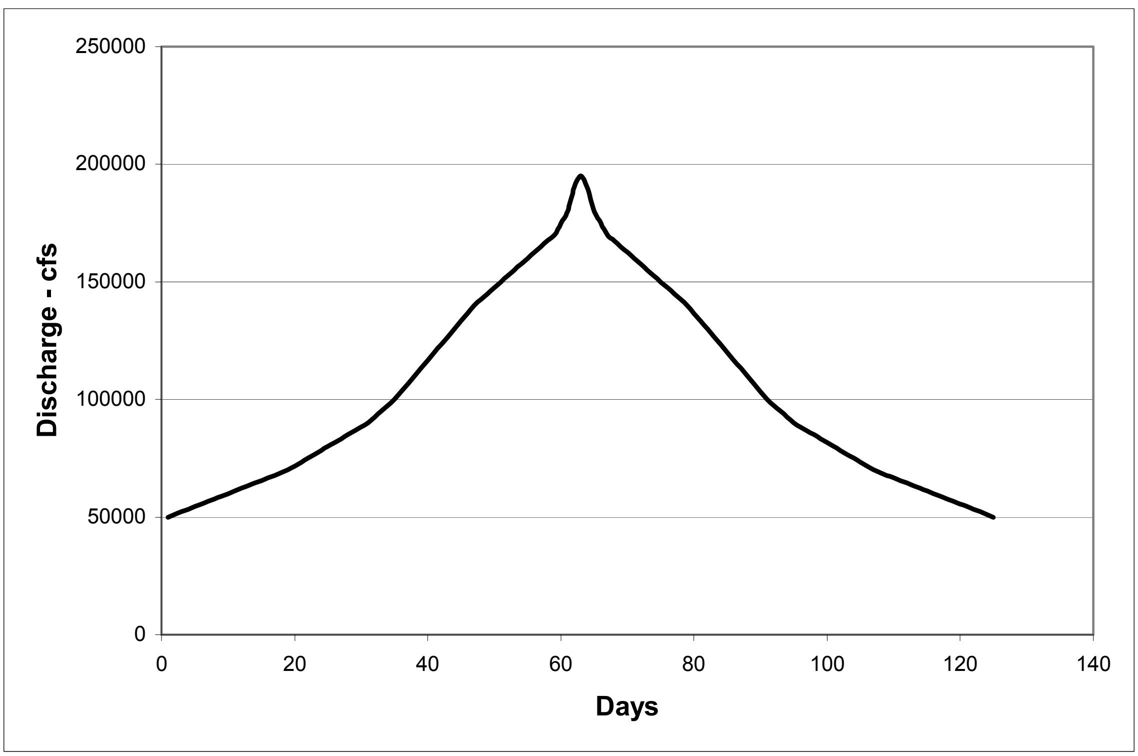


Figure 4. Idealized Arkansas River hydrograph

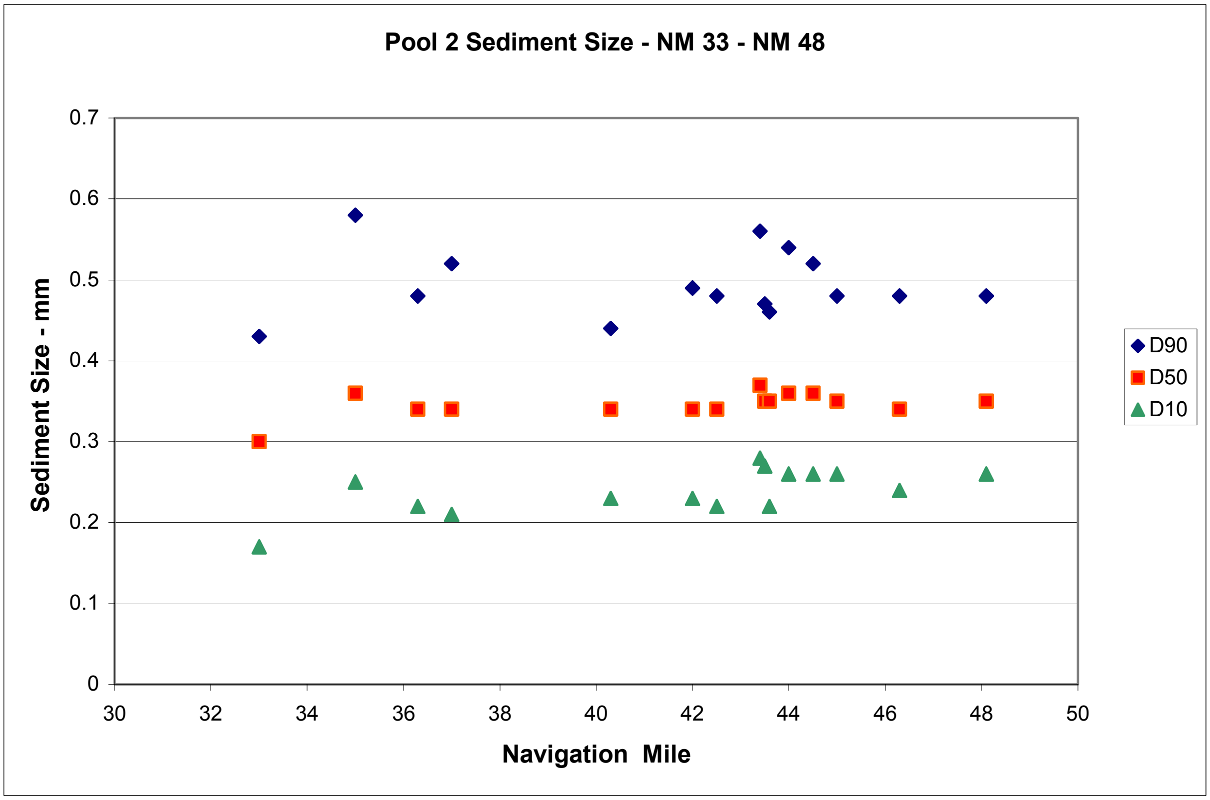
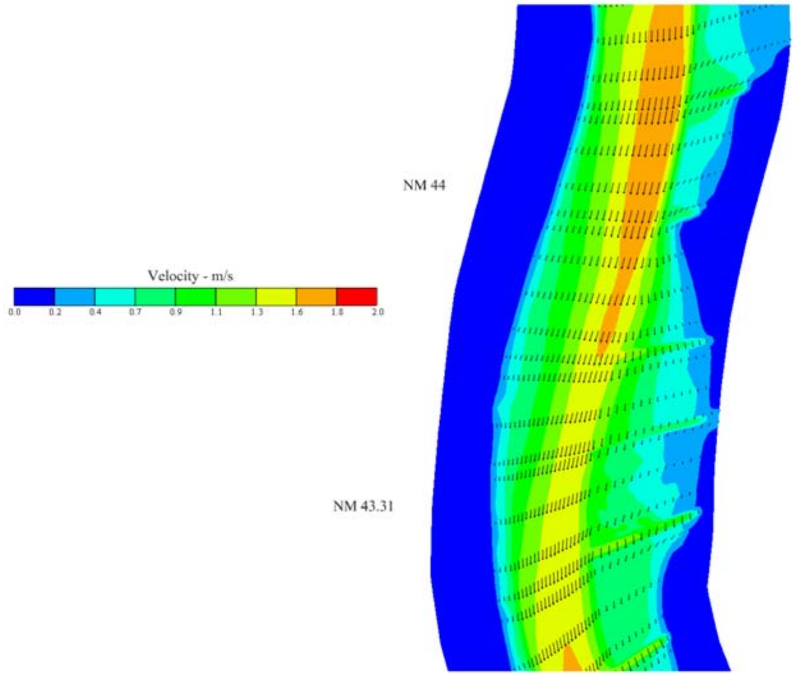
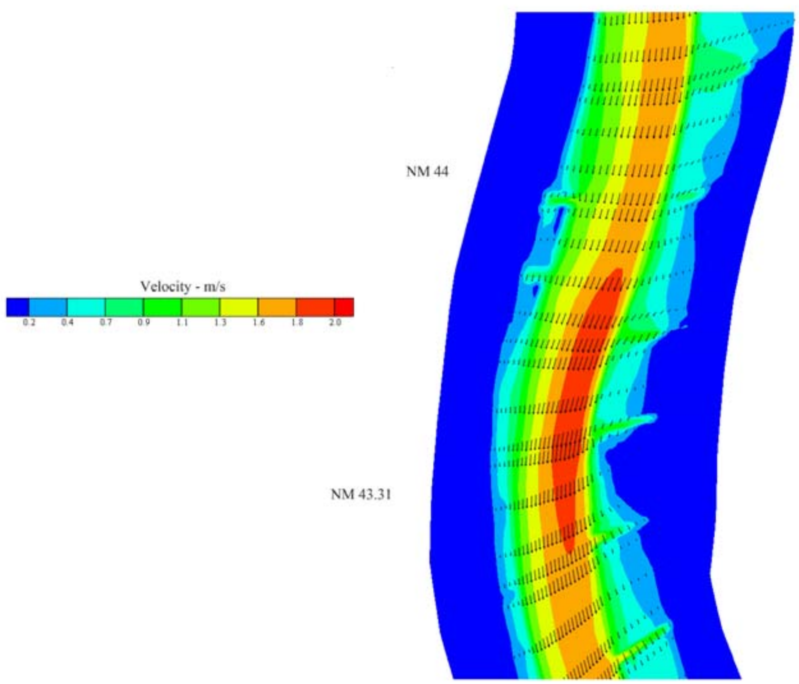


Figure 5. Sediment size fractions in Pool 2 study reach

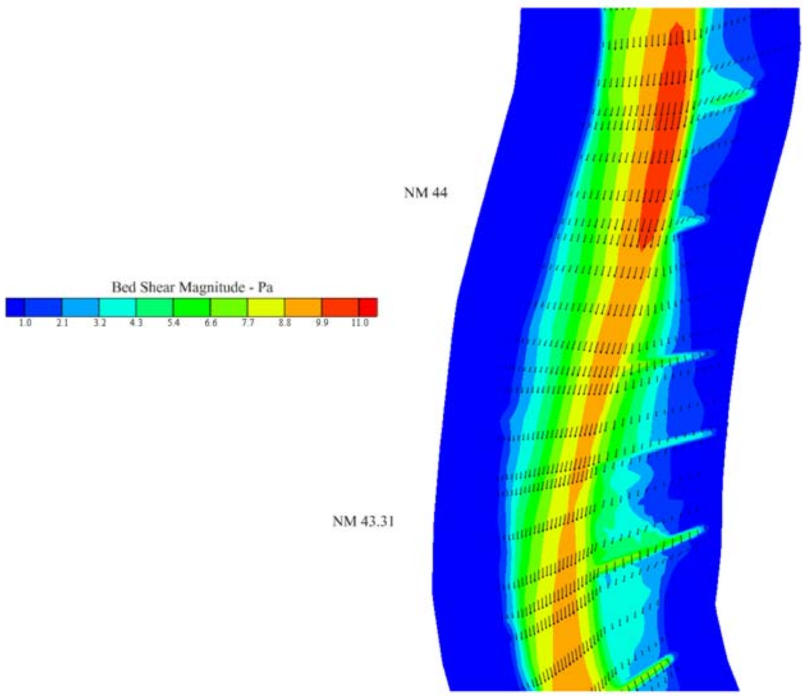


a. Base condition flow field at 120,000 cfs

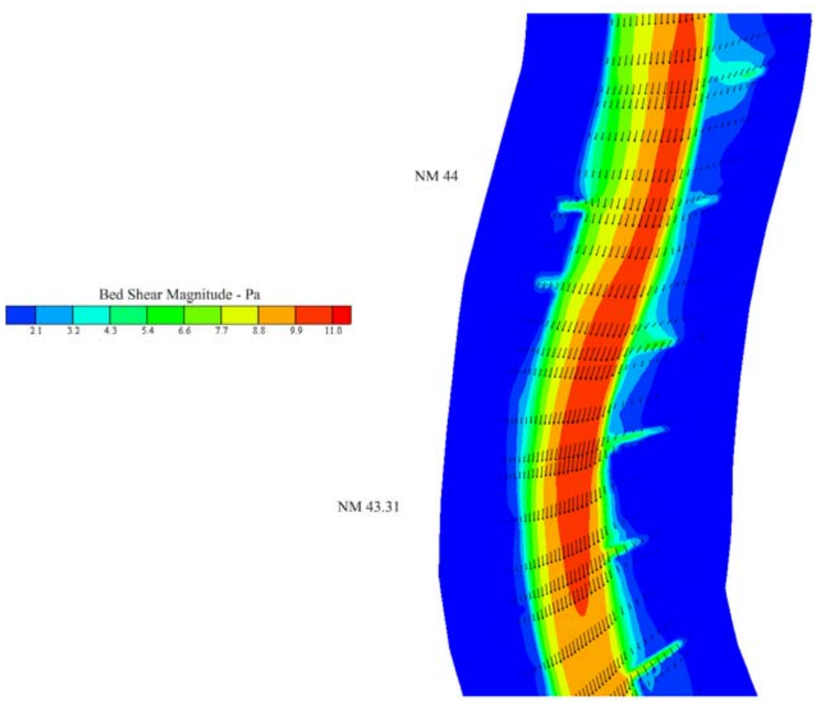


b. Plan condition flow field at 120,000 cfs

Figure 6. Base and plan simulation flow field at 120,000 cfs

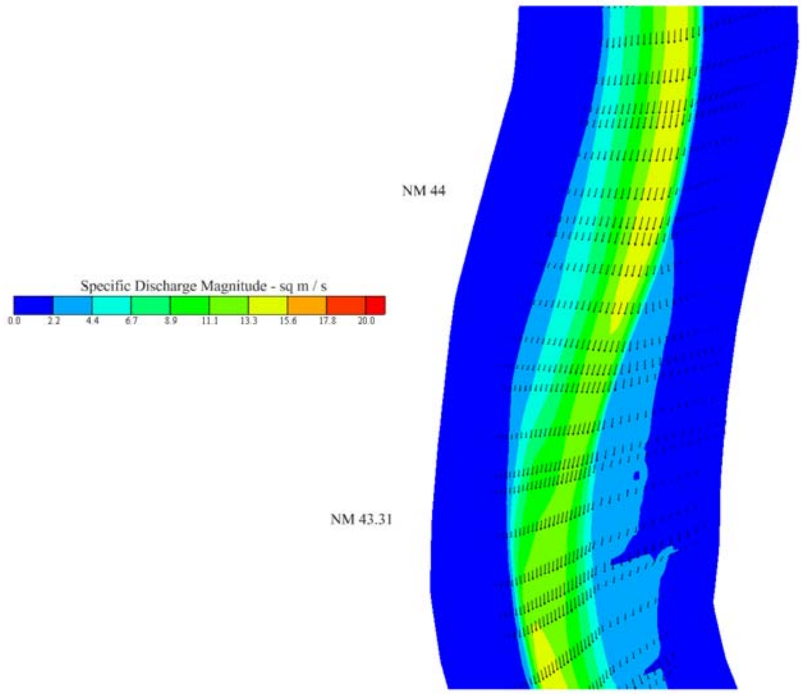


a. Base condition bed shear magnitude at 120,000 cfs

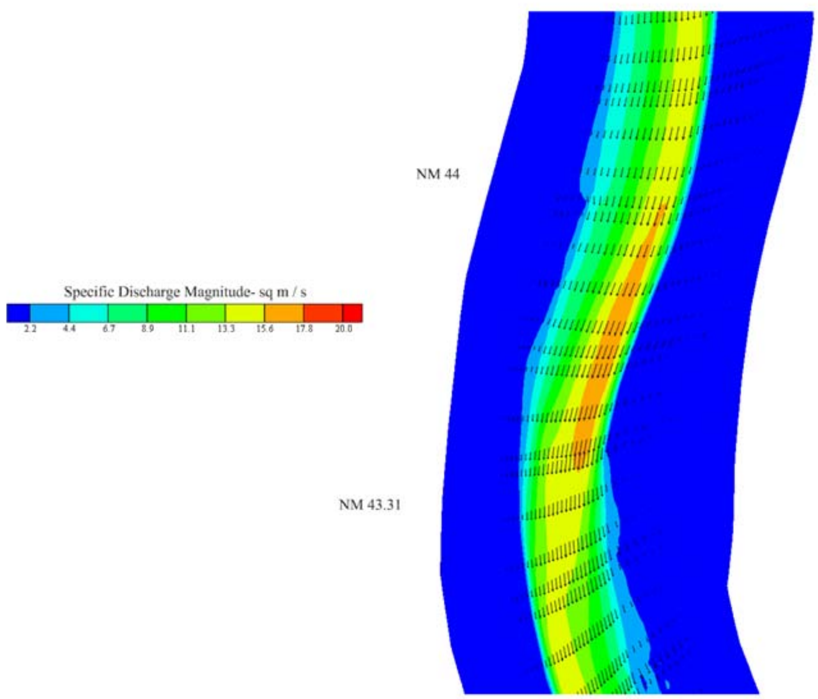


b. Plan condition bed shear magnitude at 120,000 cfs

Figure 7. Base and plan condition bed shear magnitude at 120,000 cfs

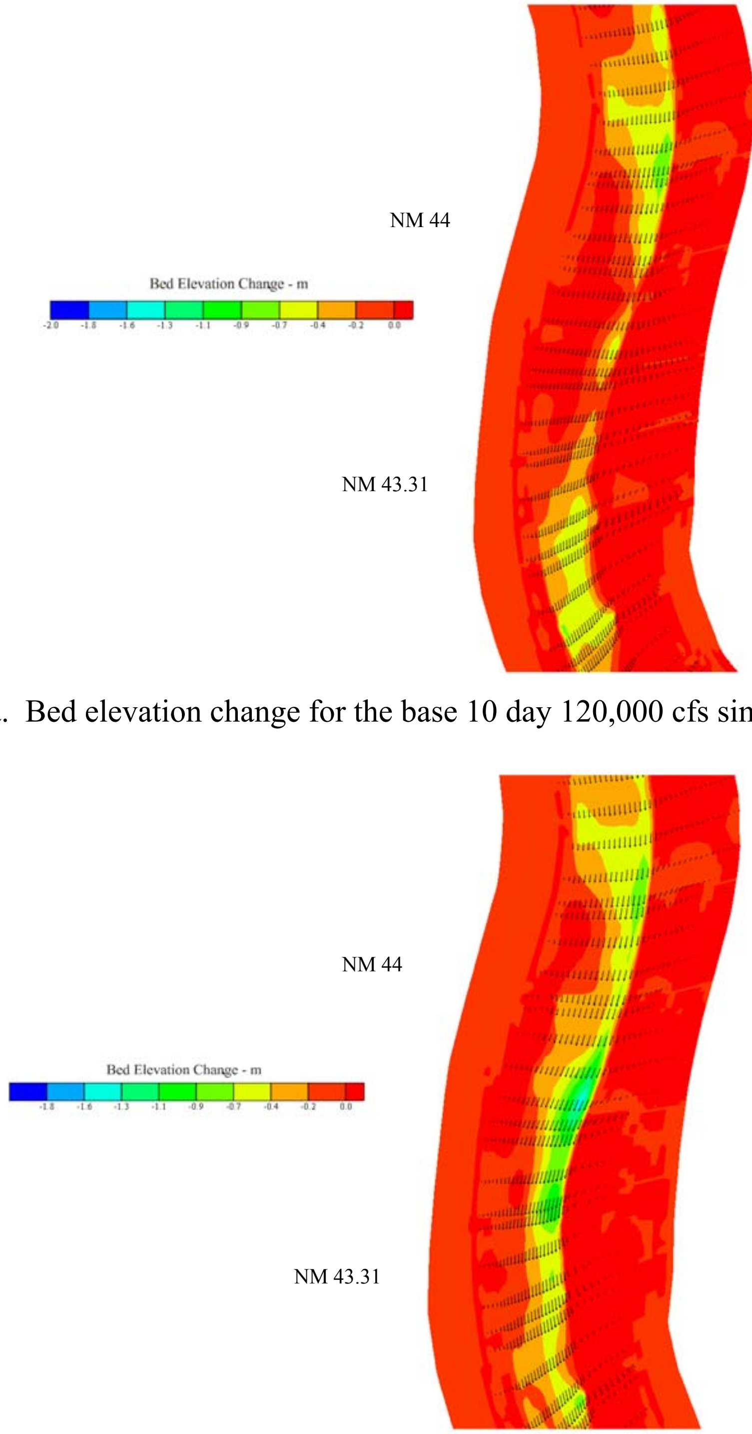


a. Base condition specific discharge at 120,000 cfs



b. Plan condition specific discharge at 120,000 cfs

Figure 8. Base and plan condition specific discharge at 120,000 cfs



a. Bed elevation change for the base 10 day 120,000 cfs simulation

b. Bed elevation change for the plan 10 day 120,000 cfs simulation

Figure 9. Change in bed elevation from the base to plan 10 day 120,000 cfs simulation

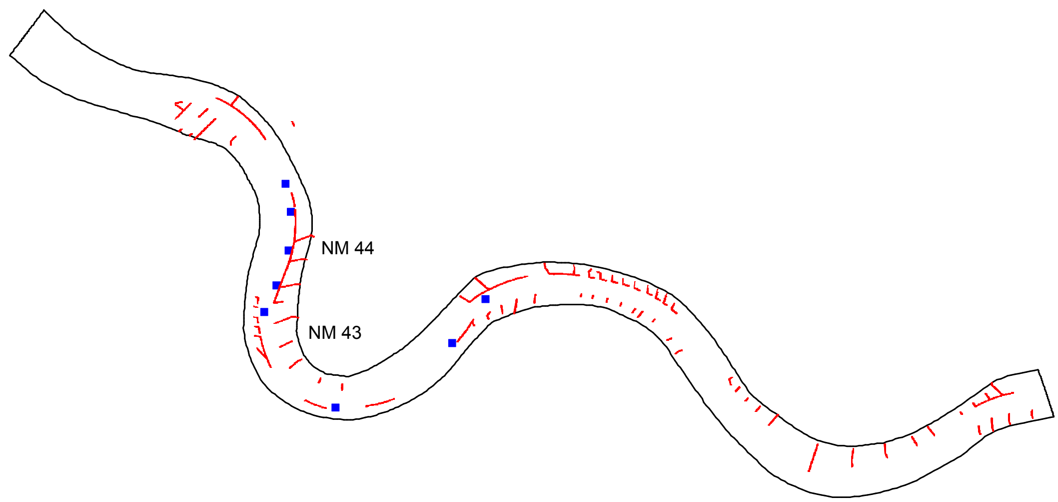


Figure 10. Transects (in blue) where bed elevation change was evaluated

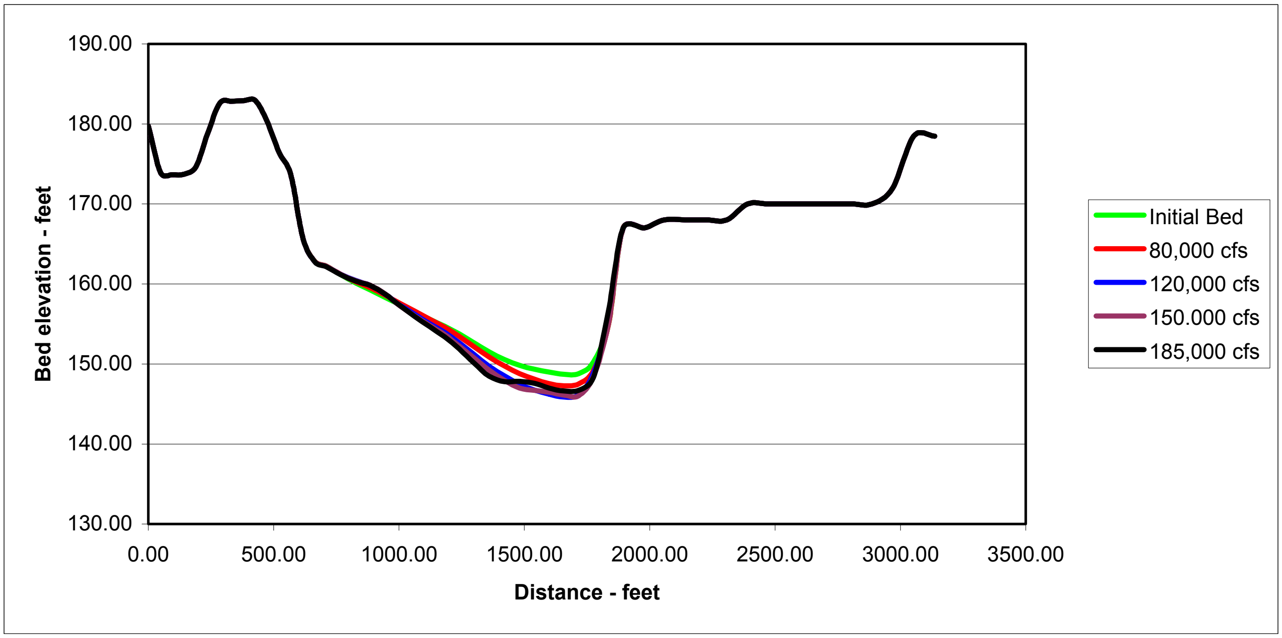


Figure 11. Bed elevation change from base to plan – 10-day steady state simulations at NM 43.6 in the navigation channel

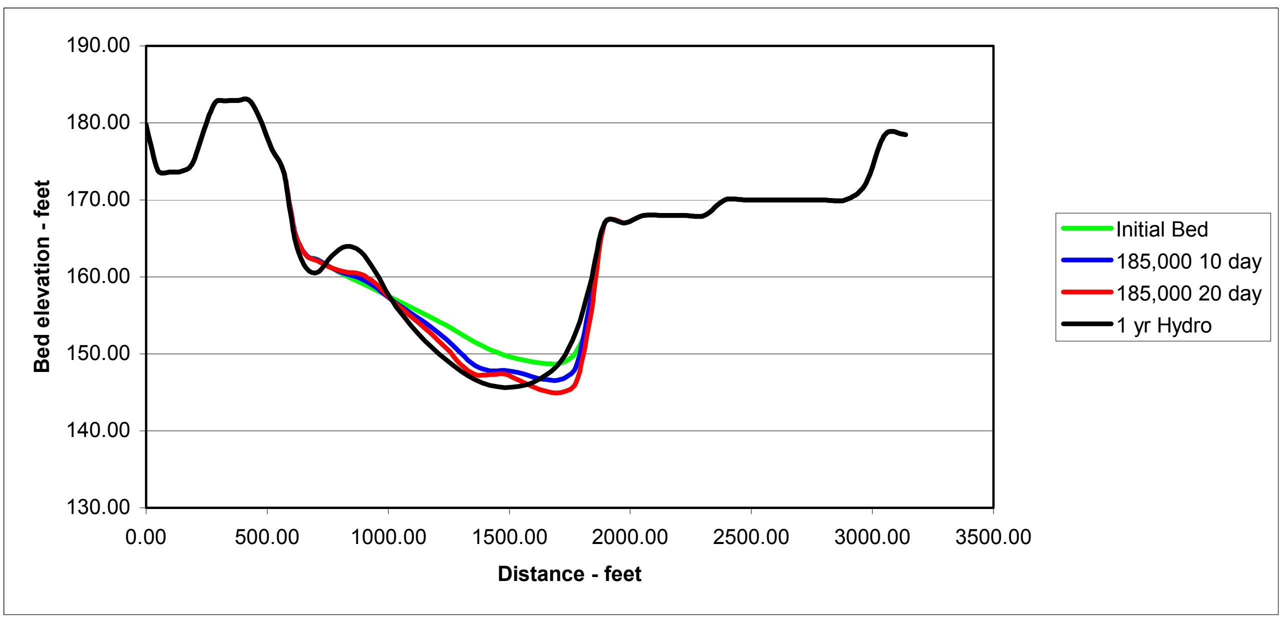


Figure 12. Bed elevation change from base to plan – channel-forming simulations at NM 43.6 in the navigation channel

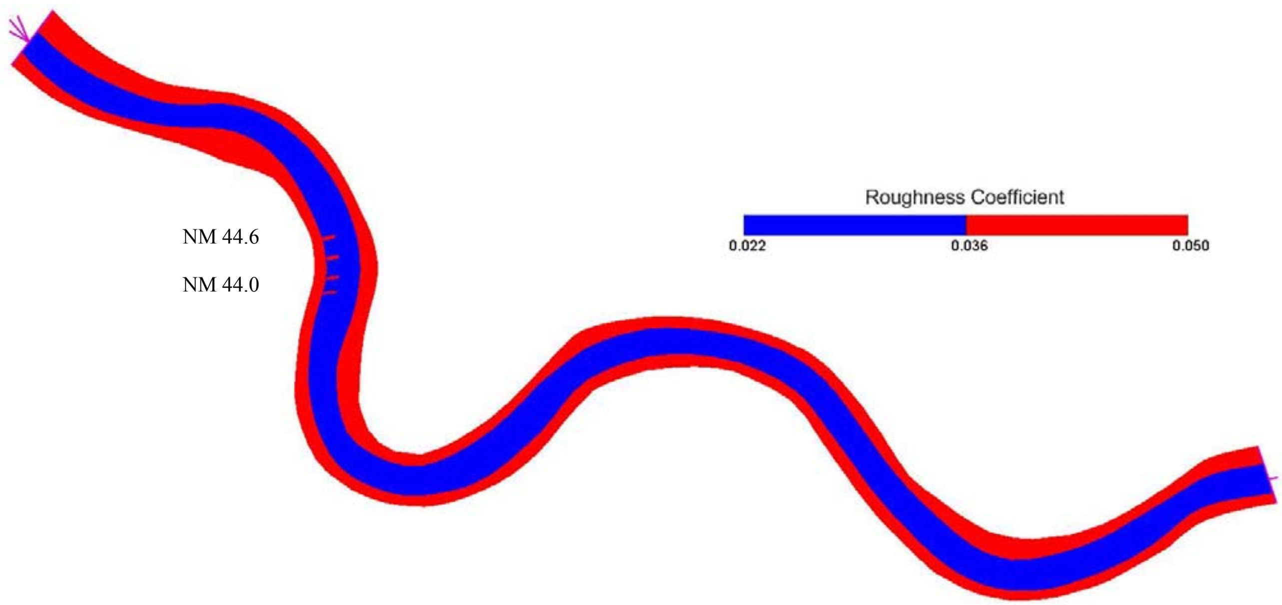
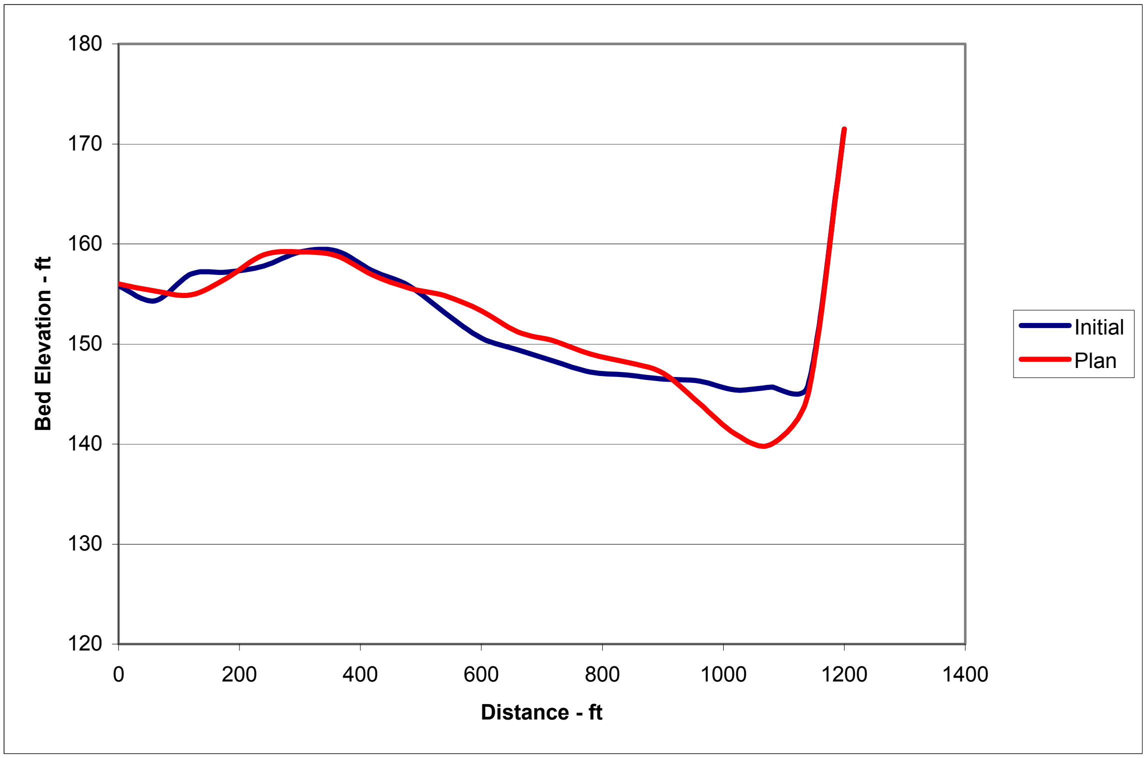
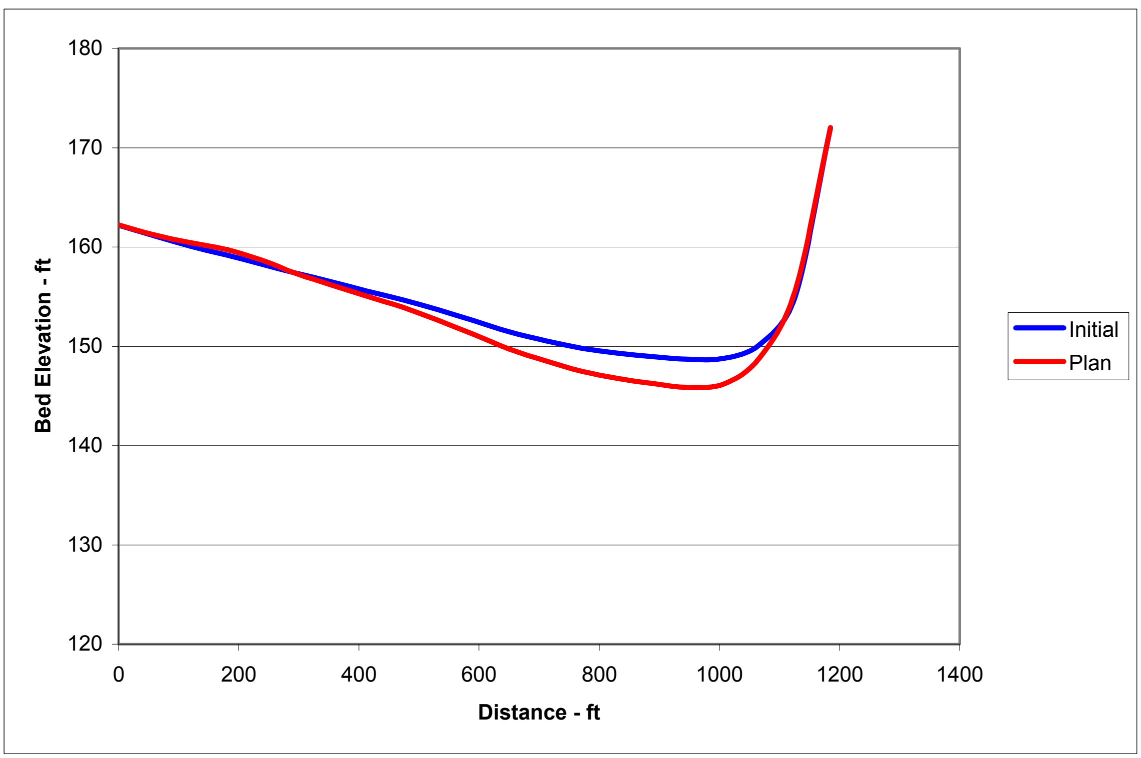


Figure 13. Location of right bank dikes on roughness coefficient map

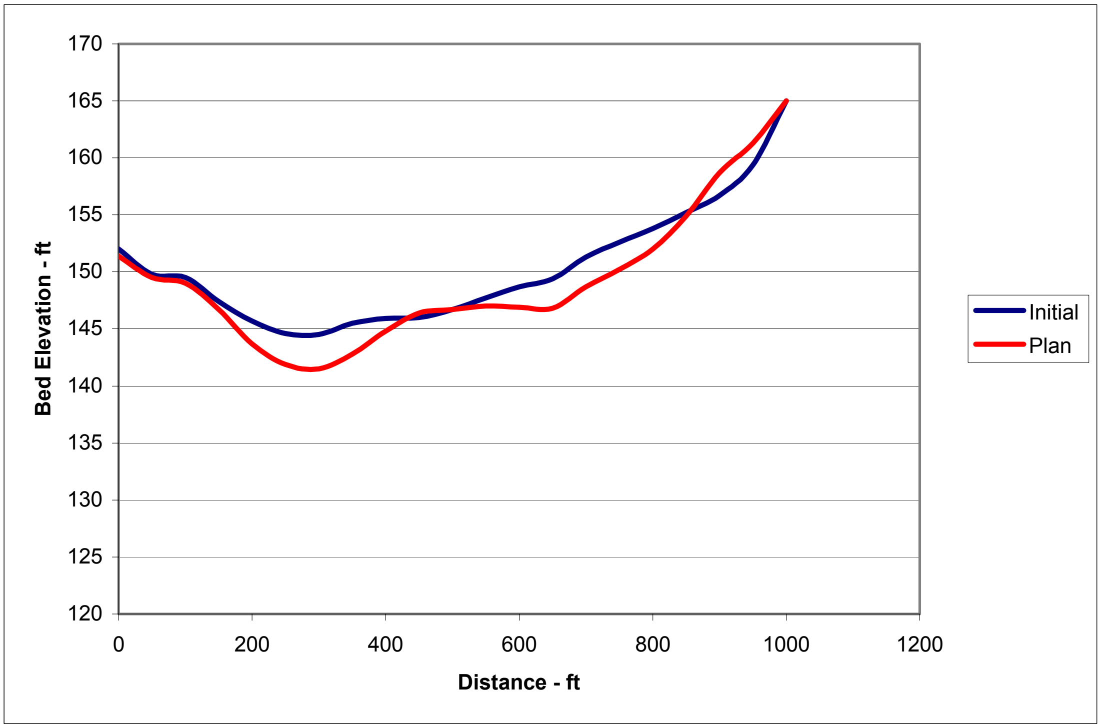


a. Results from the survey at NM 43.6 for the 120,000 cfs event

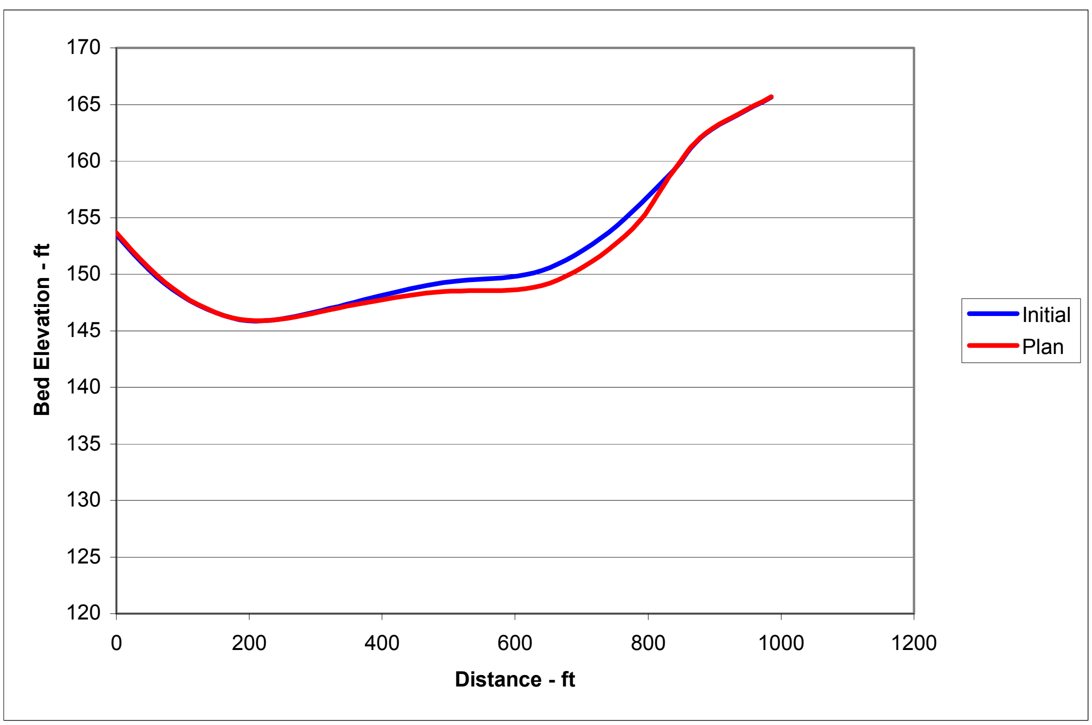


b. Results from the model simulation at NM 43.6 for the 120,000 cfs event

Figure 14. Comparison of the simulated and measured results for the 120,000 cfs event



a. Results from the survey at NM 43.31 for the 120,000 cfs event



b. Results from the model simulation at NM 43.31 for the 120,000 cfs event

Figure 15. Comparison of the simulated and measured results for the 120,000 cfs event

APPENDIX A

80,000 cfs Steady State Flow Event Results

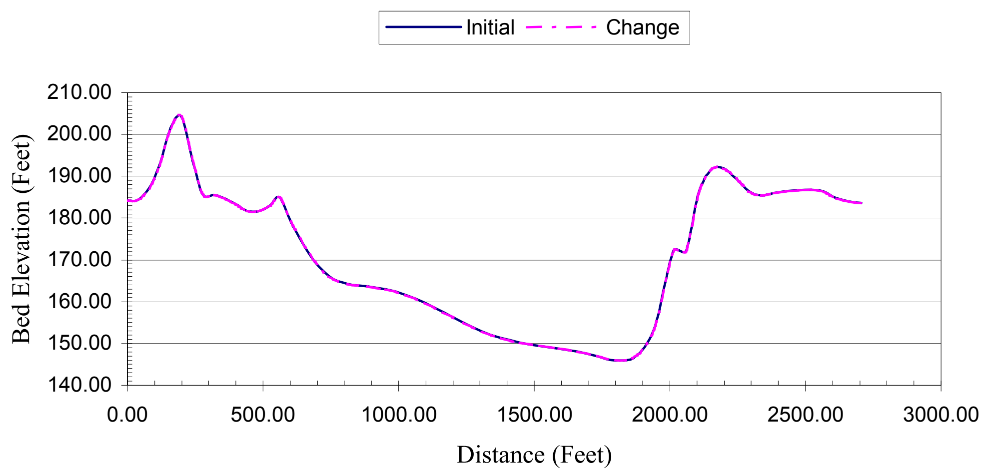


Figure 1a. Initial and final bed elevation for the 80,000 cfs ten day steady state simulation - NM 44.77

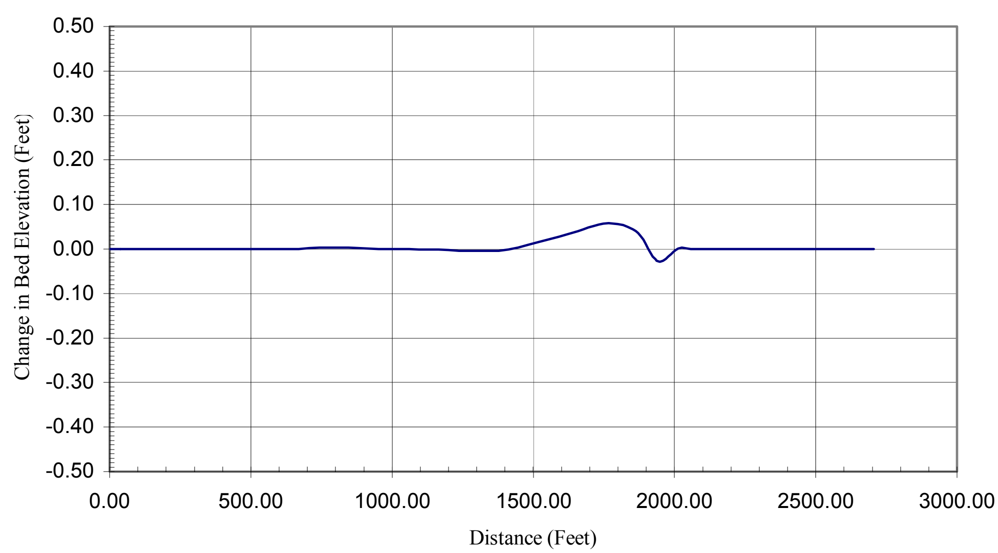


Figure 2a. Bed elevation change for the 80,000 cfs ten day steady state simulation - NM 44.77

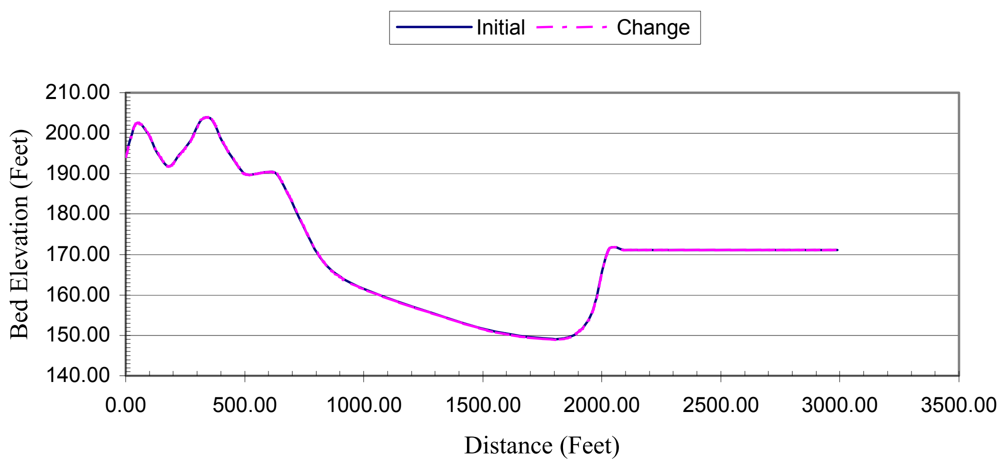


Figure 3a. Initial and final bed elevation for the 80,000 cfs ten day steady state simulation - NM 44.41

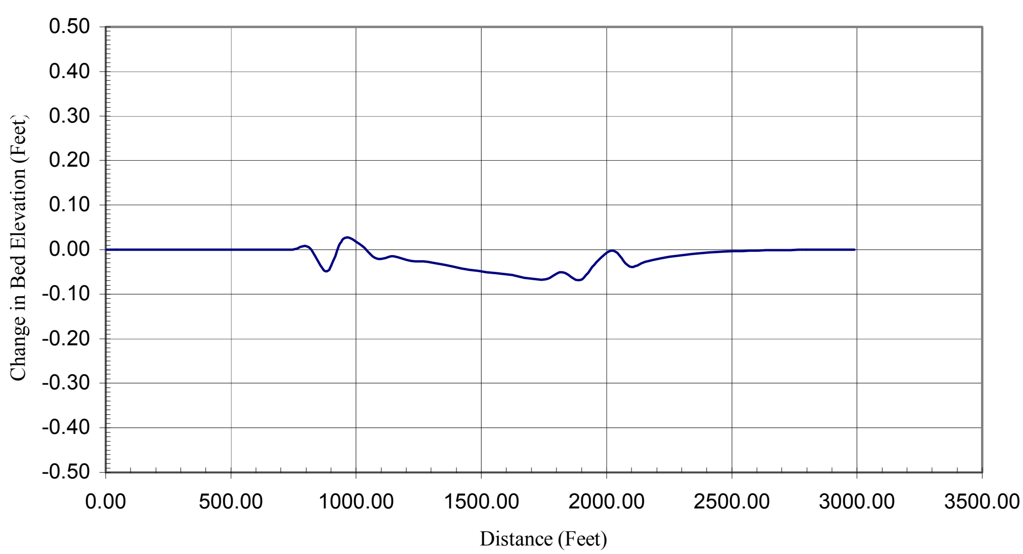


Figure 4a. Bed elevation change for the 80,000 cfs ten day steady state simulation - NM 44.41

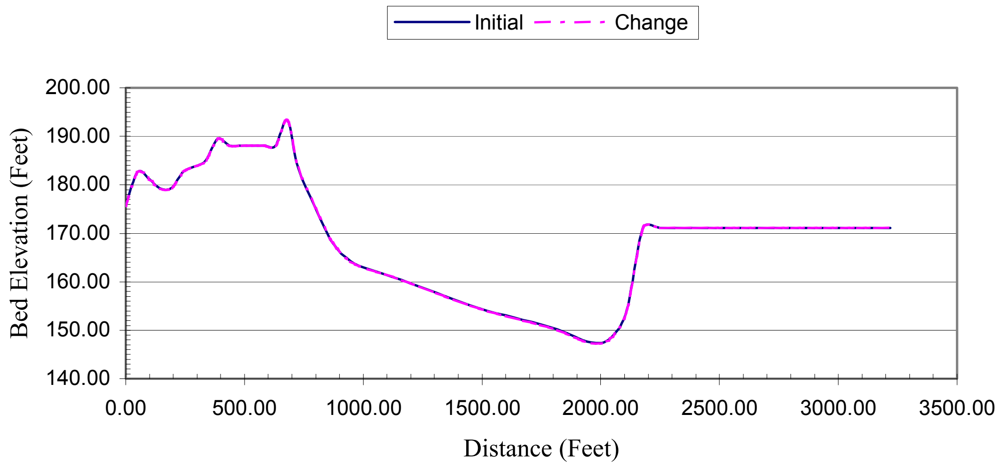


Figure 5a. Initial and final bed elevation for the 80,000 cfs ten day steady state simulation - NM 44.00

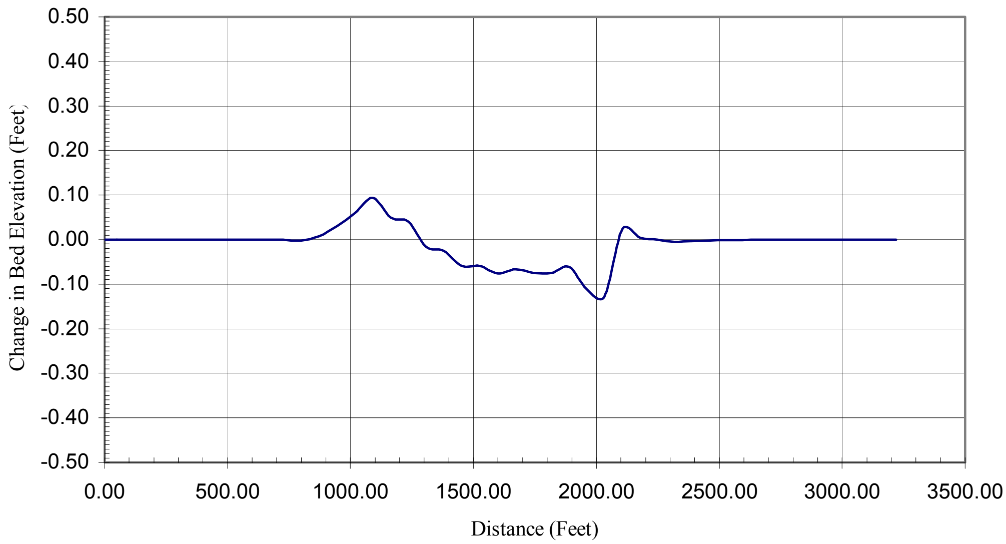


Figure 6a. Bed elevation change for the 80,000 cfs ten day steady state simulation - NM 44.00

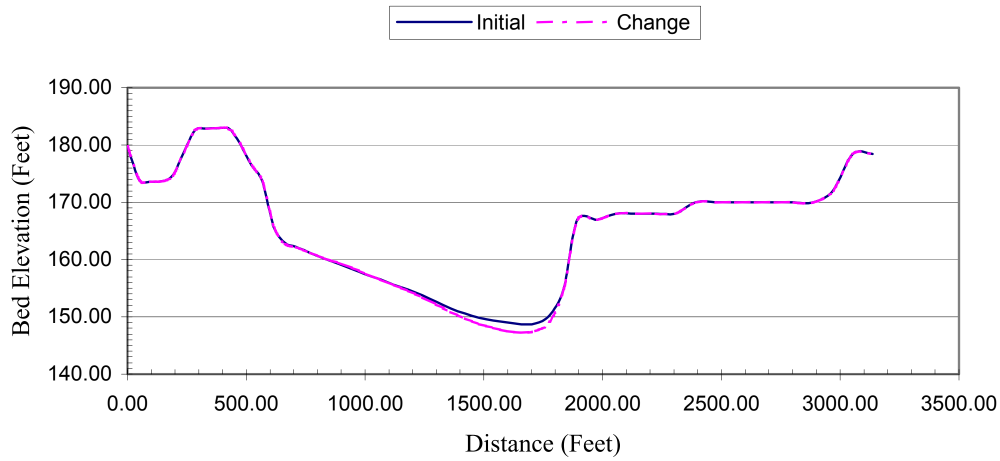


Figure 7a. Initial and final bed elevation for the 80,000 cfs ten day steady state simulation - NM 43.60

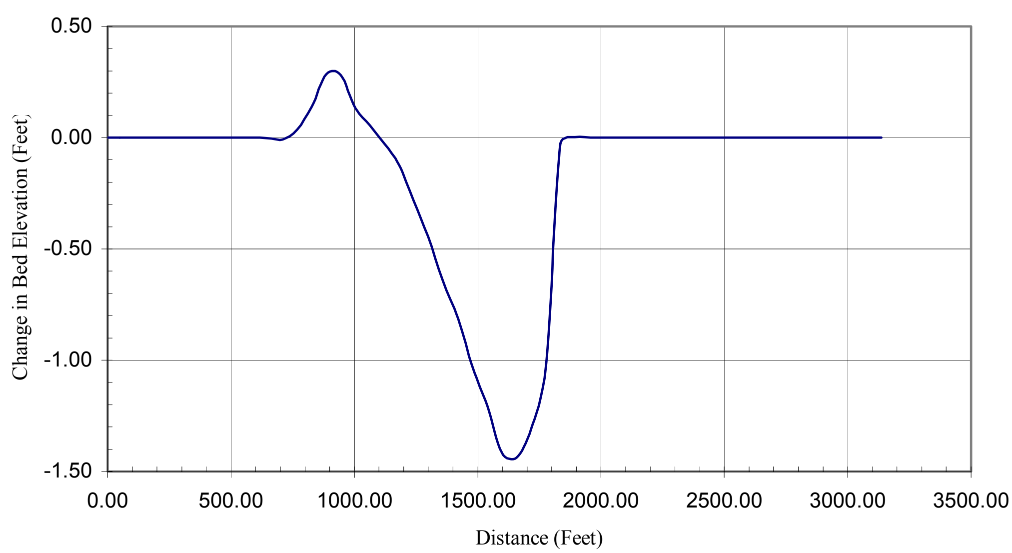


Figure 8a. Bed elevation change for the 80,000 cfs ten day steady state simulation - NM 43.60

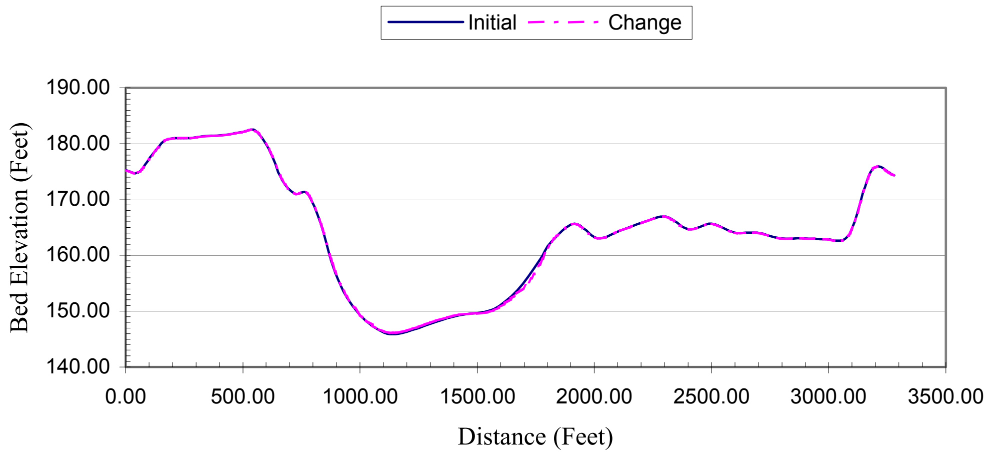


Figure 9a. Initial and final bed elevation for the 80,000 cfs ten day steady state simulation - NM 43.31

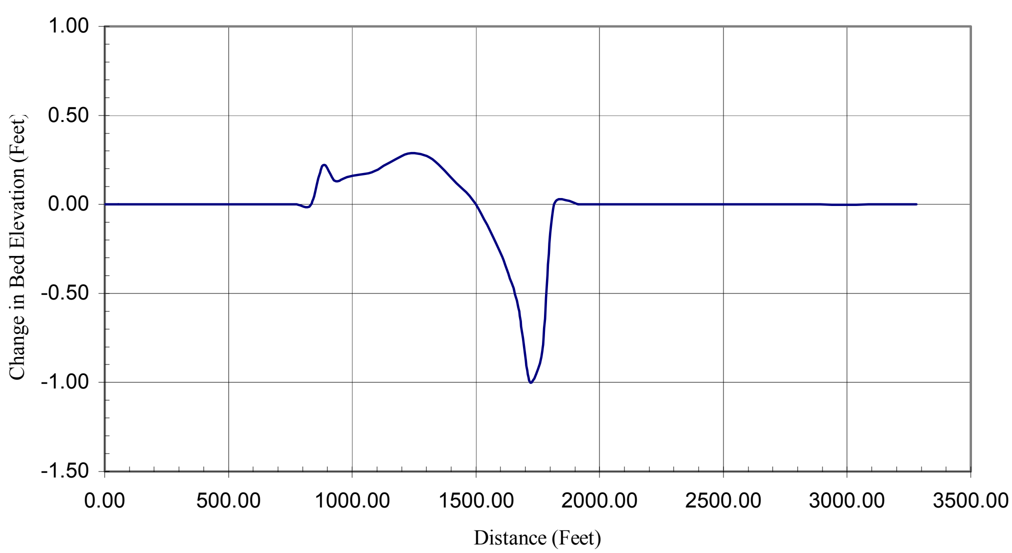


Figure 10a. Bed elevation change for the 80,000 cfs ten day steady state simulation - NM 43.31

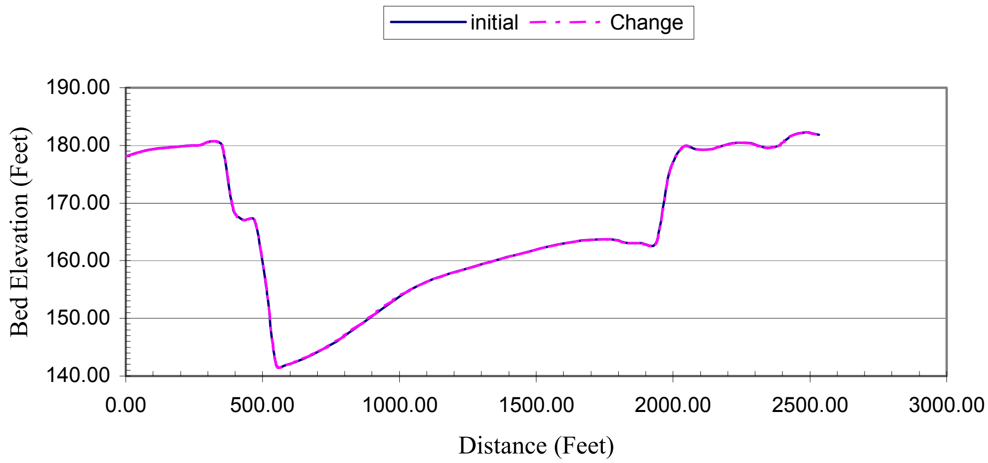


Figure 11a. Initial and final bed elevation for the 80,000 cfs ten day steady state simulation - NM 41.86

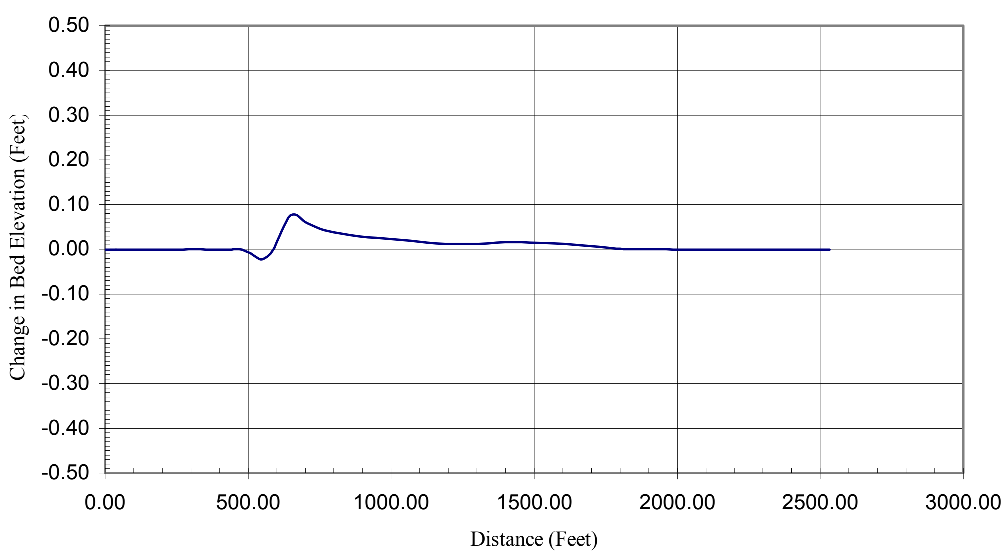


Figure 12a. Bed elevation change for the 80,000 cfs ten day steady state simulation - NM 41.86

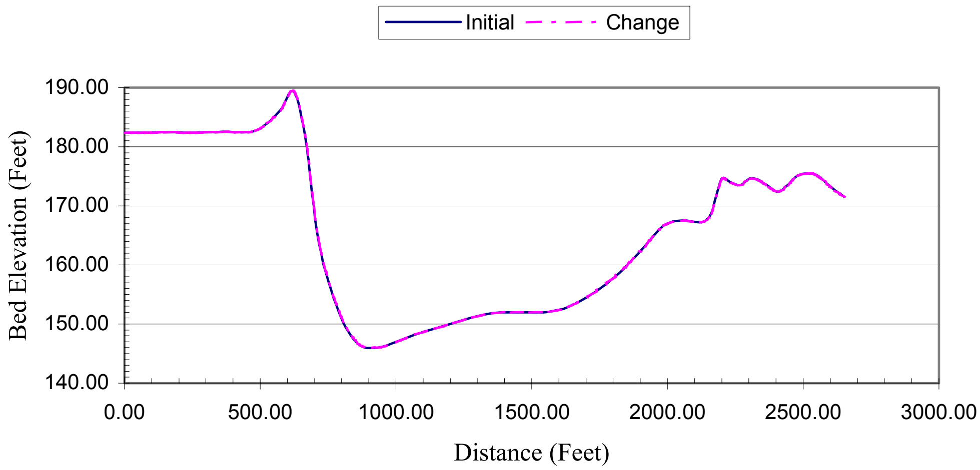


Figure 13a. Initial and final bed elevation for the 80,000 cfs ten day steady state simulation - NM 40.36

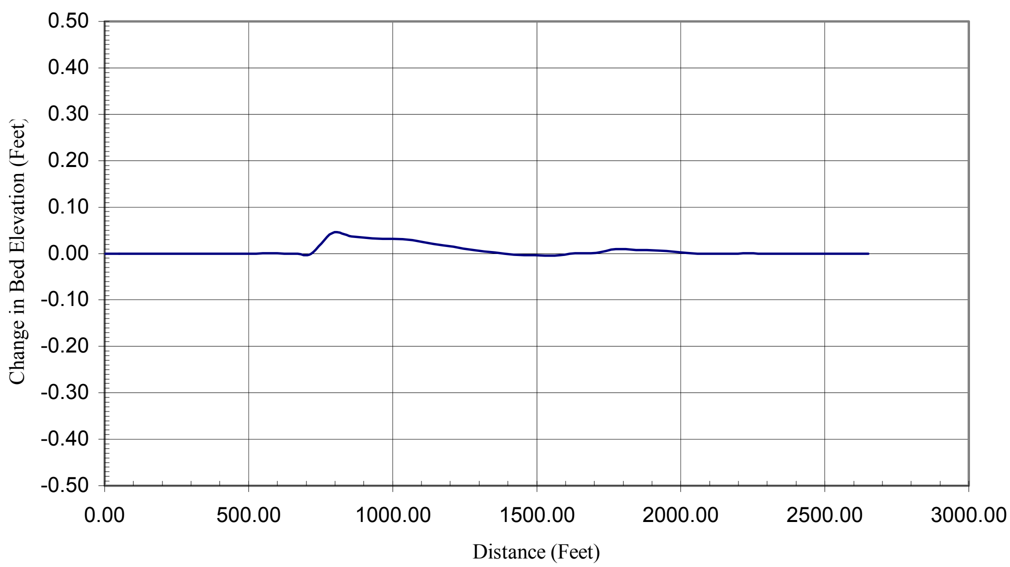


Figure 14a. Bed elevation change for the 80,000 cfs ten day steady state simulation - NM 40.36

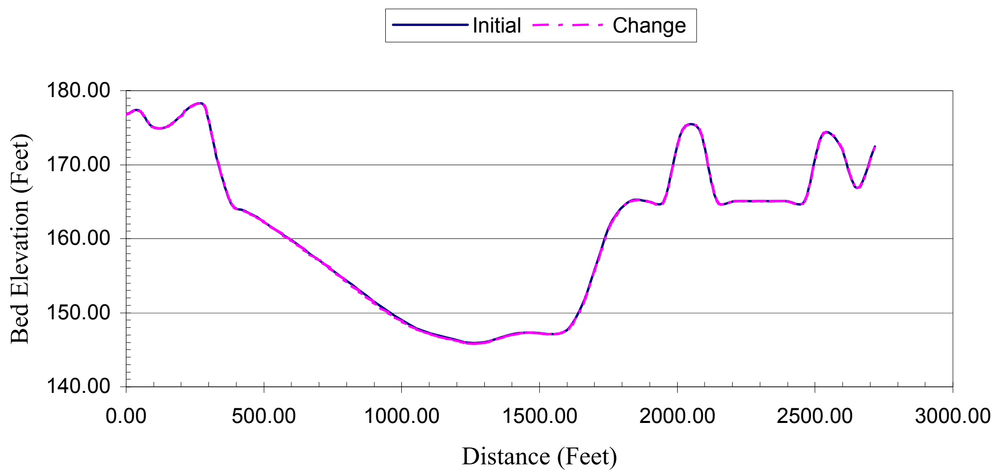


Figure 15a. Initial and final bed elevation for the 80,000 cfs ten day steady state simulation - NM 39.73

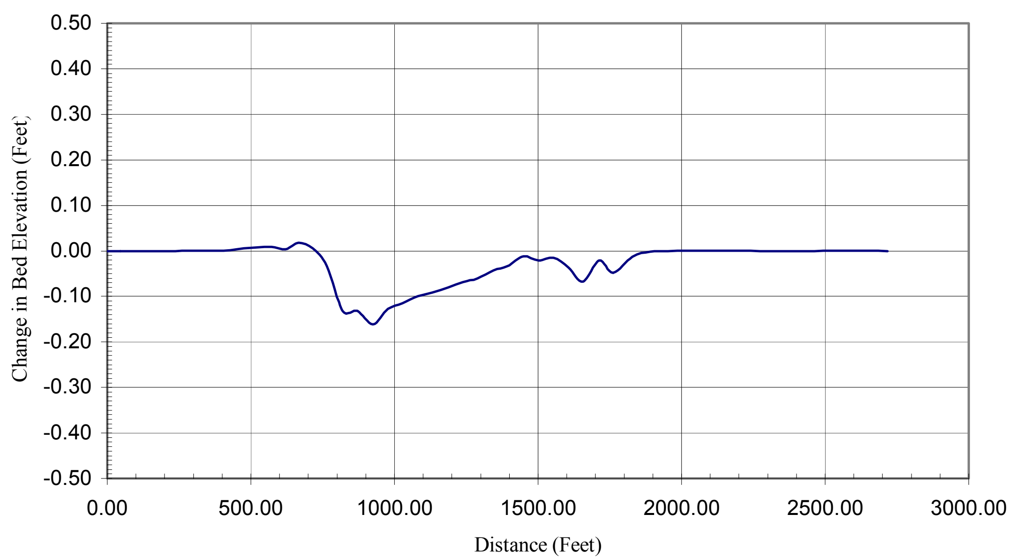


Figure 16a. Bed elevation change for the 80,000 cfs ten day steady state simulation - NM 39.73

APPENDIX B

120,000 cfs Steady State Flow Event Results

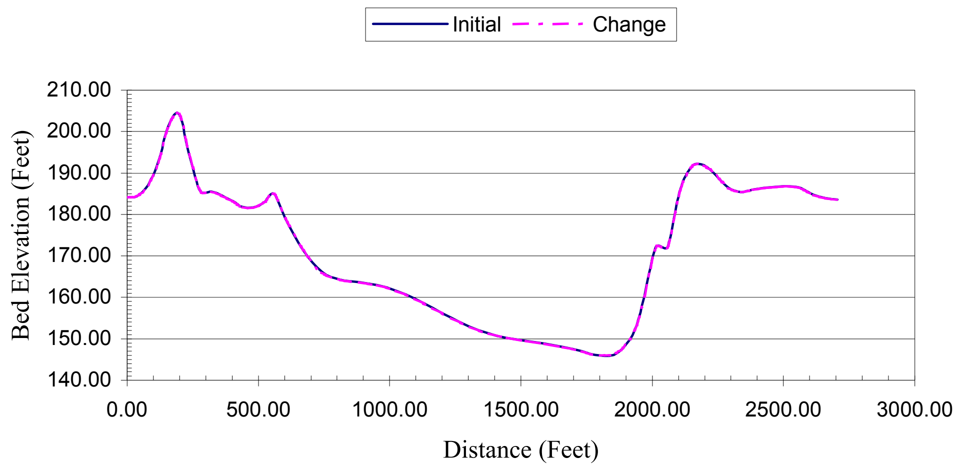


Figure 1b. Initial and final bed elevation for the 120,000 cfs ten day steady state simulation - NM 44.77

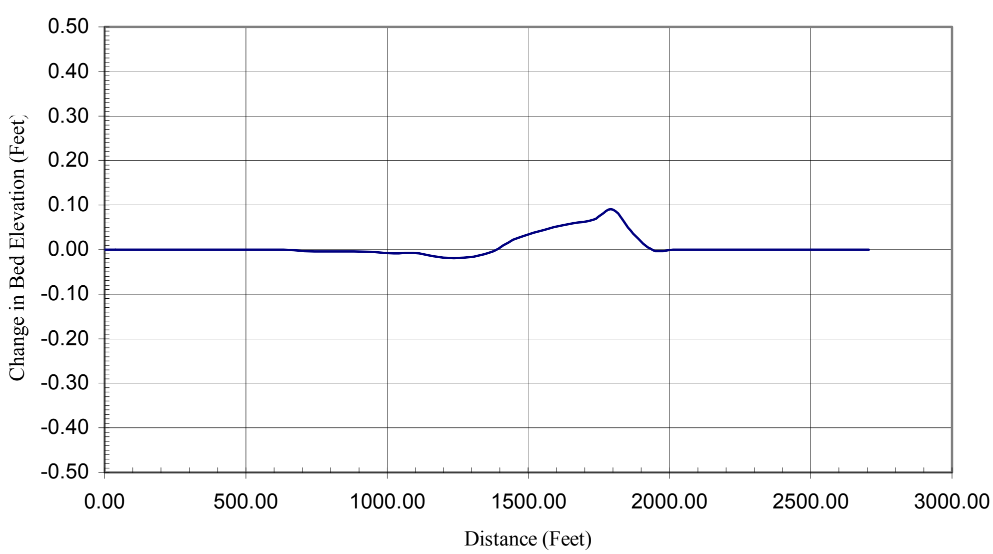


Figure 2b. Bed elevation change for the 120,000 cfs ten day steady state simulation - NM 44.77

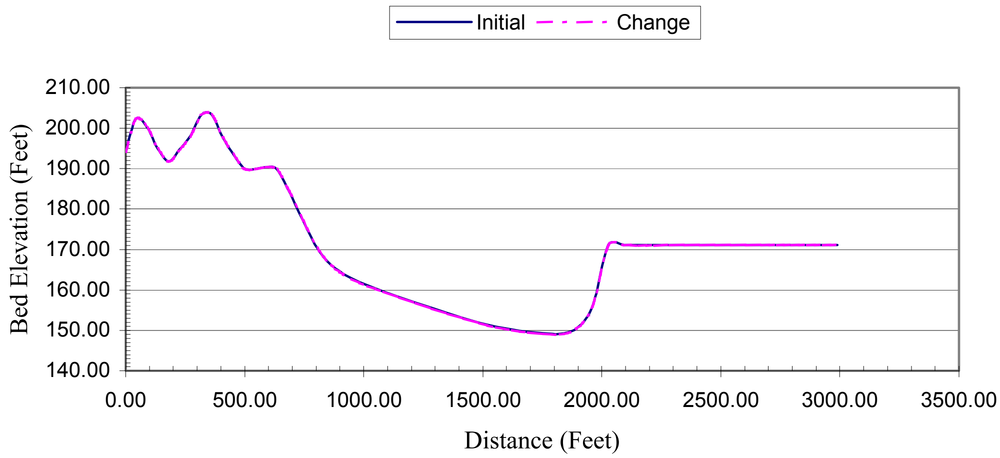


Figure 3b. Initial and final bed elevation for the 120,000 cfs ten day steady state simulation - NM 44.41

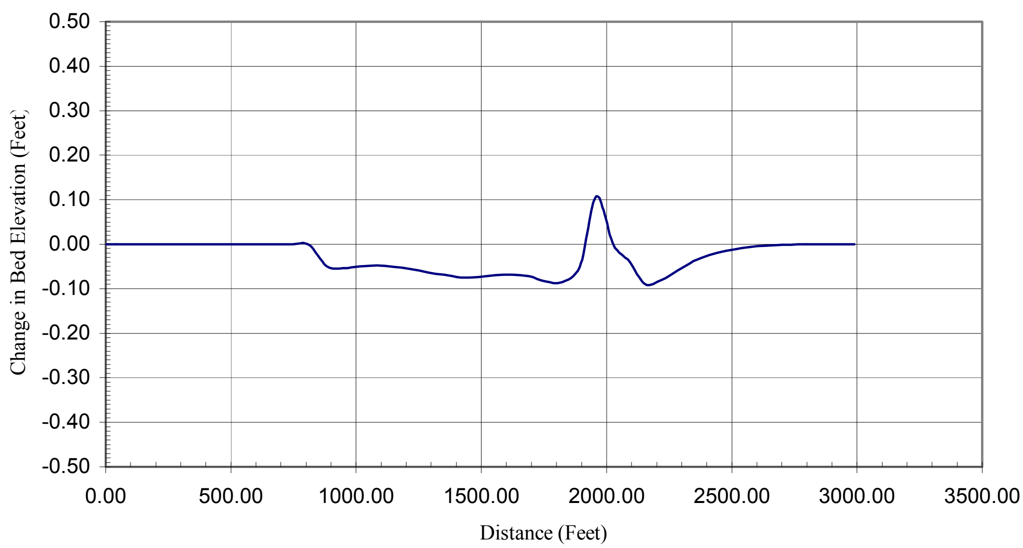


Figure 4b. Bed elevation change for the 120,000 cfs ten day steady state simulation - NM 44.41

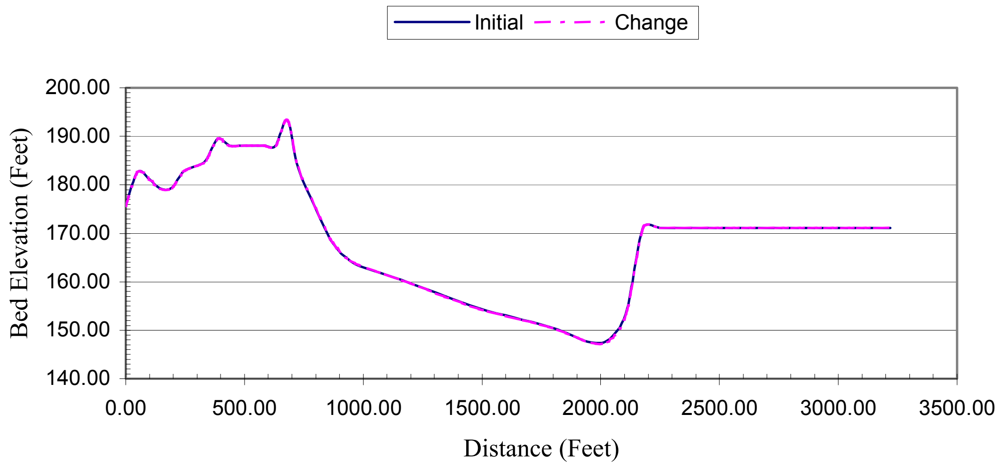


Figure 5b. Initial and final bed elevation for the 120,000 cfs ten day steady state simulation - NM 44.00

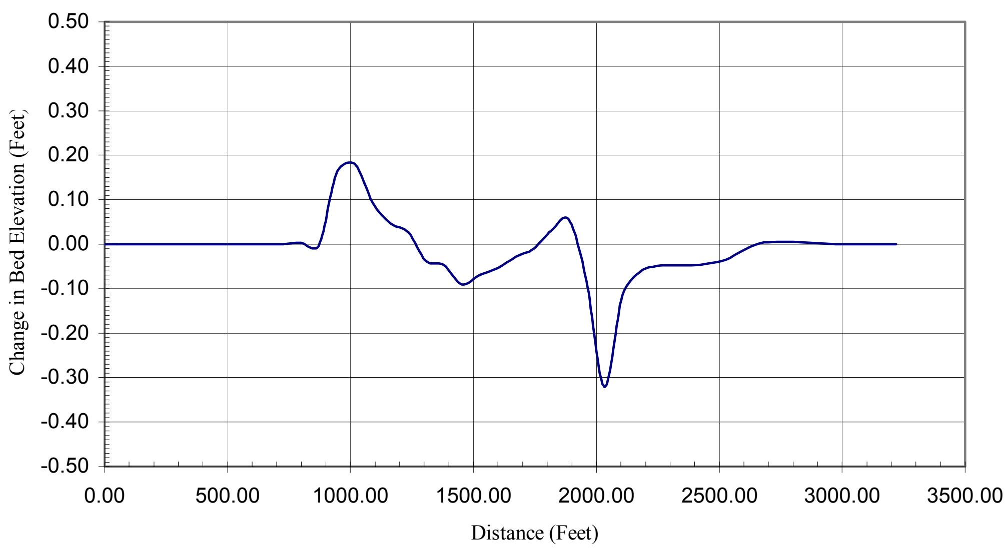


Figure 6b. Bed elevation change for the 120,000 cfs ten day steady state simulation - NM 44.00

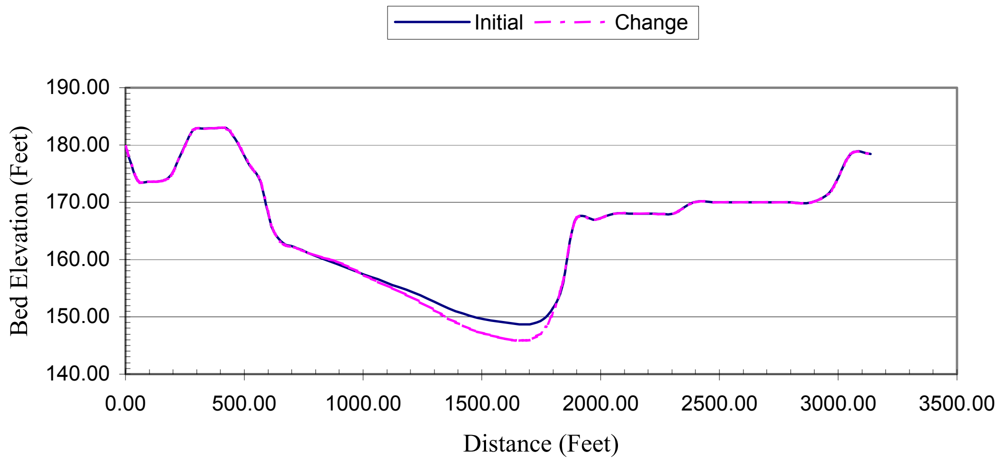


Figure 7b. Initial and final bed elevation for the 120,000 cfs ten day steady state simulation - NM 43.60

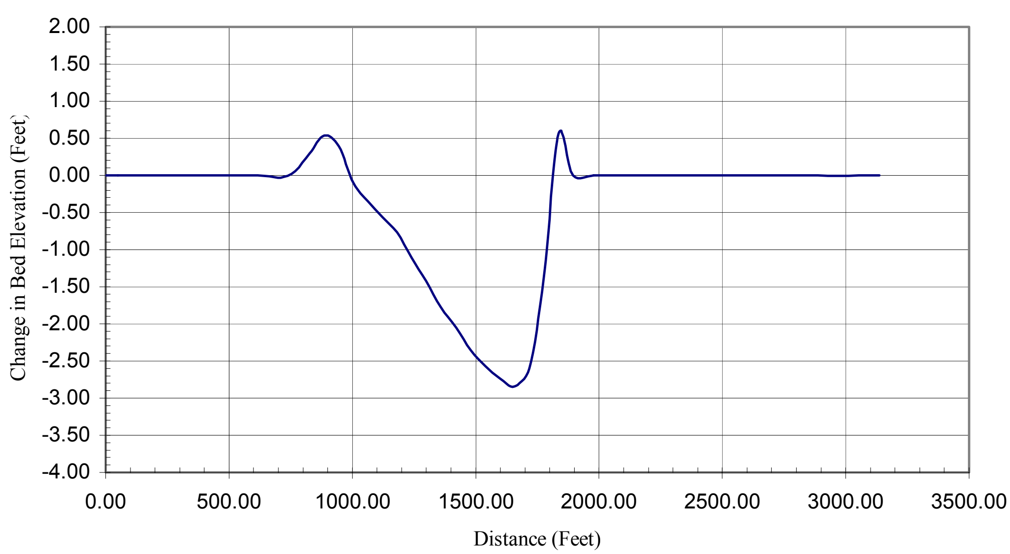


Figure 8b. Bed elevation change for the 120,000 cfs ten day steady state simulation - NM 43.60

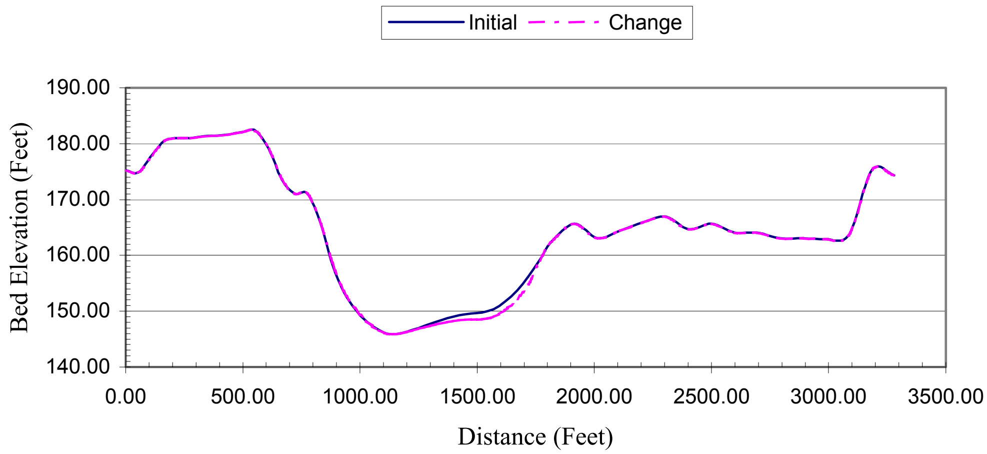


Figure 9b. Initial and final bed elevation for the 120,000 cfs ten day steady state simulation - NM 43.31

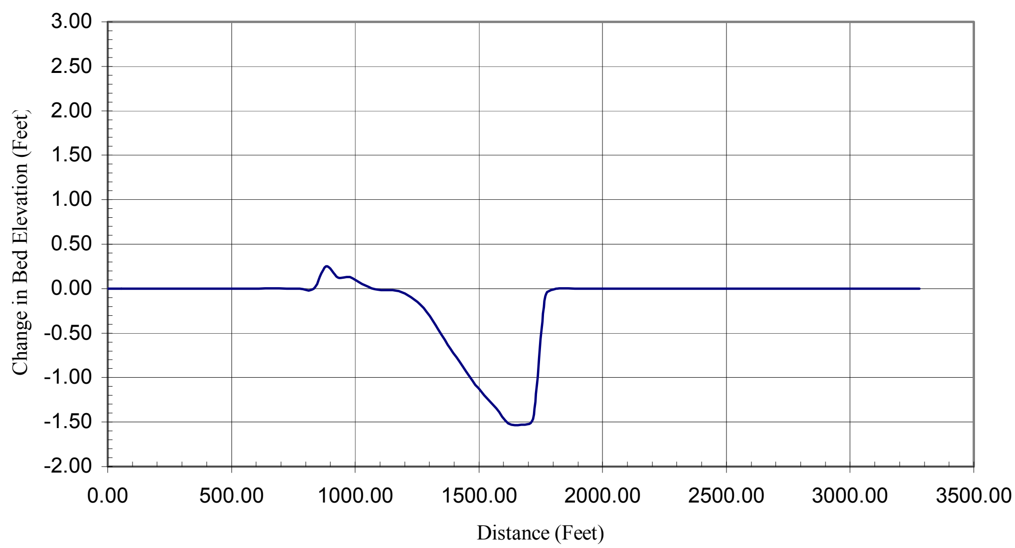


Figure 10b. Bed elevation change for the 120,000 cfs ten day steady state simulation - NM 43.31

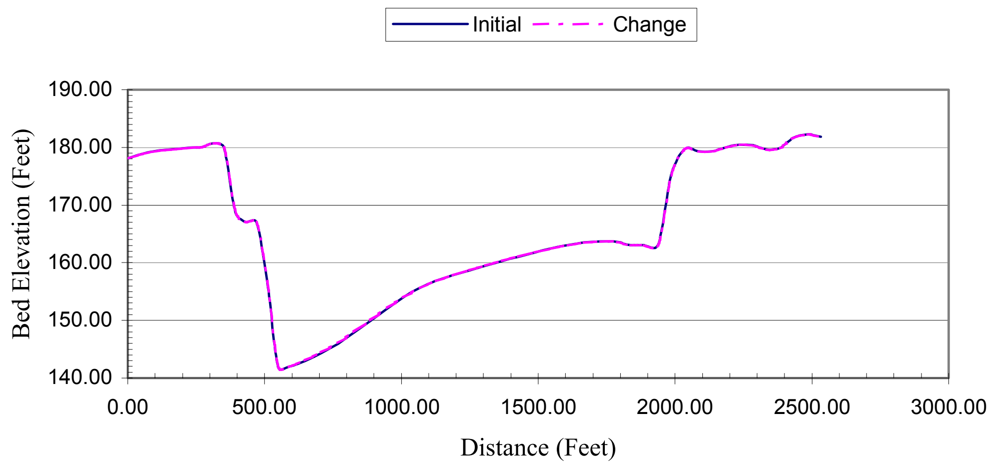


Figure 11b. Initial and final bed elevation for the 120,000 cfs ten day steady state simulation - NM 41.86

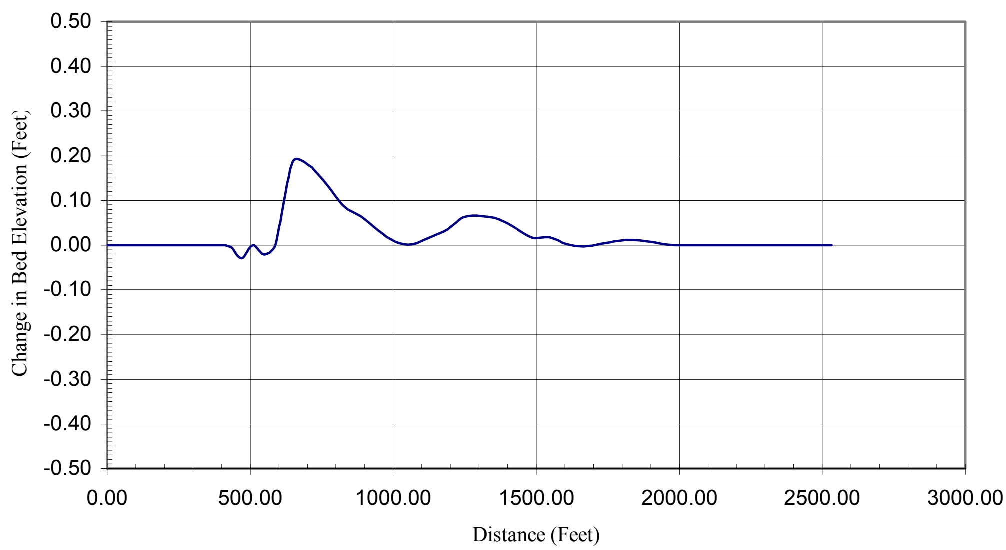


Figure 12b. Bed elevation change for the 120,000 cfs ten day steady state simulation - NM 41.86

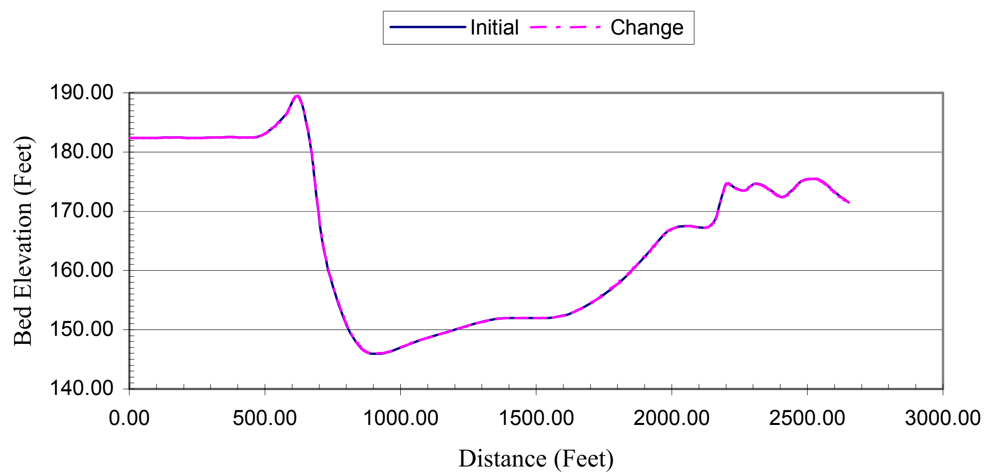


Figure 13b. Initial and final bed elevation for the 120,000 cfs ten day steady state simulation - NM 40.36

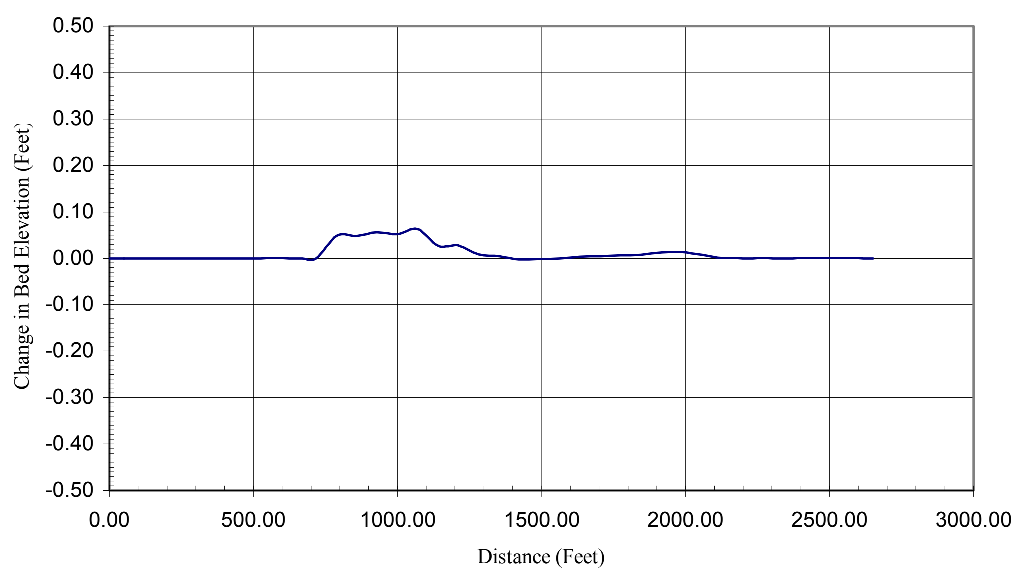


Figure 14b. Bed elevation change for the 120,000 cfs ten day steady state simulation - NM 40.36

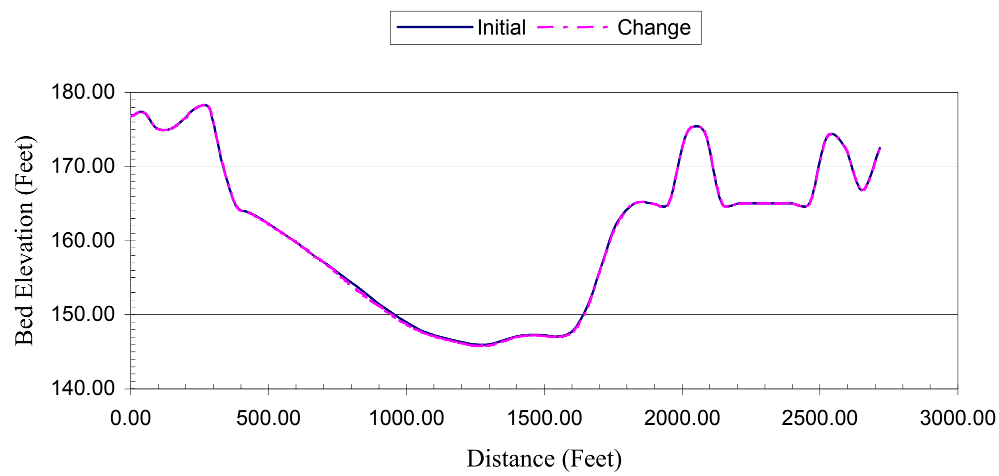


Figure 15b. Initial and final bed elevation for the 120,000 cfs ten day steady state simulation - NM 39.73

Figure 16b. Bed elevation change for the 120,000 cfs ten day steady state simulation - NM 39.73

APPENDIX C

150,000 cfs Steady State Flow Event Results

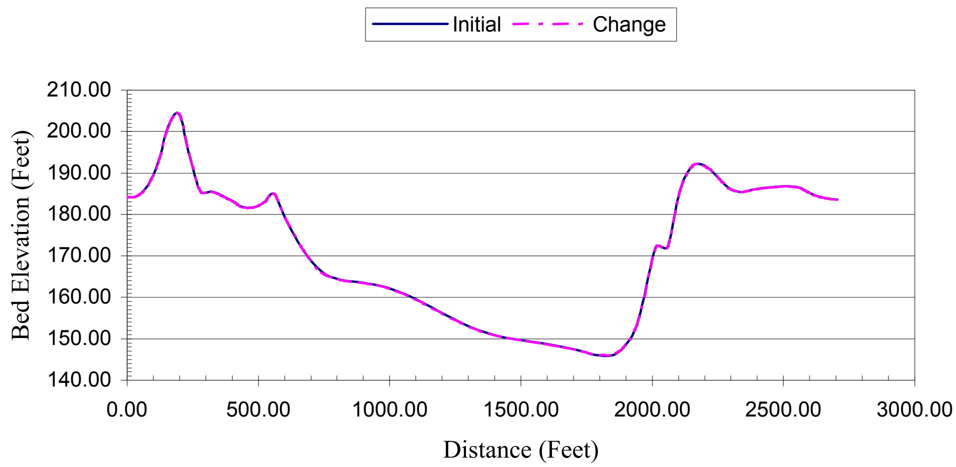


Figure 1c. Initial and final bed elevation for the 150,000 cfs ten day steady state simulation - NM 44.77

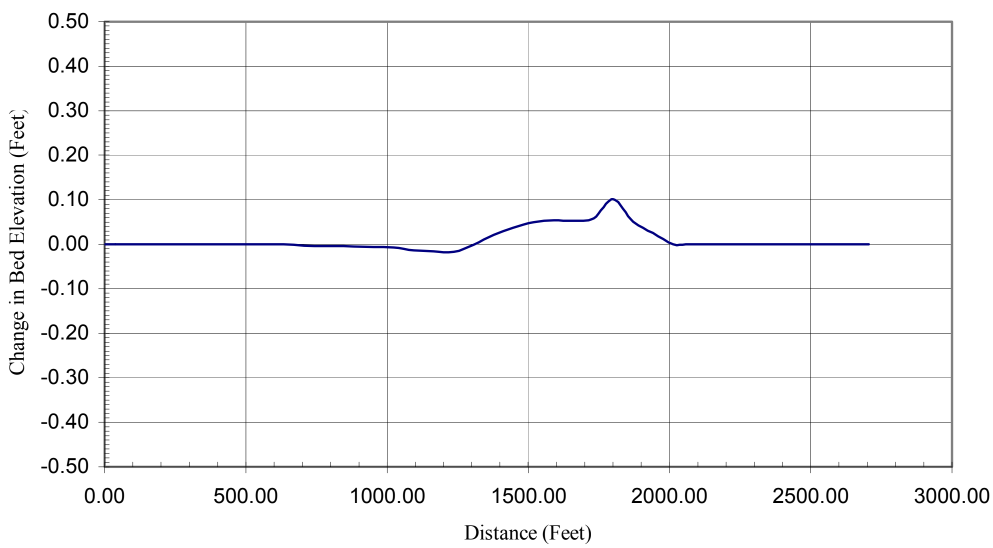


Figure 2c. Bed elevation change for the 150,000 cfs ten day steady state simulation - NM 44.77

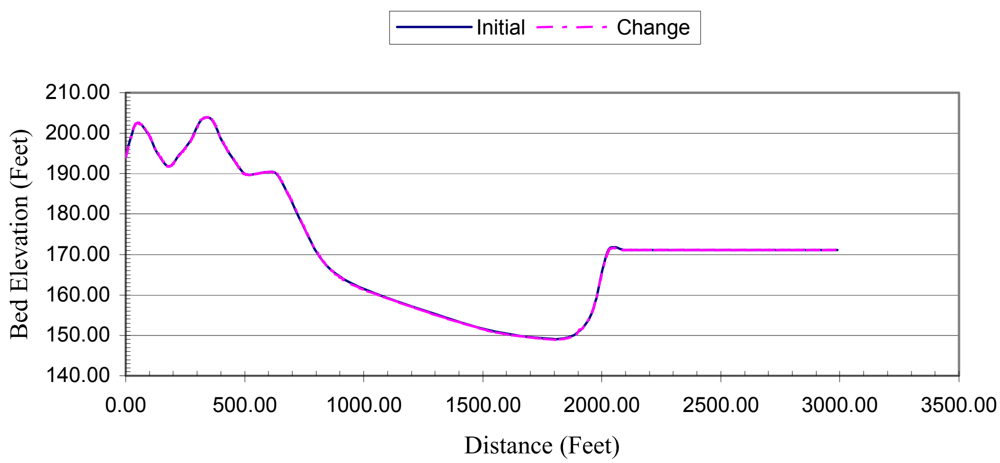


Figure 3c. Initial and final bed elevation for the 150,000 cfs ten day steady state simulation - NM 44.41

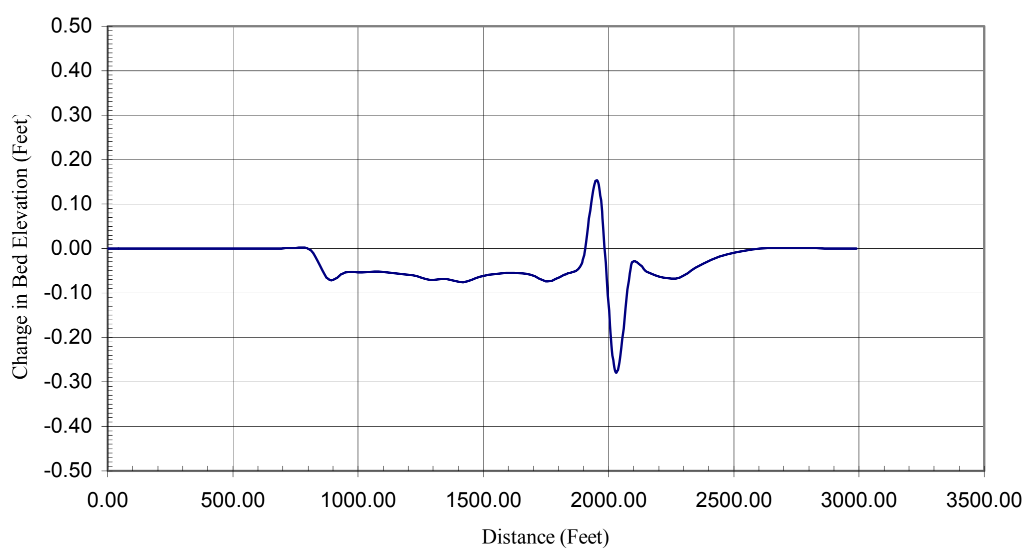


Figure 4c. Bed elevation change for the 150,000 cfs ten day steady state simulation - NM 44.41

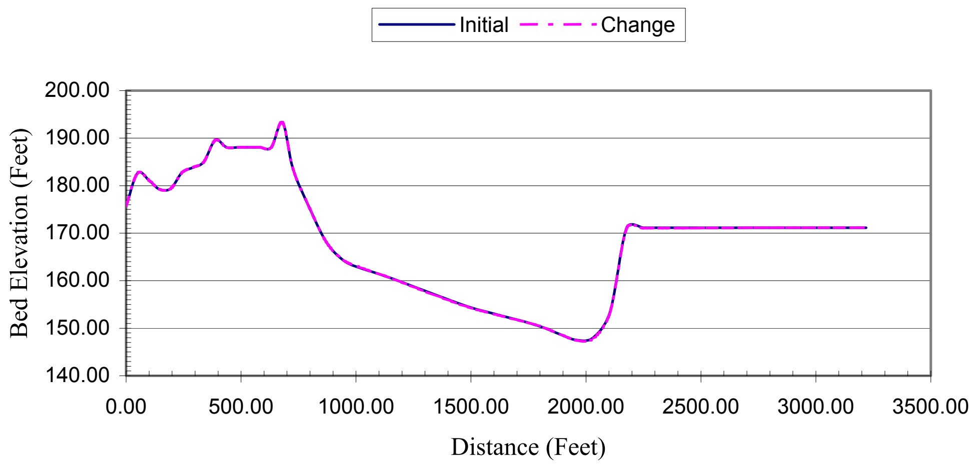


Figure 5c. Initial and final bed elevation for the 150,000 cfs ten day steady state simulation - NM 44.00

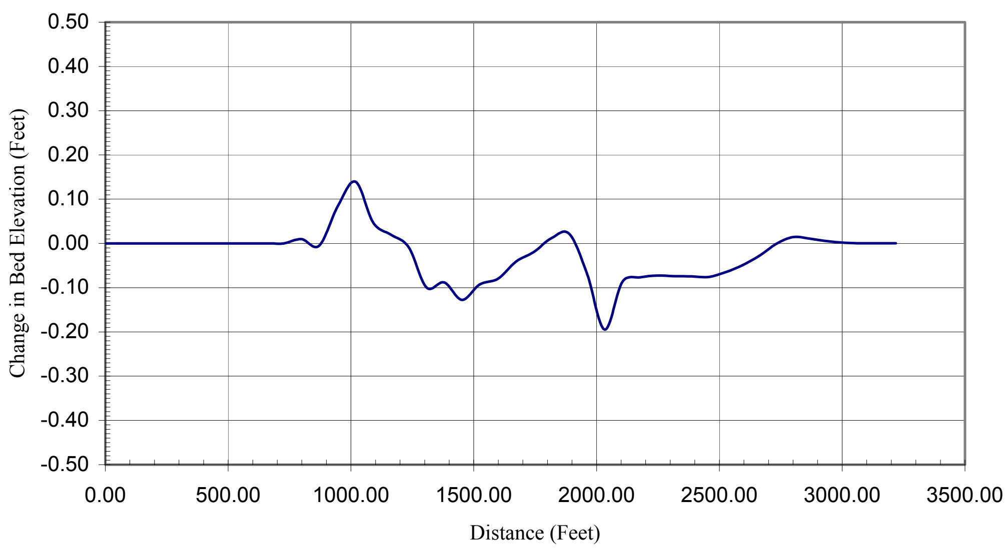


Figure 6c. Bed elevation change for the 150,000 cfs ten day steady state simulation - NM 44.00

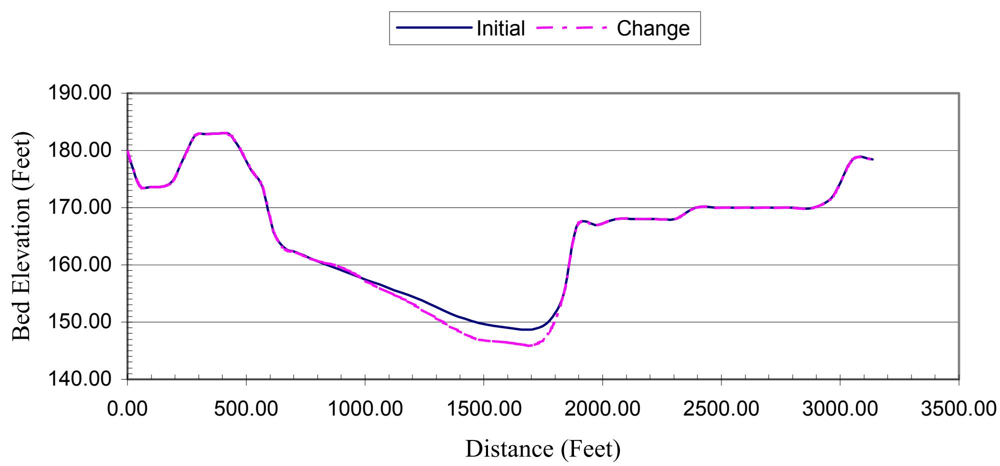


Figure 7c. Initial and final bed elevation for the 150,000 cfs ten day steady state simulation - NM 43.60

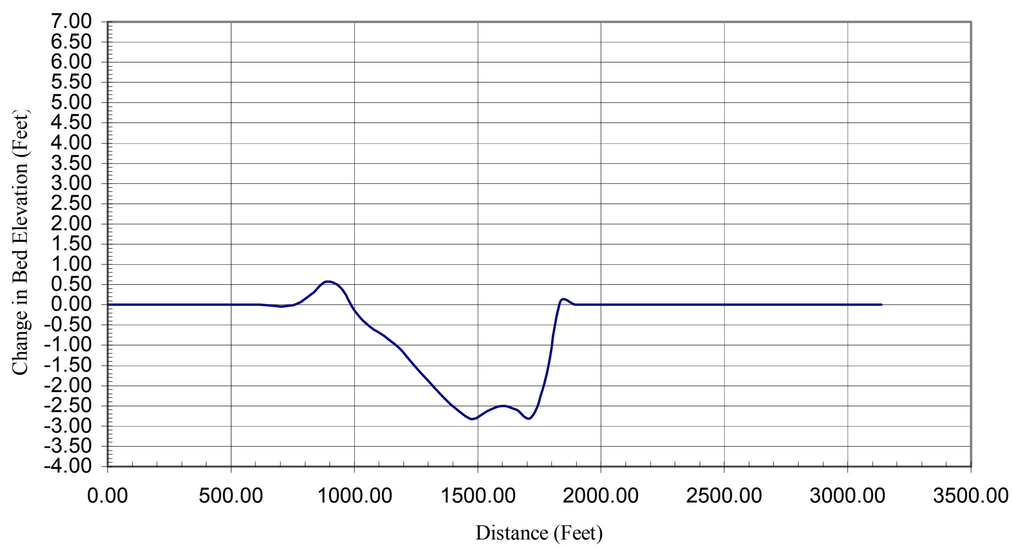


Figure 8c. Bed elevation change for the 150,000 cfs ten day steady state simulation - NM 43.60

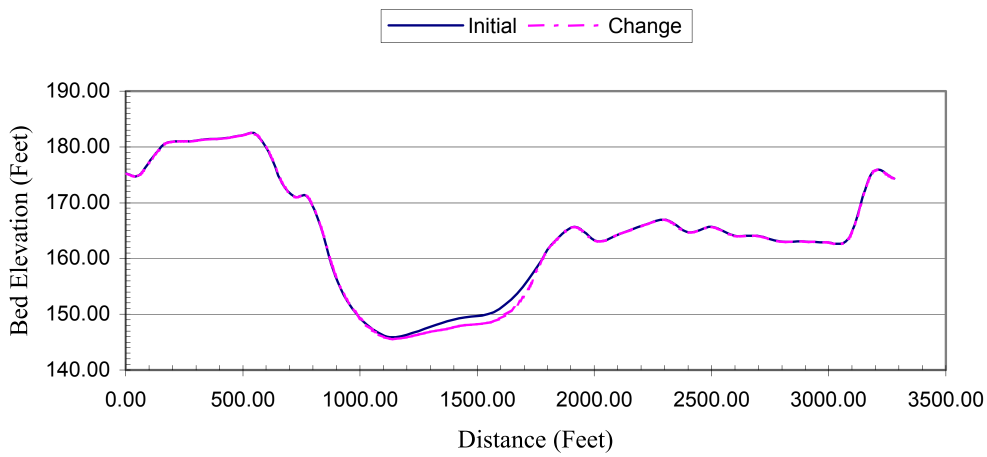


Figure 9c. Initial and final bed elevation for the 150,000 cfs ten day steady state simulation - NM 43.31

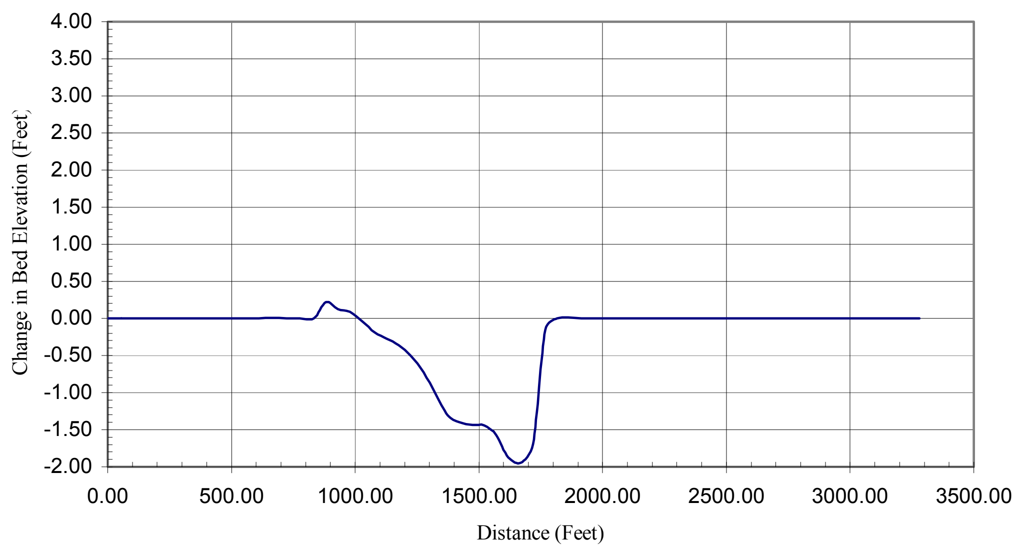


Figure 10c. Bed elevation change for the 150,000 cfs ten day steady state simulation - NM 43.31

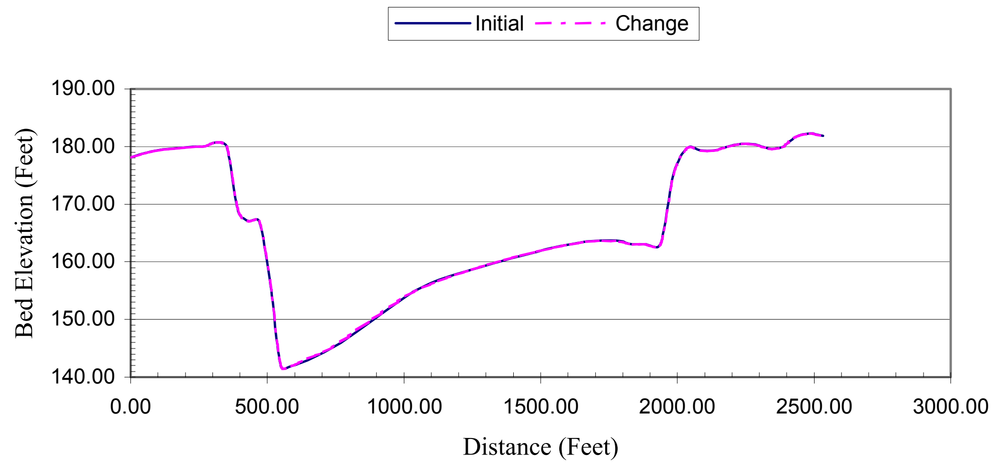


Figure 11c. Initial and final bed elevation for the 150,000 cfs ten day steady state simulation - NM 41.86

Figure 12c. Bed elevation change for the 150,000 cfs ten day steady state simulation - NM 41.86

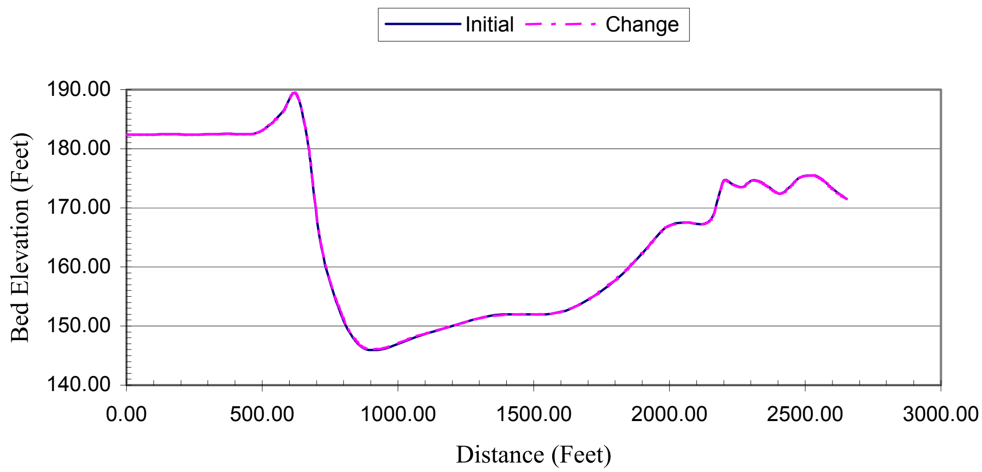


Figure 13c. Initial and final bed elevation for the 150,000 cfs ten day steady state simulation - NM 40.36

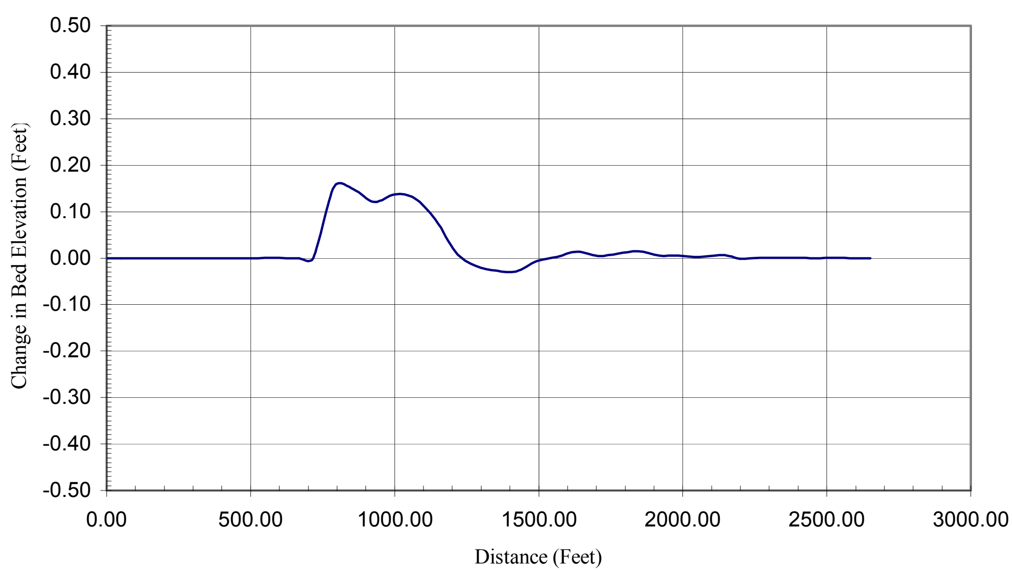


Figure 14c. Bed elevation change for the 150,000 cfs ten day steady state simulation - NM 40.36

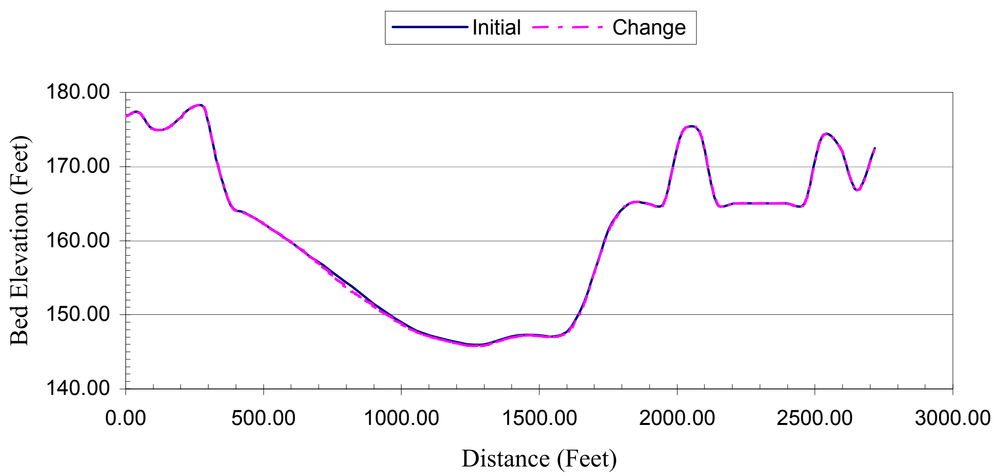


Figure 15c. Initial and final bed elevation for the 150,000 cfs ten day steady state simulation - NM 39.73

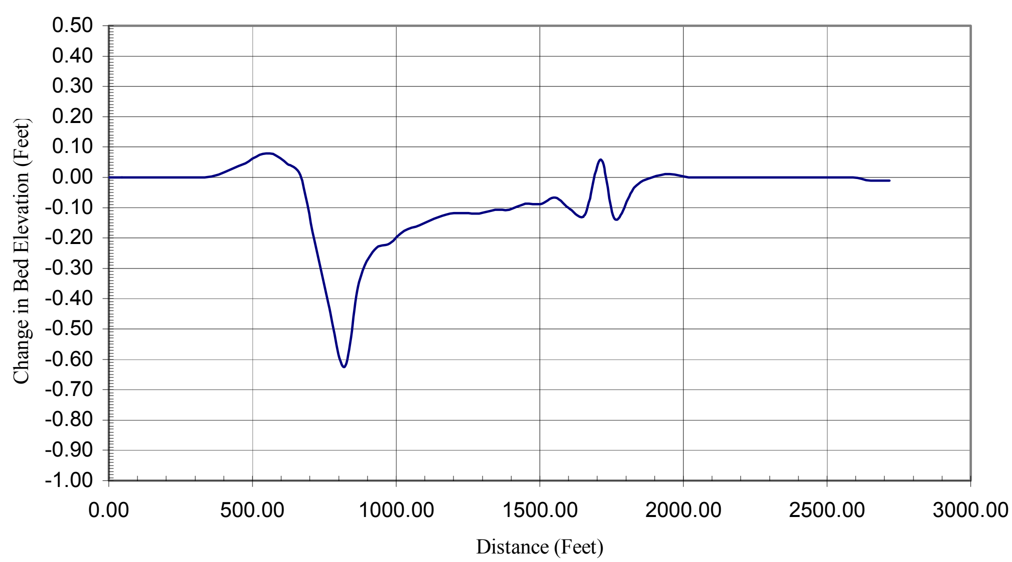


Figure 16c. Bed elevation change for the 150,000 cfs ten day steady state simulation - NM 39.73

APPENDIX D

185,000 cfs Steady State Flow Event Results

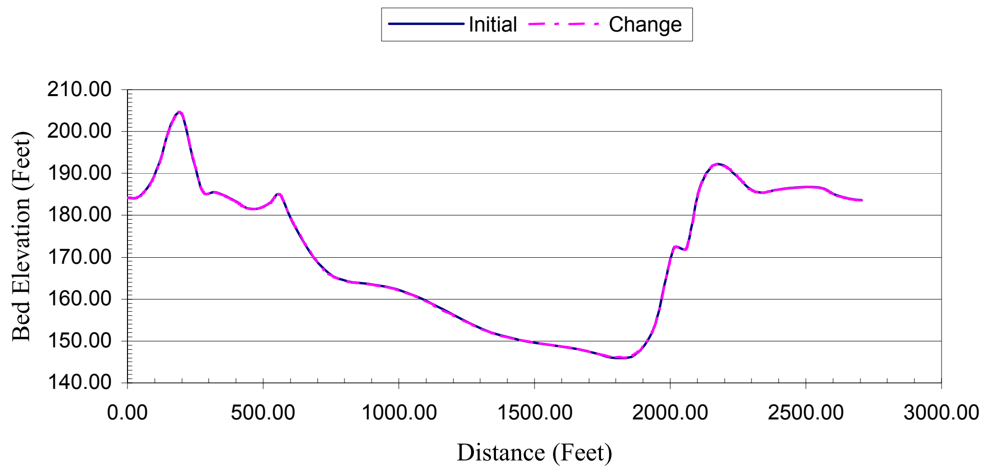


Figure 1d. Initial and final bed elevation for the 185,000 cfs ten day steady state simulation - NM 44.77

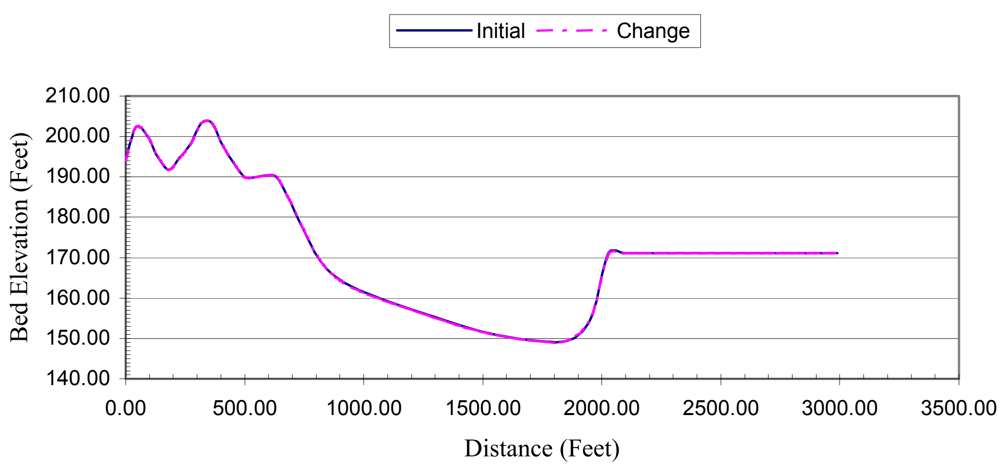


Figure 3d. Initial and final bed elevation for the 185,000 cfs ten day steady state simulation - NM 44.41

Figure 2d. Bed elevation change for the 185,000 cfs ten day steady state simulation - NM 44.77

Figure 4d. Bed elevation change for the 185,000 cfs ten day steady state simulation - NM 44.41

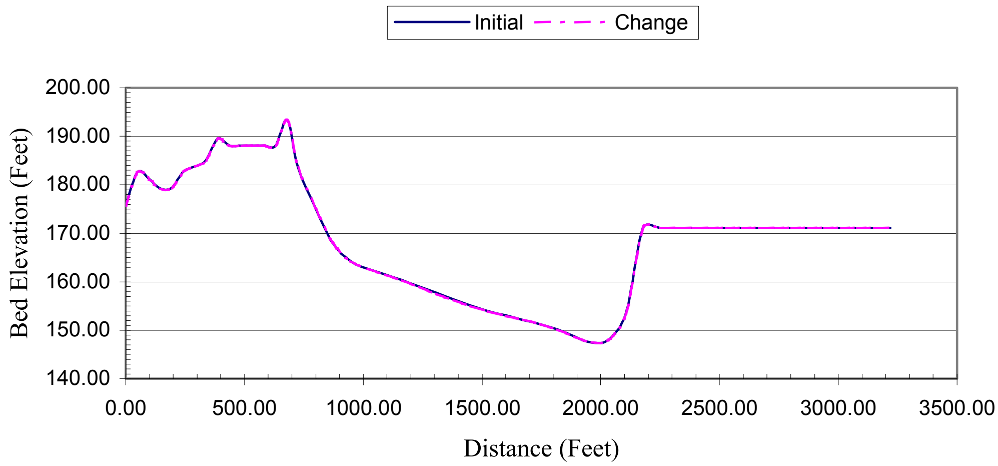


Figure 5d. Initial and final bed elevation for the 185,000 cfs ten day steady state simulation - NM 44.00

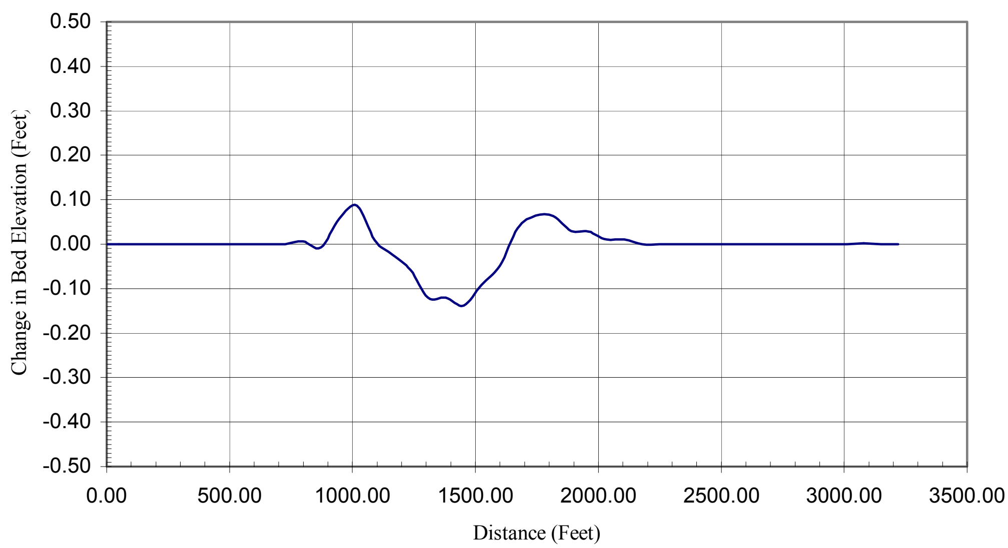


Figure 6d. Bed elevation change for the 185,000 cfs ten day steady state simulation - NM 44.00

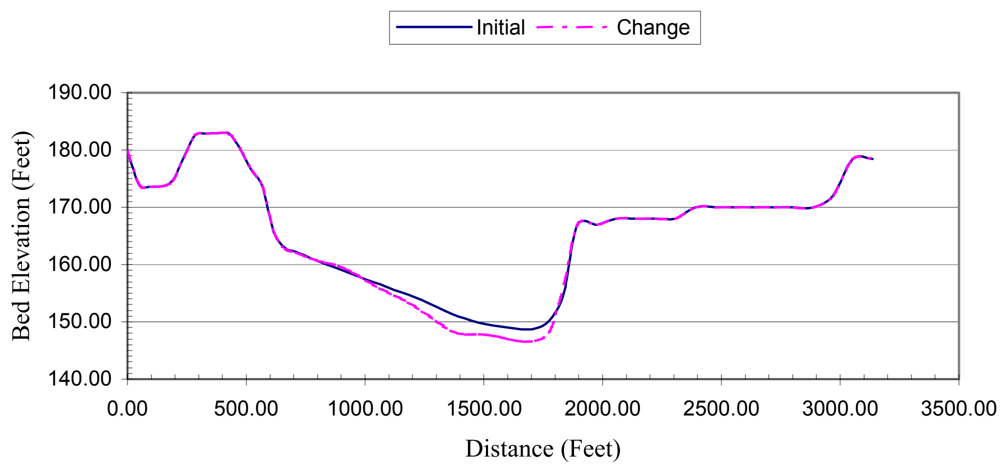


Figure 7d. Initial and final bed elevation for the 185,000 cfs ten day steady state simulation - NM 43.60

Figure 8d. Bed elevation change for the 185,000 cfs ten day steady state simulation - NM 43.60

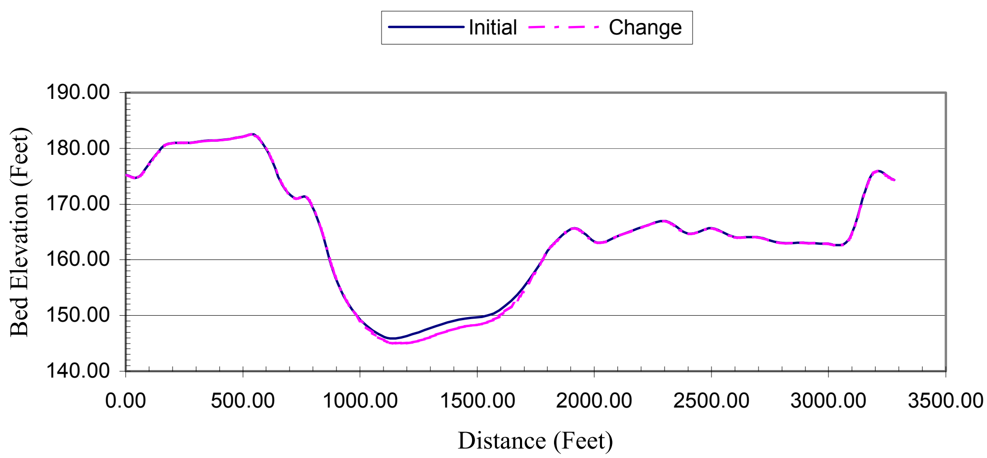


Figure 9d. Initial and final bed elevation for the 185,000 cfs ten day steady state simulation - NM 43.31

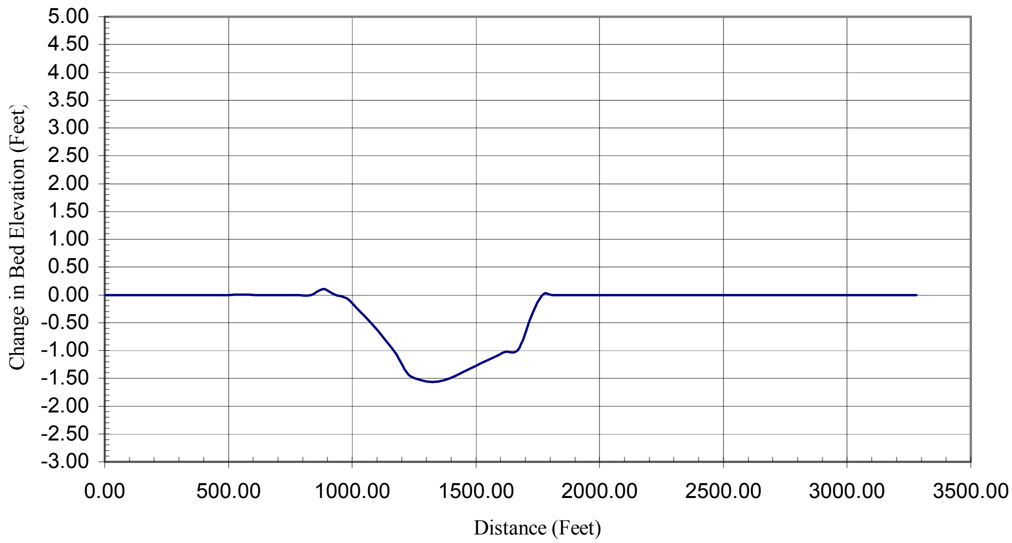


Figure 10d. Bed elevation change for the 185,000 cfs ten day steady state simulation - NM 43.31

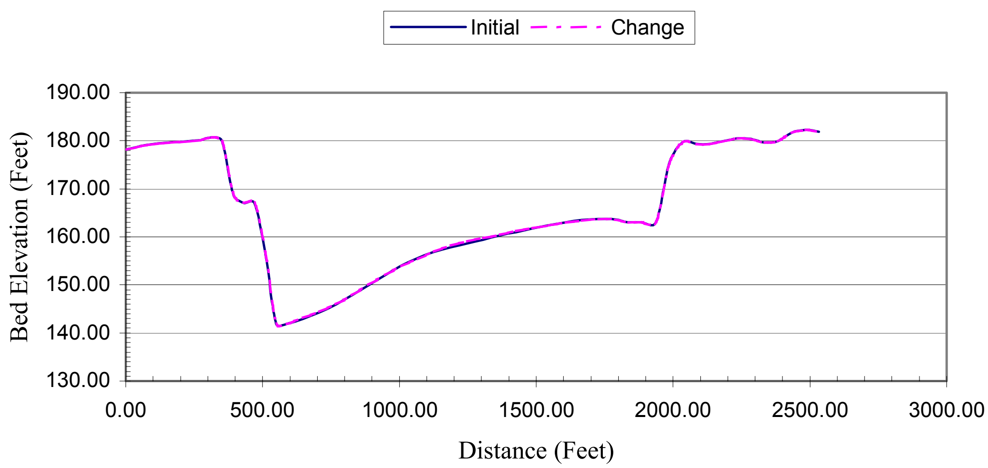


Figure 11d. Initial and final bed elevation for the 185,000 cfs ten day steady state simulation - NM 41.86

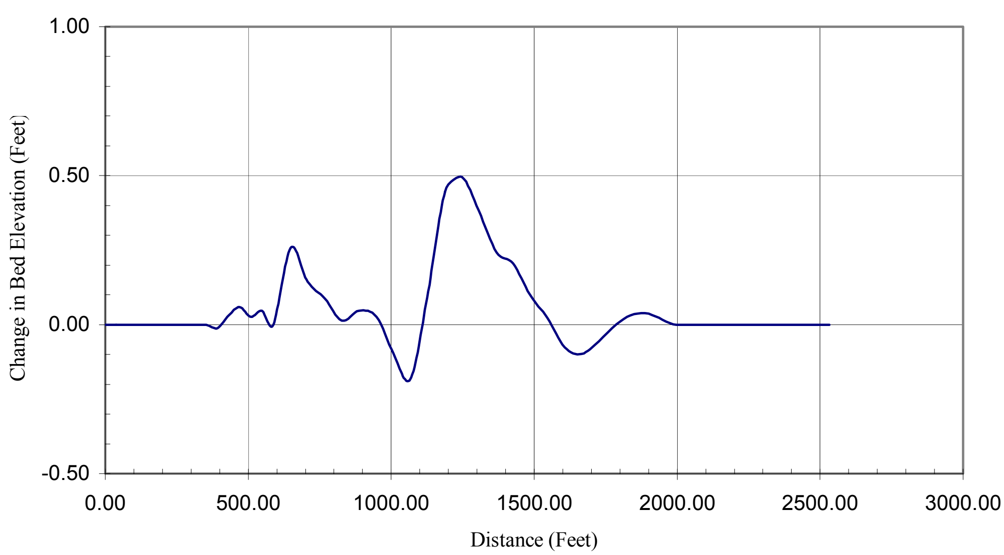


Figure 12d. Bed elevation change for the 185,000 cfs ten day steady state simulation - NM 41.86

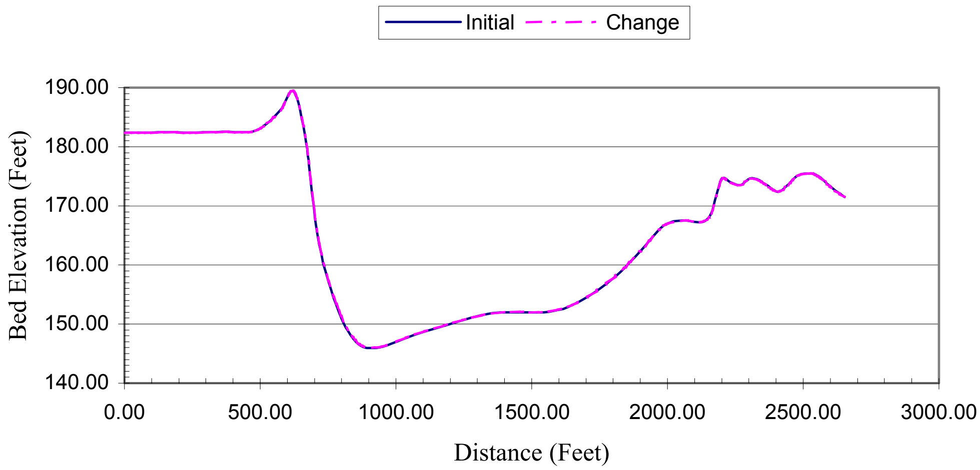


Figure 13d. Initial and final bed elevation for the 185,000 cfs ten day steady state simulation - NM 40.36

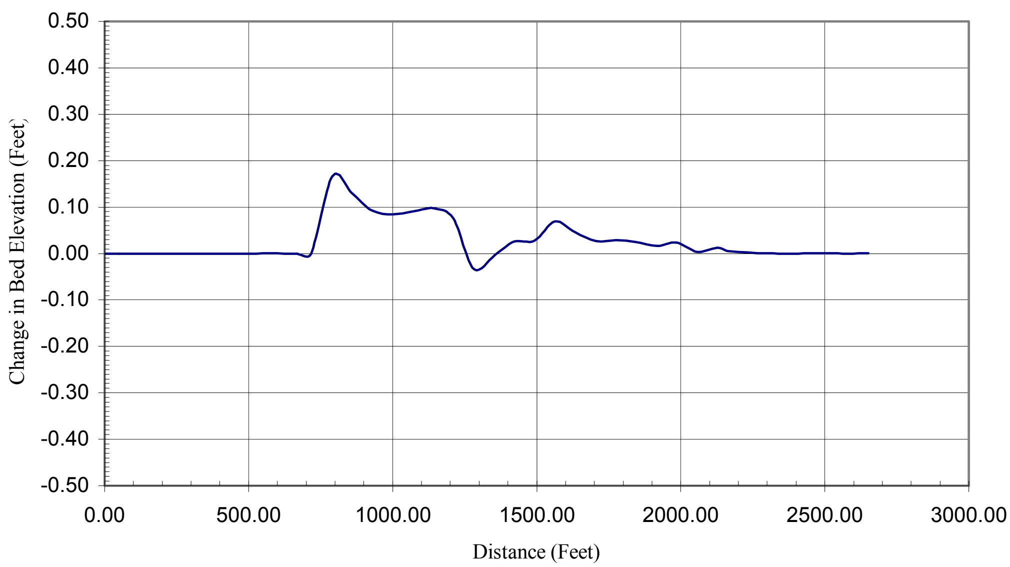


Figure 14d. Bed elevation change for the 185,000 cfs ten day steady state simulation - NM 40.36

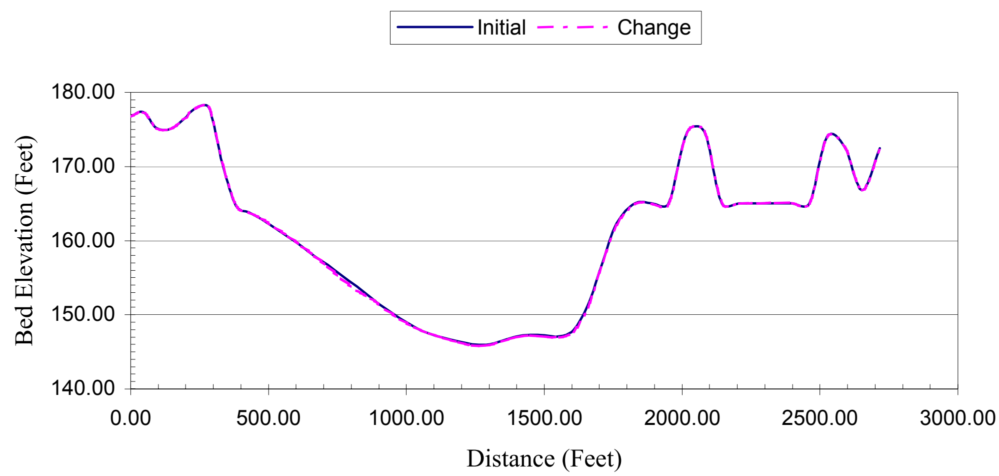


Figure 15d. Initial and final bed elevation for the 185,000 cfs ten day steady state simulation - NM 39.73

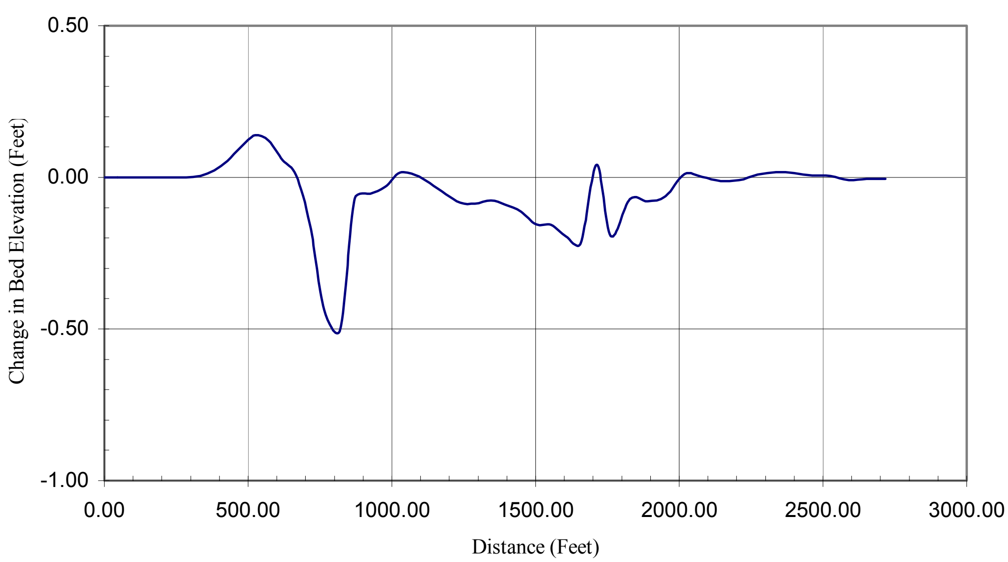


Figure 16d. Bed elevation change for the 185,000 cfs ten day steady state simulation - NM 39.73

APPENDIX E

One -Year Hydrograph Simulation Results

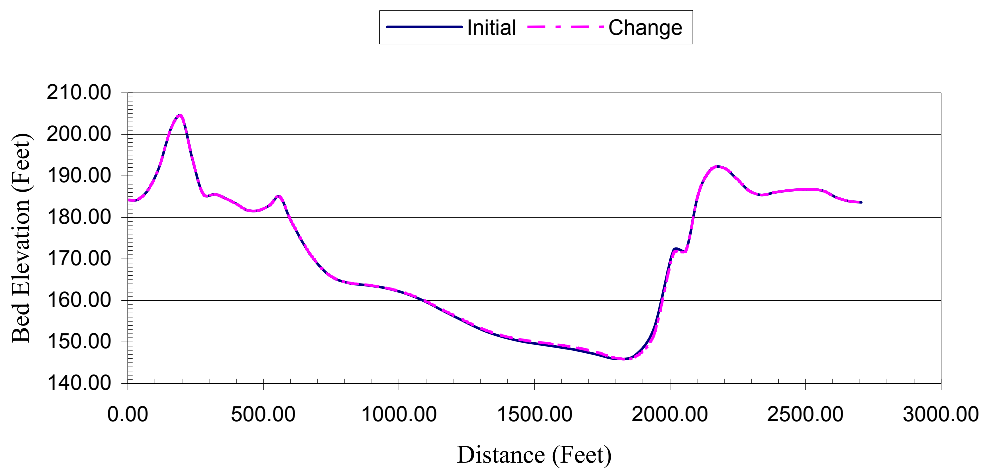


Figure 1e. Initial and final bed elevation for the 1 year hydrograph steady state simulation - NM 44.77

Figure 2e. Bed elevation change for the 1 year hydrograph steady state simulation - NM 44.77

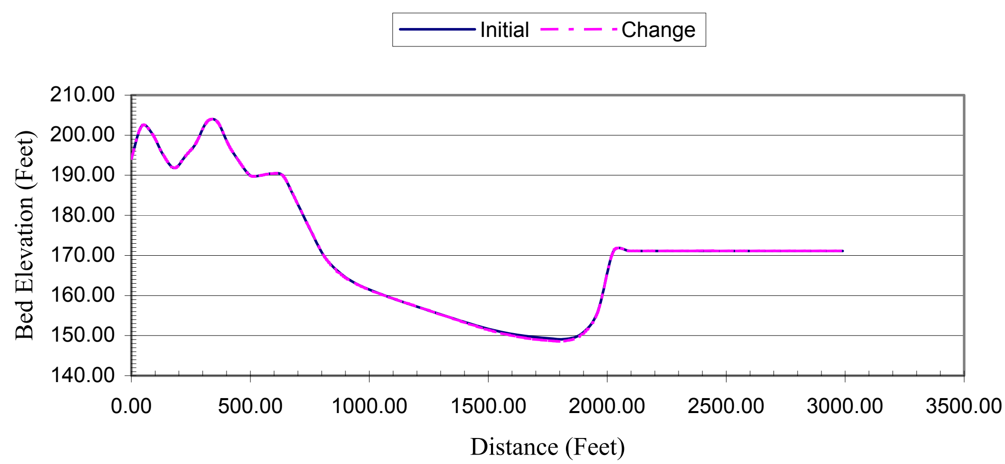


Figure 3e. Initial and final bed elevation for the 1 year hydrograph steady state simulation - NM 44.41

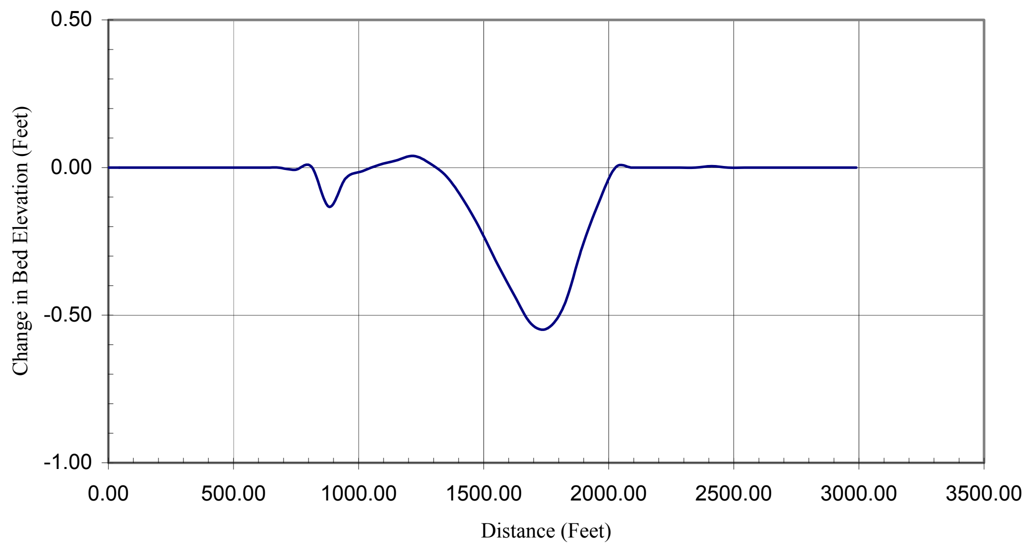


Figure 4e. Bed elevation change for the 1 year hydrograph steady state simulation - NM 44.41

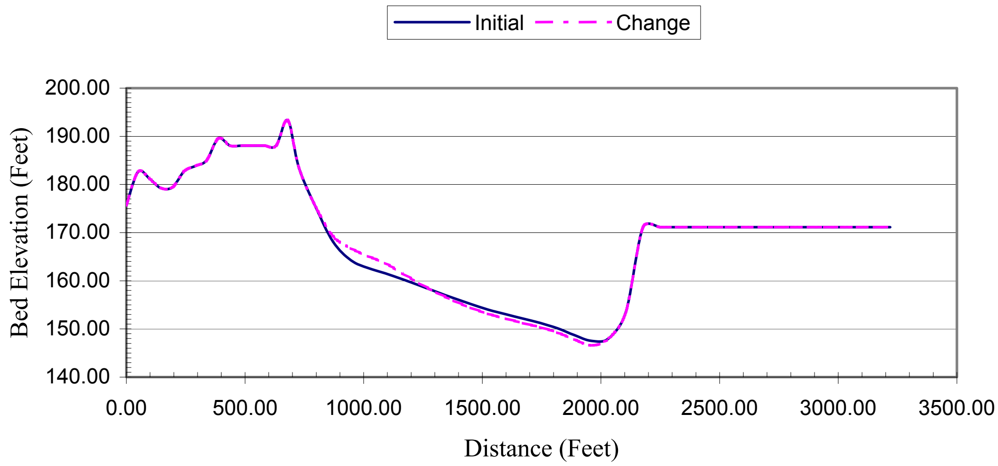


Figure 5e. Initial and final bed elevation for the 1 year hydrograph steady state simulation - NM 44.00

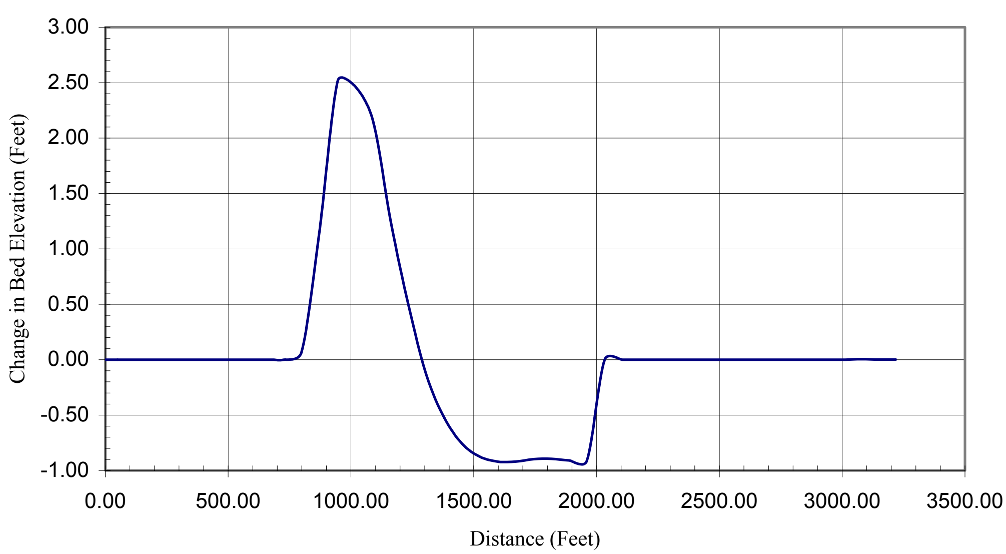


Figure 6e. Bed elevation change for the 1 year hydrograph steady state simulation - NM 44.00

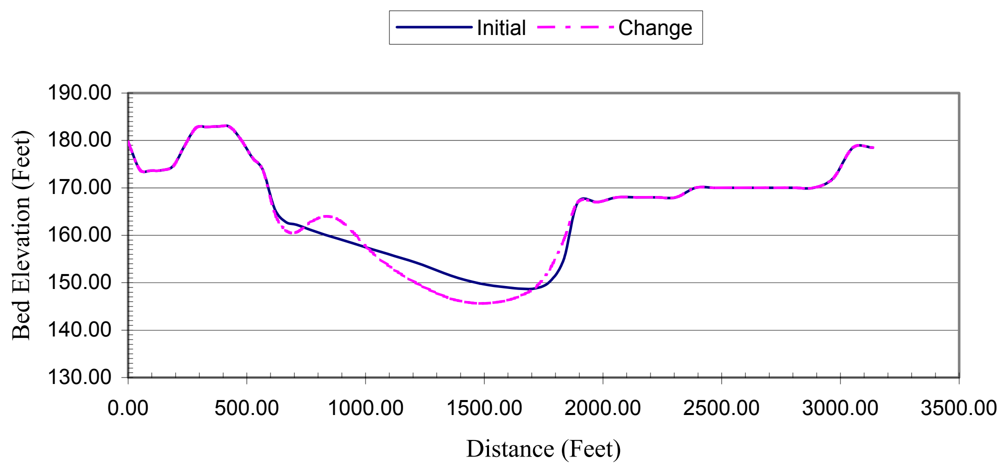


Figure 7e. Initial and final bed elevation for the 1 year hydrograph steady state simulation - NM 43.60

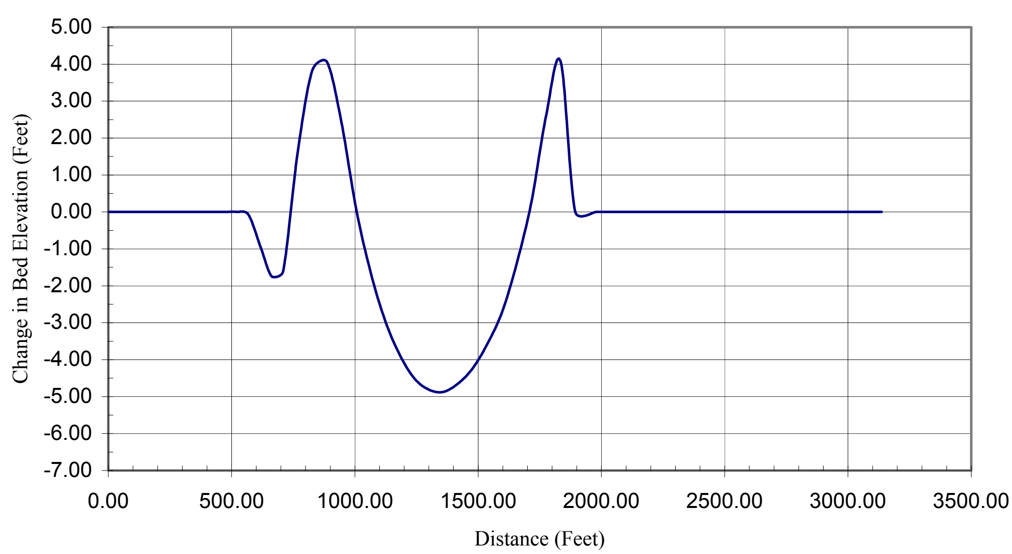


Figure 8e. Bed elevation change for the 1 year hydrograph steady state simulation - NM 43.60

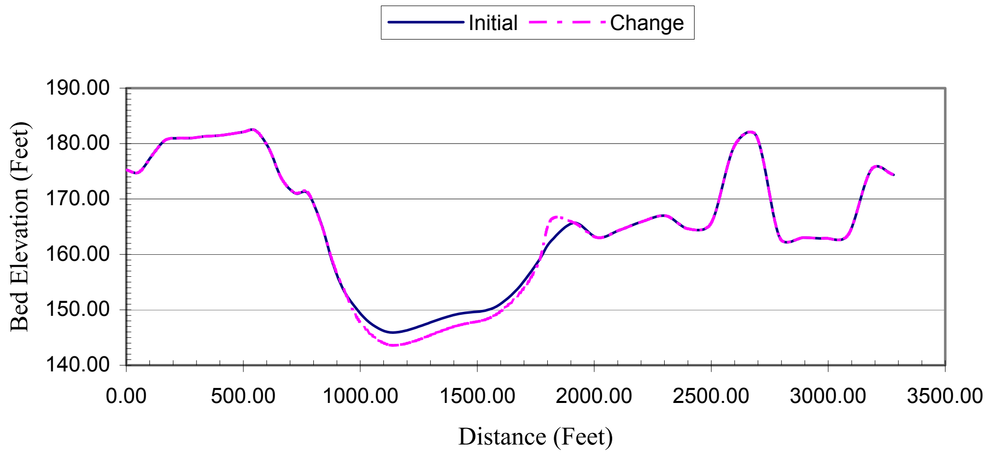


Figure 9e. Initial and final bed elevation for the 1 year hydrograph steady state simulation - NM 43.31

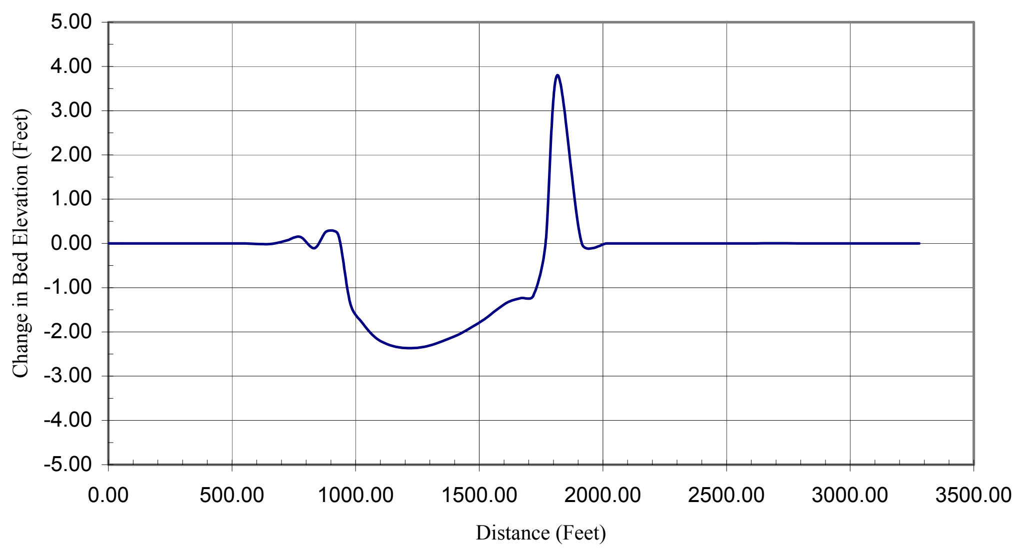


Figure 10e. Bed elevation change for the 1 year hydrograph steady state simulation - NM 43.31

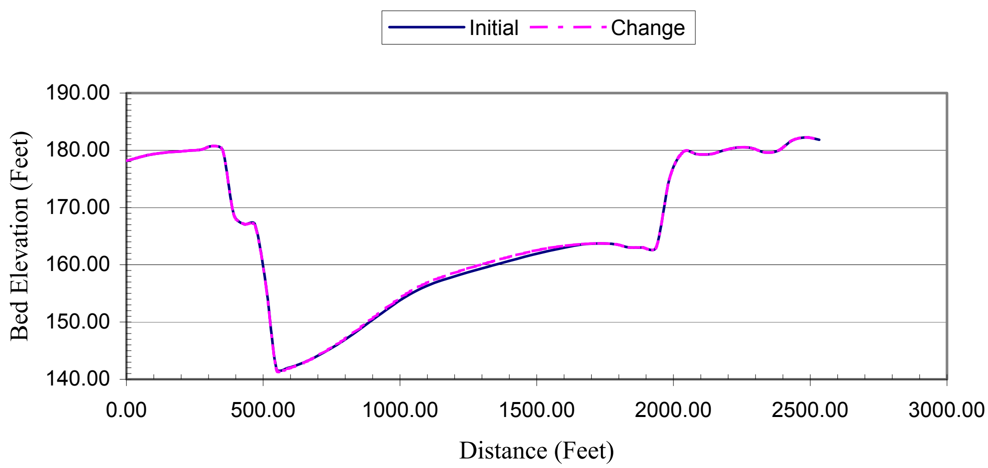


Figure 11e. Initial and final bed elevation for the 1 year hydrograph steady state simulation - NM 41.86

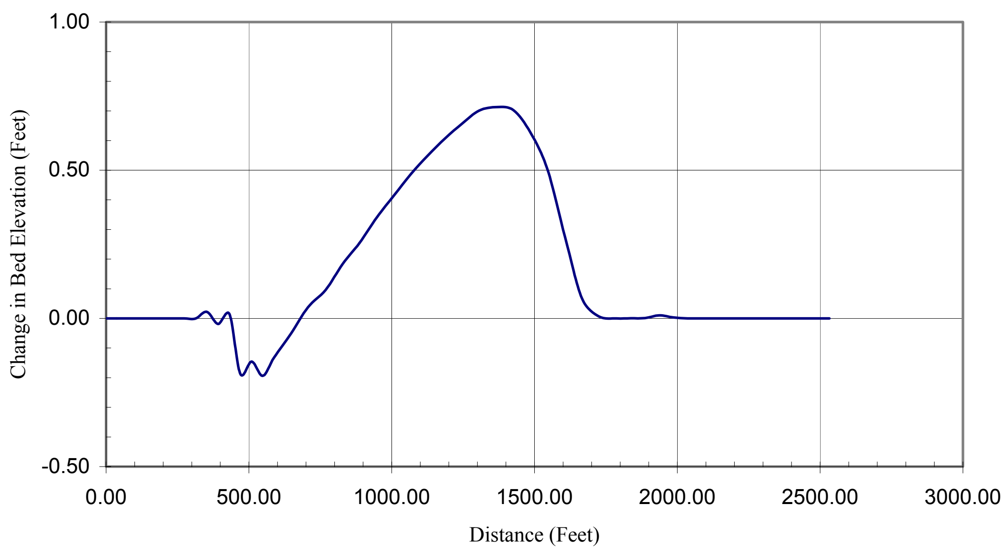


Figure 12e. Bed elevation change for the 1 year hydrograph steady state simulation - NM 41.86

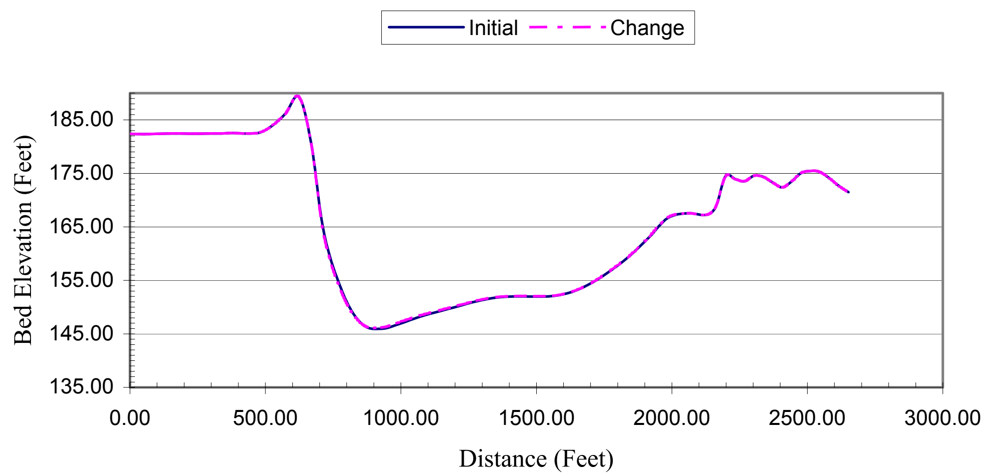


Figure 13e. Initial and final bed elevation for the 1 year hydrograph steady state simulation - NM 40.36

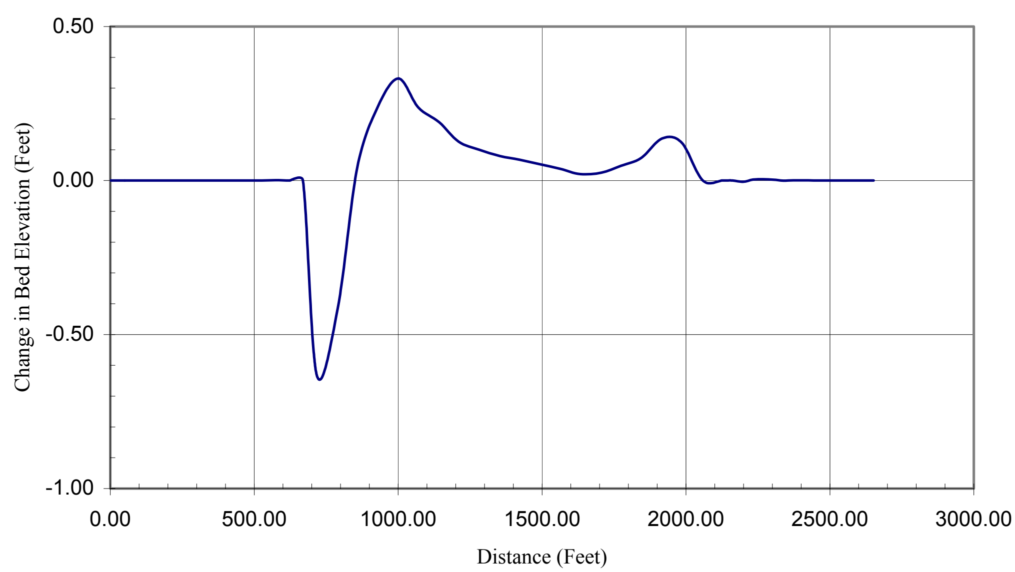


Figure 14e. Bed elevation change for the 1 year hydrograph steady state simulation - NM 40.36

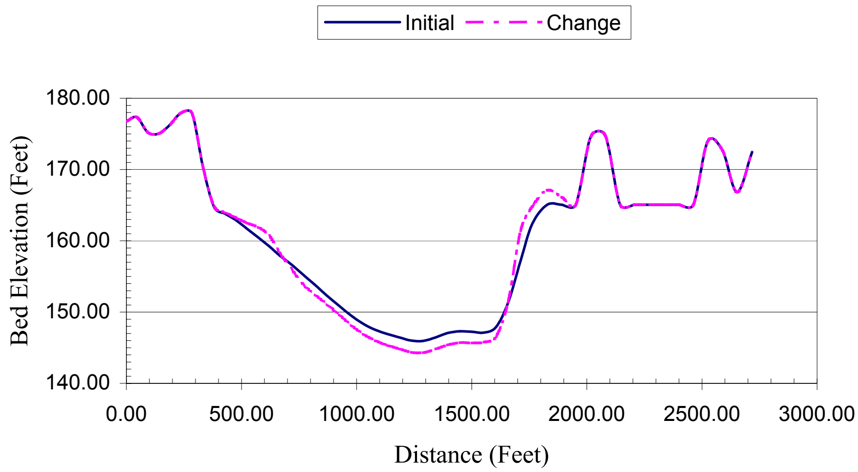


Figure 15e. Initial and final bed elevation for the 1 year hydrograph steady state simulation - NM 39.73

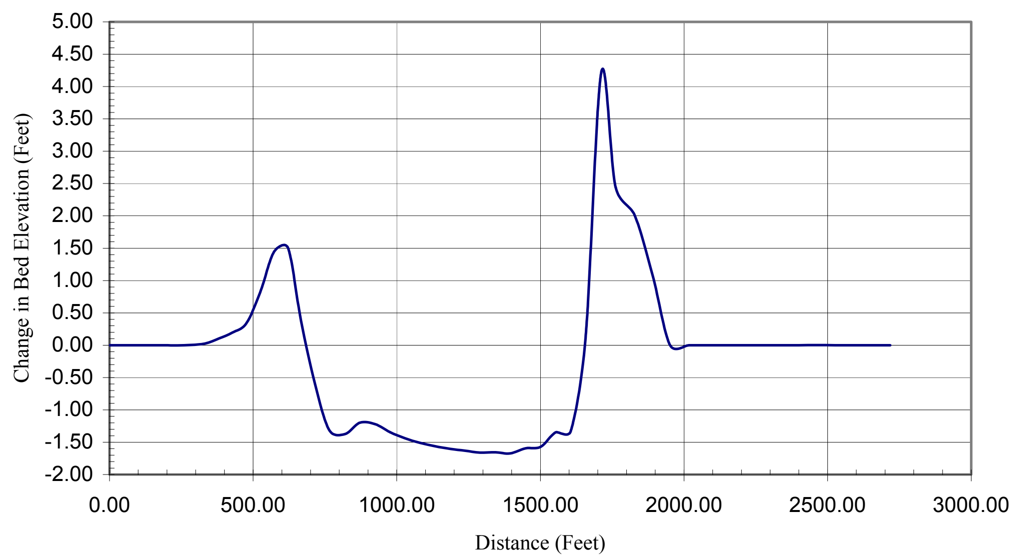


Figure 16e. Bed elevation change for the 1 year hydrograph steady state simulation - NM 39.73

APPENDIX F

Right Bank Dike Simulation Results

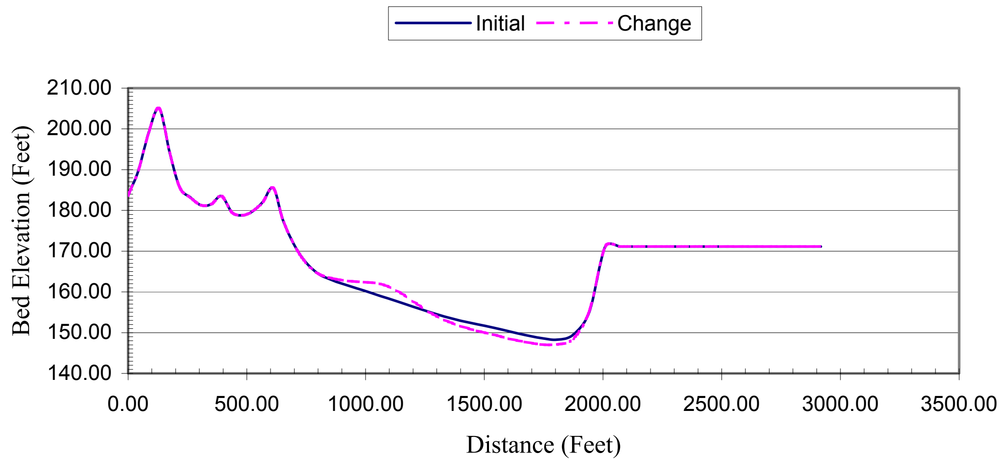


Figure 1f. Initial and final bed elevation for the right bank dike 1 year simulation - NM 44.5

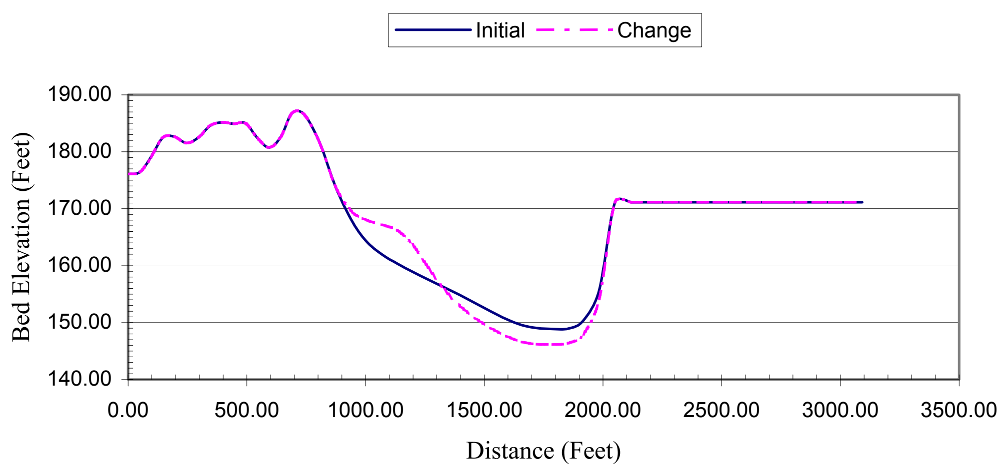


Figure 2f. Initial and final bed elevation for the right bank dike 1 year simulation - NM 44.3

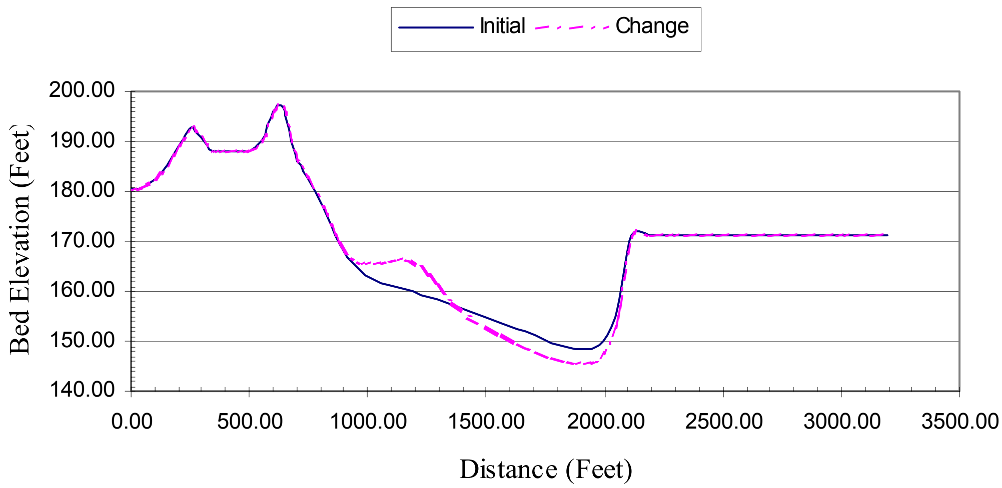


Figure 3f. Initial and final bed elevation for the right bank 1 year simulation - NM 44.10

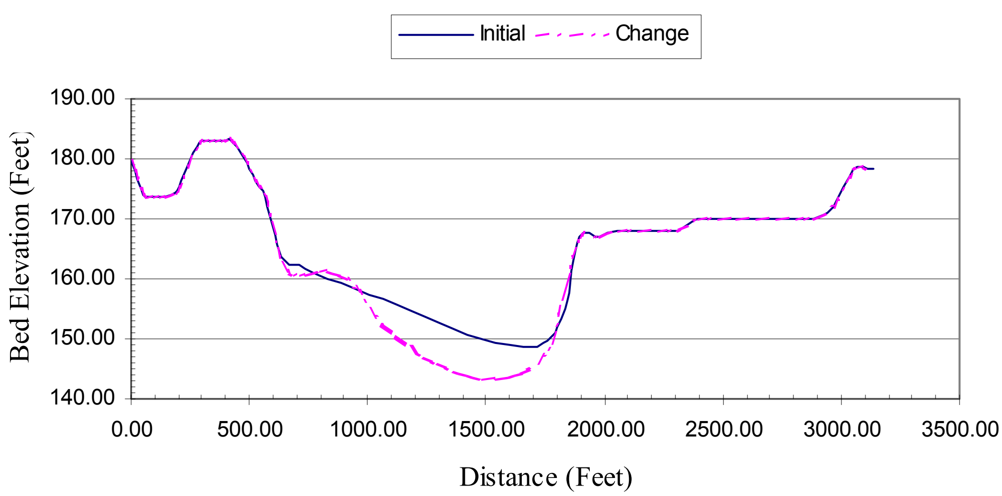


Figure 4f. Initial and final bed elevation for the right bank dike 1 year simulation - NM 43.60

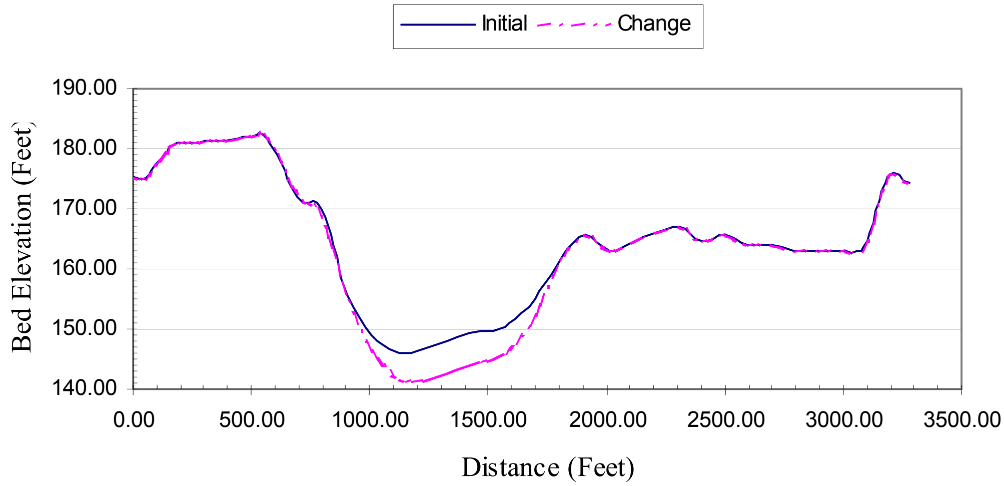


Figure 5f. Initial and final bed elevation for the right bank dike 1 year simulation - NM 43.31

APPENDIX G

Model Verification to USGS Measurements

NM 45 – NM 42

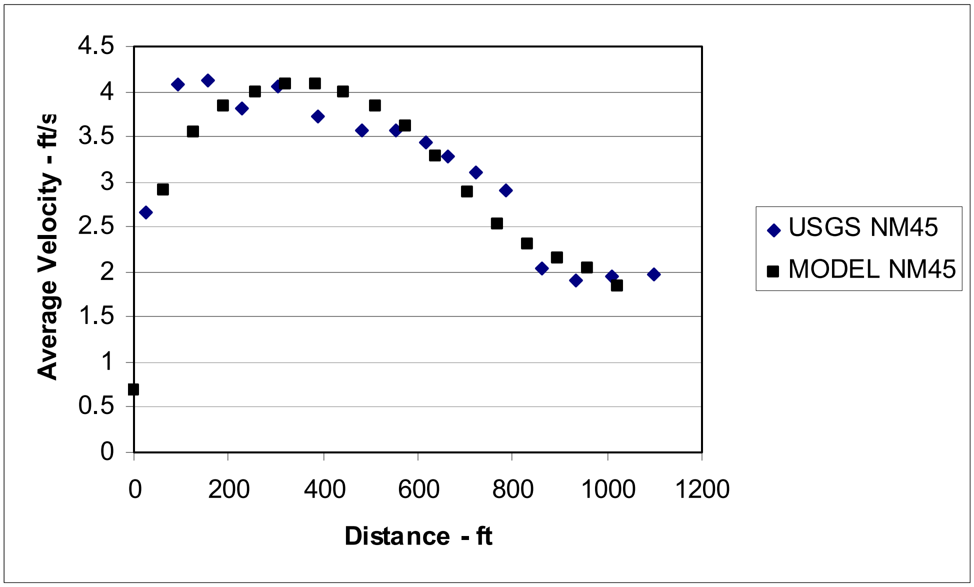


Figure 1g. Model verification to USGS velocity measurements – NM 45

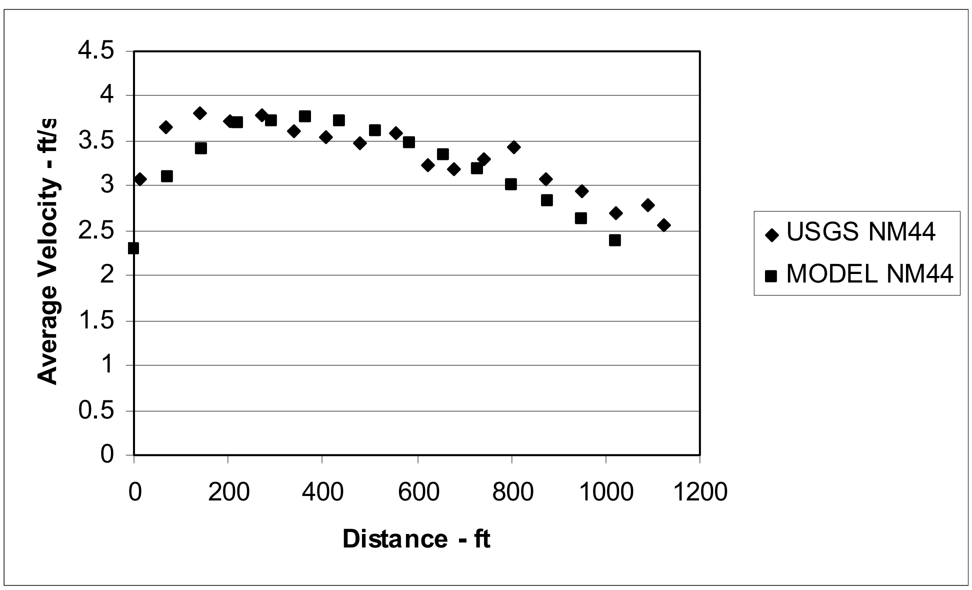


Figure 2g. Model verification to USGS velocity measurements – NM 44

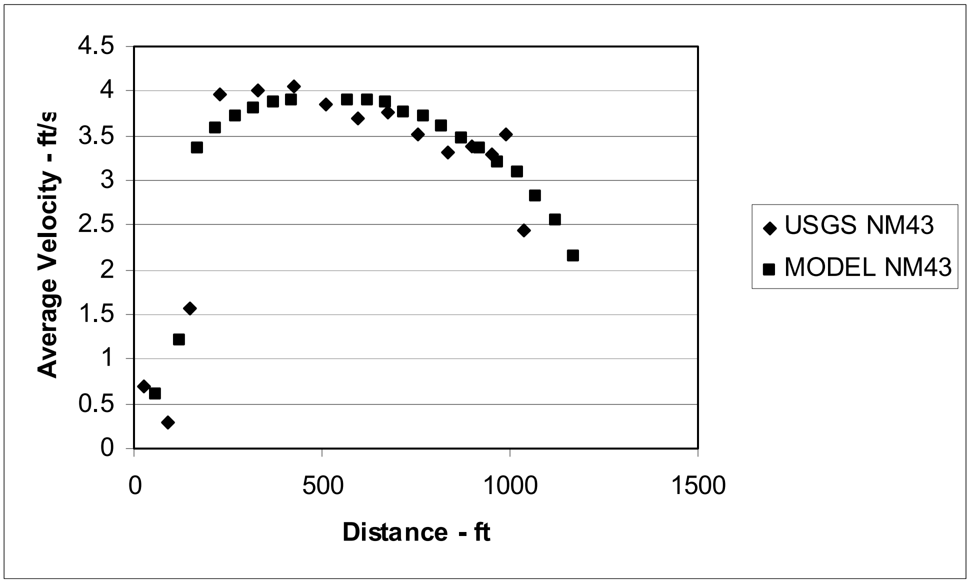


Figure 3g. Model verification to USGS velocity measurements – NM 43

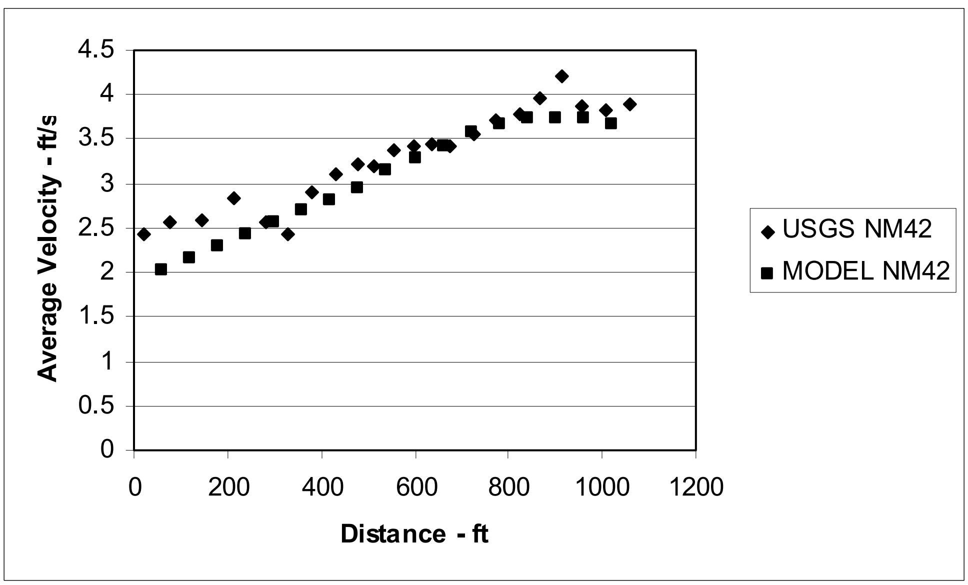


Figure 4g. Model verification to USGS velocity measurements – NM 42

APPENDIX A-3

Prototype Testing at Lock 2
By ERDC

CEERD-HN-N

MEMORANDUM FOR Commander, U.S. Army Engineer District, Little Rock, CESWL-PR-P (Mr. Ron Carmen), P.O. Box 867, Little Rock, AR 72203-0867

SUBJECT: Data Report: Results from Lock Sill Clearance, Lock Filling and Emptying and Lower Approach Field Tests, Lock 2 McClellan-Kerr Waterway Field Study, September 7-23, 2004 and Evaluation of Navigation Issues in the Upper Lock Approaches to the Locks on the Waterway

1. Enclosed is the revised subject data report that includes comments furnished by SWL after review of the original data report sent on 4 November 2004.

2. Publication of a final technical report has not been decided and will depend upon available funding.

THOMAS W. RICHARDSON
Director

Data Report
Revision 1

Results from Lock Sill Clearance, Lock Filling and Emptying, and Lower Approach Field Tests, Lock 2

McClellan-Kerr Waterway Field Study, September 7-23, 2004, and

Evaluation of Navigation Issues in the Upper Lock Approaches to the Locks on the Waterway

By

Dr. Steve Maynord

Dr. John Hite

Mr. Howard Park

U. S. Army Engineer Research and Development Center

Vicksburg, MS

Background

1. During the period 7-23 September 2004, field studies were performed at Lock 2 on the McClellan-Kerr Waterway to address concerns over lock sill clearance and lock filling and emptying due to increasing the draft of the barges using the waterway. The forces on barges moored on the lower approach wall were also measured during the field tests to determine the magnitude and timing of these forces during lock emptying. A screening analysis was also performed for the locks on the McClellan-Kerr system to identify possible outdraft problems due to increased draft in the upper approaches to the locks on the waterway. This data report summarizes the results determined from these studies.

Sill Clearance Tests

General

2. One of the concerns of a barge draft increase to 11.5 ft is clearance over the lock sills. Since most upper sills are deeper than the downstream or lower sill, this study addresses sill clearance at the lower sill. On the Arkansas River, most lower sills have a 14 ft depth over the sill when the downstream pool is at its normal pool elevation. Since any appreciable flow causes the tailwater to rise, most lower sills have depths exceeding 14 ft over most of the year. Lock 2 was selected as the field study site for two reasons. First, no significant flows enter the pool below Lock 2 so a tailwater providing close to 14 ft lower sill depth could be expected during any field study period. Second, because of the small dimensions of the pool below Lock 2, significant water level surging occurs in the pool below Lock 2. The surging has been reported to have amplitude of up to 2.5 ft from bottom of the trough to top of the crest. The surging has caused problems with tows moving into the miter gate and damage has occurred on several occasions. Even with a 2.5 ft surge, there has not been concern with sill clearance with 9 ft draft tows because of the 5 ft static clearance and 3.75 ft (5 ft-1/2*2.5 ft) dynamic clearance. The increase in draft to 11.5 ft along with the surging increases the potential for sill strike at Lock 2. Consequently, the sill clearance tests have the following two objectives:

a. Evaluate sill clearance for the Arkansas River system, 14 ft sill depth without surging.
b. Evaluate sill clearance for Lock 2, 14-14.8 ft sill depth with surging.

3. For both study objectives, both 15 barge tows requiring a double lockage and 8-barge "knockout" tows needing only a single lockage were used in testing. Tows were run upbound (entering) or downbound (exiting). While the lock was filled and emptied to induce surging for the objective 2 tests, all sill clearance tests were run with the chamber lowered and the lower miter gates opened. During the field study, the Lock was closed to traffic for 12 hours from 0700 to 1900 for testing and opened to traffic from 1900 to 0700 the next day.

4. In both study objectives, the following is used to identify the individual tests. A typical test name is "ST_15_U_NS_2" where all tests had "ST" for sill test, 15 or 8 was used for the number of barges, U or D was used for upbound or downbound, NS or WS was used for no surging

(objective 1) and with surging (objective 2), and 1-10 was the replicate number for that test condition. Some tests had as few as 2 replicates.

Instrumentation

5. The instrumentation was similar in the F&E tests and the sill clearance tests. The three capacitance staff gages in the lock chamber along with DH21 gages (Figure 1) were used to monitor water level in the sill tests. The DH21 gages were pressure cells (sample rate = 0.2 samples/sec) that ran continuously during the day whereas the capacitance gages (sample rate = 2 samples/sec) were turned off and on for each test. All water level plots used in the sill clearance evaluation are shown as elevation relative to the lower sill at Lock 2.

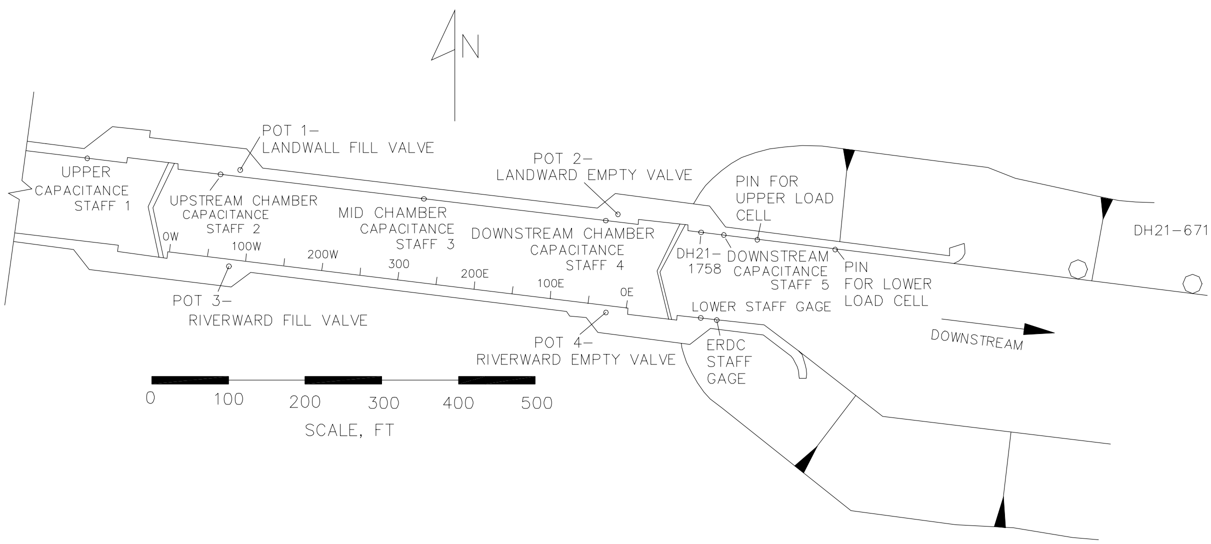


Figure 1. Layout of instrumentation used in field study

6. On board the tow, 6 dual-frequency Global Positioning System (GPS) units were used to measure vertical and horizontal motions of the tow. Two base stations (1 as a backup) were used to operate the GPS in the differential mode that allowed the accuracy needed for the sill clearance tests. The GPS collected data every 3 sec. In addition to the GPS, two total station tracking units were placed on the lock wall. Each total station "tracked" a prism that was mounted on the barges. The tracker sampled at an irregular interval that averaged about 0.9 samples per second. Figures 2-5 shows the layout of barges and Table 1 shows the locations of the GPS and tracker prisms on the barges. For example, for tests on 9/16 (all were 15 barges), GPS serial number 8141 was located on the downstream end of barge 4 as shown on Figure 2 for the downbound tests and Figure 3 for the upbound tests. The GPS units are identified by serial numbers and some of the units were in different positions on different days. For downbound exiting tows, the GPS units and tracker prisms were concentrated on the upstream end (stern) of the barges where the barge lowering was anticipated to be the greatest. For the upbound entering

tows, the units were concentrated on the upstream end (bow) of the barges where the barge lowering was anticipated to be the greatest. The concentration of units on bow and stern was not accomplished by moving the units but by moving the towboat to the other end of the barges. This could be done because both ends of the barges were raked. It becomes confusing when referring to the bow and stern of the barges because it changes for upbound and downbound tows because of the swapping of the towboat. For that reason, this report attempts to avoid bow/stern and refer to instrument positions by upstream/downstream end that did not change when swapping the towboat. The only exception to this is the towboat that had a definite bow/stern.

Towboat	Barge 5	Barge 4	Barge 3	Barge 2	Barge 1

Figure 2. Barge numbering for downbound 15 barge tow, downstream to the right.

Barge 5	Barge 4	Barge 3	Barge 2	Barge 1	Towboat

Figure 3. Barge numbering for upbound 15 barge tow, downstream to the right.

	Knockout		
Towboat	Barge 3	Barge 2	Barge 1

Figure 4. Barge numbering for downbound 8 barge tow, downstream to the right.

		Knockout	
Barge 3	Barge 2	Barge 1	Towboat

Figure 5. Barge numbering for upbound 8 barge tow, downstream to the right.

Table 1. GPS and tracker prism locations.

Date	# barges	Barge# or towboat(TB),D(downstream) end or U(upstream) end of barge, with prism (P)					
		SN#2631	SN#8120	SN#8138	SN#8141	SN#8142	SN#8145
9/16	15	TB,Stern	5,U,P	5,U	5,D,P	4,D	1,D
9/17	8	TB,Stern	3,U	3,U,P	3,D,P	1,D	2,D
9/18-9/20	15	TB,Stern	5,U,P	5,U	5,D,P	1,D	4,D
9/21-9/22	8	TB,Stern	3,U,P	3,U	3,D,P	2,D	1,D

7. The GPS and tracker elevations were compared for several different tests. In some cases the agreement was excellent (Figure 6) and less than excellent in other cases (Figure 7). In both cases, the GPS was adequate to assess sill clearance and GPS was used because of the availability of the 6 GPS units along the tow.

Water Level During Field Study

8. Figures 8-14 show water levels during the daytime test period at the DH21 Serial Number 671

water level gage near the lower cells. DH21-671 was not significantly affected by tow induced water level changes whereas DH21-1758 was affected because of its location just below the downstream miter gate. The datum for the DH21 gages was established by making a large number of observations of the time and the staff gage reading at the Lock 2 gage just below the downstream miter gate. The plots show low surging during the objective 1 tests on 9/16 and 9/17. Higher surging is present during the objective 2 tests on 9/18-9/22. The plots also show that the water level during the objective 1 tests was about 14.5 ft depth over the sill rather than the desired 14.0 ft. Even with the lower level of surging in the objective 1 tests, it was difficult to set a precise water level in the pool below Lock 2.

Results of Objective 1, System tests, Without Surging

9. Downbound, 15 barge tow, without surging The downbound 15 barge tests were started with the tow located where the front nine barges ("first cut") and the back six barges and the towboat ("second cut") were reconnected. The stern of the barges (also bow of the towboat) was located at about station 285 (15 ft upstream of center of lock at station 300). The initial test on 9/15 with the downbound 15 barge tow began scraping bottom in the lower approach channel. The lower approach was surveyed and dredged and testing was resumed on 9/16. The 9/15 test "ST_15_D_NS_1" was discarded because of the unknown effects of the grounding on sill clearance. Five replicates were run on 9/16 as shown in Table 2. In Table 2, the maximum elevation change of the barges was measured from average ambient conditions just before tow started moving out of lock and was corrected for any long period surging based on the DH21-671 located at the downstream cells. For example, in test ST_15_D_NS_2, the GPS gage 8120 at the stern of the barges dropped a maximum of 0.8 ft from ambient conditions just before the tow started moving. During the passage of the tow, the water level at DH21-671 dropped about 0.25 ft between the time just before tow movement and the time at which the 0.8 ft drop occurred on the tow. For test ST_15_D_NS_6, one emptying valve was closed to evaluate the effect of reduced area through the ports on sill clearance.

Table 2. Tests for 15 Barge Downbound Tow Without Surging

Test	Date, Time of SOS*	Engine RPM	Maximum squat of barges over sill, ft	Remarks
ST_15_D_NS_2	9/16, 1245	600	0.55	
ST_15_D_NS_3	9/16, 1354	660	0.60	
ST_15_D_NS_4	9/16, 1455	525	0.4	
ST_15_D_NS_5	9/16, 1550	660	0.5	
ST_15_D_NS_6	9/16, 1632	600	0.5	One valve open

*SOS= Stern of barges over lower sill

Figure 15 shows the GPS plot for test ST_15_D_NS_3. In the legend of Figure 15, OS@1356 refers to the time that gage passed over the lower sill. The DH21 gages are shown in Figure 16.

10. Upbound, 15 barge tow, without surging The upbound 15 barge tests were started with the tow in the downstream approach channel roughly 380 feet below the downstream miter gate. Two replicates were run on 9/16 as shown in Table 3. Figure 17 shows the GPS plot and Figure 18 shows the DH21 gages. While Figure 17 shows gages that squat about 0.4 ft, this point on the

tow was far from the lower sill. When the gages were over the sill, the maximum squat was less than 0.2 ft and occurred at GPS #8142 in both replicates. GPS 8142 was located at the downstream end of the 2nd barge entering the lock.

Table 3. Tests for 15 Barge Upbound Tow Without Surging

Test	Date, Time of BOS*	Engine RPM	Maximum squat of barges over sill, ft	Remarks
ST_15_U_NS_1	9/16, 1708	**	<0.2	
ST_15_U_NS_2	9/16, 1803	**	<0.2	

*BOS= Bow of barges over lower sill,**upbound, entering tows had widely varying engine rpm that cannot be described by a single value.

11. Downbound, 8 barge tow, without surging The 8 barge tow is referred to as a "knockout" because the towboat moves into the missing barge location during passage through locks in order to allow a single lockage. Exiting the lock requires the towboat to move back behind the barges and reconnect. This operation is referred to as a "flying face-up" or "flying knockout" because the reconnection is done while the tow is moving out of the lock. After the miter gate is opened and while in the knockout position, the towboat powers up and the tow starts exiting the lock. After the tow moves far enough downstream, the towboat disconnects from the knockout position and moves behind the barges while the barges coast out of the lock. The flying face-up results in a large amount of variation in position along the lock where the tow finishes reconnecting and starts powering out of the lock. The first 8 barge knockout test ST_08_D_NS_1 was done using the entire flying face-up procedure. The lockmaster stated that the reconnection in this test was farther out of the lock than was typical. The worst case would be when the tow was reconnected quickly. Because worst case was desired and because the flying face-up was not expected to be the important part of the exit (due to slow speeds), the tests were run with the towboat already reconnected. The upstream end of the barges was positioned at station 150W and the tow was stationary at the beginning of the test. Four replicates were run with the 8 barge downbound tow as shown in Table 4. Figure 19 shows the GPS plot and Figure 20 shows the DH21 gages for test ST_8_D_NS_4.

Table 4. Tests for 8 Barge Downbound Tow Without Surging

Test	Date, Time of SOS*	Engine RPM	Maximum squat of barges over sill, ft	Remarks
ST_8_D_NS_1	9/17, 0958	550	0.45	
ST_8_D_NS_2	9/17, 1126	600	0.45	
ST_8_D_NS_3	9/17, 1306	525	0.5	
ST_8_D_NS_4	9/17, 1424	660	0.65	

*SOS= Stern of barges over lower sill

12. Upbound 8 barge tow without surging The upbound 8 barge tests were started with the tow in the downstream approach channel roughly 380 feet below the downstream miter gate. Two replicates were run on 9/17 as shown in Table 5. Figure 21 shows the GPS plot and Figure 22 shows the DH21 gages for Test ST_8_U_NS_2.

Table 5. Tests for 8 Barge Upbound Tow Without Surging

Test	Date, Time of BOS*	Engine RPM	Maximum squat of barges over sill, ft	Remarks
ST_8_U_NS_1	9/17, 1541	**	<0.2	
ST_8_U_NS_2	9/17, 1625	**	0.25	

*BOS= Bow of barges over lower sill,**upbound entering tows had widely varying engine rpm that cannot be described by a single value.

Results of Objective 2, Lock 2 tests, With Surging

13. General The tests with surging were designed to address the sill clearance with surging. Discussions with the Lockmaster led to realization that an equally valid concern is the movement of the tow by the surge in an uncontrollable manner at the wrong time. Such movement has resulted in damage to the structure in the past. With deeper draft and thus more massive tows, the tows will be harder to get moving, harder to stop moving, and possibly do more damage on impact.

14. Surge impacts on both sill clearance and tow movement are all about timing as will be seen in the subsequent data. A large surge can be harmless if the tow is not over the sill or not attempting to moor inside the chamber. A lesser surge at the wrong time could lead to limited sill clearance or adverse movement of the tow into the structure.

15. The with-surge tests were conducted on 9/18-9/22. The study was designed to measure surge effects with the downstream weir in place to get an elevation relative to the lower sill of 14.8 ft. On 9/18, 9/19, and 9/20, the average elevation at the DH21-671 near the lower cells was 15.0, 14.7, and 15.1 ft relative to the lower sill during the 0700-1900 test period. The Lockmaster stated the system was not surging as much as it typically does and that the pool below Lock 2 is often lower than 14.8 ft and that the surging is greater with a lower pool. The observation by the Lockmaster of greater surging at the lower pool is supported by the fact that at the higher pool, more of the surge goes over the weir whereas at the lower pool, more of the surge is reflected. The decision was made by the District to complete the surging tests with a lowered pool. This decision meant that the 15 barge tests were run with a higher pool and the subsequent 8-barge tests on 9/21 and 9/22 were run with a lower pool. This decision was completely supported by this author. On 9/21 and 9/22, the average elevation of the DH21-671 at the lower cells was 14.3 and 14.1 ft relative to the lower sill. The period of the surge at Lock 2 is 27 minutes.

16. Downbound, 15 barge tow, with surging The with-surge tests were conducted with lockages to induce surging in the system. Ten replicates were run during 9/18-9/20 as shown in Table 6.

Table 6. Downbound 15 barge tests with surging

Test	Date	Miter gate opened*	Exit Begins	Stern over sill	Lock 2 empties	Lock 1 fills	Engine RPM
ST_15_D_WS_1	9/18	1048	1115	1123	0840,1030	-	600
ST_15_D_WS_2	9/18	1305	1325	1332	1250	1245	650/600
ST_15_D_WS_3	9/18	1512	1531	1536	1456	1455	650/600
ST_15_D_WS_4	9/18	1714	1738	1746	1700	1626,1646	550/600
ST_15_D_WS_5	9/19	1046	1102	1109	0834,1029	1029	650/600
ST_15_D_WS_6	9/19	1311	1339	1346	1300	-	650/600
ST_15_D_WS_7	9/19	1511	1543	1550	1454	1454	650
ST_15_D_WS_8	9/20	0947	1022	1029	0930,1045	0930	580/600
ST_15_D_WS_9	9/20	1246	1311	1319	1226	1226,1258	600
ST_15_D_WS_10	9/20	?	1541	1548	1353,1500	1423,1540	600

*After lowering of 2nd cut

17. Figures 23 and 24 show the water level at the two DH21 gages, the tow events, and the lockage times on 9/19 and 9/20. Both plots show that the two water level gages provide the same surges except during lockages or tow events. Figures 25 and 26 show the GPS and DH21 water level data for Test ST_ 15_D_WS_9.

18. <u>Upbound 15 Barge Tow With Surging</u> The upbound 15 barge tests are shown in Table 7. From the water level plots in Figures 8-14, the surging was relatively minor for the upbound 15 barge tests. The GPS and water level plots are shown in Figures 27 and 28 for test ST_15_U_WS_3.

Table 7. Upbound 15 barge tests with surging

Test	Date, Time at Bow over sill	Lock 2 Empties	Lock 1 Fills	Remarks
ST_15_U_WS_1	9/18, 1823	1700	-	
ST_15_U_WS_2	9/19, 1638	1454	1454	
ST_15_U_WS_3	9/20, 1634	1500	1540	

19. <u>Downbound 8 Barge Tow With Surging</u> The downbound 8 barge tests are shown in Table 8a. From the water level plots in Figures 8-14, this set of tests had the most significant surging of all surge tests. This was likely the result of the lower water levels on 9/21 and 9/22 and numerous lockages at both locks. Figure 29 shows the DH21 water levels, tow events, and lockages on 9/21. Note that every lockage was done when the surge was high at Lock 2 to obtain the maximum surge. Note that test ST_8_D_WS_2 occurred with the low of a relatively modest surge, test ST_8_D_WS_3 occurred about 10 minutes before the largest surge obtained in the field tests, and test ST_8_D_WS_4 occurred just past the high of a modest surge. The field study attempted to make the tow passage over the sill and the low from the surge coincident but it did not happen. Figure 30 shows the GPS data from test ST_8_D_WS_3 and Figure 31 shows the DH21 data. Note that the water level fell below the lower end of the DH21-671 gage.

Table 8a. Downbound 8 barge tests with surging.

Test	Date	Miter gate opened	Exit Begins	Stern over sill	Lock 2 empties	Lock 1 fills	Engine RPM
ST_8_D_WS_1	9/21		1046	1055	0959		600
ST_8_D_WS_2	9/21	1304	1325	1329	1248	1155,1248	650
ST_8_D_WS_3	9/21	1452	1512	1518	1440	1440,1509	525
ST_8_D_WS_4	9/21	1645	1702	1708	1634		600
ST_8_D_WS_5	9/22	0937	1000	1011	0846,0923	0910	600

20. Upbound 8 Barge tests With Surging The Lockmaster reported that numerous lockages were required through the night but the lower pool was not significantly surging. The field team had difficulty identifying highs and lows to determine when to cycle the locks. Two relicates were run for the 8 barge tests as shown in Table 8b. The water levels, tow events, and lockages on 9/22 are shown in Figure 32. Note in Figure 32 that the lockages were not timed as well as on 9/21. The Lockages at 0910 and 1227 at Lock 1 were on a low or intermediate water level at Lock 2 that may have damped the surge. Squat was not significant for these tests similar to other upbound tests and GPS data are not presented.

Table 8b. Upbound 8 Barge Tests With Surging

Test	Date, Time at Bow over sill	Lock 2 Empties	Lock 1 Fills	Remarks
ST_8_U_WS_1	9/22, 1135	0846, 0923, 1115	0910	
ST_8_U_WS_2	9/22, 1319	1249	1227	

Analysis of Results and Conclusions for Lock Sill Clearance Tests

System Tests, Without Surge, 14 ft Sill Depth

21. Based on the elevation change measured in 8 and 15 barge tows traveling either upbound or downbound, maximum squat of the barges while over the lower sill was 0.65 ft. Squat was greater for downbound exiting tows compared to upbound entering tows. The Lock 2 tests were run at 14.5 ft depth over sill as opposed to the desired value of 14.0 ft. For the 11.5 ft x 105 ft tow, the blockage ratio for 14.5 ft sill depth is 0.757 compared to the desired value for 14 ft sill depth of 0.784. Based on data from Maynord (1987) for downbound exiting tows plotted in Figure 33, squat had a weak dependence on blockage ratio in the range of 0.747 to 0.83 and decreased with increasing blockage ratio. At these large blockage ratios, an increase in blockage ratio is more than offset by a decrease in speed. The 140 RPM curve from the Maynord data is most consistent with the squat magnitudes measured at Lock 2. Based on the 140 RPM curve, squat at blockage ratio of 0.784 would be 93% of squat at blockage ratio of 0.757. The Lock 2 field tests were run with typical amounts of thrust from the propellers. Should an increased thrust be used, squat will increase. Using the 157 RPM curve to represent the higher thrust and 140 RPM to represent typical conditions, squat increased 22% at a blockage ratio of 0.784. Based on the correction for blockage ratio and the increase for larger propeller thrust, squat should not exceed 0.74 ft. Based on a static clearance of 14-11.5 = 2.5 ft and maximum squat of 0.74 ft, the

underway clearance is 1.76 ft. Based on the underway clearance, this writer believes the 11.5 ft draft has a negligible chance of sill strike.

Lock 2 tests, With Surge, 14-14.8 ft Sill Depth

22. The surge effects on vertical motion of the tow at Lock 2 are significantly greater than the squat effects. On 9/21 at about 1525, a surge of amplitude of 3 ft was generated at the gage below the miter gate. Note that about 0.6 ft of the 3 ft surge is due to the motion of the tow (see Figures 16 and 20). This surge magnitude is close to the 2.5 ft reported by the Lockmaster as the maximum surge if the Lockmaster was referring to amplitude without the tow motion affects. The 3 ft surge was generated by timing the emptying of Lock 2 and the filling of Lock 1 to obtain a large surge and doing so for several cycles. Test ST_8_D_WS_3 passed over the lower sill 10 minutes before the 3 ft surge reached its lowest elevation. Had the tow and the surge arrived at the sill at the same time, the clearance over the sill could have been about 0.7 ft or less. The "or less" in the preceeding sentence comes from the fact that if the minimum level from the surge was at the sill, the depth over the sill would be 12.2 ft. The blockage ratio for the 11.5X105 ft tow would be 0.900 and the maximum squat of 0.74 ft determined for these tests could be larger. While the Maynord data in Figure 33 show a decrease in squat for increasing blockage ratio, that is only valid for a self propelled tow that reaches a terminal speed based on its blockage ratio. In the case of tow exiting the lock with a falling water level, the surge could be accelerating the tow while the blockage ratio is increasing which could lead to large values of squat. The preceeding scenario leading to sill strike is unlikely because: (1) the lower pool would have to be about 14 ft, (2) the surge would have to be about 3 ft (with tow motion), and (3) the surge and tow passage would have to coincide. If any one of these 3 conditions is not met, the tow will not come close to the sill.

23. The preceeding 3 conditions lead to solutions that can greatly reduce potential for sill strike with surging at Lock 2. First, the pool below Lock 2 should be maintained as high as possible. Not only does the higher pool provide greater static clearance, it also reduces surging because more of the surge goes over the weir at Lock 1 rather than being reflected at lower water levels. Second, operation of Locks 1 and 2 could be modified to reduce surging. This will be discussed subsequently.

24. While sill clearance at Lock 2 with surging appears adequate except for extreme conditions, the concern of the Lockmaster about surge affects on unplanned tow movement remains a concern. Such movement could lead to greater damage than in the past because of the larger mass of the tow. Addressing this problem can be done by either timing the tow entry/exit to avoid problem times (some of which is done now) or modifying Lock 1 and 2 operation to reduce surging. It is important to note that operational changes will not eliminate the surge. Two operational changes could lead to lesser surging.

1) Extend emptying time at Lock 2 and filling time at Lock 1 to spread out the effects of the discharge or release over more of the surge period of 27 minutes. This could be done by using slower valve speeds and possibly limiting maximum valve openings.
2) Similar to the field tests, time the lockages to affect the surge. The field tests simultaneously emptied Lock 2 and filled Lock 1 when the surge was high at Lock 2 and low at Lock 1 to obtain large surges. Had Lock 2 and Lock 1 been emptied and filled

when the surge was low at Lock 2 and high at Lock 1, the surge would likely have been reduced. This requires further study but this writer believes a simple operational plan can be developed.

One other change at Lock 2 that should help entry and exit is to clear the blocked ports behind the downstream long wall.

Sill Clearance, General Conclusion

It is unlikely that barges drafting 11.5-ft on the MKARNS will strike any downstream lock sill provided some operational procedures are followed. Conclusion is that no modifications to the downstream sill will be required and only the minor change of reducing tow entering and exiting speeds will be required for 11.5-ft drafts.

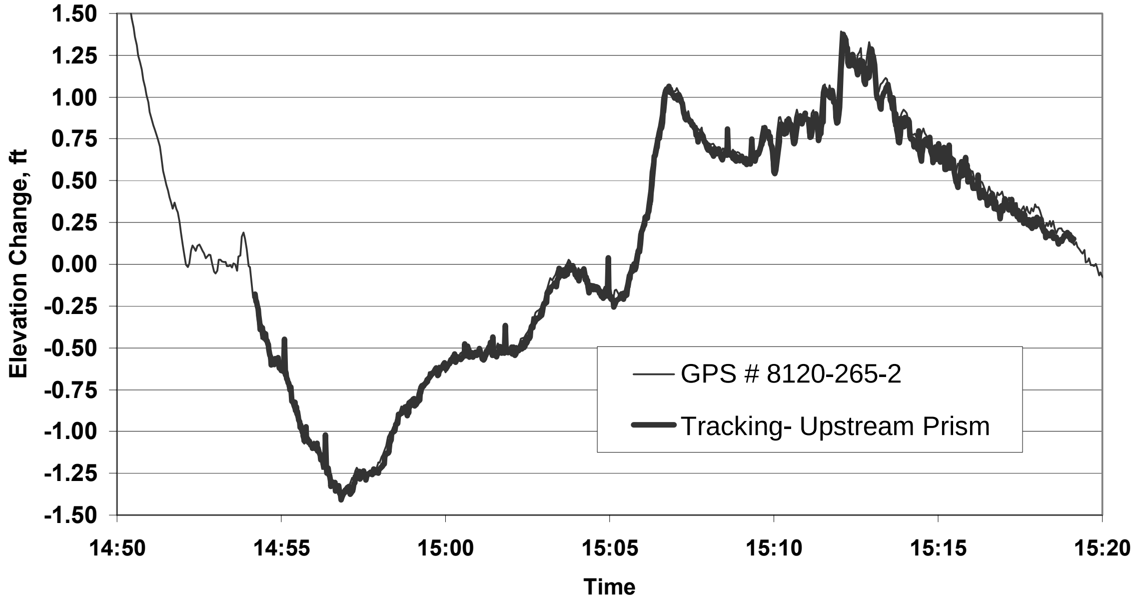


Figure 6. GPS Versus Tracker, Test ST_08_D_WS_3, 9/21

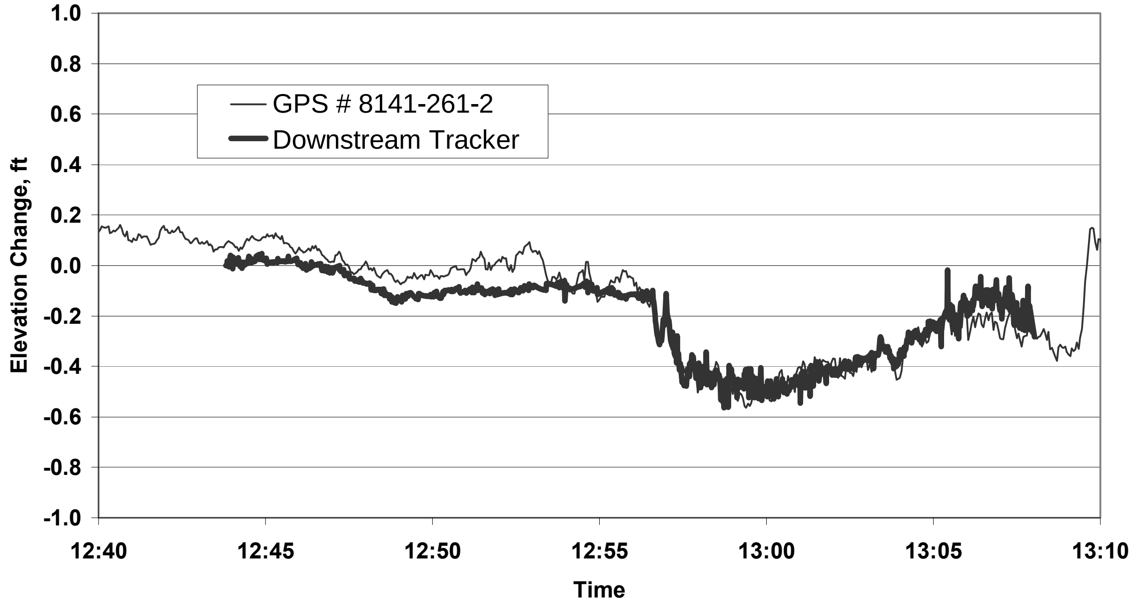


Figure 7. GPS Versus Tracker, Test ST_08_D_NS_3, 9/17

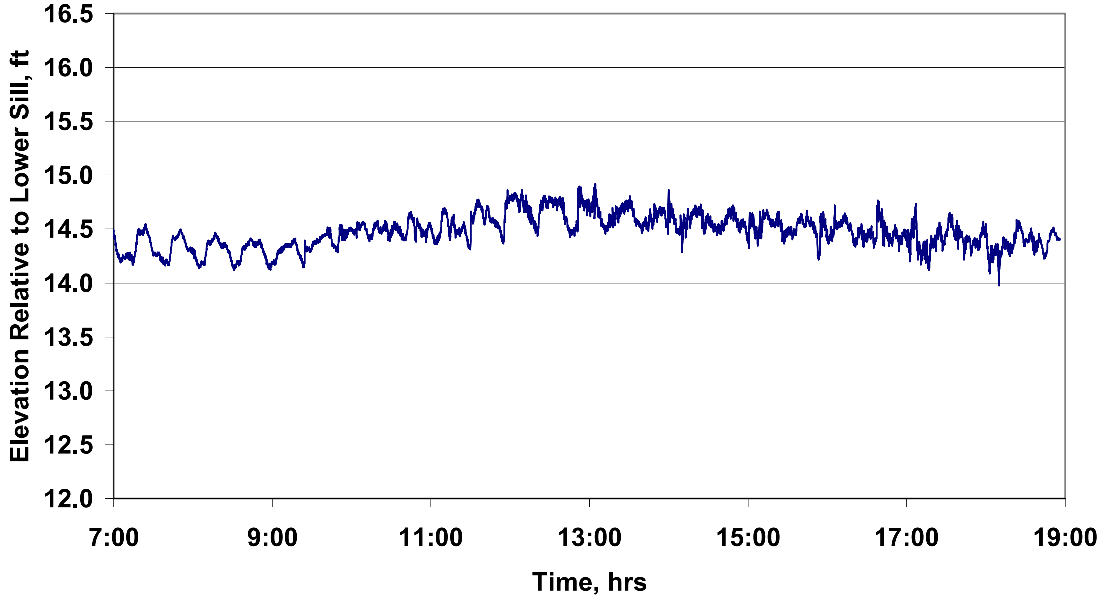


Figure 8. DH21 Serial Number 671 Near Lower Cells on 9/16

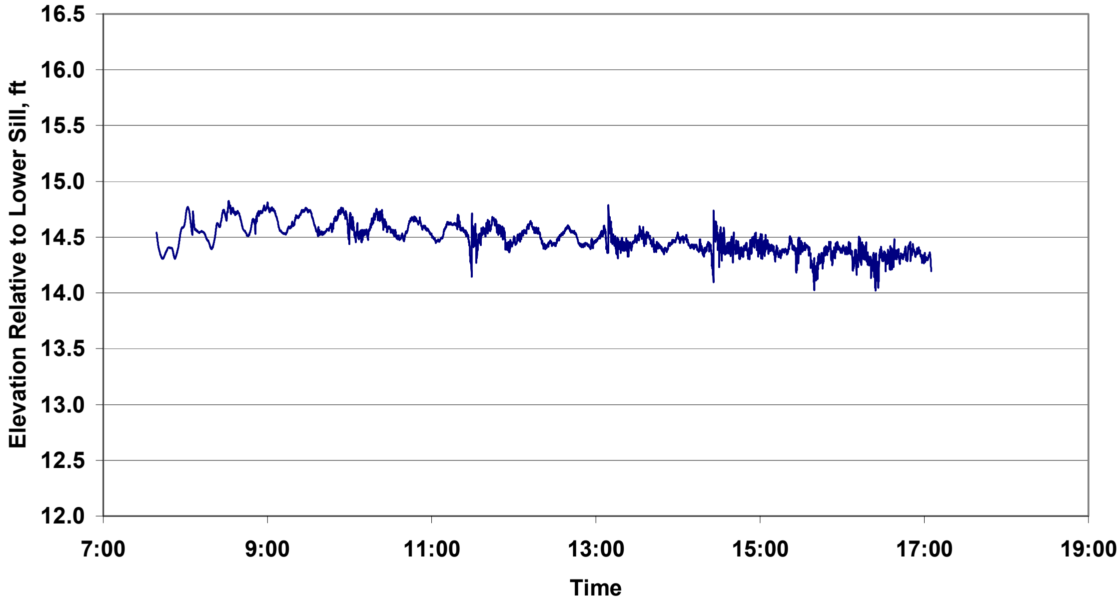


Figure 9. DH21 Serial Number 671 Near Lower Cells on 9/17

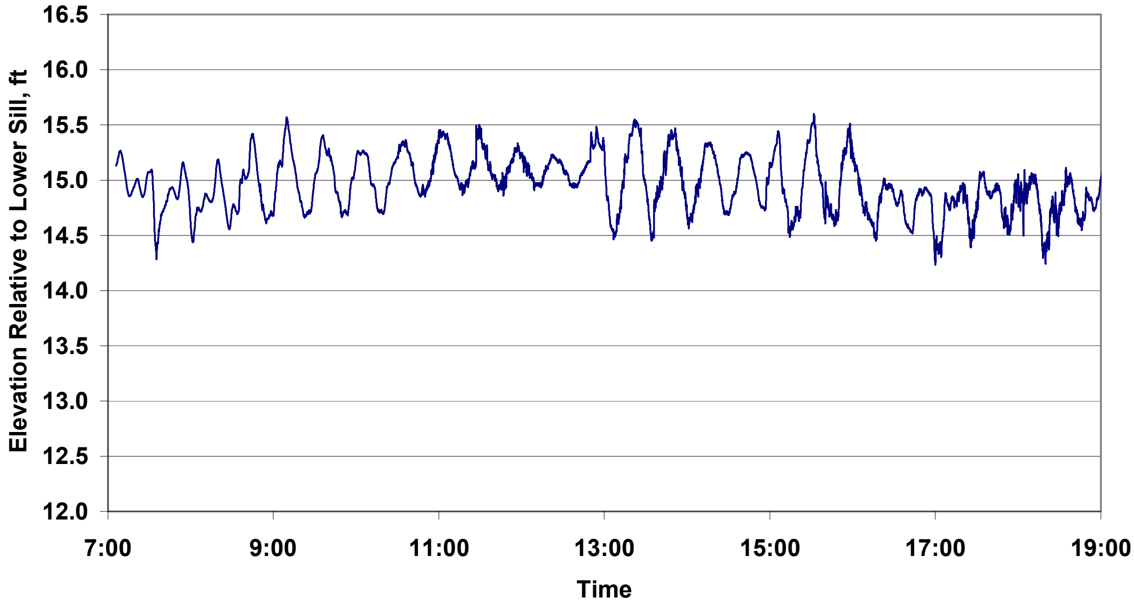


Figure 10. DH21 Serial Number 671 Near Lower Cells on 9/18

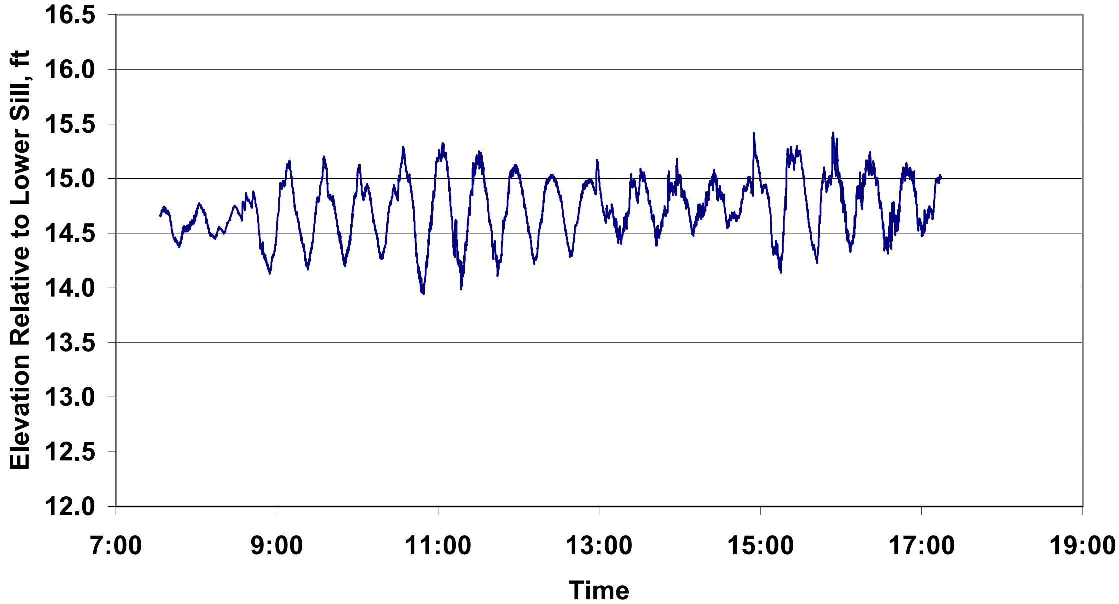


Figure 11. DH21 Serial Number 671 Near Lower Cells on 9/19

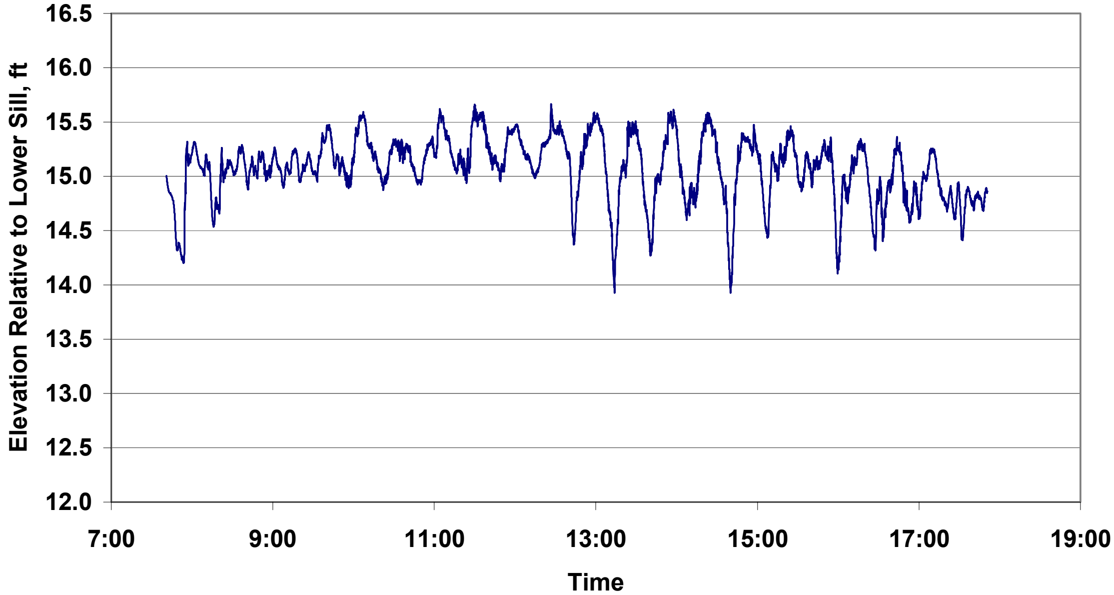


Figure 12. DH21 Serial Number 671 Near Lower Cells on 9/20

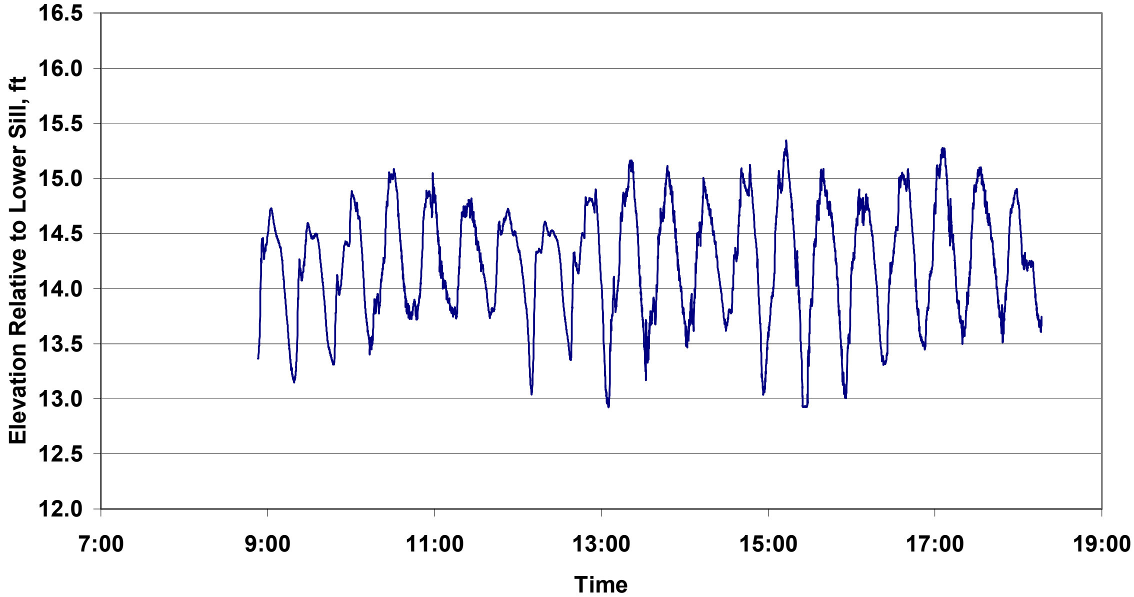


Figure 13. DH21 Serial Number 671 Near Lower Cells on 9/21

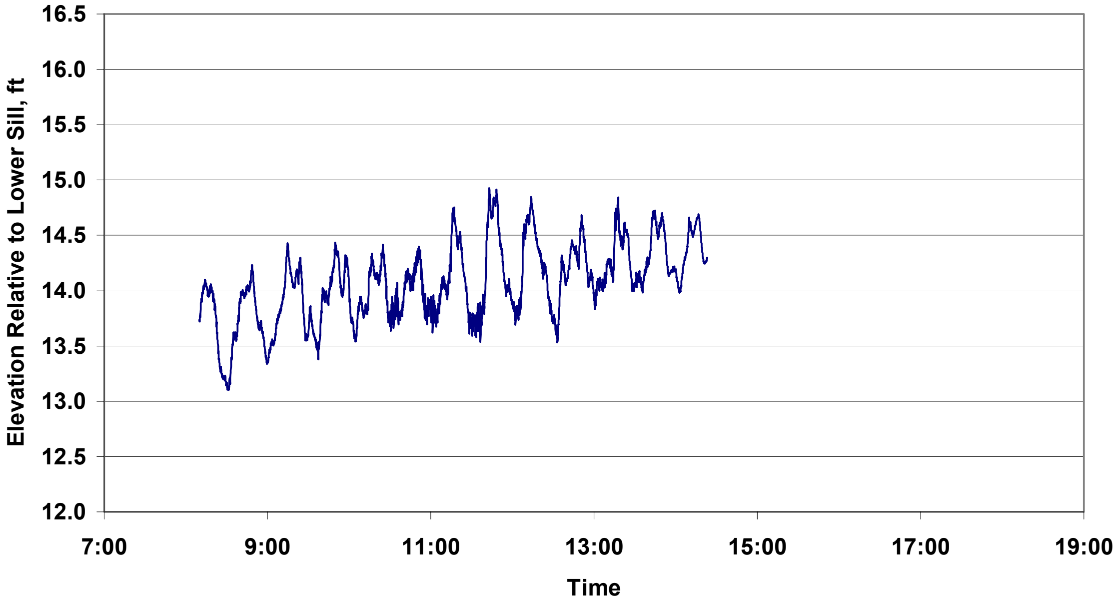


Figure 14. DH21 Serial Number 671 Near Lower Cells on 9/22

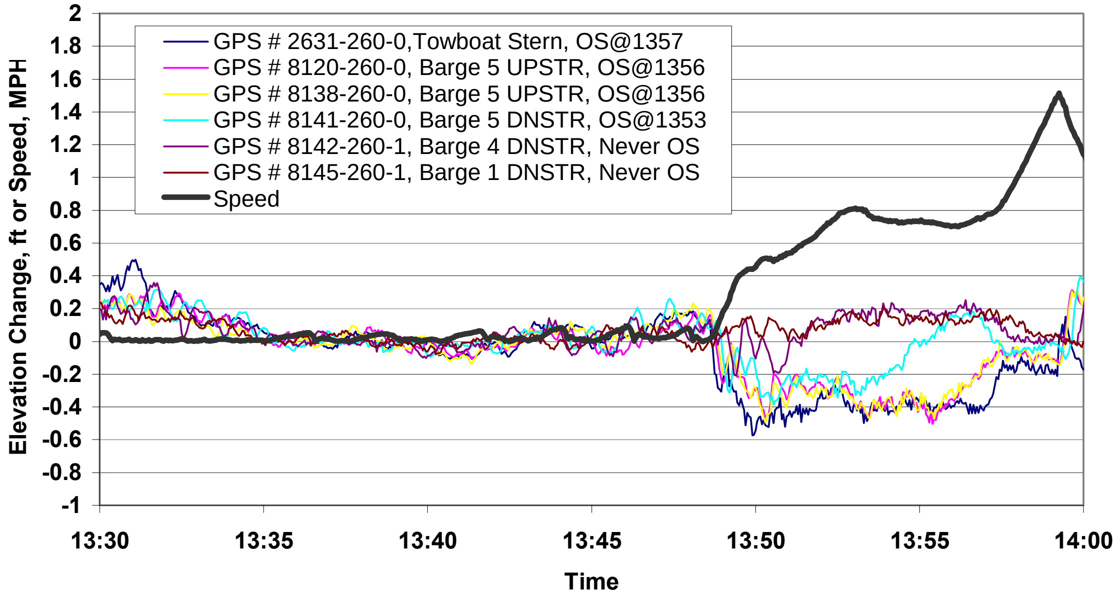


Figure 15. GPS, ST_15_D_NS_3, 9/16

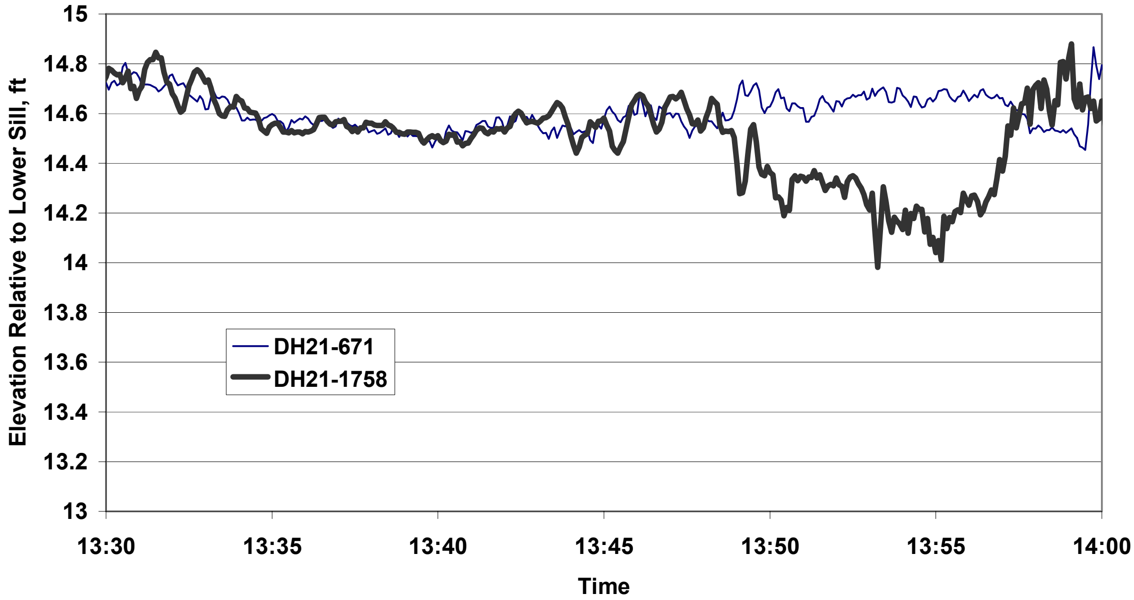


Figure 16. ST_15_D_NS_3, DH21 Water Level Gages on 9/16

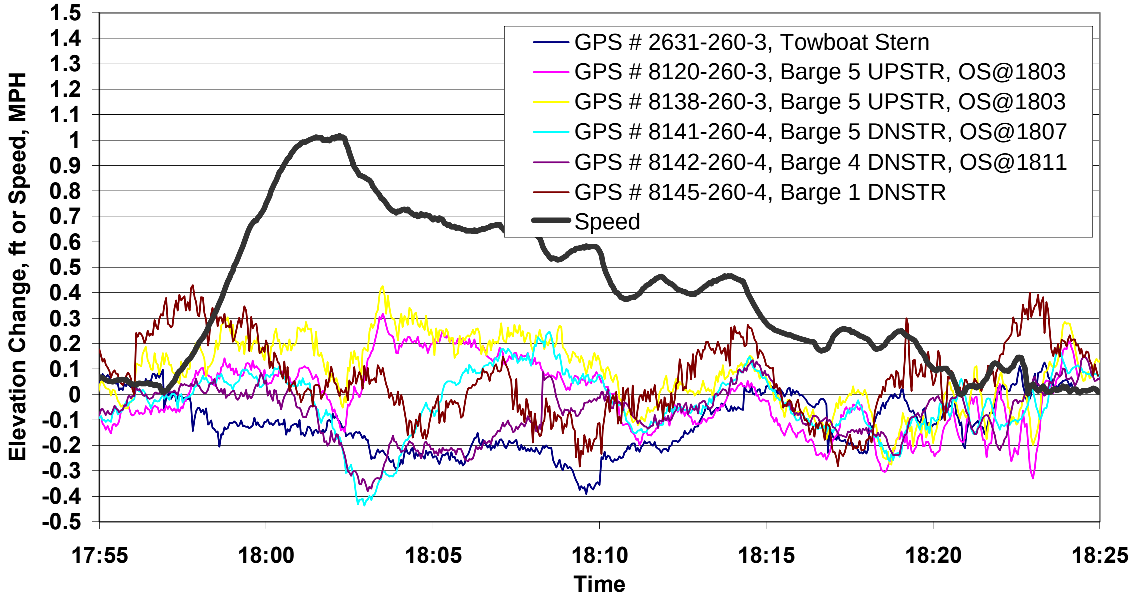


Figure 17. GPS, ST_15_U_NS_2, 9/16

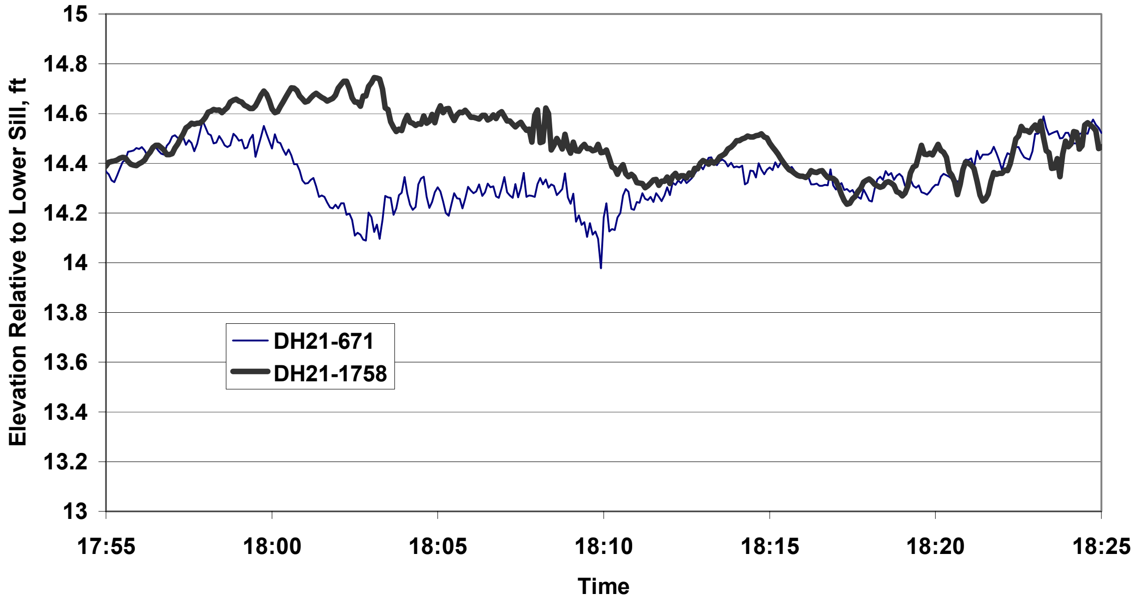


Figure 18. ST_15_U_NS_2, DH21 Water Level Gages on 9/16

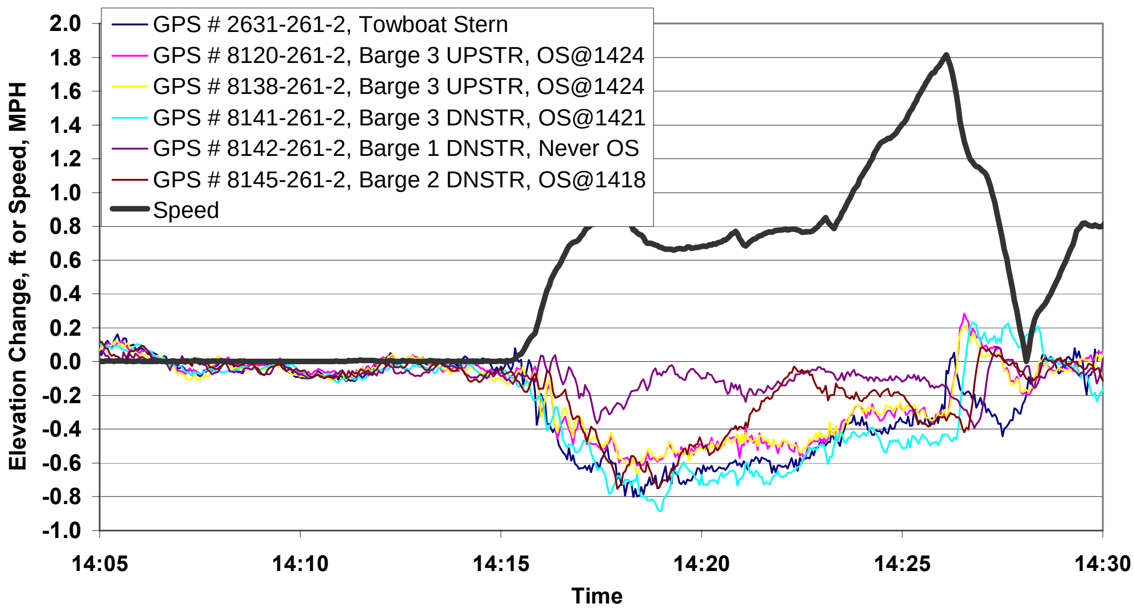


Figure 19. GPS, ST_08_D_NS_4

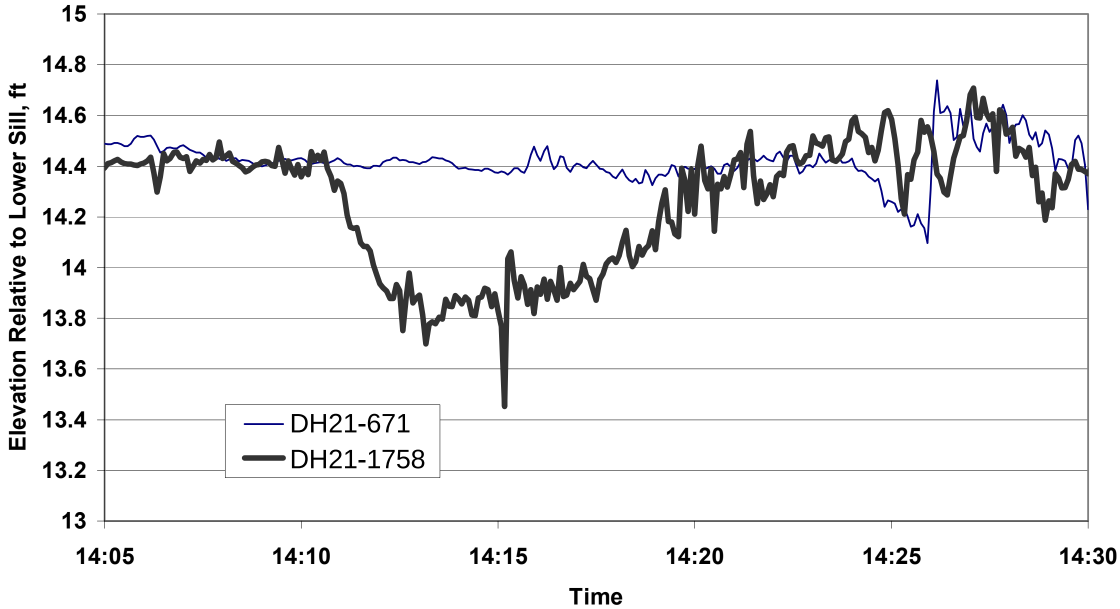


Figure 20. ST_08_D_NS_4, DH21 Gages on 9/17

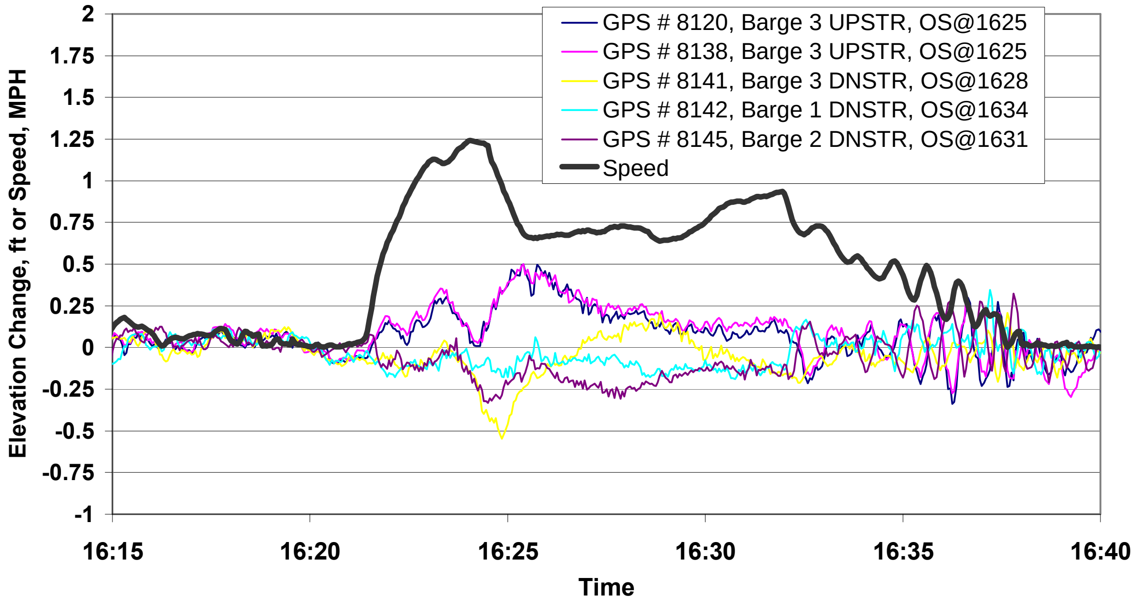


Figure 21. GPS, ST_8_U_NS_2

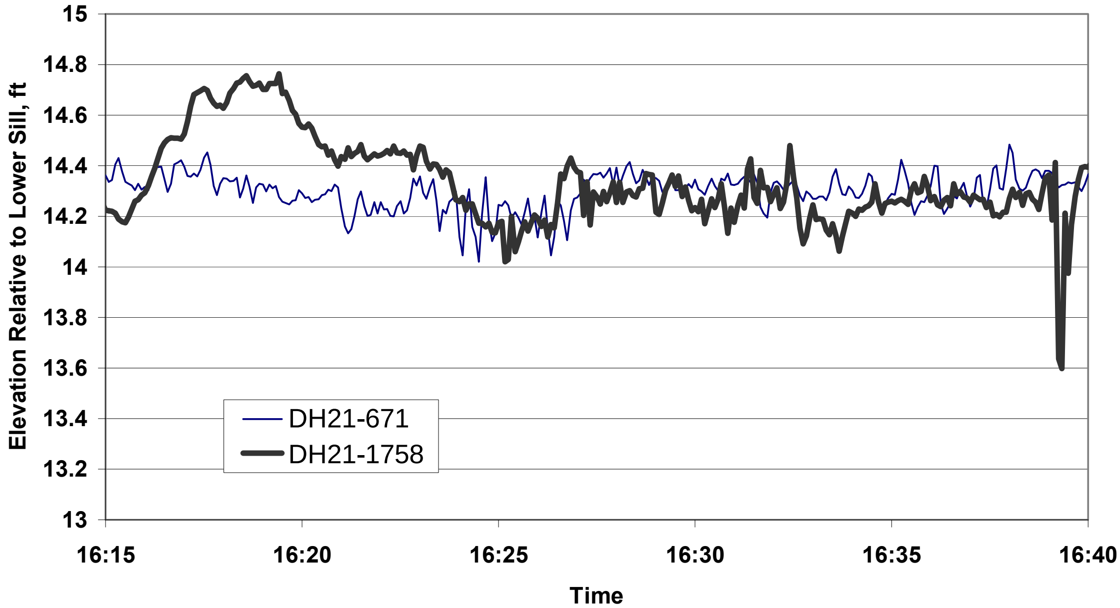


Figure 22. ST_08_U_NS_2, DH21 Gages on 9/17

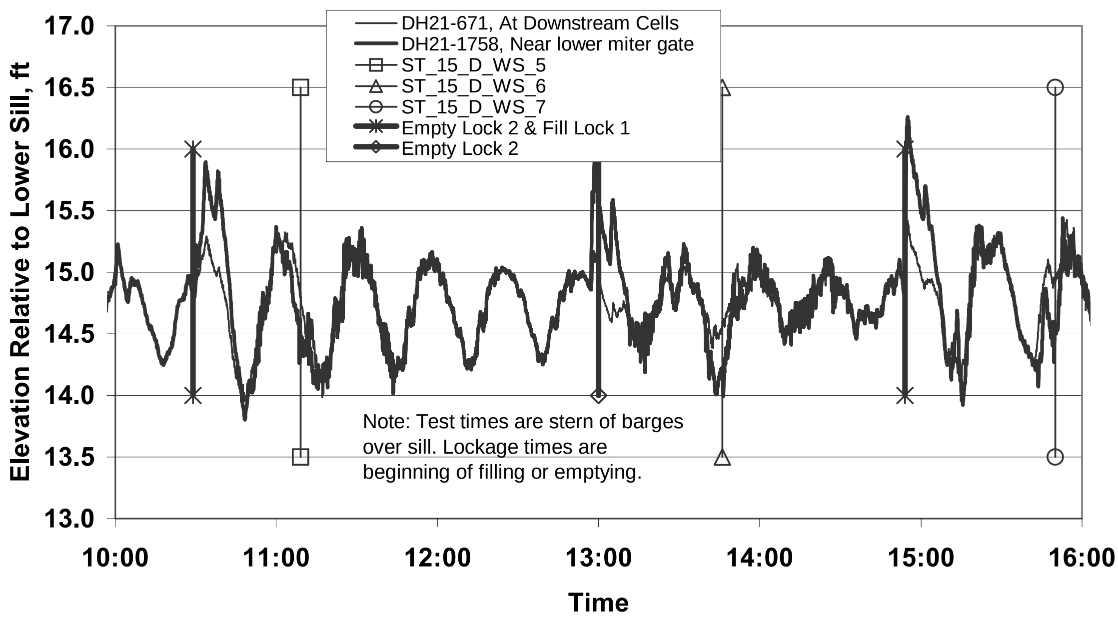


Figure 23. DH21 Gages, Tow Events, and Lockages on 9/19

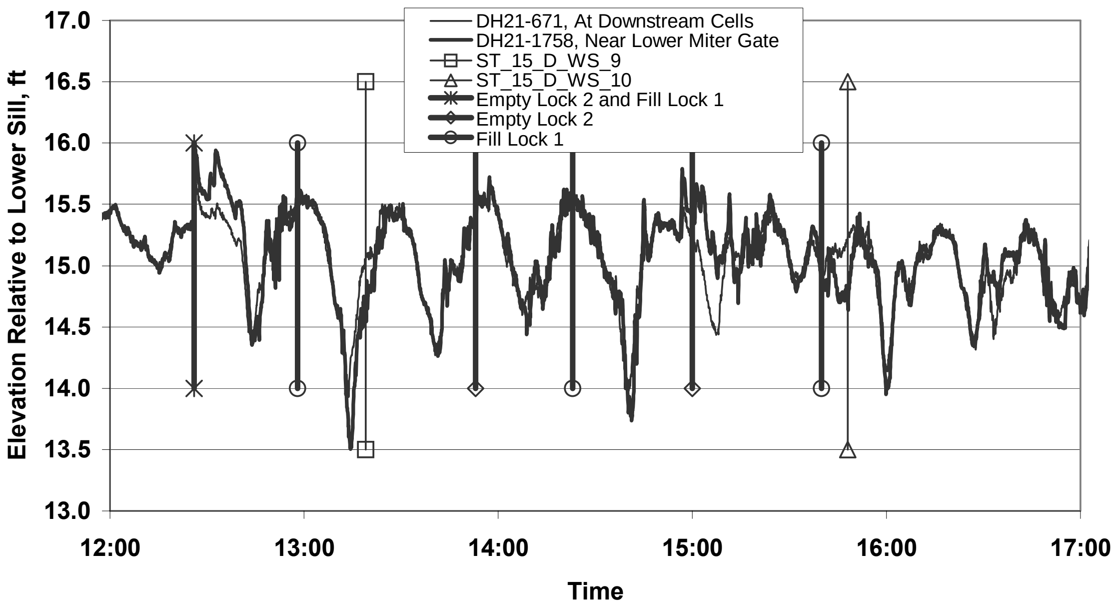


Figure 24. DH21 Gages, Tow Events, and Lockages on 9/20

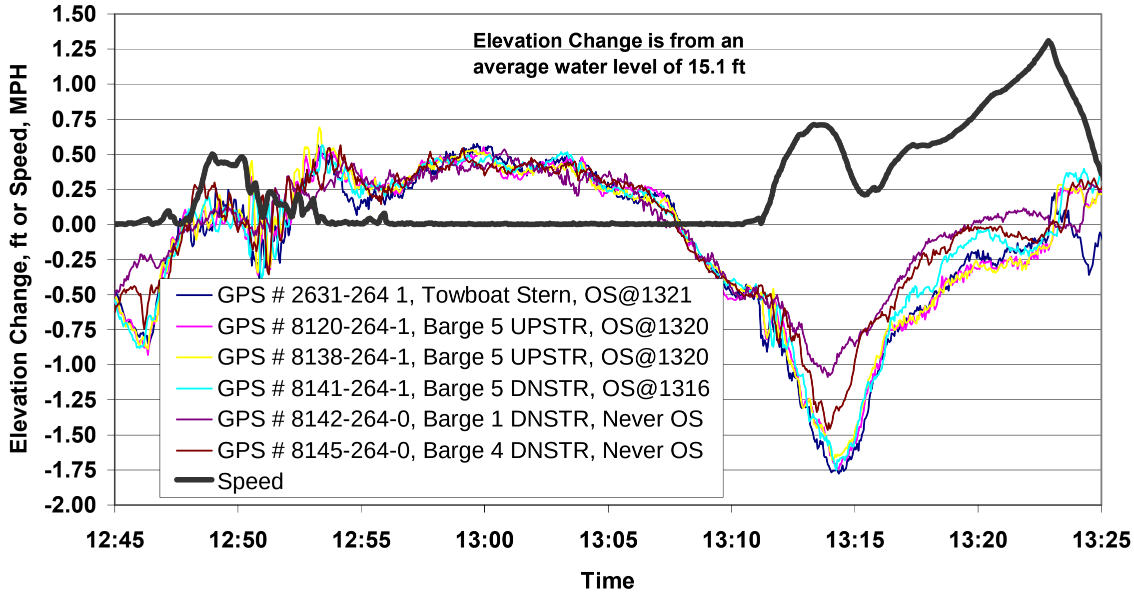


Figure 25. GPS, Test ST_15_D_WS_9, 9/20

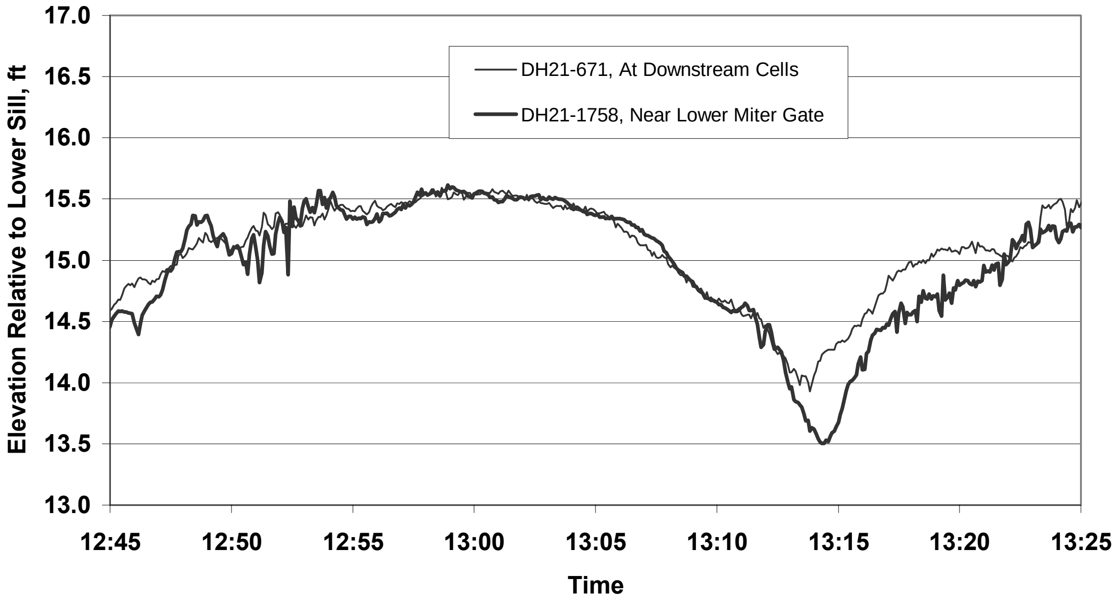


Figure 26. ST_15_D_WS_9, DH21 Gages on 9/20

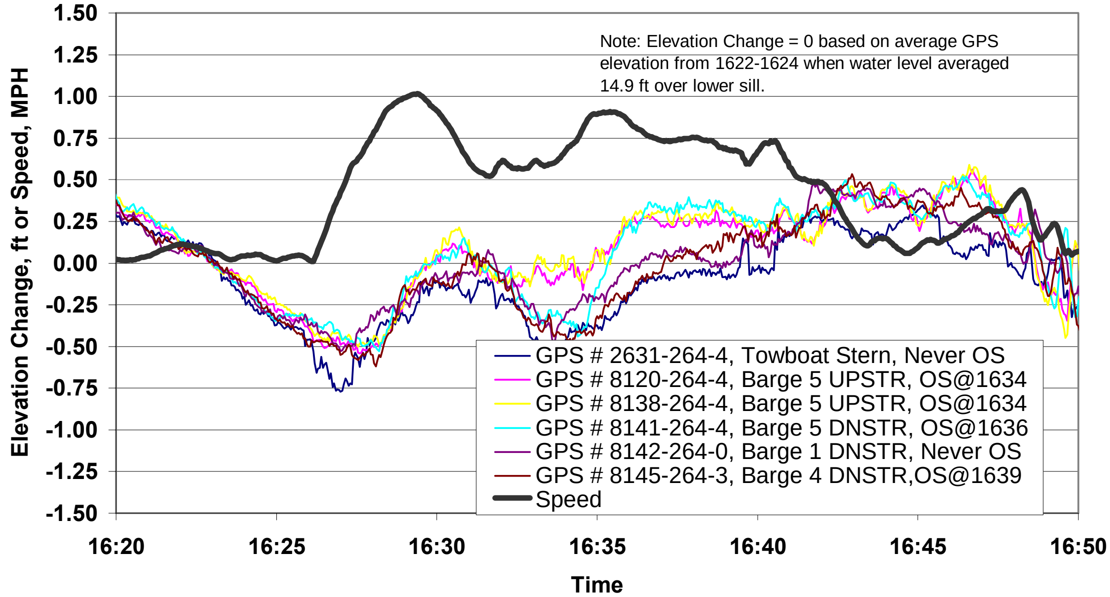


Figure 27. GPS, Test ST_15_U_WS_3, 9/20

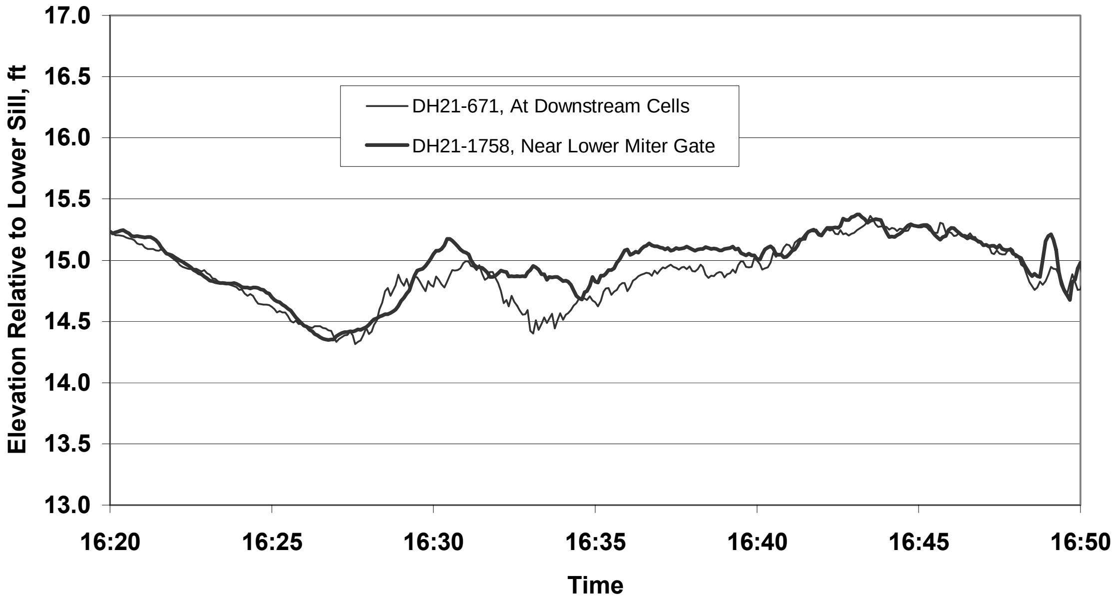


Figure 28. ST_15_U_WS_3, DH21 Gages on 9/20

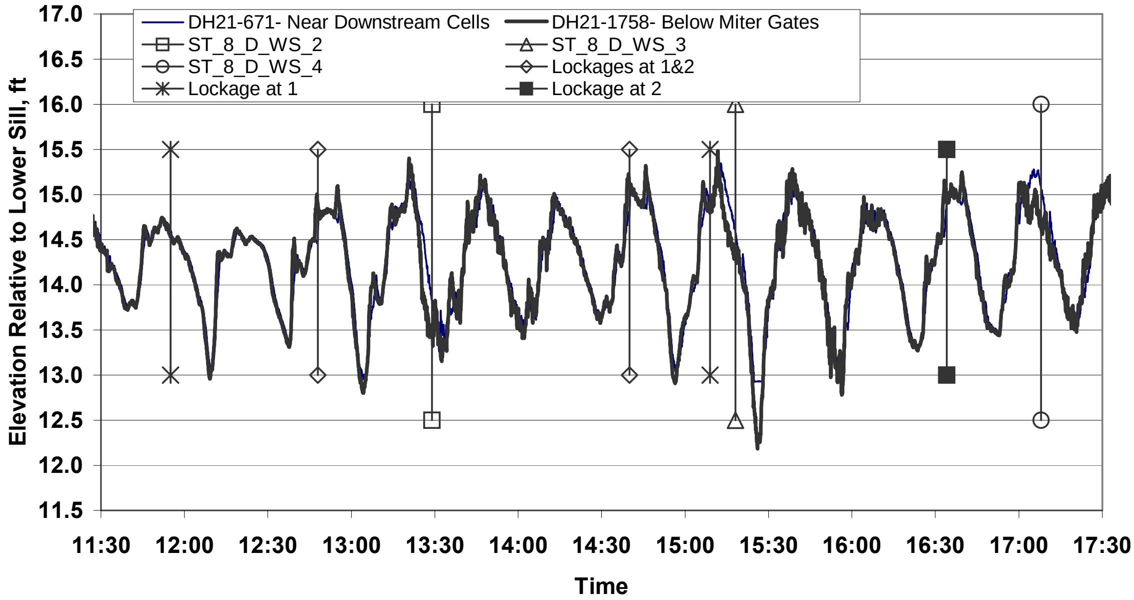


Figure 29. DH21 Gages, Tow Events, and Lockages on 9/21

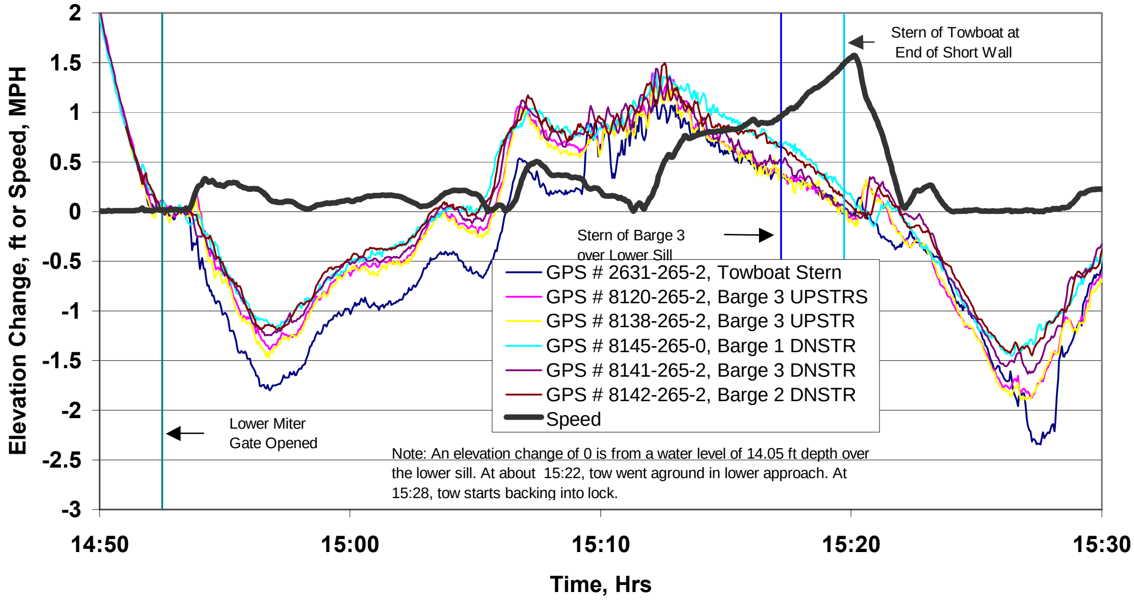


Figure 30. GPS, Test ST_08_D_WS_3, 9/21

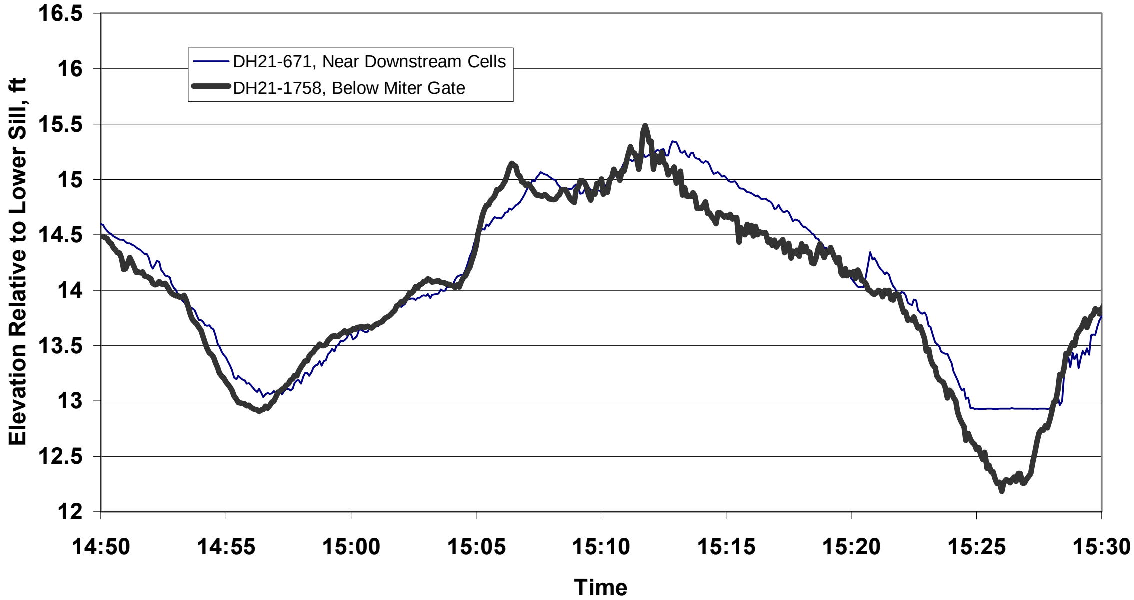


Figure 31. Test ST_08_D_WS_3, DH21 Water Level Gages on 9/21

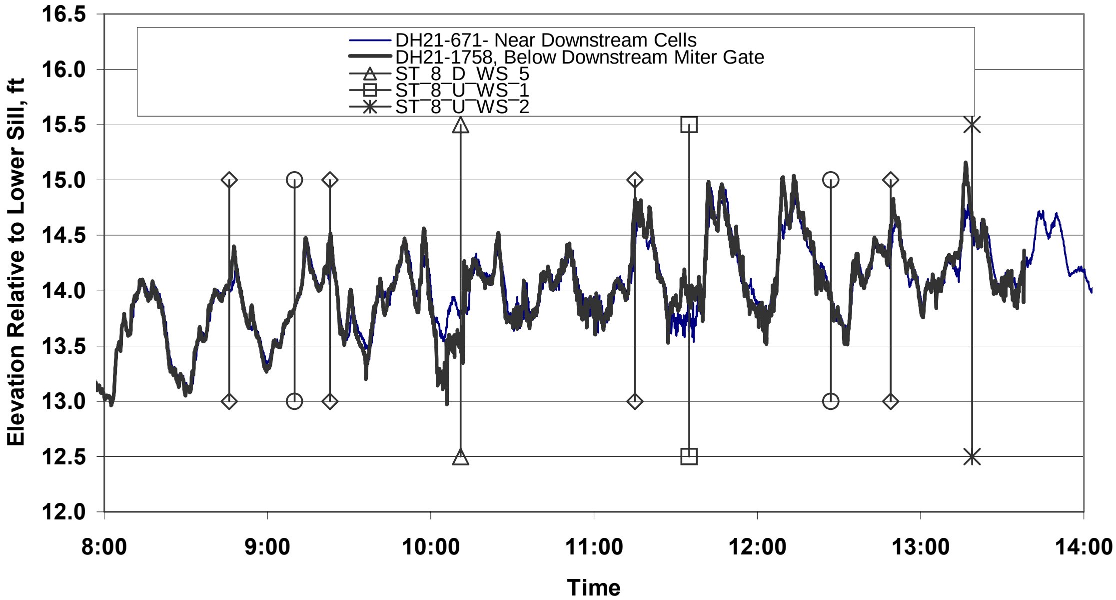


Figure 32. DH21 Gages, Tow Events, and Lockages on 9/22

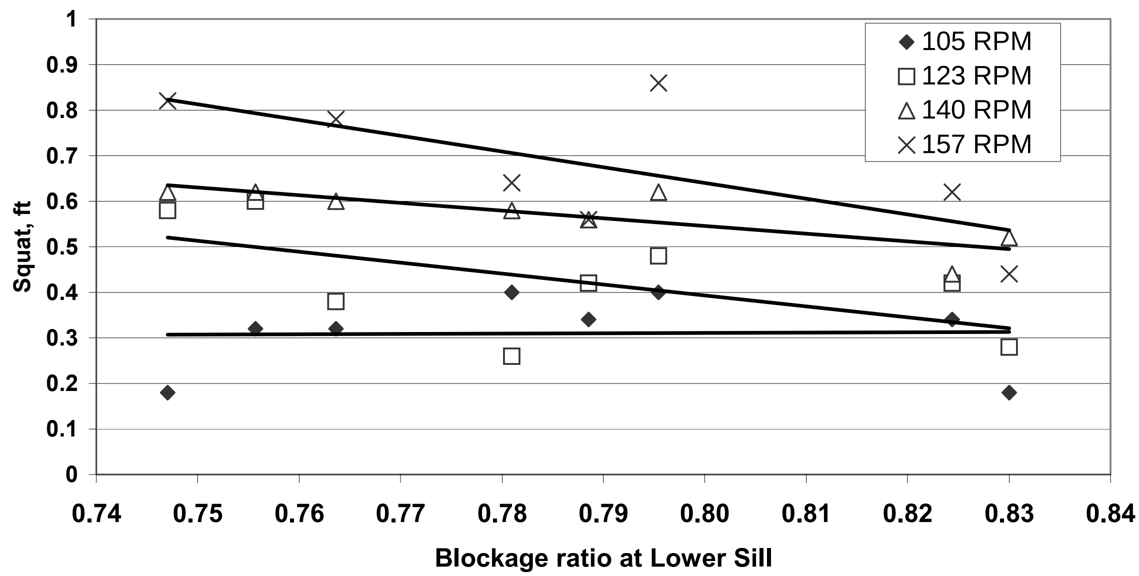


Figure 33. Squat at Stern of Barges versus Blockage Ratio for Downbound Exiting Tows from Maynord (1987)

Lock Filling and Emptying Tests

25. The primary concerns for filling and emptying the lock chamber with a tow drafted greater than 9 ft are hawser forces on the tow in the chamber and the increase in filling and emptying times to accommodate the larger draft. Lock 2 was chosen as the field site for the lock filling and emptying tests since the submergence over the sill could be set at 14 ft, which is the minimum on the waterway. The tailwater at Lock 2, normally el 143, was lowered to el 142 for the tests. The roof el of the chamber ports was 128.5 which provides a clearance of 4.5 ft for a 9-ft draft barge and 2 ft for an 11.5-ft draft barge, also the minimum clearance on the waterway. The method employed to determine the hawser forces was to measure the water-surface slope in the chamber and relate this slope to the forces in the mooring lines. Hawser forces were not measured in the chamber due to the short time frame allowed to perform the tests. If the forces due to drag and inertia are neglected and assuming the barges act as a single rigid vessel and the vessel blockage area has no effect on the hawser forces, the force required to hold a vessel in place is a function of water-surface slope only. The weight of the barges multiplied by the water slope gives an approximation of the longitudinal hawser force. Comparisons made between measured hawser forces and hawser forces computed from the water-surface slope from model studies have shown reasonable agreement.

26 Instrumentation in Lock Filling and Emptying Tests Water-surface elevations were measured using capacitance gages upstream and downstream from the lock and inside the chamber (Figure 1). Valve movement was monitored using string potentiometers. The movement of the hydraulic cylinder during the lock operation was detected by the potentiometers and this movement was related the vertical opening between the floor of the culvert and the bottom lip of the reverse tainter valve. The details of the valve lifting mechanism were obtained

from Lock 2 personnel. The exact relationship between the valve openings and hydraulic cylinder movement could not be determined since this would have required dewatering each valve well. The timing of the initial valve opening and valve position changes during the lock operation is exact. GPS units and electronic surveying equipment, a tracking total station, were placed on the barges inside the chamber to monitor barge movement during the lock operations. The total station base units were placed on the river wall of the lock and the prisms (signal reflectors) were placed on the barges. The base unit tracked the prism movement during the lock operations.

27. Filling and Emptying without Barges Tests 1-4 were conducted without barges in the chamber to check out the data acquisition system and collect initial water-surface elevation data. A filling test was performed which represented a normal filling operation according to the lock operator. The results from this test along with the results from all filling and emptying tests are provided in Table 9. The filling time for test 1 was 15.0 min and the maximum water-surface differential determined between the upstream and downstream capacitance gages was 0.253 ft. Figures 34 and 35 provide the valve opening during the test and the water-surface elevation during the filling operation. Similar data were collected for all tests. An emptying test was performed next without barges in the chamber. The emptying time was 13.1 min. This operation was considered to be a normal operation according to the lock operators.

Table 9.
Test Conditions and Results for Filling and Emptying Tests
Data From Capacitance Gages

Test No.	Barge Draft, ft	Initial Chamber El	Lift, ft	Lock Operation	Operation Time, min	Maximum End to End WS Diff, ft	WS Slope ft/ft	Est. Haw. Force, tons
1	N/A	142.0	21.1	Filling	15	0.253	0.0005	
2	N/A	162.6	20.6	Emptying	13.1	0.228	0.00045	
3	N/A	142.4	20.6	Filling	7.7	-0.194	-0.00038	
4	N/A	141.9	20.6	Filling	7.4	-0.195	-0.00039	
5	9	142.1	21.2	Filling	15.7	0.163	0.000332	5.6
6	9	162.2	20.7	Emptying	17	-0.139	-0.00027	-4.7
7	9	142.25	21.25	Filling	15.3	0.138	0.000273	4.7
8	9	162.1	20.5	Emptying	13.2	0.161	0.000318	5.5
9	9	142.9	20.0	Filling	15.1	-0.178	--0.00035	-6.1
10	9	161.85	19.85	Emptying	13.7	-0.201	-0.0004	-6.8
13	11.5	141.9	21.4	Filling	18.7	-0.162	-0.00032	-7.1
14	11.5	162.7	21.2	Emptying	15.6	0.125	0.000247	5.4
15	11.5	142.3	21.1	Filling	13.5	0.179	0.000354	7.8
16	11.5	162.5	20.8	Emptying	11.2	0.154	0.000304	6.7
17	11.5	142.4	20.5	Filling	12.5	-0.159	-0.00031	-6.9
18	11.5	162.5	20.4	Emptying	9.7	0.154	0.000304	6.7
19	11.5	162.0	20.1	Emptying	10.1	0.147	0.00029	6.4
20	11.5	142.5	20.7	Filling	14.3	-0.172	-0.00034	-7.5

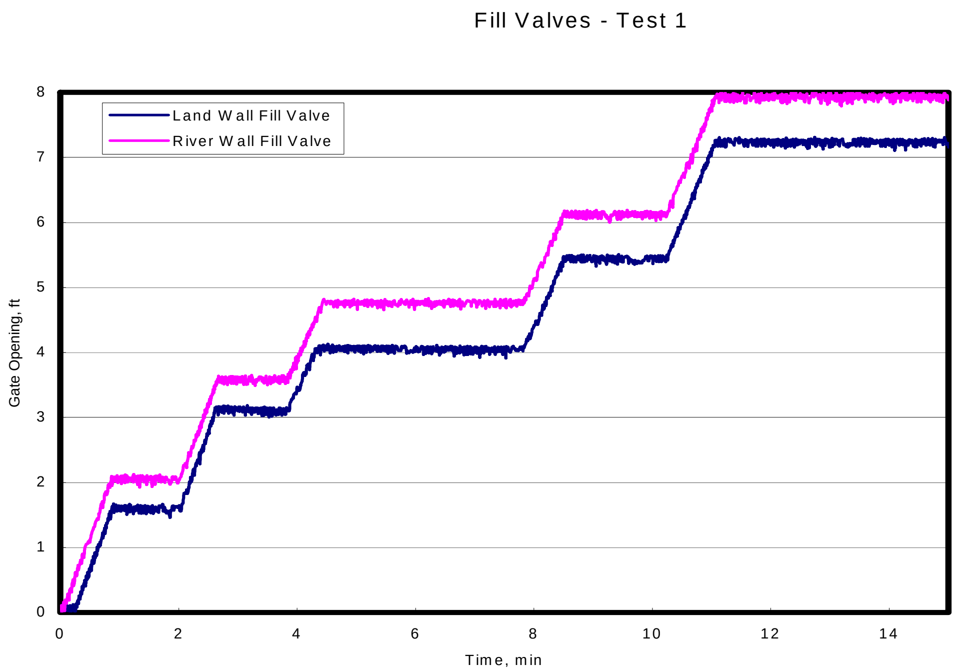


Figure 34. Filling valve operation during test 1

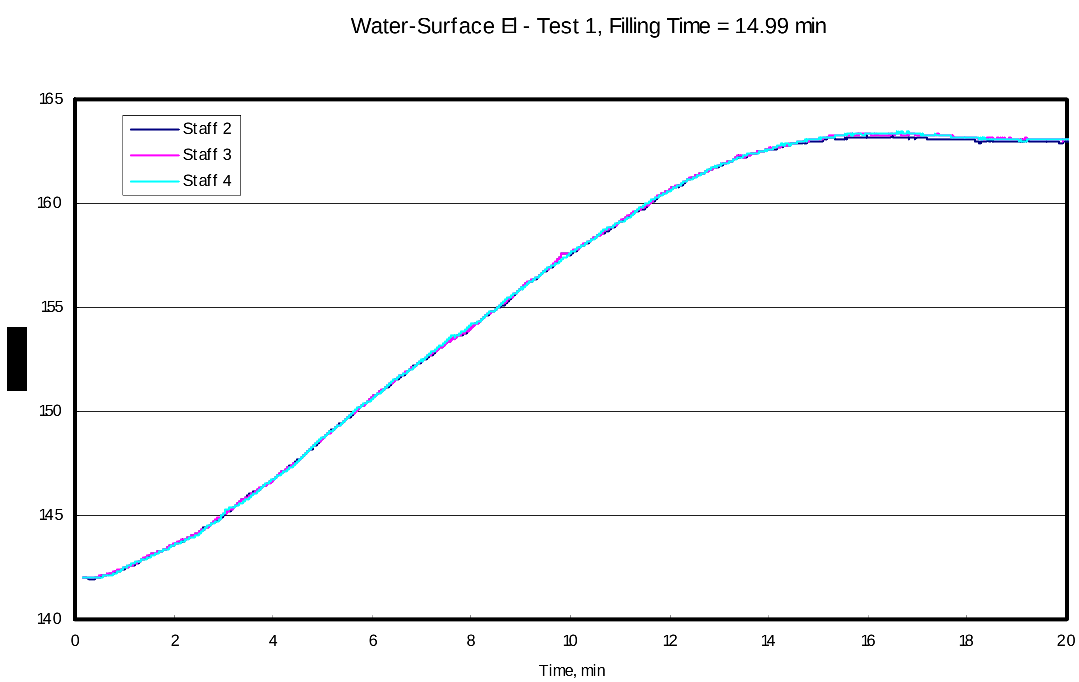


Figure 35. Filling curves from test 1

28. Two fast filling tests were performed to determine the filling times with fast and continuous

valve openings. The river wall filling valve was opened in 2.4 min and the potentiometer for the land wall valve was not working for this test. The lock filled in 7.7 min. The lock filled in 7.4 min for the second fast filling test with the river wall valve opening in 2.6 min and the land wall valve opening in 2.4 min. These test results indicate the filling system was still performing as designed.

29. <u>Filling and Emptying with 9-ft draft Barges</u> The next tests were performed with nine barges drafted to 9 ft and moored on the river wall of the lock. Three filling and three emptying tests were performed with the 9-ft draft barges. The first filling test, test 5, was operated to represent a normal filling operation with no tow or barges located in the upper approach. The lock filled in 15.7 min and the lift was 21.2 ft. The maximum end-to-end water-surface differential determined from the capacitance gages was 0.163 ft and occurred 122 sec after filling began as shown in Figure 36. This relates to a hawser force of 5.6 tons. The Corps guidance suggests that the filling and emptying systems should be designed so that the hawser forces determined from physical model studies are no greater than 5 tons for the desired filling and emptying times. From conversations with the deck hands and the tow boat pilot, the mooring forces from this test did not present any problem during lock filling.

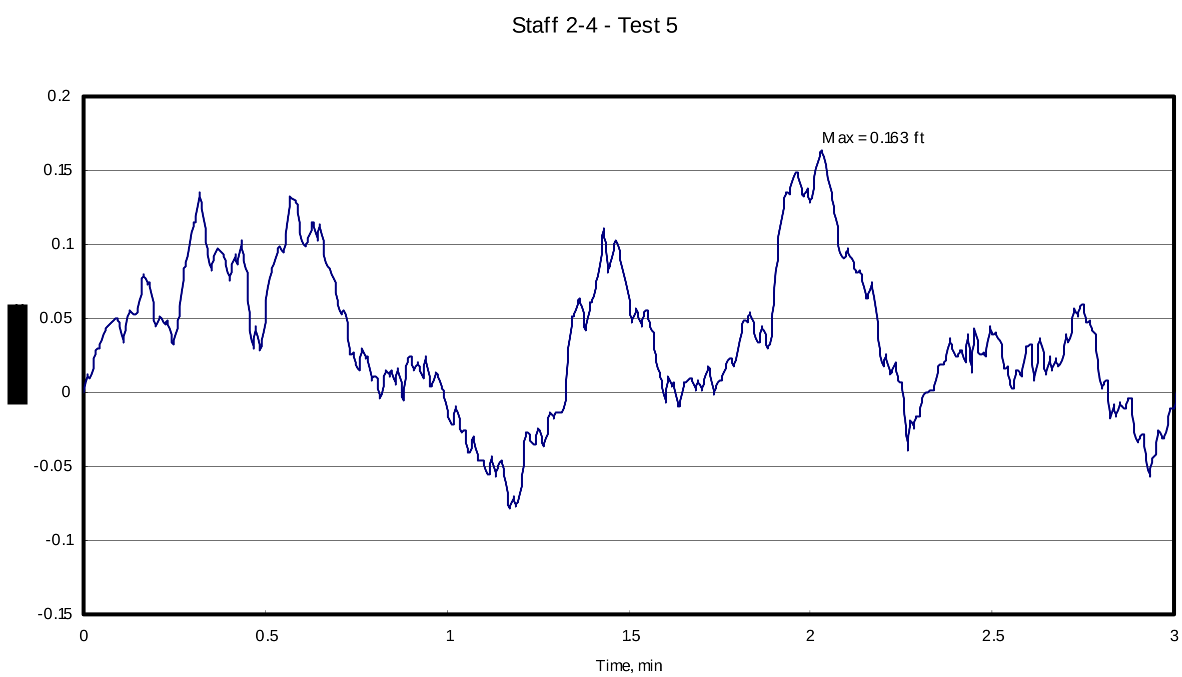


Figure 36. Maximum end-to-end water-surface differential, test 5

30. The maximum end-to-end water-surface differential determined from the tracking station data for test 5 was -0.093 ft and occurred 44 sec after the filling operation began as shown in Figure 37. The results from the tracking station data for all the filling and emptying tests are shown in Table 10. The elevations of the tracking prism were adjusted to the water-level el for convenience in making comparison to the capacitance gage data. A negative value indicates the tracking prism on the downstream barge is higher than the tracking prism on the upstream barge.

This measured differential from the tracking station data is less than the value determined from the capacitance gages and also occurred at a different time during the filling operation. This indicates that the end-to-end slope of the barges and the end-to-end slope of the water-surface do not coincide during the filling operation. This should be expected since the barges probably do not truly act as a single rigid vessel.

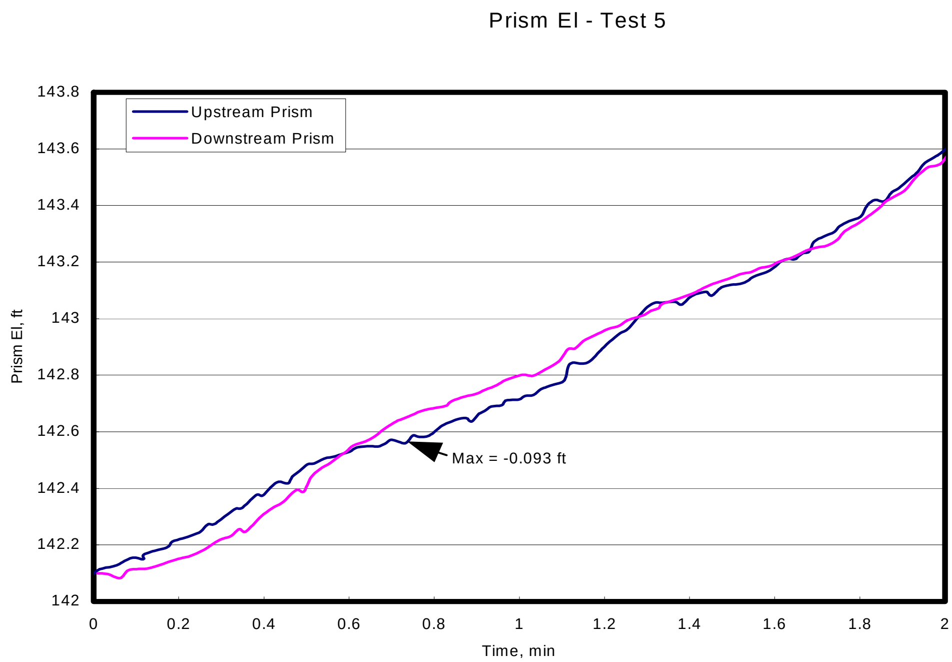


Figure 37. Prism el's from test 5

Table 10. Test Conditions and Results Tracking Station Data							
Test No.	Barge Draft, ft	Lock Operation	Operation Time, min		Maximum End to End Diff., ft		Barge Slope ft/ft
5	9	Filling	15.7		-0.093		-0.00016
6	9	Emptying	17.0				
7	9	Filling	15.3				
8	9	Emptying	13.2		0.049		8.57E-05
9	9	Filling	15.1		-0.108		-0.00019
10	9	Emptying	13.7		0.085		0.000149
13	11.5	Filling	18.7		0.137		0.000255
14	11.5	Emptying	15.6		0.072		0.000134
15	11.5	Filling	13.5		0.072		0.000134
16	11.5	Emptying	11.2		0.164		0.000306
17	11.5	Filling	12.5		0.13		0.000242
18	11.5	Emptying	9.7		0.08		0.000149
19	11.5	Emptying	10.1		0.07		0.00013
20	11.5	Filling	14.3		0.12		0.000224

31. The comparison of the end-to-end water-surface differential and the end-to-end prism differential for tests 6-10 were similar to those observed in test 5. The magnitude of the prism differential was less than the water-surface differential and the timing of these occurrences did not coincide. Prism data were not available for tests 6 and 7. The results show that estimating the hawser forces from the lock water-surface slope is somewhat conservative and the actual hawser forces experienced by the tow in the chamber for these tests is less than those values shown in Table 11.

32. Valve Operations Valve operations during the tests were performed manually by the lock duty operator. Normal operations were requested with the nine 9-ft draft barges in the chamber. Conversations with lock personnel revealed that the operations are different depending on the tow and barge involved in the locking procedure. The filling operation is slower when a tow and barges are moored in the upstream approach. Likewise, the emptying operation is slower when barges are moored in the lower approach. Test 6 is an example of the method the lock is operated when barges are moored in the lower approach. The emptying time was 17 min compared to an emptying time of 13.2 for test 8. The valve operations performed during tests 6 and 8 are shown in Figures 38 and 39, respectively. In test 6, the maximum valve opening was 6 ft, at 9.3 min and in test 8, the maximum valve opening was 8 ft at 9.2 min. The valve operations during tests 5, 7, and 9 were fairly similar. The valves were opened in increments of 2 ft to a maximum of around 8 ft for tests 7 and 9 and a 1 ft stop was also made during test 5.

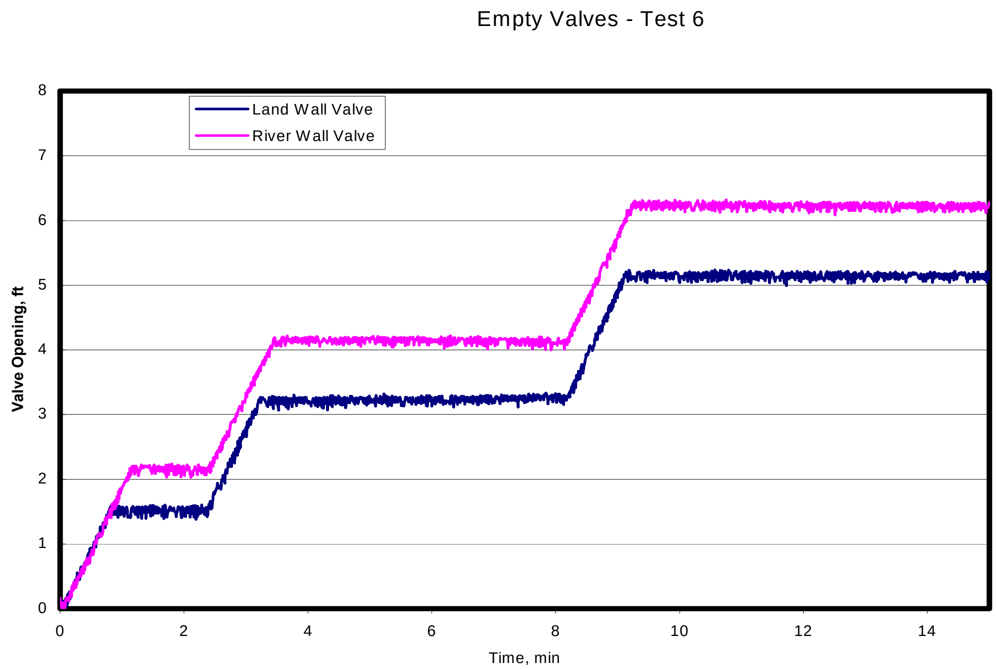


Figure 38. Empty valve operations during test 6

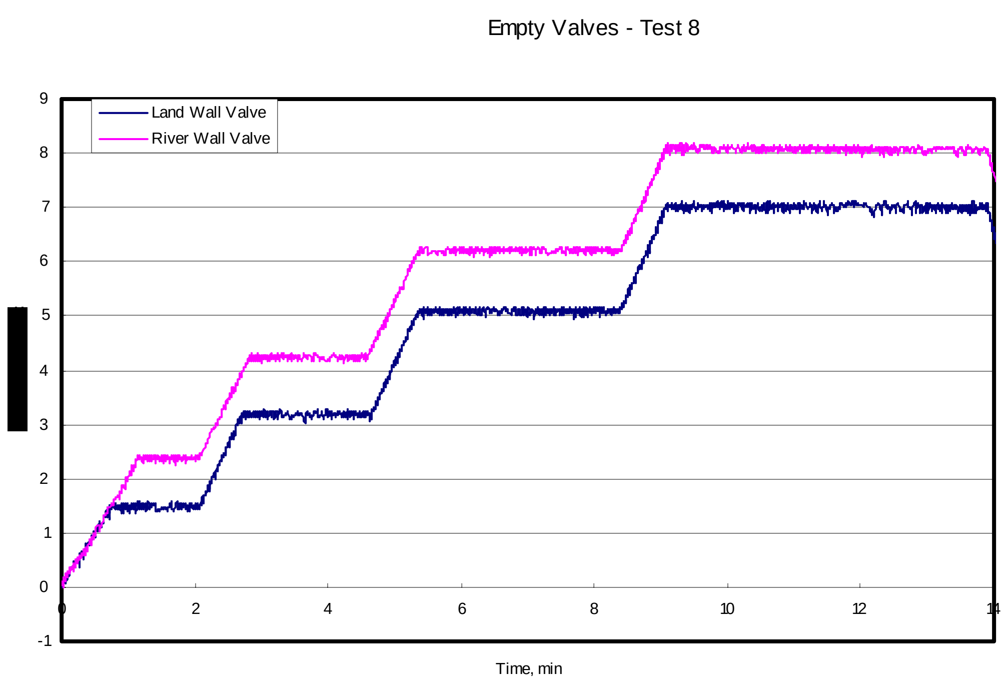


Figure 39. Empty valve operations during test 8

33. The lock filling and emptying systems for the McClellan-Kerr Waterway were originally designed to fill and empty with continuous valve operations and to pass the tow and barges in a

single lockage. This provided quick lock operation times and favorable flow distributions. Changes in tow and barge configurations over the years have forced changes to the lock operations. Tows with more than 8 barges are quite common and these require a double lockage. It was apparent from the tests conducted with the 9-ft draft barges that lock operations between 13 and 17 min are considered normal. A filling time of around 15 min and an emptying time between 13 and 14 min appeared to be the normal conditions. Stepped valve operations are used to avoid rapid changes in water level in the lock approaches where a tow and barges are moored. A fast emptying operation is not desired at Lock 2 due to the surging that occurs in the canal between Locks 1 and 2.

34. Filling and Emptying with 11.5-ft draft Barges Eight tests were performed with nine barges drafted to 11.5 ft, 4 filling tests and 4 emptying tests. The first filling test, test 13, was performed slower than a normal type operation to insure no problems were encountered during lock filling. The valves were opened to 1 ft and held for 2 min and then opened incrementally to 6 ft at 10. 4 min. The filling time was 18.7 min and the maximum end-to end water-surface differential was -0.162 ft and occurred at 100 sec after the valves began opening. This water-surface slope relates to a computed hawser force of 7.1 tons. No excessive turbulence or forces were observed during test 13. The first emptying test, test 14, was also performed slightly slower than a normal type operation. The valves were opened in increments of 2 ft to a maximum of 6 ft in 9 min. The emptying time was 15.6 min and the maximum end-to-end water-surface differential was 0.125 ft and occurred 70 sec after the valves began to open. The computed hawser force for this water-surface slope was 5.4 tons.

35. Since no problems were observed during the first filling and emptying tests with the 11.5-ft draft barges, the lock operator was requested to operate the lock faster than the first tests. Tests 17 and 18 were the fastest tests performed. The lock was filled in 12.5 min during test 17 and the maximum end-to-end differential water-surface differential was –0.159 ft at 98 sec. These results were very similar to those in test 13 even though the lock filled much quicker in test 17. The quicker filling time achieved during test 17 was attributed primarily to valve operation and the lift was also 0.9 ft less. The lock was emptied in 9.7 min for test 18 with a maximum end-to-end differential of 0.154 ft at 104 sec. The faster emptying time was again attributed to the valve operation and the lift was 0.8 ft less than the lift in test 14. The valves were opened incrementally to 12 ft during test 18 compared to a maximum valve opening of 6 ft during test 14.

36. The results from the filling and emptying test conducted with the 11.5-ft draft barges show that filling and emptying times as fast as those observed with the 9-ft draft barges can be achieved with the 11.5-ft draft barges. The chamber turbulence was not excessive and the computed forces in the mooring lines were also not considered excessive. The lock was actually filled and emptied faster with the deeper draft barges than with the 9-ft draft barges. Similar observations were made with the deeper draft barges concerning the comparison of the water-surface slope to the barge slope. The water slope was greater than the barge slope and the timing of the maximum end-to-end differentials did not coincide. The maximum differentials observed on the barge prisms occurred shortly (within 20 sec) after the valves began to open and the upstream end of the barge was higher than the downstream end.

37. The operation of the valves is a key factor in the chamber performance. It was apparent that quicker times and less water-surface slope could be achieved depending on how the valves are operated. Comparison of valve operations for tests 14 and 18, Figures 40 and 41, show that opening the valve to full open from 8 ft helped reduce the overall emptying time. Lock 2 emptying operations are also slowed to help reduce the surging in the canal.

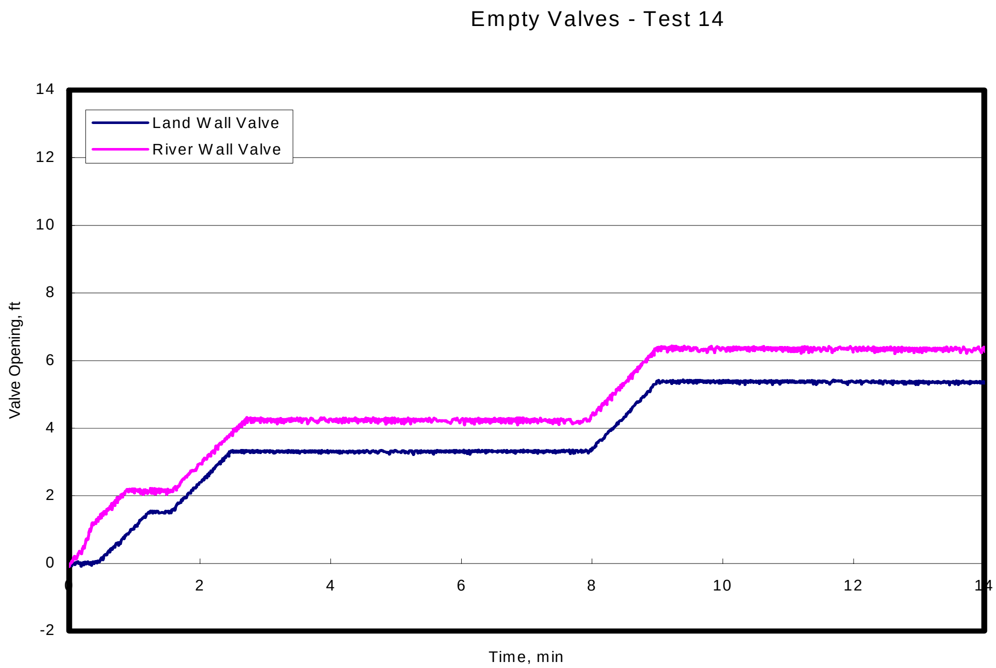


Figure 40. Empty valve operations during test 14

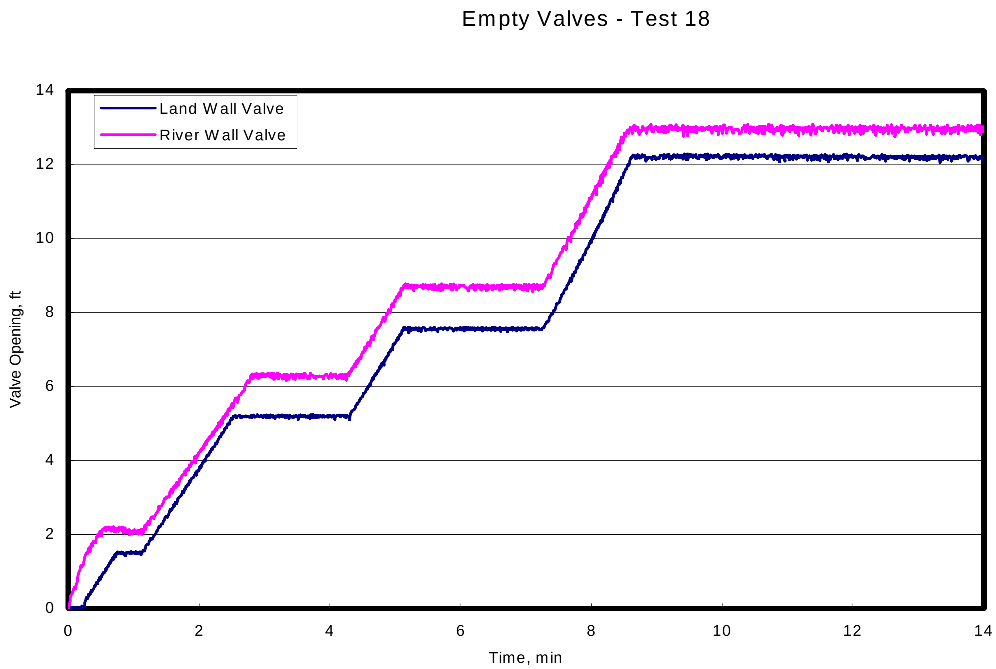


Figure 41. Empty valve operations during test 18

38. Recommendations for Lock Filling and Emptying The filling and emptying test results with the deeper draft barges show that lock filling operations as fast as 12.5 min and lock emptying operations as fast as 9.7 min did not cause large hawser forces or any noticeable increase in turbulence for the lifts evaluated. The lifts during the tests with the deeper draft barges varied from 20.1 to 21.4 ft. The lock was operated faster than the tests performed with the 9-ft draft barges, which demonstrates that the deeper draft barges will not have a significant impact on lock filling and emptying operations. Both the filling valves were operated in nearly similar manners during the filling tests. One valve often lagged the other slightly, but this did not cause any noticeable problems with chamber performance. With the tow moored on the river wall, opening the river wall valve slightly ahead of the land wall valve probably helps keep the tow on the wall. Opening the valves at drastically different speeds is not recommend for the deeper draft barges since these barges have less clearance between the bottom of the barges and the top of the chamber ports. A significantly different discharge from one side may set up an adverse transverse seiche in the chamber. If one valve is out of operation, the operating valve should be considerably slower than a normal operation. Hawser forces during lock emptying with normal valve operations (valves operated similarly) are typically not as large as those during filling. During these tests, the valves were operated similarly and no large hawser forces were observed during emptying.

39. These tests have demonstrated that the hawser forces with the deeper draft barges will not be considerably higher if the locks are operated in the manner they are currently operated. Since the locks are typically operated much slower due to vessels in the upper and lower approaches, the increase in hawser forces with this type of operation would not be greater than the increased forces due to the increase in mass. These hawser forces are expected to be higher since there is additional mass with the deeper draft. Operating the filling and emptying valves as they are

operated currently when a tow is in the either the upper or lower approach will be satisfactory for the deeper draft barges. With slow and similar valve operations, the water level in the chamber is fairly level and excessive forces do not occur. This would be true for the other side port systems on the waterway that have at least a 2 ft or greater clearance between the top of the chamber port and lifts less than 21 ft. For the two side port systems with lifts greater than 21 ft (Ozark and Weber Falls), the operating valves may have to be slowed to determine the safe filling time with the deeper draft barges. Operating the valves at low speeds with higher lifts may cause adverse low pressures downstream from the valves. Data obtained from these field tests could be used to validate a numerical model that could then be used to predict operating conditions and pressures for side port systems with lifts greater than 21 ft.

40. The two locks with bottom lateral systems are designed to produce very uniformly distributed flows during lock filling and emptying. The energy from jets discharging from the ports during filling is dissipated near the bottom of the chamber and no significant increase in hawser forces would be expected with the deeper draft barges due to a change in the hydraulic flow conditions in the chamber. The increase in hawser forces would be the result of more mass with the deeper draft. The increase in hawser forces should be (11.5/9) or 30 percent more than is currently experienced with the 9-ft draft barges. Further investigation into typical lock operations should be performed at Ozark and Weber Falls before evaluation of hawsers forces is initiated.

Lower Approach Tests

41. The field study also included tests to measure the forces on barges moored in the lower approach during emptying operations. Three tests were performed with 9-ft draft barges and three tests were performed with 11.5-ft draft barges. The purpose of the tests was to determine the magnitude of the forces that barges experience while they are moored in the lower approach during a double lockage. Six barges were moored on the land side of the lower approach wall during the tests.

42. <u>Instrumentation for Lower Approach Tests</u> Two load cells were used to measure the forces on the barges during lock emptying. A 250 kip load cell was used on the upstream end of the barge and a 150 kip load cell was used on the downstream end of the barge. For the upper load cell, mooring line was wrapped around the mooring pin located 89 ft downstream from the lower land wall pintle and connected to a shackle that was connected to the load cell. A 1 in. steel cable was then connected to a shackle on the other end of the load cell and the other end of the cable was connected to a turnbuckle that was used to tension the line. For the lower cell, mooring line was wrapped around another mooring pin located 204 ft downstream from the lower land wall pintle and connected to a shackle connected to the load cell. The shackle on the other end of the load cell was connected to a cleat mounted on the barge. GPS units were placed on each end of the barges and one in the middle. Electronic surveying equipment was also used. Prisms were placed on each end of the barges and a base unit was used to track the prisms during the lock emptying. The water level was measured using a capacitance gage (staff 5) in a ladder well located on the land wall 49 ft downstream from the lower pintle.

43. <u>Load Measurements with 9-ft draft Barges</u> The lines were pretensioned before the test in an

effort to keep the lines in tension during the test. For the first test (test 11), the land wall valve was opened first and the river wall valve began opening about 1.5 min later. The land wall valve was opened to about 5 ft and then closed after 9.2 min. The river wall was opened to 6 ft at 12.25 min. The emptying time was 21.0 min. for test 11. The water level measured at staff 5 during test 11 is shown in Figure 42 and the valve operation for this test shown in Figure 43. At 2.57 min, a force of 2.3 tons was measured by the upstream load cell and 12.7 tons was measured by the downstream load cell as shown in Figure 44. This occurred shortly after the land wall valve was opened to 3 ft and the river wall valve was at 2 ft. The force in the upstream load cell dropped below the pretension force at 3.8 min and remained below this value until the end of the test. This indicated that the forces on the barge were all in the downstream direction after this time period and the entire load was transferred to the downstream load cell. A load of 13.4 tons was measured at 7.9 min and 12.7 min on the downstream load cell. The timing of these forces occurred at about the same time the water level peaks were measured with staff 5 as shown in Figure 42. The upper and lower prism el's for the prisms that were mounted on the barges are shown in Figure 45. The maximum slope on the barges occurred at 12.36 min after the test was begun. The maximum hawser force estimated from the barge slope was 13.2 tons. This is in good agreement with the maximum downstream force measured. Table 11 provides the results from test 11 along with the results from the other lower approach load tests. The maximum downstream force measured during the tests with the 9-ft draft barges was 23.1 tons in test 12A. Further analysis needs to be performed for this test since the load cell pre tension was questionable.

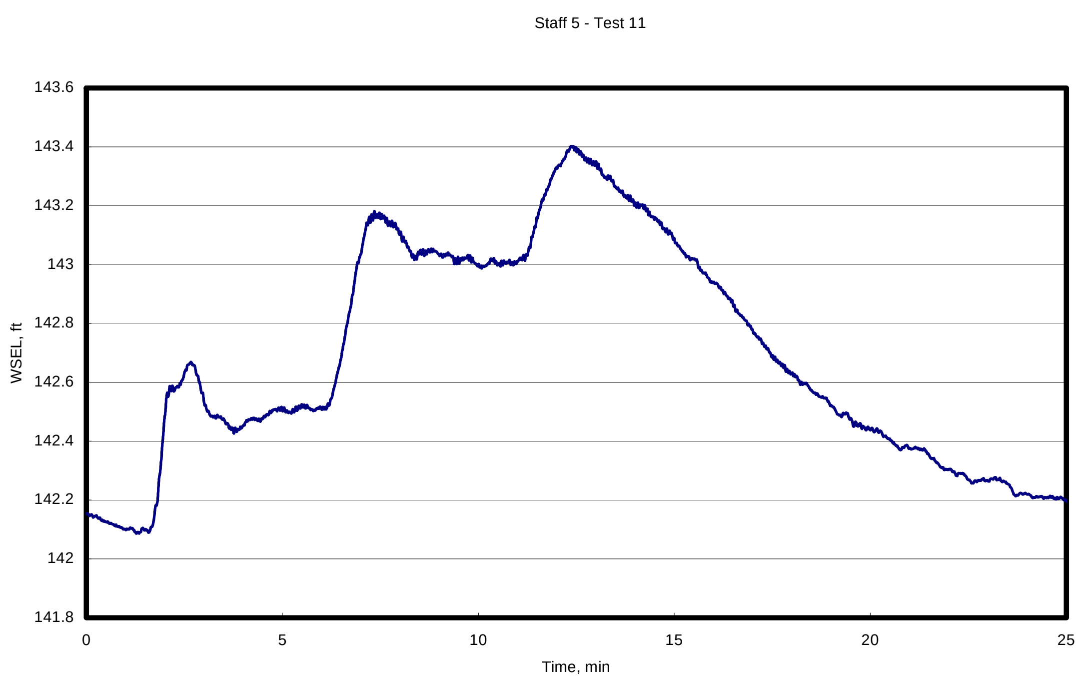


Figure 42. Water-surface el in lower pool during test 11

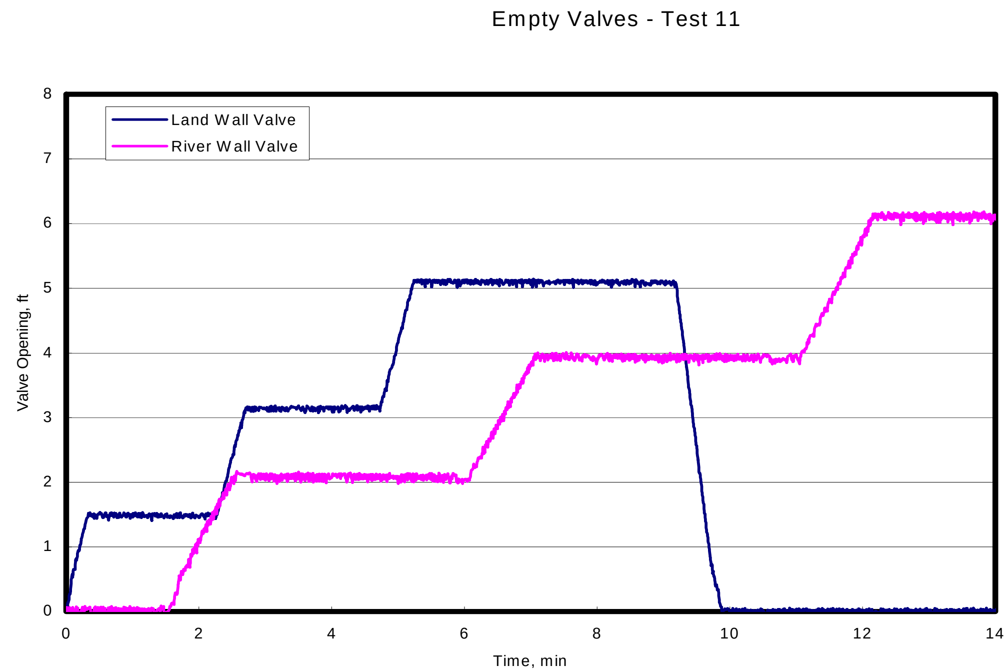


Figure 43. Empty valve operation during test 11

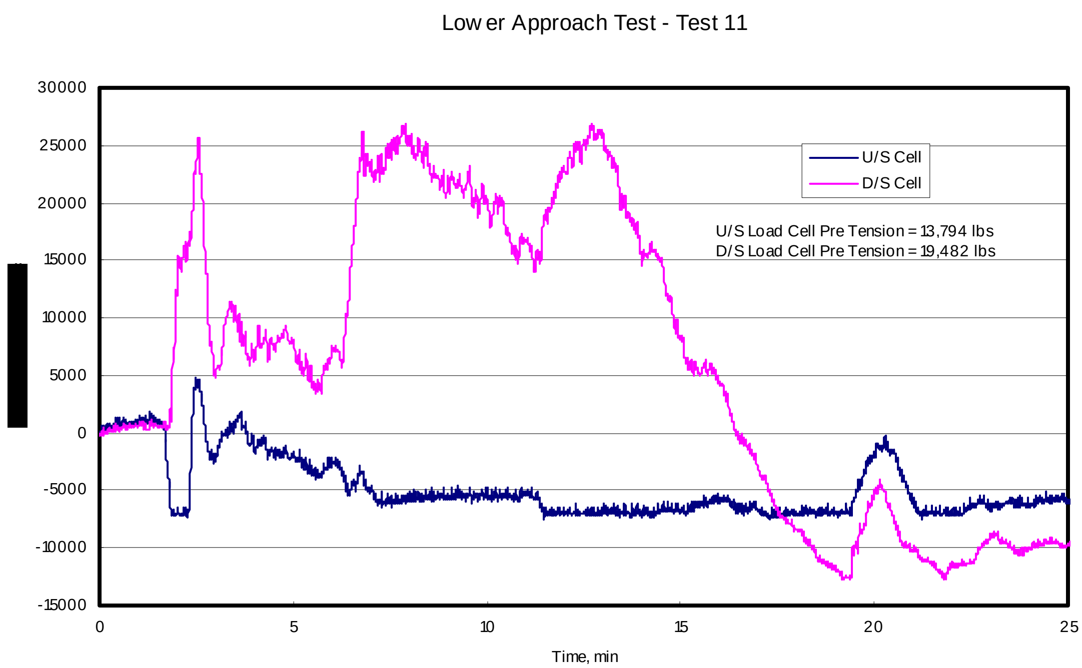


Figure 44. Load measurements during test 11

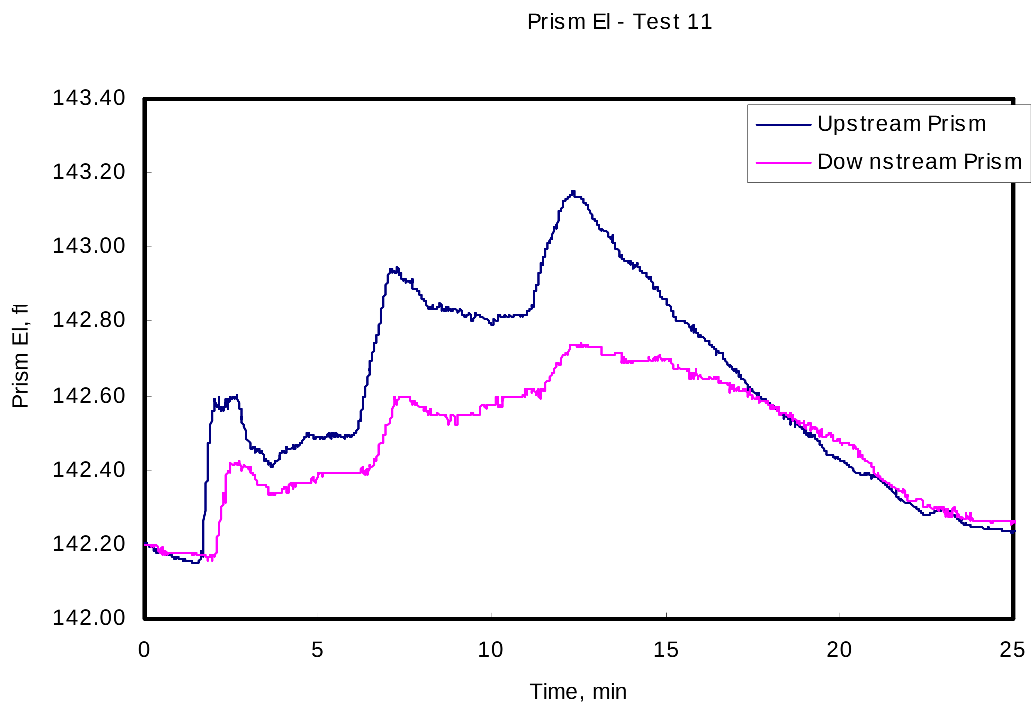


Figure 45. Prism el's during test 11

Table 11. Test Conditions and Results for Lower Approach Tests									
Test No.	Barge Draft, ft	Initial Chamber El	Initial Lower Pool El	Maximum Prism Diff., ft	Time of Maximum Prism Diff., min	Barge Slope, ft/ft	Estimated Longitudinal Hawser Force, tons	Maximum Measured D/S Force, tons	Time of Maximum Measured Force, min
11	9	162.1	142.2	0.437	12.36	0.001146	13.2	13.4	12.73
12	9	162	142.3	0.432	29.08	0.001133	13.0	18.7	17.35
12A	9	162.5	142.9	0.371	9.82	9.73753E	11.2	23.1	10.69
12B	11.5	162.2	142.3	1.024	17.26	0.002687	30.9	31.7	17.27
12C	11.5	162.4	142.5	1.06	6.77	0.002782	32.0	33.3	14.5
12D	11.5	162.4	142.6	0.732	11.97	0.001921	22.1	30.0	5.84

44. Load Measurements with 11.5-ft draft Barges Three tests were also performed with six 11.5-ft draft barges moored to the lower land wall. The results from these tests are shown in Table 11. The maximum downstream forces were similar for these tests with the largest force of 33.3 tons measured during test 12C. Load cell measurement during test 12C ended slightly before the peak force occurred, however prism data, collected for a longer time period, indicated the maximum force was 32 tons. Further analyses will be performed for the lower approach load data and a more detailed discussion of the results will be provided in the final technical report.

45. General Discussion of Lower Approach Load Measurement Results The results from the load measurements generally show that the largest forces occur several minutes after the lock begins to empty. During the initial discharge from the lock outlet, the flow bulks up underneath the barges, which caused an upstream force on the upper load cell and a downstream force on the lower load cell. As the lock continued to empty, the water level in the lower approach began to rise creating a slope in the water-surface between the upper and lower ends of the barges. The prism data showed a difference of just over 1 ft between the upper and lower barges for tests test12B and test 12C. In 4 of the 6 tests, the highest downstream measured forces occurred at near the times the slope was the greatest. The surging in canal between lock 2 and lock 1 can also generate forces in the mooring lines. If the return surge occurred at about the same time the water level in the lower approach from the lock emptying was increasing, forces higher than were measured in these tests could be expected. Conversations with lock personnel indicate that the mooring lines for barges moored in the lower approach have broken due to the surging in the canal. These tests were performed with six barges moored in the lower approach and if similar conditions that were observed during these tests occurred with nine barges, the forces would be 50 percent larger. The broken lines probably occur as a result of the mooring line going slack and then rapidly going into tension due to the lock emptying, surging or combination of the two.

46. The forces experienced by barges in the lower approach are a topic that has been discussed with other Districts and also proposals have been submitted to perform research. There is minimal guidance for what the allowable forces should be for barges moored between the lower approach walls during emptying operations. Forces greater than 30 tons were measured during the tests at Lock 2 Arkansas River. Slowing the emptying time can reduce the forces, however at Lock 2 if the operation is too slow, the return surge in the canal causes high forces. Further studies should be performed to better understand the relationship between the emptying operation and the hawser forces in the lower approach. This problem is not specific to the Arkansas River Locks.

Navigation Issues in the Upper Lock Approaches

General Considerations

47. In order to perform an analysis of deeper draft tows (from 8.5 ft to 11.5 ft) and the potential impacts on navigation conditions in the upper lock approaches of the locks on the Arkansas River, a certain amount and type of field and office data were required. The data required were the following.

a. As-built detailed “drawing of the upper approach walls at each of the projects on the

Arkansas River system
b. Bathymetry data in the upper lock approaches at each of the projects on the Arkansas River system.

These data were provided by each of the district offices with jurisdiction on the Arkansas River system, i.e., Little Rock and Tulsa. These data were received in various formats from digital Cad "drawings to scanned tif images of the original as built "drawings.

48. After receiving these data from each of the district office, pertinent information for the data analysis, such as, pool elevation, guard wall length, elevation of the top of ports, and intercepted cross-sectional area, were extracted or computed. The following is a tabulation of the pertinent data that was extracted or computed from the information provided by the Little Rock and Tulsa District offices.

49. The references used to perform the analysis of deeper drafted tows and the potential impacts to the navigability at each of the projects were:

a. EM 1110-2-1611, Layout and Design of Shallow Draft Waterways
b. ERDC/CHL TR-04-4, Design Considerations for Upper Approaches to Navigation Locks

50. The following key points or ideas are found in EM 1110-2-1611, Chapter 10 (Design of Lock Approaches), Section 1 (Upper Lock Approach), paragraph 10-2 (Ports in Guard Walls).

a. Ports in the upper guard wall eliminate or reduce cross current ("outdraft") near the end of the guard wall by allowing a large portion of the flow intercepted by the wall to pass under the wall.
b. As a general rule, the ratio of the sum of the total cross-sectional area of the port in the wall to the sum of the intercepted cross-sectional flow area ($\Sigma A_{ports} / \Sigma A_{xs}$) should be about 1.0.
c. In most cases, the top of the ports in the guard wall should be placed about 4 to 6 ft below the bottom of a loaded barge.

The following key points or ideas are found in ERDC/CHL TR-04-4, Chapter 4 (Summary and Conclusions).

d. The results of numerous physical and numerical model experiments were combined to determine hydraulic considerations for the basic layout of multi-cell, long-span, and floating guard walls.
e. For specific wall type, i.e., multi-cell, long-span, and floating guard walls, the following ratios of the sum of the total cross-sectional area of the port in the wall to the sum of the intercepted cross-sectional flow area ($\Sigma A_{ports} / \Sigma A_{xs}$) were determined as a starting point for guard wall configurations.
   (a.) Multi-Cell Guard Wall: $\Sigma A_{ports} / \Sigma A_{xs} = 0.9$
   (b.) Long-Span Guard Wall: $\Sigma A_{ports} / \Sigma A_{xs} = 1.4$
   (c.) Floating Guard Wall: $\Sigma A_{ports} / \Sigma A_{xs} = 1.9$

51. The objective was to develop these ratios that would balance the "outdraft" (flow around the

upstream of guard wall) and "draw" towards the guard wall (flow pulling the tow towards the wall). Excessive "outdraft" would likely result in a downbound tow either being swept toward or around the upstream end of the guard wall or require a considerable amount of maneuvering to align with and enter the lock. Conversely, excessive "draw" towards the wall could result in downbound tows striking the wall with extreme force or impede an upbound tow from moving off the guard wall and proceeding upstream (pinning).

52. It should be noted that the target ratio of ΣA_{ports} / ΣA_{xs} that are shown in the US Army Engineer Research and Development Center (ERDC) TR-04-4 were developed for guard wall with circular cells that form the port in the guard wall. Some of the lock projects on the Arkansas River have circular cells forming the ports; however, quite a few of the lock projects have rectangular shape buttress that form the port in the guard. Therefore, the target ratios may not necessarily apply to guard walls that have rectangular buttress type port openings.

53. One would suspect that the shape of the entrance to the port in the guard wall would affect the hydraulic efficiency of the guard wall and how it allows passage of flow through the wall. With that in mind, one would think that due to the hydraulic inefficiencies in an almost purely rectangular shaped port entrance, the ΣA_{ports} would need to be larger to provide a satisfactory guard wall port design.

Data Analysis for Upper Approach Walls

54. There are 17 lock projects on the Arkansas River system. However, of the 17 lock projects, Norrell Lock and Dam (Pool 1) and Lock and Dam No 2 (Pool 2) were not considered in the analysis since both locks are located in the Post Canal and it is assumed that there is very little current moving in the lock approaches with exception of surges due to lock filling and emptying.

55. That leaves 15 lock projects that were used in the analysis. They are as follows:

a. Pool 3 – Joe Hardin
b. Pool 4 – Emmett Sanders
c. Pool 5
d. Pool 6 – David D. Terry
e. Pool 7 – Murray
f. Pool 8 – Toad Suck Ferry
g. Pool 9 – Arthur V. Ormond
h. Pool 10 – Dardanelle
i. Pool 11 – Ozark – Jeta Taylor
j. Pool 13 – James E. Trimble
k. Pool 14 – W. D. Mayo
l. Pool 15 – Robert S. Kerr
m. Pool 16 – Webbers Falls
n. Pool 17 – Chouteau
o. Pool 18 – Newt

56. Of the 15 lock projects, four of the projects have ported guard walls of similar design to what was referred to as a multi-cell guard wall. The support piers for the approach wall are

cylindrical in shape. The four locks are Emmett Sanders, David D. Terry, Robert S. Kerr, and Webbers Falls. Seven of the lock projects, Joe Hardin, Toad Suck Ferry, Ozark – Jeta Taylor, James E. Trimble, W.D. Mayo, Chouteau, and Newt, have ported guard walls that are similar to the multi-cell walls, but are different. These seven projects have guard walls that have large rectangular shaped support piers with rounded corners entering the port. These guard walls would more than likely perform very similar to the multi-cell wall with some deviation. Three of the lock projects, Lock 5, Murray, and Arthur V. Ormond, have ported guard walls that have narrow rectangular shaped support piers for the guard walls.

57. Table 12 shows pertinent information for the analysis. Information that was extracted from the data provided for each project was normal operating pool elevation, guard wall length, elevation of the top of ports, and approach bathymetry. If there exist a minimum operating pool at any of the projects, the effects on navigation should be considered; however, unless the minimum operating pool exist a large percentage of the time, the normal operating pool should be used. Information, such as the ΣA_{ports}, port height, ΣA_{xs}, and the ratio of the ΣA_{ports} / ΣA_{xs} were computed from the information that was provided. In some instances where there may not have been enough bathymetry information in shallow water areas, assumptions of 1 on 3 side slopes from the last bathymetric data point was shown. This was necessary to compute ΣA_{xs}. In order to compute the ΣA_{ports}, a uniform channel invert near the port openings was used. These two values were needed to determine an approximate value of the ratio of the ΣA_{ports} / ΣA_{xs}.

58. Table 12 was constructed to address the issue of clearance from the bottom of a loaded barge to the top of ports in the guard wall. The table shows clearance requirements with barges drafted 8.5 ft and 11.5 ft. The EM 1110-2-1611 suggests that the top of the ports be 4 to 6 ft below the bottom of loaded barge.

59. Using a loaded barge drafting 8.5 ft, ten, possibly eleven of the 15 lock projects on Arkansas River system currently meet the 4 to 6 ft clearance described in the EM. They are Joe Hardin, Emmett Sanders, Lock 5, David D. Terry, Murray, Toad Suck Ferry, Ozark – Jeta Taylor, James E. Trimble, Arthur V. Ormond, Robert S. Kerr, and Webbers Falls. Three of the 15 projects fail to meet the EM requirements. They are W.D. Mayo, Chouteau, and Newt.

60. Increasing the draft of a loaded barge to 11.5 ft, the data suggest that all 15 lock projects on the Arkansas River system would fail to meet the clearance requirement stated in the EM.

61. Using a target ratio for the ΣA_{ports} / ΣA_{xs} equal to about 0.9 or 1.0 as stated in the EM and the TR, Table 12 suggest that four of the lock projects have fairly balanced "outdraft" versus "draw" toward the guard wall since the ΣA_{ports} / ΣA_{xs} range from 0.8 to 1.2. They are Emmett Sanders, Toad Suck Ferry, and W.D. Mayo, and Robert S. Kerr.

62. Table 12 also suggest that Joe Hardin, Lock 5, David S. Terry, Ozark-Jeta Taylor, and Newt might have more "draw" towards the guard wall than the afore mentioned locks since the ratio of ΣA_{ports} / ΣA_{xs} range from 1.3 to 1.6. This indicates that the ports may be somewhat oversized allowing more flow through the wall. This would also indicate that the "outdraft" should be minimal.

63. The data also indicate that a substantial “outdraft” is likely at James E. Trimble and Webbers Falls, since the ratio of the ΣA_{ports} / ΣA_{xs} was 0.5 and 0.1, respectively. At projects where there is significant “outdraft”, “draw” towards the guard wall would usually be minimal.

Observations

64. Based only on the data provided for this analysis, the guidance set forth in EM 1110-2-1611 and ERDC/CHL-TR-04-4, and not having any other prototype data such as current directions and magnitudes in the upper lock approaches, tow track plots, or industry comments, the following observations are drawn for the upper approach guard walls at 15 lock projects on the Arkansas River system for the current vessel draft of 8.5 ft.

a. Three of the approach walls of the 15 lock projects on the Arkansas River system do not meet the suggested clearance of 4 to 6 ft between the bottom of the barge and the top of the ports. They are W.D. Mayo, Chouteau, and Newt.

b. Four of the approach walls appear to have fairly good guard wall design, in that the ratio of ΣA_{ports} / ΣA_{xs} is fairly close to 1.0. The four projects are Emmett Sanders, Toad Suck Ferry, W.D. Mayo, and Robert S. Ker

c. Five projects appear to have less “outdraft” and more “draw” towards the guard wall, in that the ratio of ΣA_{ports} / ΣA_{xs} ranged from 1.3 to 1.6. This would indicate that the ports in the guard wall could be slightly oversized and allow more flow through the wall. The five projects are Joe Hardin, Lock 5, David S. Terry, Ozark-Jeta Taylor, and Newt.

d. Two of the lock projects appear to have the potential for a significant outdraft problem in that the ratio of the ΣA_{ports} / ΣA_{xs} was 0.5 and 0.3. They are James E. Trimble and Webbers Fallslocks.

65. For the proposed vessel draft of 11.5 ft on the Arkansas River system, the following observations are drawn based only on the data provided for this analysis and the guidance set forth in EM 1110-2-1611 and ERDC/CHL-TR-04-4.

a. Deeper draft vessels would likely intensify any adverse effects to navigation, such as “outdraft” or “draw” towards the wall, that currently exist at the projects. If the lateral water-surface gradient remains the same at all the projects, forces produced by the vessel due to “outdraft” and “draw” towards the guard wall would likely increase. This could potentially result in tows striking the guard wall with more force or an upbound vessel being pinned against the wall.

b. All 15 projects on the river system would fail to meet the clearance requirements of 4 to 6 ft that is set forth in the EM.

(1.) At 3 of the projects, i.e., W.D. Mayo, Chouteau, and Newt, the bottom of the barge would be 0.5 ft to 4.5 ft below the top of the ports in the guard wall.

(2.) At 6 of the projects, i.e., Lock 5, Arthur V. Ormond, Ozark – Jeta Taylor, James E. Trimble, Robert S. Kerr, and Webber Falls, the bottom of the barge would be 0.5 ft to 1.5 ft above the top of the ports in the guard wall.

(3). At 5 of the project, i.e., Joe Hardin, Emmett Sanders, David S. Terry, Murray, and Toad Suck Ferry, the bottom of the barge would be 2.5 ft to 3.5 ft above the top of the ports in the guard wall.

c. At least according to the data and the computed values, it appears that deeper draft vessels on the waterway could potentially experience more difficult navigation conditions and possibly safety concerns at some of the lock projects on the waterway.

Recommendations and Conclusions for Upper Approach Analysis

66. Increasing the design vessel draft on Arkansas River system from 8.5 ft to 11.5 ft could have negative impacts on the existing navigation conditions for tows entering and leaving the upper lock approaches of the projects on the Arkansas River.

67. All other factors remaining the same, such as project operating procedures, stage-discharge relationship, other hydraulic factors, vessel horsepower, and vessels drafting 11.5 ft versus 8.5 ft would experience more difficult navigation conditions with regard to “outdraft”, “draw” towards the wall, or “pinning” on the wall.

68. Since some or all of the projects on the Arkansas River system could potentially experience ome negative impacts to the current navigation conditions at each of the projects, the ERDC recommends that additional discussions be conducted between representatives of the ERDC, Little Rock District, Tulsa District, and towing industry in order to determined navigation conditions at each of the projects on the Arkansas River. This would include discussions on the navigability of tow entering the upper lock approach, i.e., “outdraft”, “draw towards the wall”, and “pinning”. These discussions, along with guidance set forth in EM 1110-2-1611 and ERDC/CHL TR-04-4, will be used to determine AR locks having the highest potential for lock approach problems as a result of increased draft.

69. For locks having the highest potential for approach problems, the ERDC recommends the use of a physical model to evaluate the effects on navigation conditions for tow entering the upper lock approach for vessels drafting 8.5 ft versus 11.5 ft. Evaluation of increased draft effects may require only a single model study, but possibly as many as 4 model studies to answer the effects of deeper draft vessels on navigation conditions in the upper lock approaches. The number of model studies that are required will depend greatly on the outcome of the initial model study of increased draft effects.

TABLE 12

LOCK	Lock No.	River Mile	Approx. Wall Length	Pool Elev.	Elev. Top of Ports	Distance Port is Below Pool	Clearance from 8.5 ft draft barge to Top of Ports	Clearance from 11.5 ft draft barge to Top of Ports	Sum of Port Length	Approx. Height of Port	Sum of Area Port ΣA_{PORTS}	Intercepted X-Sect Area ΣA_{XS}	$\Sigma A_{PORTS} / \Sigma A_{XS}$
Norrell Lock and Dam	1	10.3	190.0	142.0	135.0	7.0	-1.5	-4.5					
Lock # 2	2	13.3	190.0	162.0	157.0	5.0	-3.5	-6.5					
Joe Hardin Lock and Dam (# 3)	3	50.2	540.0	182.0	168.0	14.0	5.5	2.5	300.9	20.0	6017.0	4277.0	1.4
Emmett Sanders L&D (# 4)	4	66.0	540.0	196.0	182.0	14.0	5.5	2.5	286.0	20.0	5720.0	5274.0	1.1
Lock and Dam # 5	5	86.3	540.0	213.0	200.0	13.0	4.5	1.5	320.0	24.5	7840.0	5129.0	1.5
David D. Terry L&D	6	108.1	540.0	231.0	217.0	14.0	5.5	2.5	304.0	17.0	5168.0	3906.0	1.3
Murray Lock and Dam	7	125.4	540.0	249.0	234.0	15.0	6.5	3.5	342.0				
Toad Suck Ferry Lock and Dam	8	155.9	540.0	265.0	251.0	14.0	5.5	2.5	262.5	21.0	5512.5	4467.0	1.2
Authur V. Ormand Lock and Dam	9	176.9	540.0	284.0	272.0	12.0	3.5	0.5	324.0				
Dardanelle Lock and Dam	10	205.5				0.0							
Ozark - Jeta Taylor Lock and Dam	11	256.8	540.0	370.0	357.0	13.0	4.5	1.5	321.5	20.0	6430.0	4051.5	1.6
James E. Trimble L & D (#13)	13	292.8	540.0	391.0	378.0	13.0	4.5	1.5	320.0	11.0	3520.0	7020.0	0.5
W. D. Mayo Lock and Dam (#14)	14	319.6	540.0	412.0	402.0	10.0	1.5	-1.5	250.0	22.0	5500.0	6710.0	0.8
Robert S. Kerr Lock and Dam (#15)	15	336.2	630.0	458.0	445.0	13.0	4.5	1.5	225.0	37.0	8325.0	10197.0	0.8
Webbers Falls Lock and Dam (#16)	16	366.6	250.0	487.0	474.0	13.0	4.5	1.5	89.0	4.0	356.0	3352.0	0.1
Chouteau Lock and Dam (#17)	17	401.4	190.0	511.0	500.0	11.0	2.5	-0.5	88.0				
Newt Lock and Dam (#18)	18	421.6	540.0	532.0	522.0	10.0	1.5	-1.5	263.0	21.0	5523.0	3352.0	1.6

NOTES:

1) Norrell Lock and Lock #2, i.e., Pools 1 and 2 were not used in the data analysis since they are located in the post canal.
2) Information on Dardanelle was not available at the time of this report.
3) Blank cells in the table are places where it was felt that to many assumptions were needed to compute the values or the information was not available.
4) Negative values in the clearance columns indicate that the bottom of the barge would be below the top of the port and positive would be above the top of the port.

70. A final technical report will be furnished at a later date if desired and will contain documentation for all the field tests. This report is intended to provide most of the final results, discussion, and recommendations. Please contact Drs. Steve Maynord (601) 634-3284, John Hite (601) 634-2402 or Mr. Howard Park (601) 634-4011 for additional information concerning this report.

APPENDIX A-4

Suspended and Bed Sediment Data
and 70,000 cfs Velocity Profiles
By USGS

Suspended Sediment Samples

Pool 2

Station number	Pool # & River Mile	mm-dd-yyyy	TIMES	Discharge, instantaneous, cubic feet per second	Temperature, water, degrees Celsius	Suspended sediment, fall diameter (deionized water), percent smaller than 0.063 millimeters	Suspended sediment, fall diameter (deionized water), percent smaller than 0.125 millimeters	Suspended sediment, fall diameter (deionized water), percent smaller than 0.25 millimeters	Suspended sediment, fall diameter (deionized water), percent smaller than 0.5 millimeters	Suspended sediment concentration, milligrams per liter	Suspended sediment load, tons per day
STATION		DATES	TIMES	P00061	P00010	P70342	P70343	P70344	P70345	P80154	P80155
340509091280901	2 - 33.0	1/27/2004	1630	66200	7.6	0	12	84	100	21	3700
340829091391101	2 - 48.1	1/27/2004	1100	72400	7.6	0	10	54	100	21	4110

Suspended Sediment Samples

Pool 6
N.M. 109.3

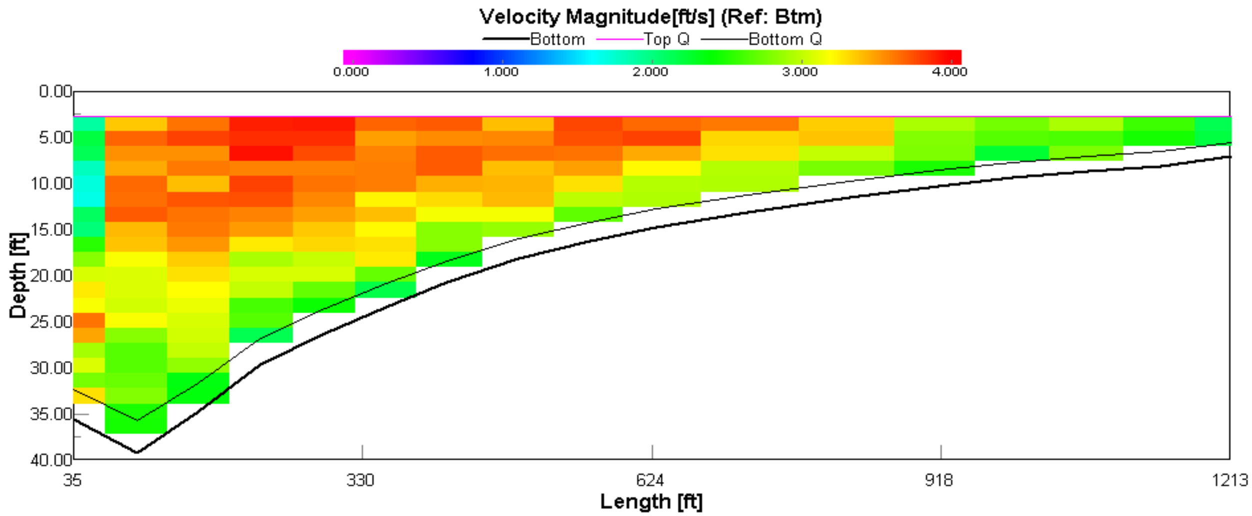
			Date as yyyy-mm-dd	Sample time	# P00061 Discharge, instantaneous, cubic feet per second	# P00010 Temperature, water, degrees Celsius	# P70342 Suspended sediment, fall diameter (deionized water), percent smaller than 0.063 millimeters	# P70343 Suspended sediment, fall diameter (deionized water), percent smaller than 0.125 millimeters	# P70344 Suspended sediment, fall diameter (deionized water), percent smaller than 0.25 millimeters	# P70345 Suspended sediment, fall diameter (deionized water), percent smaller than 0.5 millimeters	# P80154 Suspended sediment concentration, milligrams per liter	# P80155 Suspended sediment load, tons per day
Station Number	Latitude	Longitude	DATES	TIMES	P00061	P00010	P70342	P70343	P70344	P70345	P80154	P80155
07263620	34 40 07	92 09 18	20040310	0830	138000	12.1	83	87	94	100	72	26800

Pool 13
N.M. 292

			Date as yyyy-mm-dd	Sample time	# P00061 Discharge, instantaneous, cubic feet per second	# P00010 Temperature, water, degrees Celsius	# P70342 Suspended sediment, fall diameter (deionized water), percent smaller than 0.063 millimeters	# P70343 Suspended sediment, fall diameter (deionized water), percent smaller than 0.125 millimeters	# P70344 Suspended sediment, fall diameter (deionized water), percent smaller than 0.25 millimeters	# P70345 Suspended sediment, fall diameter (deionized water), percent smaller than 0.5 millimeters	# P80154 Suspended sediment concentration, milligrams per liter	# P80155 Suspended sediment load, tons per day
Station Number	Latitude	Longitude	DATES	TIMES	P00061	P00010	P70342	P70343	P70344	P70345	P80154	P80155
07250550	35 20 56	94 17 54	20040309	945	131000	12.9	88	92	96	100	217	76800

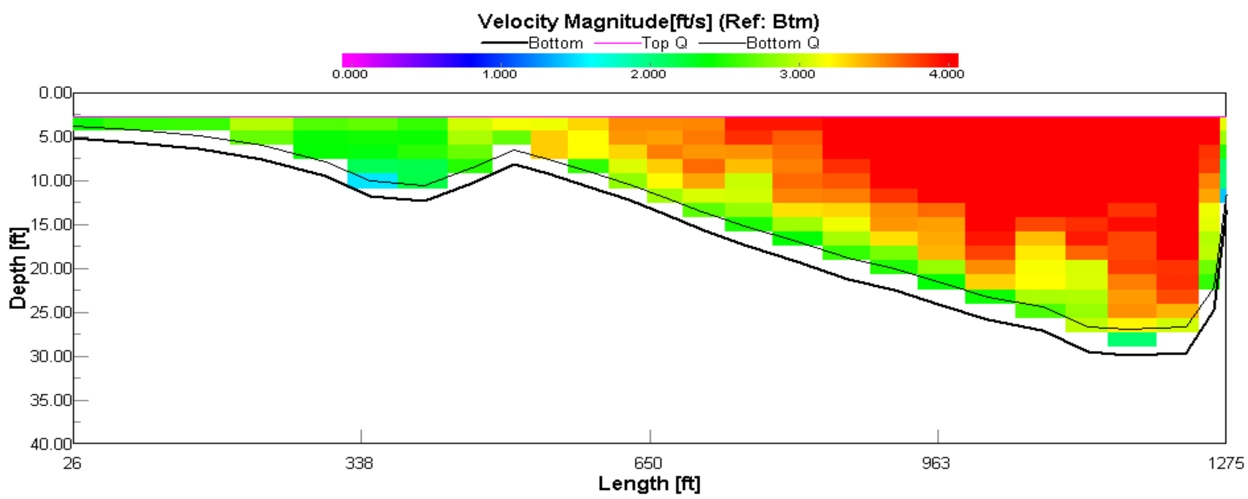
Pool 2 – NM 33

Velocity Profile – Q=70,000 cfs

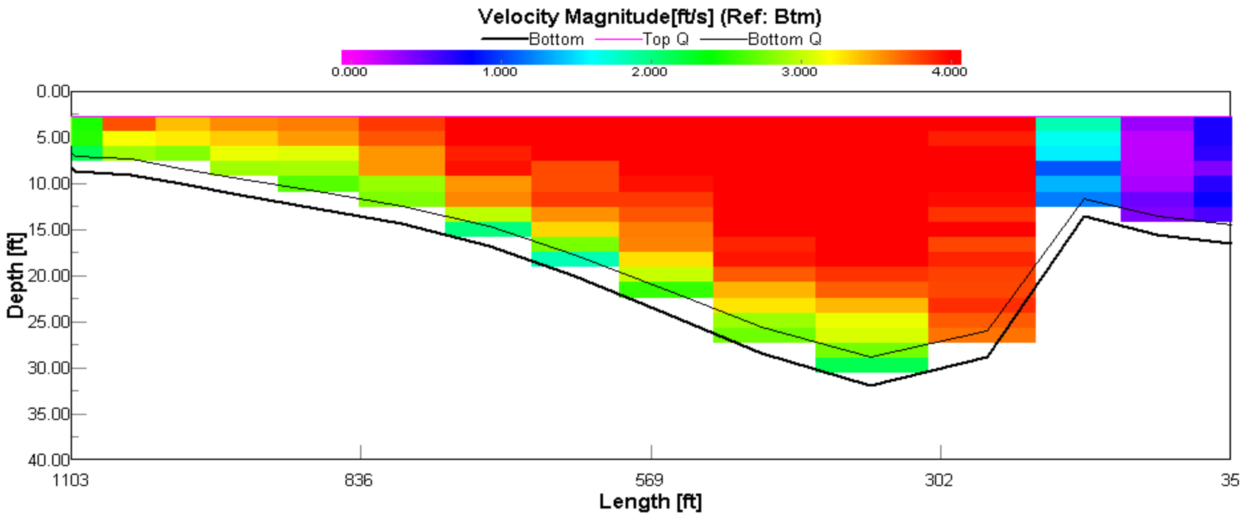


Pool 2 - NM 42

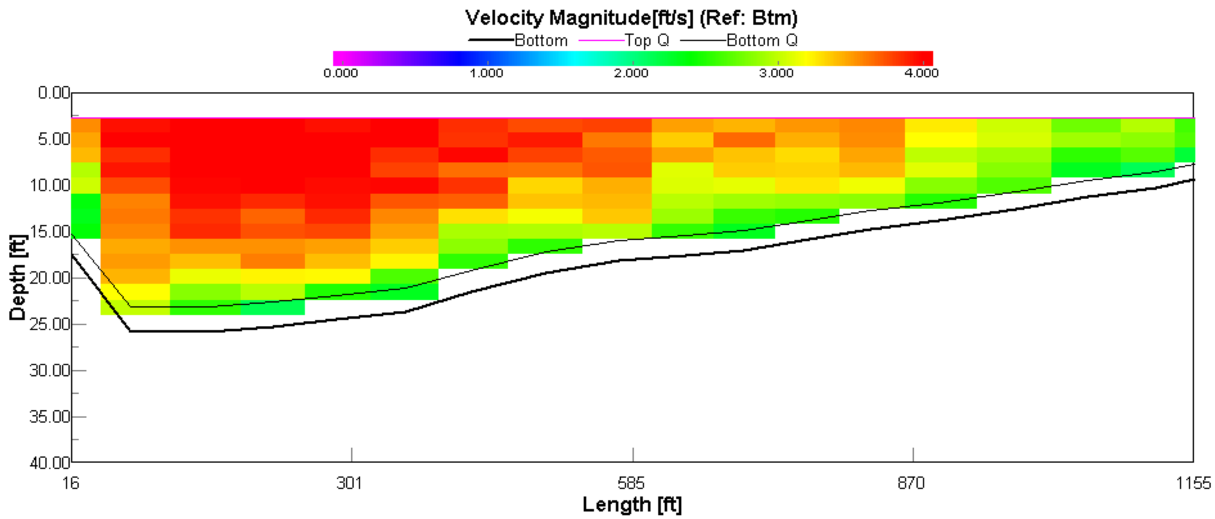
Velocity Profile – Q=70,000 cfs



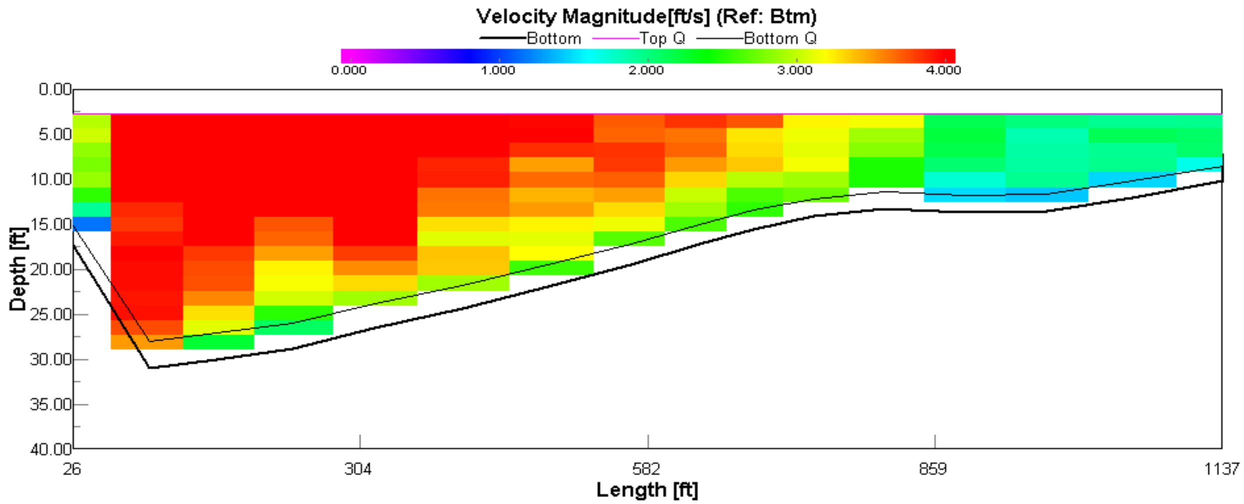
Pool 2 - NM 43
Velocity Profile – Q=70,000 cfs



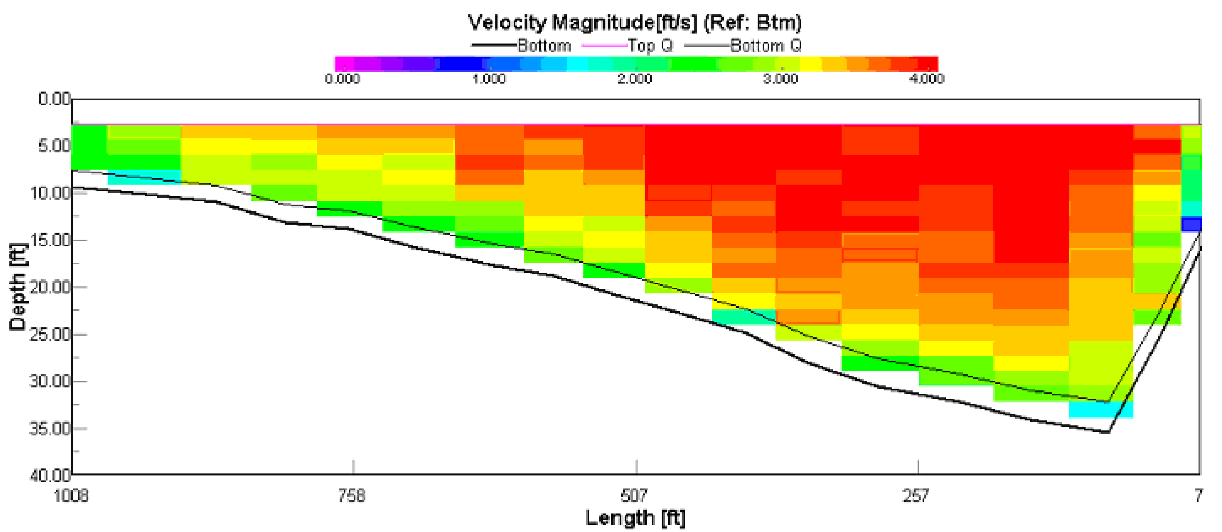
Pool 2 - NM 44
Velocity Profile – Q=70,000 cfs



Pool 2 - NM 45
Velocity Profile – Q=70,000 cfs



Pool 2 - NM 48
Velocity Profile – Q=70,000 cfs



Summation of Bed Sediment Sample Locations

ARKANSAS RIVER NAVIGATION STUDY - PHASE II					
Bed Sediment Sample Locations (Arkansas & Oklahoma)					
Obtained by USGS – Sep-Nov 2003					
	LOCATION				
	Bend	Crossing	Disposal Area	Lock App	Total
POOL #2					
NM	22.8	23.2	23.2L		
NM	22.9	28.2	27.2L		
NM	27.0	28.5	28.3L		
NM	31.6	33.0	32.3L		
NM	32.0	36.3	32.3R		
NM	35.0	40.3	36.4L		
NM	37.0	43.4	38.0L		
NM	42.0	43.5	43.8L		
NM	42.5	43.6	47.0L		
NM	44.0	46.3	49.7R		
NM	44.5	48.1			
NM	45.0				
NM	49.0			49.75	
					35
POOL #3					
NM	55.5	61.2		50.3	
NM	58.0	61.5			
NM	61.0	65.2			
NM	62.5				
NM	64.2			65.6	
					10
POOL #4					
NM	81.0	79.0	70.4L	66.2	
NM	83.0	79.2			
NM	84.0	79.4			
NM	85.0	79.6			
NM		79.8			
NM		80.0		85.9	
					13
POOL #5					
NM	91.3	96.2	95.7L	86.5	
NM	94.7	96.3	103.0L		
NM	95.0	96.6	107.0L		

NM	98.1	96.7			
NM	100.0	96.9			
NM	101.0	97.4			
NM	103.0	99.2			
NM	105.7	101.5			
NM		101.7			
NM		102.0			
NM		106.7		107.75	
					24
POOL #6					
NM				124.9	
					1
POOL #7					
NM	128.1	126.7	126.7L	125.5	
NM	130.0	128.8	134.5L		
NM	133.5	130.7	138.2L		
NM	136.5	131.8	142.0R		
NM	140.5	135.1	150.5L		
NM	145.0	135.3	152.0R		
NM	147.0	137.6	154.0R		
NM	147.5	138.8	154.1L		
NM	150.0	142.6			
NM	152.5	142.9			
NM	154.5	145.3			
NM		145.8			
NM		146.0			
NM		146.2			
NM		146.7		155.35	
					36
POOL# 8					
NM	166.0	164.6	171.0L	155.95	
NM	169.0	164.8	175.2R		
NM	169.5	165.0			
NM	170.0	165.9			
NM	171.5	167.0			
NM	174.0	170.8			
NM	175.0	171.8			
NM		172.5			
		175.7		176.35	
					20
POOL #9					
NM	182.2	181.0	183.2R	177.0	

NM	182.4	181.4	188.5R		
NM	182.8	181.7	189.6L		
NM	183.0	184.5	194.0L		
NM	184.0	185.0	201.0L		
NM	187.0	185.2			
NM	188.0	186.4			
NM	190.0	186.9			
NM	190.5	188.7			
NM	190.8	189.5			
NM	194.0	191.8			
NM	195.0	192.8			
NM	199.0	193.7			
NM	200.0	196.1			
NM	202.0	197.5			
NM	203.0	198.0		204.6	
NM	204.0	201.3		204.8	
					42
Dardanelle					
NM	228.0	221.8	230.0L	205.6	
NM	232.3	222.8	230.0R		
NM	234.0	223.0	236.0R		
NM	235.0	224.0	239.0L		
NM	237.0	225.0	245.7L		
NM	238.0	229.8	248.0R		
NM	240.5	231.0			
NM	241.0	233.9			
NM	243.0	236.1			
NM	245.0	236.3			
NM	247.0	237.6			
NM	249.0	238.9			
NM	251.0	240.8			
NM	252.0	241.9			
NM	253.0	244.0			
NM	255.0	246.1			
NM		248.0			
NM		249.6			
NM		249.8			
NM		253.7			
NM		254.0			
NM		256.0		256.2	**46**

Ozark					
NM	276.0	271.7	279.4L	256.9	
NM	277.0	272.5	282.7L		
NM	278.0	275.4	283.0R		
NM	280.0	278.7	285.8R		
NM	282.0	279.7	290.5R		
NM	283.0	280.3			
NM	284.5	281.0			
NM	286.5	283.7			
NM	288.6	284.0			
NM	289.5	285.3			
NM	291.5	290.3			
NM	292.0			292.3	**30**
NM					
POOL #13					
NM	312.0	314.3	310.0R	292.9	
NM	313.0	314.5	314.0R		
NM	315.0		318.0L		
NM	316.0				
NM	317.0				
NM	318.0				
NM	319.0				**13**
POOL #14					
NM					**0**
POOL #15					
SBC		6.0			
SBC		6.4			
SBC		6.8			
SBC		7.0			
SBC		7.2			
SBC		7.6			
NM	351.0	348.0			
NM	352.0	348.5			
NM	354.0	349.0			
NM	355.0	353.0			
NM	358.2	353.4			
NM	361.3	355.6			
NM	362.0	356.0			
NM	364.0	357.0			
NM		358.8			
NM		360.0			

NM		360.7			
NM		362.5			
NM		364.7			
NM		365.8			**28**
POOL #16					
NM	394.2	392.0			
NM	394.5	392.6			
NM	394.8	393.0			
NM	395.5	393.3			
NM	396.0	394.8			
NM	397.0	398.0			
NM	398.6	399.0			
NM	400.6	399.8			
		401.0			**17**
POOL #17					
NM					**0**
POOL #18					
NM	445.0	443.7			
NM		444.0			
NM		444.2			
NM		444.5			
NM		444.7			**6**
TOTAL					**321**

POOL 2

BED SEDIMENT SAMPLES

				Date as yyyy-mm-dd	Sample time	# P00010 Temperature, water, degrees Celsius	# P00540 Residue, fixed nonfilterable, as %	# P00530 Residue, total nonfilterable, as %	# P00535 Loss on ignition, from nonfilterable residue, as %	# P80164 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.063 millimeters	# P80165 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.125 millimeters	# P80166 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.25 millimeters	# P80167 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.5 millimeters	# P80168 Bed sediment, dry sieved, sieve diameter, percent smaller than 1 millimeter	# P80169 Bed sediment, dry sieved, sieve diameter, percent smaller than 2 millimeters	# P80170 Bed sediment, dry sieved, sieve diameter, percent smaller than 4 millimeters	# P80171 Bed sediment, dry sieved, sieve diameter, percent smaller than 8 millimeters	# P80172 Bed sediment, dry sieved, sieve diameter, percent smaller than 16 millimeters	# P80181 Total sediment, fall diameter (deionized water), percent smaller than 0.002 millimeters	# P80182 Total sediment, fall diameter (deionized water), percent smaller than 0.004 millimeters	# P80183 Total sediment, fall diameter (deionized water), percent smaller than 0.008 millimeters	# P80184 Total sediment, fall diameter (deionized water), percent smaller than 0.016 millimeters	# P80185 Total sediment, fall diameter (deionized water), percent smaller than 0.031 millimeters
Station Number	Latitude	Longitude	Pool # & River Mile	DATES	TIMES	P00010	P00540	P00530	P00535	P80164	P80165	P80166	P80167	P80168	P80169	P80170	P80171	P80172	P80181	P80182	P80183	P80184	P80185
335848091231601	33 58 48	91 23 16	2 - 22.8	20030923	0720	25.3	100	77	0	0	1	17	96	100									
335850091232101	33 58 50	91 23 21	2 - 22.9	20030923	0730	25.3	100	76	0	0	0	14	95	100									
335900091234001	33 58 01	91 23 40	2 - 23.2	20030923	0740	25.3	100	77	0	0	0	13	100										
335921091234101	33 59 21	91 23 41	2 - 23.2 L	20030923	0750		100	75	0	1	7	51	96	100									
340125091261201	34 01 25	91 26 12	2 - 27.0	20030923	0800	25.2	100	79	0	0	0	13	88	100									
340149091261001	34 01 49	91 26 10	2 - 27.2 L	20030923	0830		100	74	0	0	0	7	90	100									
340229091260501	34 02 29	91 26 05	2 - 28.2	20030923	0845	25.3	100	79	0	0	0	11	97	99	100								
340233091255501	34 02 33	91 25 55	2 - 28.3 L	20030923	0900		100	77	0	3	6	15	75	99	100				1	1	1	2	1.8
340249091260001	34 02 49	91 25 60	2 - 28.5	20030323	0910	25.3	100	79	0	0	0	8	87	98	100								
340503091265901	34 05 03	91 26 59	2 - 31.6	20030923	0925	25.3	100	78	0	0	0	24	92	100									
340509091271501	34 05 09	91 27 15	2 - 32.0	20030923	0930	25.3	100	77	0	0	0	15	86	99	100								
340515091272801	34 05 15	91 27 28	2 - 32.3 L	20030923	0940		100	78	0	0	1	55	100										
340509091273401	34 05 09	91 27 34	2 - 32.3 R	20030923	0955		100	76	0	0	0	10	93	100									
340509091280901	34 05 09	91 28 09	2 - 33.0	20030923	1005	25.3	100	74	0	0	0	33	100										
340424091301401	34 04 24	91 30 14	2 - 35.0	20030923	1020	25.3	100	78	0	0	0	10	82	98	100								
340508091311001	34 05 08	91 31 10	2 - 36.3	20030923	1035	25.3	100	76	0	0	0	16	94	100									
340513091310901	34 05 13	91 31 09	2 - 36.4 L	20030923	1040		100	78	0	0	4	41	99	100									
340535091313201	34 05 35	91 31 32	2 - 37.0	20030923	1045	25.4	100	76	0	0	0	18	88	99	100								
340618091323501	34 06 18	91 32 35	2 - 38.0 L	20030923	1105		99	58	1	3	13	67	98	99	100				1	1	1	1	1.8
340549091342701	34 05 49	91 34 27	2 - 40.3	20030923	1120	25.4	100	75	0	0	0	15	99	100									
340510091360001	34 05 10	91 35 60	2 - 42.0	20030923	1200	25.5	100	78	0	0	0	14	91	100									
340522091362401	34 05 22	91 36 24	2 - 42.5	20030923	1210	25.5	100	79	0	0	0	18	93	100									
340622091362601	34 06 22	91 36 26	2 - 43.4	20030923	1215	25.5	100	81	0	0	0	3	84	99	100								
340628091362401	34 06 28	91 36 24	2 - 43.5	20030923	1225	25.5	100	77	0	0	0	5	95	100									
340637091362101	34 06 37	91 36 21	2 - 43.6	20030923	1230	25.5	100	79	0	0	0	5	96	99	99	100							
340640091361701	34 06 40	91 36 17	2 - 43.8 L	20030923	1240		100	79	0	0	1	10	69	93	95	95	98	100					
340650091362001	34 06 50	91 36 20	2 - 44.0	20030923	1250	25.6	100	78	0	0	0	9	86	97	99	100							
340702091361901	34 07 02	91 36 19	2 - 44.5	20030923	1315	25.7	100	78	0	0	0	8	87	99	100								
340732091363301	34 07 32	91 36 33	2 - 45.0	20030923	1320	25.7	100	77	0	0	0	9	92	100									
340805091373401	34 08 05	91 37 34	2 - 46.3	20030923	1330	25.7	100	78	0	0	0	11	92	100									
340812091381601	34 0812	91 38 16	2 - 47.0 L	20030923	1340		100	75	0	0	1	17	96	100									
340829091391101	34 08 29	91 39 11	2 - 48.1	20030923	1355	25.7	100	77	0	0	0	9	92	100									
340915091394801	34 09 15	91 39 48	2 - 49.0	20030923	1400	25.7	100	76	0	0	0	5	85	99	100								
340925091401601	34 09 25	91 40 16	2 - 49.7 R	20030923	1410		100	79	0	0	1	20	81	99	100								
340939091402401	34 09 39	91 40 24	2 - 49.75 LA	20030923	1420	25.9	100	67	0	0	2	26	92	100									

POOL 3

BED SEDIMENT SAMPLES

				Date as yyyy-mm-dd	Sample time	# P00010 Temperature, water, degrees Celsius	# P00540 Residue, fixed nonfilterable, as %	# P00530 Residue, total nonfilterable, as %	# P00535 Loss on ignition, from nonfilterable residue, as %	# P80164 Bed sediment, dry sieved, sieve diameter,	# P80165 Bed sediment, dry sieved, sieve diameter,	# P80166 Bed sediment, dry sieved, sieve diameter,	# P80167 Bed sediment, dry sieved, sieve diameter,	# P80168 Bed sediment, dry sieved, sieve diameter,	# P80169 Bed sediment, dry sieved, sieve diameter,	# P80170 Bed sediment, dry sieved, sieve diameter,	# P80171 Bed sediment, dry sieved, sieve diameter,	# P80172 Bed sediment, dry sieved, sieve diameter,	# P80181 Total sediment, fall diameter (deionized water),	# P80182 Total sediment, fall diameter (deionized water),	# P80183 Total sediment, fall diameter (deionized water),	# P80184 Total sediment, fall diameter (deionized water),	# P80185 Total sediment, fall diameter (deionized water),
Station Number	Latitude	Longitude	Pool # & River Mile	Dates	TIMES	P00010	P00540	P00530	P00535	P80164	P80165	P80166	P80167	P80168	P80169	P80170	P80171	P80172	P80181	P80182	P80183	P80184	P80185
340955091405201	34 09 55	91 40 52	3 - 50.3 LA	20030922	1115	25.4	100	75	0	1	2	6	60	98	100				1	1	1	1	1
341003091453501	34 10 03	91 45 35	3 - 55.5	20030922	1145	25.5	100	77	0	0	0	8	85	97	99	100							
341204091470701	34 12 04	91 47 07	3 - 58.0	20030922	1200	25.5	100	77	0	0	0	9	93	99	99	100							
341251091500101	34 12 51	91 50 01	3 - 61.0	20030922	1220	25.5	100	76	0	0	0	16	84	98	99	99	100						
341257091501101	34 12 57	91 50 11	3 - 61.2	20030922	1230	25.4	100	76	0	0	0	12	90	100									
341312091502601	34 13 12	91 50 26	3 - 61.5	20030922	1235	25.7	100	76	0	0	0	12	79	95	97	98	100						
341338091511701	34 13 38	91 51 17	3 - 62.5	20030922	1245	25.2	100	78	0	0	0	9	78	97	100								
341353091530801	34 13 53	91 53 08	3 - 64.2	20030922	1255	25.7	100	77	0	0	0	2	63	96	100								
341419091535601	34 14 19	91 53 56	3 - 65.2	20030922	1305	25.9	100	80	0	0	0	5	60	87	93	94	97	100					
341433091540901	34 14 33	91 54 09	3 - 65.6 LA	20030922	1315	26.1	100	74	0	2	6	41	96	100					1	1	1	1	1

POOL 4

BED SEDIMENT SAMPLES

				Date as yyyy-mm-dd	Sample time	# P00010 Temperature, water, degrees Celsius	# P00540 Residue, fixed nonfilterable, as %	# P00530 Residue, total nonfilterable, as %	# P00535 Loss on ignition, from nonfilterable residue, as %	# P80164 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.063 millimeters	# P80165 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.125 millimeters	# P80166 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.25 millimeters	# P80167 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.5 millimeters	# P80168 Bed sediment, dry sieved, sieve diameter, percent smaller than 1 millimeter	# P80169 Bed sediment, dry sieved, sieve diameter, percent smaller than 2 millimeters	# P80170 Bed sediment, dry sieved, sieve diameter, percent smaller than 4 millimeters	# P80171 Bed sediment, dry sieved, sieve diameter, percent smaller than 8 millimeters	# P80172 Bed sediment, dry sieved, sieve diameter, percent smaller than 16 millimeters	# P80181 Total sediment, fall diameter (deionized water), percent smaller than 0.002 millimeters	# P80182 Total sediment, fall diameter (deionized water), percent smaller than 0.004 millimeters	# P80183 Total sediment, fall diameter (deionized water), percent smaller than 0.008 millimeters	# P80184 Total sediment, fall diameter (deionized water), percent smaller than 0.016 millimeters	# P80185 Total sediment, fall diameter (deionized water), percent smaller than 0.031 millimeters
Station Number	Latitude	Longitude	Pool # & River Mile	DATES	TIMES	P00010	P00540	P00530	P00535	P80164	P80165	P80166	P80167	P80168	P80169	P80170	P80171	P80172	P80181	P80182	P80183	P80184	P80185
341504091542701	34 15 04	91 54 27	4 - 66.2 LA	20031105	1530	20.6	99	69	1	12	42	99	100						3	4	5	6	8
341754091561201	34 17 54	91 56 12	4 - 70.4 L	20031105	1405		100	74	0	1	16	90	100										
341929092031101	34 19 29	92 03 11	4 - 79.0	20031105	1450	20.6	100	79	0	0	0	4	79	99	100								
341941092032101	34 19 41	92 03 21	4 - 79.2	20031105	1445	20.6	100	77	0	0	0	3	54	88	96	98	100						
341949092032701	34 19 49	92 03 27	4 - 79.4	20031105	1440	20.6	100	77	0	0	0	2	54	90	96	99	100						
342001092033501	34 20 01	92 03 35	4 - 79.6	20031105	1435	20.6	100	78	0	0	0	5	57	99	100								
342010092034101	34 20 10	92 03 41	4 - 79.8	20031105	1430	20.6	100	77	0	0	0	4	74	95	99	100							
342017092034501	34 20 17	92 03 45	4 - 80.0	20031105	1425	20.6	100	76	0	0	0	6	79	95	98	100							
342108092040601	34 21 08	92 04 06	4 - 81.0	20031105	1420	20.5	100	76	0	0	0	6	67	90	91	92	93	100					
342249092035601	34 22 49	92 03 56	4 - 83.0	20031105	1410	20.5	100	77	0	0	0	10	96	100									
342332092040901	34 23 32	92 04 09	4 - 84.0	20031105	1405	20.5	99	76	1	0	0	3	76	99	100								
342412092045701	34 24 12	92 04 57	4 - 85.0	20031105	1400	20.5	100	78	0	0	0	3	79	98	100								
342433092054101	34 24 33	92 05 41	4 - 85.9	20031105	1350	20.5	100	76	0	0	2	40	96	99	99	100							

POOL 5

BED SEDIMENT SAMPLES

				Date as yyyy-mm-dd	Sample time	# P00010 Temperature, water, degrees Celsius	# P00540 Residue, fixed nonfilterable, as %	# P00530 Residue, total nonfilterable, as %	# P00535 Loss on ignition, from nonfilterable residue, as %	# P80164 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.063 millimeters	# P80165 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.125 millimeters	# P80166 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.25 millimeters	# P80167 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.5 millimeters	# P80168 Bed sediment, dry sieved, sieve diameter, percent smaller than 1 millimeter	# P80169 Bed sediment, dry sieved, sieve diameter, percent smaller than 2 millimeters	# P80170 Bed sediment, dry sieved, sieve diameter, percent smaller than 4 millimeters	# P80171 Bed sediment, dry sieved, sieve diameter, percent smaller than 8 millimeters	# P80172 Bed sediment, dry sieved, sieve diameter, percent smaller than 16 millimeters	# P80173 Bed sediment, dry sieved, sieve diameter, percent smaller than 32 millimeters	# P80181 Total sediment, fall diameter (deionized water), percent smaller than 0.002 millimeters	# P80182 Total sediment, fall diameter (deionized water), percent smaller than 0.004 millimeters	# P80183 Total sediment, fall diameter (deionized water), percent smaller than 0.008 millimeters	# P80184 Total sediment, fall diameter (deionized water), percent smaller than 0.016 millimeters	# P80185 Total sediment, fall diameter (deionized water), percent smaller than 0.031 millimeters
Station Number	Latitude	Longitude	Pool# & River Mile	DATES	TIMES	P00010	P00540	P00530	P00535	P80164	P80165	P80166	P80167	P80168	P80169	P80170	P80171	P80172	P80173	P80181	P80182	P80183	P80184	P80185
342452092061501	34 24 52	92 06 15	5 - 86.5 LA	20031105	1130	20	100	36	0	4	6	22	39	40	45	59	79	100		3	3	3	3	4
342817092063501	34 28 17	92 06 35	5 - 91.3	20031105	1115	20	100	84	0	0	0	2	47	92	98	99	100							
343007092090001	34 30 07	92 09 00	5 - 94.7	20031105	1055	20	100	78	0	0	0	16	92	99	100									
343019092085801	34 30 19	92 08 58	5 - 95.0	20031105	1050	20	100	78	0	0	0	14	84	98	99	99	100							
343025092084601	34 30 25	92 08 46	5 - 95.7 L	20031105	1035		100	78	0	0	0	14	92	100										
343116092083301	34 31 16	92 08 33	5 - 96.2	20031105	1025	20	100	79	0	0	0	6	60	98	100									
343122092083001	34 31 22	92 08 30	5 - 96.3	20031105	1020	20	100	76	0	0	0	6	87	100										
343128092082801	34 31 28	92 08 28	5 - 96.6	20031105	1015	20	100	78	0	0	0	6	78	99	100									
343134092082401	34 31 34	92 08 24	5 - 96.7	20031105	1010	20	100	76	0	0	0	5	52	89	96	98	100							
343144092081801	34 31 44	92 08 18	5 - 96.9	20031105	1005	20	100	80	0	0	0	4	49	90	98	99	100							
343210092080401	34 32 10	92 08 04	5 - 97.4	20031105	1000	20	88	82	12	0	0	7	63	95	99	100								
343253092081401	34 32 53	92 08 14	5 - 98.1	20031105	0955	20	100	80	0	0	0	7	65	98	100									
343329092090901	34 33 29	92 09 09	5 - 99.2	20031105	0945	20	100	78	0	0	0	1	62	95	100									
343354092095501	34 33 54	92 09 55	5 - 100.0	20031105	0940	20	100	80	0	0	0	3	68	98	100									
343441092100701	34 34 41	92 10 07	5 - 101.0	20031105	0935	20	100	77	0	0	0	4	53	82	89	92	95	100						
343507092095401	34 35 07	92 09 54	5 - 101.5	20031105	0930	20	100	80	0	0	0	4	64	93	98	99	100							
343515092094401	34 35 15	92 09 44	5 - 101.7	20031105	0925	20	100	80	0	0	0	6	72	95	99	100								
343528092093101	34 35 28	92 09 31	5 - 102.0	20031105	0920	20	100	80	0	0	0	8	58	80	86	90	93	100						
343605092091101	34 36 05	92 09 11	5 - 103.0	20031105	0905	20	100	79	0	0	0	3	57	94	98	100								
343609092090201	34 36 09	92 09 02	5 - 103.0 L	20031105	0855		100	76	0	0	1	16	94	100										
343803092102301	34 38 03	92 10 23	5 - 105.7	20031105	0845	20	100	74	0	0	0	6	37	54	61	69	81	100						
343901092100301	34 39 01	92 10 03	5 - 106.7	20031105	0835	20	100	79	0	0	0	0	24	84	93	95	98	100						
343910092094601	34 39 10	92 09 46	5 - 107.0 L	20031105	0825		100	77	0	0	1	5	25	76	90	95	97	100						
343944092092901	34 39 44	92 09 29	5 - 107.75 LA	20031105	0820	20	99	75	1	2	8	18	35	76	90	94	97	97	100	1	1	1	1	1

POOL 7

BED SEDIMENT SAMPLES

				Date as yyyy-mm-dd	Sample time	# P00010 Temperature, water, degrees Celsius	# P00540 Residue, fixed nonfilterable, as %	# P00530 Residue, total nonfilterable, as %	# P00535 Loss on ignition, from nonfilterable residue, as %	# P80164 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.063 millimeters	# P80165 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.125 millimeters	# P80166 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.25 millimeters	# P80167 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.5 millimeters	# P80168 Bed sediment, dry sieved, sieve diameter, percent smaller than 1 millimeter	# P80169 Bed sediment, dry sieved, sieve diameter, percent smaller than 2 millimeters	# P80170 Bed sediment, dry sieved, sieve diameter, percent smaller than 4 millimeters	# P80171 Bed sediment, dry sieved, sieve diameter, percent smaller than 8 millimeters	# P80172 Bed sediment, dry sieved, sieve diameter, percent smaller than 16 millimeters	# P80181 Total sediment, fall diameter (deionized water), percent smaller than 0.002 millimeters	# P80182 Total sediment, fall diameter (deionized water), percent smaller than 0.004 millimeters	# P80183 Total sediment, fall diameter (deionized water), percent smaller than 0.008 millimeters	# P80184 Total sediment, fall diameter (deionized water), percent smaller than 0.016 millimeters	# P80185 Total sediment, fall diameter (deionized water), percent smaller than 0.031 millimeters
Station Number	Latitude	Longitude	Pool # & River Mile	DATES	TIMES	P00010	P00540	P00530	P00535	P80164	P80165	P80166	P80167	P80168	P80169	P80170	P80171	P80172	P80181	P80182	P80183	P80184	P80185
344730092214201	34 47 30	92 21 42	7 - 125.5 LA	20031104	1420	20.9	100	74	0	4	4	8	96	100					2	2	3	3	3
344822092221901	34 48 22	92 22 19	7 - 126.7 L	20031104	1410		99	68	1	0	2	20	89	98	99	100							
344833092224701	34 48 33	92 22 47	7 - 126.7	20031104	1405	20.9	100	75	0	8	16	59	80	84	87	90	93	100	2	2	2	3	4
344911092232001	34 49 11	92 23 20	7 - 128.1	20031104	1355	20.9	100	74	0	0	0	6	63	91	97	100							
344915092240701	34 49 15	92 24 07	7 - 128.8	20031104	1345	20.9	100	72	0	0	1	20	97	98	99	100							
344926092251201	34 49 26	92 25 12	7 - 130.0	20031104	1340	20.9	100	77	0	0	0	6	84	98	100								
345008092254201	34 50 08	92 25 42	7 - 130.7	20031104	1330	20.9	100	71	0	0	0	4	72	93	99	100							
345039092262101	34 50 39	92 26 21	7 - 131.8	20031104	1320	20.9	100	76	0	0	0	5	77	97	100								
345122092273701	34 51 22	92 27 37	7 - 133.5	20031104	1310	20.9	100	77	0	0	0	10	86	98	99	100							
345209092274401	34 50 09	92 27 44	7 - 134.5 L	20031104	1255		99	76	1	3	20	83	100										
345248092273901	34 52 48	92 27 39	7 - 135.1	20031104	1250	20.8	100	74	0	0	1	6	55	69	71	72	76	100					
345300092272601	34 53 00	92 27 26	7 - 135.3	20031104	1245	20.8	100	78	0	0	0	6	81	98	100								
345359092270401	34 53 59	92 27 04	7 - 136.5	20031104	1235	20.8	100	80	0	0	0	4	65	90	97	100							
345459092273001	34 54 59	92 27 30	7 - 137.6	20031104	1230	20.8	100	78	0	0	0	2	65	98	100								
345513092273801	34 55 13	92 27 38	7 - 138.2 L	20031104	1225		100	79	0	0	0	0	1	63	94	98	100						
345544092275801	34 55 44	92 27 58	7 - 138.8	20031104	1215	20.8	100	79	0	0	0	1	58	87	96	100							
345700092302401	34 57 00	92 30 24	7 - 142.0 R	20031104	1150		99	66	1	2	8	47	96	100									
345701092284201	34 57 01	92 28 42	7 - 140.5	20031104	1200	20.8	100	79	0	0	0	3	50	82	94	99	100						
345705092311201	34 57 05	92 31 12	7 - 142.9	20031104	1135	20.7	100	81	0	0	0	2	71	96	100								
345707092305301	34 57 07	92 30 53	7 - 142.6	20031104	1140	20.7	100	81	0	0	0	2	67	94	99	100							
345716092331001	34 57 16	92 33 10	7 - 145.0	20031104	1125	20.7	100	79	0	0	0	1	24	72	91	97	99	100					
345721092333101	34 57 21	92 33 31	7 - 145.3	20031104	1115	20.7	100	81	0	0	0	1	22	82	92	93	95	100					
345732092335701	34 57 32	92 33 57	7 - 145.8	20031104	1110	20.7	99	84	1	0	0	2	14	49	80	91	97	100					
345733092335601	34 57 33	92 33 56	7 - 146.0	20031104	1100	20.7	100	81	0	0	0	2	23	58	73	83	88	100					
345744092342001	34 57 44	92 34 20	7 - 146.2	20031104	1055	20.7	100	81	0	0	0	0	21	89	98	100							
345804092345001	34 58 04	92 34 50	7 - 146.7	20031104	1050	20.6	100	80	0	0	0	0	26	82	94	98	100						
345820092350601	34 58 20	92 35 06	7 - 147.0	20031104	1045	20.6	100	80	0	0	0	1	33	82	96	98	99	100					
345841092352301	34 58 41	92 35 23	7 - 147.5	20031104	1035	20.6	100	79	0	0	0	2	31	73	91	96	100						
350039092354401	35 00 39	92 35 44	7 - 150.0	20031104	1015	20.6	100	77	0	0	0	1	70	96	100								
350053092351601	35 00 53	92 35 16	7 - 150.5 L	20031104	1000		100	78	0	0	1	16	97	100									
350157092340501	35 01 57	92 34 05	7 - 152.0 R	20031104	0950		100	83	0	0	1	21	79	92	96	98	100						
350205092334101	35 02 05	92 33 41	7 - 152.5	20031104	0940	20.4	100	79	0	0	0	0	48	90	98	100							
350312092324201	35 03 12	92 32 42	7 - 154.1 L	20031104	0905		100	82	0	0	0	0	12	56	83	96	99	100					
350320092325401	35 03 20	92 32 54	7 - 154.0 R	20031104	0915		100	77	0	0	6	63	99	100									
350335092323701	35 03 35	92 32 37	7 - 154.5	20031104	0900	20.5	100	80	0	0	0	2	19	88	98	100							
350401092322801	35 04 01	92 32 28	7 - 155.35 LA	20031104	0855	20.5	100	79	0	0	0	0	9	75	97	99	100						

POOL 8

BED SEDIMENT SAMPLES

				Date as yyyy-mm-dd	Sample time	# P00010 Temperature, water, degrees Celsius	# P00540 Residue, fixed nonfilterable, as %	# P00530 Residue, total nonfilterable, as %	# P00535 Loss on ignition, from nonfilterable residue, as %	# P80164 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.063 millimeters	# P80165 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.125 millimeters	# P80166 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.25 millimeters	# P80167 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.5 millimeters	# P80168 Bed sediment, dry sieved, sieve diameter, percent smaller than 1 millimeter	# P80169 Bed sediment, dry sieved, sieve diameter, percent smaller than 2 millimeters	# P80170 Bed sediment, dry sieved, sieve diameter, percent smaller than 4 millimeters	# P80171 Bed sediment, dry sieved, sieve diameter, percent smaller than 8 millimeters	# P80172 Bed sediment, dry sieved, sieve diameter, percent smaller than 16 millimeters	# P80173 Bed sediment, dry sieved, sieve diameter, percent smaller than 32 millimeters	# P80181 Total sediment, fall diameter (deionized water), percent smaller than 0.002 millimeters	# P80182 Total sediment, fall diameter (deionized water), percent smaller than 0.004 millimeters	# P80183 Total sediment, fall diameter (deionized water), percent smaller than 0.008 millimeters	# P80184 Total sediment, fall diameter (deionized water), percent smaller than 0.016 millimeters	# P80185 Total sediment, fall diameter (deionized water), percent smaller than 0.031 millimeters
Station Number	Latitude	Longitude	Pool # & River Mile	DATES	TIMES	P00010	P00540	P00530	P00535	P80164	P80165	P80166	P80167	P80168	P80169	P80170	P80171	P80172	P80173	P80181	P80182	P80183	P80184	P80185
350423092322101	35 04 23	92 32 21	8 - 155.95 LA	20031103	1250	21.3	100	75	0	4	6	12	24	31	36	44	60	72	100	0	2	2	3	3
350430092381101	35 04 30	92 38 11	8 - 164.6	20031103	1225	21.3	100	78	0	0	0	2	35	53	60	67	75	94	100	0	0	0	0	0.2
350430092381901	35 04 30	92 38 19	8 - 164.8	20031103	1220	21.3	100	79	0	0	0	1	46	89	98	100								
350433092383001	35 04 33	92 38 30	8 - 165.0	20031103	1215	21.3	100	79	0	0	0	1	66	94	98	99	99	100						
350436092393601	35 04 36	92 39 36	8 - 165.9	20031103	1145	21.3	100	83	0	0	0	1	43	92	95	96	100							
350436092394901	35 04 36	92 39 49	8 - 166.0	20031103	1140	21.2	100	77	0	0	0	1	49	96	100									
350437092404401	35 04 37	92 40 44	8 - 167.0	20031103	1135	21.2	100	83	0	0	0	2	29	61	81	94	97	100						
350443092424501	35 04 43	92 42 45	8 - 169.0	20031103	1125	21.5	100	80	0	0	0	1	48	72	85	94	99	100						
350444092430801	35 04 44	92 43 08	8 - 169.5	20031103	1120	21.4	100	82	0	0	0	1	48	89	98	99	100							
350535092433001	35 05 05	92 43 30	8 - 170.0	20031103	1115	21.4	98	89	2	0	0	0	35	85	95	98	100							
350539092433701	35 05 39	92 43 37	8 - 170.8	20031103	1105	21.0	99	80	1	0	0	1	57	96	99	100								
350549092433001	35 05 49	92 43 30	8 - 171.0 L	20031103	1100		100	77	0	0	1	27	96	99	100									
350614092432901	35 06 14	92 43 29	8 - 171.5	20031103	1050	20.8	100	75	0	0	0	1	13	47	84	94	99	100						
350639092433201	35 06 39	92 43 32	8 - 171.8	20031103	1045	20.9	100	81	0	0	0	0	34	79	92	98	99	100						
350711092434501	35 07 11	92 43 45	8 - 172.5	20031103	1035	20.9	100	85	0	0	0	1	26	67	86	92	96	100						
350817092443401	35 08 17	92 44 34	8 - 174.0	20031103	1030	20.7	100	74	0	0	0	0	40	80	92	94	98	100						
350825092453501	35 08 25	92 45 35	8 - 175.0	20031103	1025	20.7	100	76	0	0	0	1	22	73	86	92	95	100						
350825092454901	35 08 25	92 45 49	8 - 175.2 R	20031103	1015		100	77	0	0	0	1	37	88	96	98	99	100						
350826092461401	35 08 26	92 46 14	8 - 175.7	20031103	1005	20.5	100	78	0	0	0	1	19	42	67	82	90	100						
350843092464101	35 08 43	92 46 41	8 - 176.35 LA	20031103	0955	20.9	100	81	0	0	0	3	10	24	40	56	74	96	100					

POOL 9

BED SEDIMENT SAMPLES

				Date as yyyy-mm-dd	Sample time	# P00010 Temperature, water, degrees Celsius	# P00540 Residue, fixed nonfilterable, as %	# P00530 Residue, total nonfilterable, as %	# P00535 Loss on ignition, from nonfilterable residue, as %	# P80164 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.063 millimeters	# P80165 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.125 millimeters	# P80166 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.25 millimeters	# P80167 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.5 millimeters	# P80168 Bed sediment, dry sieved, sieve diameter, percent smaller than 1 millimeter	# P80169 Bed sediment, dry sieved, sieve diameter, percent smaller than 2 millimeters	# P80170 Bed sediment, dry sieved, sieve diameter, percent smaller than 4 millimeters	# P80171 Bed sediment, dry sieved, sieve diameter, percent smaller than 8 millimeters	# P80172 Bed sediment, dry sieved, sieve diameter, percent smaller than 16 millimeters	# P80173 Bed sediment, dry sieved, sieve diameter, percent smaller than 32 millimeters
Station Number	Latitude	Longitude	Pool # & River Mile	DATES	TIMES	P00010	P00540	P00530	P00535	P80164	P80165	P80166	P80167	P80168	P80169	P80170	P80171	P80172	P80173
350722092472101	35 07 22	92 47 21	9 - 177.0 LA	20031028	1300	20	94	82	6	0	2	11	36	58	72	82	95	100	
350853092495701	35 08 53	92 49 57	9 - 181.0	20031028	1220	19.8	100	80	0	0	0	1	33	68	83	89	94	100	
350913092500101	35 09 13	92 50 01	9 - 181.4	20031028	1215	19.8	100	80	0	0	1	4	37	62	76	86	94	100	
350925092500401	35 09 25	92 50 04	9 - 181.7	20031028	1210	19.7	100	80	0	0	0	0	12	59	93	98	100		
350927093031301	35 09 27	93 03 13	9 - 195.0	20031028	0820	19.3	99	75	1	0	0	0	10	50	64	70	74	77	100
350932093021701	35 09 32	93 02 17	9 - 194.0	20031028	0900	19.3	100	73	0	0	0	0	14	83	98	100			
350934093041101	35 09 34	93 04 11	9 - 196.1	20031028	0815	19.5	99	75	1	0	0	3	32	50	64	80	96	100	
350936093015201	35 09 36	93 01 52	9 - 193.7	20031028	0905	19.3	100	76	0	0	0	1	14	43	54	61	69	74	100
350941093021801	35 09 41	93 02 18	9 - 194.0 L	20031028	0845		100	80	0	0	1	9	55	88	96	99	100		
350952092502001	35 09 52	92 50 20	9 - 182.2	20031028	1205	19.7	100	76	0	0	0	0	17	64	79	84	88	96	100
350954093005801	35 09 54	93 00 58	9 - 192.8	20031028	0910	19.3	100	83	0	0	0	0	10	73	97	100			
351003092502801	35 10 03	92 50 28	9 - 182.4	20031028	1155	19.6	100	80	0	0	0	0	8	58	87	97	99	100	
351008092510601	35 10 08	92 51 06	9 - 183.2 R	20031028	1140		100	79	0	0	1	9	42	72	79	82	86	96	100
351008092595501	35 10 08	92 59 55	9 - 191.8	20031028	0920	19.3	100	78	0	0	0	13	14	68	96	100			
351014092580801	35 10 14	92 58 08	9 - 190.0	20031028	0945	19.3	100	77	0	0	0	1	25	42	59	86	99	100	
351015092504401	35 10 15	92 50 44	9 - 182.8	20031028	1150	19.6	100	80	0	0	0	1	29	71	78	80	83	98	100
351016092504701	35 10 16	92 50 47	9 - 183.0	20031028	1145	19.6	100	80	0	0	0	1	19	68	88	95	99	100	
351016092531901	35 10 16	92 53 19	9 - 185.2	20031028	1110	19.4	100	79	0	0	0	1	26	87	94	97	100		
351016093065701	35 10 16	93 06 57	9 - 199.0	20031028	0755	19.9	100	79	0	0	0	1	19	45	52	61	70	81	100
351017092530501	35 10 17	92 53 05	9 - 185.0	20031028	1115	19.4	100	78	0	0	0	2	31	88	99	100			
351017092585601	35 10 17	92 58 56	9 - 190.8	20031028	0930	19.3	100	80	0	0	0	0	13	88	99	100			
351019092542701	35 10 19	92 54 27	9 - 186.4	20031028	1100	19.4	100	79	0	0	0	0	0	44	84	95	96	100	
351019092573701	35 10 19	92 57 37	9 - 189.6 L	20031028	0955		100	78	0	0	0	46	99	100					
351020092583901	35 10 20	92 58 39	9 - 190.5	20031028	0935	19.3	100	76	0	0	0	0	7	48	82	95	98	100	
351021092524101	35 10 21	92 52 41	9 - 184.5	20031028	1120	19.4	100	79	0	0	0	2	34	67	78	85	92	100	
351021093060201	35 10 21	93 06 02	9 - 198.0	20031028	0800	19.9	97	76	3	0	0	0	4	14	26	50	82	95	100
351023093052301	35 10 23	93 05 23	9 - 197.5	20031028	0805	19.5	100	74	0	0	0	1	21	41	55	60	63	72	100
351024092570701	35 10 24	92 57 07	9 - 189.5	20031028	1005	19.3	100	82	0	0	0	0	7	37	64	78	84	100	
351027092564201	35 10 27	92 56 42	9 - 188.5 R	20031028	1030		100	89	0	0	0	0	0	15	28	42	55	79	100
351028092514701	35 10 28	92 51 47	9 - 184.0	20031028	1130	19.4	100	75	0	0	0	0	21	76	94	99	100		
351030092545201	35 10 30	92 54 52	9 - 186.9	20031028	1055	19.3	100	80	0	0	0	0	17	82	94	98	99	100	
351032092545901	35 10 32	92 54 59	9 - 187.0	20031028	1050	19.3	100	89	0	0	0	0	16	53	59	65	85	88	100
351033092564901	35 10 33	92 56 49	9 - 188.7	20031028	1020	19.3	100	79	0	0	0	0	37	87	98	100			
351037092560801	35 10 37	92 56 08	9 - 188.0	20031028	1045	19.3	100	81	0	0	0	0	18	48	56	61	69	82	100
351043093074601	35 10 43	93 07 46	9 - 200.0	20031028	0745	19.9	100	84	0	0	0	4	17	36	52	68	91	100	
351132093080701	35 11 32	93 08 07	9 - 201.0 L	20031028	0735		98	86	2	0	1	3	21	48	61	69	75	88	100
351156093081701	35 11 56	93 08 17	9 - 201.3	20031028	0725	19.9	99	80	1	0	0	2	13	26	35	48	60	100	
351226093082101	35 12 26	93 08 21	9 - 202.0	20031028	0715	19.9	98	75	2	0	0	1	10	29	42	56	78	100	
351315093084801	35 13 15	93 08 48	9 - 203.0	20031027	1505	20.5	100	72	0	0	0	0	4	17	28	40	50	66	100
351404093091701	35 14 04	93 09 17	9 - 204.0	20031027	1455	20.5	100	81	0	0	0	1	25	71	81	85	88	95	100
351420093092701	35 14 20	93 09 27	9 - 204.6 LA	20031027	1445	20.6	100	73	0	0	0	2	12	45	62	76	87	100	
351425093093101	35 14 25	93 09 31	9 - 204.8 LA	20031027	1440	20.6	95	83	5	0	0	1	6	28	46	58	68	89	100

POOL DARDANELLE

BED SEDIMENT SAMPLES

				Date as yyyy-mm-dd	Sample time	# P00010 Temperature, water, degrees Celsius	# P00540 Residue, fixed nonfilterable, as %	# P00530 Residue, total nonfilterable, as %	# P00535 Loss on ignition, from nonfilterable residue, as %	# P80164 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.063 millimeters	# P80165 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.125 millimeters	# P80166 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.25 millimeters	# P80167 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.5 millimeters	# P80168 Bed sediment, dry sieved, sieve diameter, percent smaller than 1 millimeter	# P80169 Bed sediment, dry sieved, sieve diameter, percent smaller than 2 millimeters	# P80170 Bed sediment, dry sieved, sieve diameter, percent smaller than 4 millimeters	# P80171 Bed sediment, dry sieved, sieve diameter, percent smaller than 8 millimeters	# P80172 Bed sediment, dry sieved, sieve diameter, percent smaller than 16 millimeters	# P80173 Bed sediment, dry sieved, sieve diameter, percent smaller than 32 millimeters	# P80158 Bed sediment, fall diameter (deionized water), percent smaller than 0.063 millimeters	# P80159 Bed sediment, fall diameter (deionized water), percent smaller than 0.125 millimeters	# P80160 Bed sediment, fall diameter (deionized water), percent smaller than 0.25 millimeters	# P80161 Bed sediment, fall diameter (deionized water), percent smaller than 0.5 millimeters	# P80162 Bed sediment, fall diameter (deionized water), percent smaller than 1 millimeter	# P80163 Bed sediment, fall diameter (deionized water), percent smaller than 2 millimeters	# P80181 Total sediment, fall diameter (deionized water), percent smaller than 0.002 millimeters	# P80182 Total sediment, fall diameter (deionized water), percent smaller than 0.004 millimeters
Station Number	Latitude	Longitude	Pool # & River Mile	DATES	TIMES	P00010	P00540	P00530	P00535	P80164	P80165	P80166	P80167	P80168	P80169	P80170	P80171	P80172	P80173	P80158	P80159	P80160	P80161	P80162	P80163	P80181	P80182
352441093320401	35 24 41	93 32 04	D - 235.0	20031008	0750	21.8	100	77	0	0	1	14	62	82	90	96	100										
352422093323001	35 24 22	93 32 30	D - 236.0 R	20031008	0800		100	78	0	0	3	31	98	100													
352425093323801	35 24 25	93 32 38	D - 236.1	20031008	0810	21.8	100	74	0	0	0	6	49	76	87	94	99	100									
352422093324301	35 24 22	93 32 43	D - 236.3	20031008	0817	21.8	100	77	0	0	0	9	70	93	99	100											
352330093334701	35 23 30	93 33 47	D - 237.0	20031008	0825	21.7	100	77	0	0	1	6	54	93	98	100											
352309093345101	35 23 09	93 34 51	D - 237.6	20031008	0835	21.7	100	79	0	0	0	1	21	76	95	100											
352259093353801	35 22 59	93 35 38	D - 238.0	20031008	0840	21.7	99	78	1	0	0	1	18	65	93	98	100										
352255093355701	35 22 55	93 35 57	D - 238.9	20031008	0850	21.6	100	83	0	0	0	1	16	49	70	80	88	98	100								
352258093361001	35 22 58	93 36 10	D - 239.0 L	20031008	0900		100	80	0	0	1	13	24	75	99	100											
352249093372101	35 22 49	93 37 21	D - 240.5	20031008	0915	21.6	100	81	0	0	0	4	20	54	72	82	91	100									
352303093375701	35 23 03	93 37 57	D - 240.8	20031008	0920	21.7	100	78	0	0	0	15	38	68	91	97	99	100									
352307093380201	35 23 07	93 38 02	D - 241.0	20031008	0925	21.7	100	75	0	0	0	13	41	59	67	76	82	100									
352323093384301	35 23 23	93 38 43	D - 241.9	20031008	0940	21.7	100	80	0	0	0	6	61	97	99	100											
352332093390201	35 23 32	93 39 02	D - 243.0	20031008	0955	21.7	99	69	1	0	0	1	23	53	75	84	93	100									
352301093405201	35 23 01	93 40 52	D - 244.0	20031008	1008	21.7	100	78	0	0	0	0	1	75	99	100											
352231093413601	35 22 31	93 41 36	D - 245.0	20031008	1015	21.7	100	80	0	0	0	5	33	66	82	96	100										
352234093421901	35 22 34	93 42 19	D - 245.7 L	20031008	1025		99	83	1	0	2	23	44	49	55	65	80	100									
352237093425101	35 22 37	93 42 51	D - 246.1	20031008	1035	21.7	99	79	1	0	0	10	42	64	78	85	88	100									
352256093433401	35 22 56	93 43 34	D - 247.0	20031008	1045	21.7	99	74	1	5	6	13	34	53	61	70	87	100								3	4
352251093441201	35 22 51	93 44 12	D - 248.0 R	20031008	1110		97	85	3	0	1	4	15	36	56	71	84	95	100								
352256093441601	35 22 56	93 44 16	D - 248.0	20031008	1100	21.7	99	71	1	5	18	35	47	54	60	70	87	100								3	3
352242093452801	35 22 42	93 45 28	D - 249.0	20031008	1220	22	99	64	1	0	2	12	18	28	40	57	77	94	100								
352253093460301	35 22 53	93 46 03	D - 249.6	20031008	1235	22	98	81	2	0	1	16	21	28	42	59	84	100									
352300093461601	35 23 00	93 46 16	D - 249.8	20031008	1245	22	99	78	1	2	3	21	26	31	40	55	70	89	100							2	2
352331093470201	35 23 31	93 47 02	D - 251.0	20031008	1255	22	99	78	1	5	6	45	80	82	85	92	98	100								4	4
352417093474801	35 24 17	93 47 48	D - 252.0	20031008	1305	21.9	99	82	1	0	1	10	42	61	69	76	92	100									
352451093480601	35 24 51	93 48 06	D - 253.0	20031008	1320	21.9	93	61	7											77	87	90	95	97	100	21	24
352541093482601	35 25 41	93 48 26	D - 253.7	20031008	1335	21.9	99	77	1	2	3	12	56	68	74	83	94	100								2	2
352603093483001	35 26 03	93 48 30	D - 254.0	20031008	1345	21.9	99	77	1	2	4	47	65	67	69	74	84	88	100							1	1
352653093481901	35 26 53	93 48 19	D - 255.0	20031008	1400	21.9	100	74	0	2	6	46	55	60	68	78	86	92	100							1	1
352745093482601	35 27 45	93 48 26	D - 256.0	20031008	1415	21.9	99	74	1	0	1	10	24	39	51	61	71	93	100								
352759093483301	35 27 59	93 48 33	D - 256.2 LA	20031008	1420	21.9	94	77	6	0	0	7	15	21	30	46	71	100									
351509093101901	35 15 09	93 10 19	D - 205.6 LA	20031009	0810	21.3	97	63	3					76	84	92	100			45	51	57	65			28	31
352053093234301	35 20 53	93 23 43	D - 221.8	20031027	1045	19.6	93	36	7					99	100					94	95	96	98			45	51
352131093243701	35 21 31	93 24 37	D - 222.8	20031027	1055	19.3	98	62	2											22	74	98	100			8	9
352143093245201	35 21 43	93 24 52	D - 223.0	20031027	1105	19.3	100	74	0	1	4	96	98	99	100												
352222093250801	35 22 22	93 25 08	D - 224.0	20031027	1115	19.2	98	66	2											22	23	88	98	100		12	13
352320093252801	35 23 20	93 25 28	D - 225.0	20031027	1120	19.5	99	67	1											28	29	98	100			15	16
352542093255501	35 25 42	93 25 55	D - 228.0	20031027	1140	19.5	100	76	0	0	1	20	78	92	98	100											
352532093272101	35 25 32	93 27 21	D - 229.8	20031027	1145	19.5	100	78	0	0	0	11	84	98	100												
352529093273101	35 25 29	93 27 31	D - 230.0 L	20031027	1155		100	75	0	0	5	96	100														
352524093271801	35 25 24	93 27 18	D - 230.0 R	20031027	1205		100	80	0	0	0	9	62	85	95	98	98	100									
352419093284601	35 24 19	93 28 46	D - 231.0	20031027	1215	19.3	99	75	1	10	10	12	68	92	95	97	99	100								7	8
352345093294601	35 23 45	93 29 46	D - 232.3	20031027	1225	19.5	100	76	0											4	6	30	94	100		3	3
352433093305801	35 24 33	93 30 58	D - 233.9	20031027	1235	19.5	99	77	1	0	1	18	78	96	99	100											
352437093310701	35 24 37	93 31 07	D - 234.0	20031027	1240	19.5	100	78	0	0	0	15	69	94	99	100											

POOL OZARK

BED SEDIMENT SAMPLES

				Date as yyyy-mm-dd	Sample time	# P00010 Temperature, water, degrees Celsius	# P00540 Residue, fixed nonfilterable, as %	# P00530 Residue, total nonfilterable, as %	# P00535 Loss on ignition, from nonfilterable residue, as %	# P80164 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.063 millimeters	# P80165 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.125 millimeters	# P80166 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.25 millimeters	# P80167 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.5 millimeters	# P80168 Bed sediment, dry sieved, sieve diameter, percent smaller than 1 millimeter	# P80169 Bed sediment, dry sieved, sieve diameter, percent smaller than 2 millimeters	# P80170 Bed sediment, dry sieved, sieve diameter, percent smaller than 4 millimeters	# P80171 Bed sediment, dry sieved, sieve diameter, percent smaller than 8 millimeters	# P80172 Bed sediment, dry sieved, sieve diameter, percent smaller than 16 millimeters	# P80173 Bed sediment, dry sieved, sieve diameter, percent smaller than 32 millimeters	# P80181 Total sediment, fall diameter (deionized water), percent smaller than 0.002 millimeters	# P80182 Total sediment, fall diameter (deionized water), percent smaller than 0.004 millimeters	# P80183 Total sediment, fall diameter (deionized water), percent smaller than 0.008 millimeters	# P80184 Total sediment, fall diameter (deionized water), percent smaller than 0.016 millimeters	# P80185 Total sediment, fall diameter (deionized water), percent smaller than 0.031 millimeters
Station Number	Latitude	Longitude	Pool # & River Mile	DATES	TIMES	P00010	P00540	P00530	P00535	P80164	P80165	P80166	P80167	P80168	P80169	P80170	P80171	P80172	P80173	P80181	P80182	P80183	P80184	P80185
352008094171101	35 20 08	94 17 11	O - 292.0	20031007	1300	21.8	100	81	0	0	1	7	67	80	83	86	90	95	100					
352035094163501	35 20 35	94 16 35	O - 291.5	20031007	1255	21.8	100	80	0	0	0	0	36	81	93	99	100							
352042094172901	35 20 42	94 17 29	O - 292.3 LA	20031007	1310	21.8	99	76	1	0	0	2	20	44	66	80	88	97	100					
352055094154801	35 20 55	94 15 48	O - 290.5 R	20031007	1245		99	84	1	1	4	8	24	48	65	72	79	90	100					
352105094154401	35 21 05	94 15 44	O - 290.3	20031007	1240	21.8	100	78	0	0	0	0	60	99	100									
352114094140001	35 21 14	94 14 00	O - 288.6	20031007	1225	21.8	100	78	0	0	0	2	63	83	92	97	99	100						
352124094144501	35 21 24	94 14 45	O - 289.5	20031007	1230	21.8	100	76	0	0	0	4	79	95	98	100								
352148094115401	35 21 48	94 11 54	O - 286.5	20031007	1215	21.7	100	75	0	0	0	1	50	93	99	100								
352213094111201	35 22 13	94 11 12	O - 285.8 R	20031007	1200		100	78	0	0	1	16	57	83	91	94	94	95	100					
352228094105901	35 22 28	94 10 59	O - 285.3	20031007	1155	21.9	100	82	0	0	0	0	51	87	96	99	100							
352240094083201	35 22 40	94 08 32	O - 283.0 R	20031007	1125		99	74	1	10	43	96	100							2	2	2	2	3
352241094090501	35 22 41	94 09 05	O - 283.7	20031007	1140	21.9	100	78	0	0	0	2	67	92	98	100								
352242094083401	35 22 42	94 08 34	O - 283.0	20031007	1120	21.7	100	78	0	0	0	1	49	73	87	97	100							
352245094093301	35 22 45	94 09 33	O - 284.0	20031007	1145	21.9	100	77	0	0	0	3	68	91	97	99	100							
352245094100101	35 22 45	94 10 01	O - 284.5	20031007	1150	21.9	100	78	0	0	0	2	55	80	93	99	100							
352319094080001	35 23 19	94 08 00	O - 282.7 L	20031007	1040		100	79	0	0	0	3	57	82	95	99	100							
352329094075301	35 23 29	94 07 53	O - 282.0	20031007	1030	21.5	100	77	0	0	0	1	65	94	97	97	98	100						
352415094080301	35 24 15	94 08 03	O - 281.0	20031007	1020	21.5	100	76	0	0	0	1	10	42	71	79	87	100						
352433094081101	35 24 33	94 08 11	O - 280.3	20031007	1015	21.5	99	80	0	0	0	1	9	38	74	95	99	100						
352449094082301	35 24 49	94 08 23	O - 280.0	20031007	1012	21.5	100	79	0	0	0	1	28	71	91	95	98	100						
352520094084201	35 25 20	94 08 42	O - 279.7	20031007	1005	21.5	100	74	0	0	0	4	62	83	87	90	96	100						
352528094084601	35 25 28	94 08 46	O - 279.4 L	20031007	0950		99	72	1	15	57	97	99	100						3	4	4	5	7
352609094083601	35 26 09	94 08 36	O - 278.7	20031007	0935	21.5	100	76	0	0	0	3	78	92	96	98	100							
352642094080901	35 26 42	94 08 09	O - 278.0	20031007	0930	21.3	100	78	0	0	0	1	50	80	96	100								
352645094054501	35 26 45	94 05 45	O - 275.4	20031007	0900	21.1	100	78	0	0	0	3	34	54	66	74	82	95	100					
352656094061801	35 26 56	94 06 18	O - 276.0	20031007	0910	21.2	100	71	0	0	0	2	62	89	99	100								
352704094071901	35 27 04	94 07 19	O - 277.0	20031007	0920	21.3	100	78	0	0	0	2	76	94	97	100								
352718094024601	35 27 18	94 02 46	O - 272.5	20031007	0845	21	100	76	0	0	0	4	67	86	91	94	99	100						
352727094021101	35 27 27	94 02 11	O - 271.2	20031007	0835	20.9	100	78	0	0	0	3	59	90	98	100								
352831093485501	35 28 31	93 48 55	O - 256.9 LA	20031007	1435	22.5	91	55	9	26	42	65	75	79	84	91	96	100		12	13	14	16	18

POOL 13

BED SEDIMENT SAMPLES

				Date as yyyy-mm-dd	Sample time	# P00010 Temperature, water, degrees Celsius	# P00540 Residue, fixed nonfilterable, as %	# P00530 Residue, total nonfilterable, as %	# P00535 Loss on ignition, from nonfilterable residue, as %	# P80164 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.063 millimeters	# P80165 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.125 millimeters	# P80166 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.25 millimeters	# P80167 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.5 millimeters	# P80168 Bed sediment, dry sieved, sieve diameter, percent smaller than 1 millimeter	# P80169 Bed sediment, dry sieved, sieve diameter, percent smaller than 2 millimeters	# P80170 Bed sediment, dry sieved, sieve diameter, percent smaller than 4 millimeters	# P80171 Bed sediment, dry sieved, sieve diameter, percent smaller than 8 millimeters	# P80172 Bed sediment, dry sieved, sieve diameter, percent smaller than 16 millimeters	# P80173 Bed sediment, dry sieved, sieve diameter, percent smaller than 32 millimeters	# P80181 Total sediment, fall diameter (deionized water), percent smaller than 0.002 millimeters	# P80182 Total sediment, fall diameter (deionized water), percent smaller than 0.004 millimeters	# P80183 Total sediment, fall diameter (deionized water), percent smaller than 0.008 millimeters	# P80184 Total sediment, fall diameter (deionized water), percent smaller than 0.016 millimeters	# P80185 Total sediment, fall diameter (deionized water), percent smaller than 0.031 millimeters
Station Number	Latitude	Longitude	Pool # & River Mile	DATES	TIMES	P00010	P00540	P00530	P00535	P80164	P80165	P80166	P80167	P80168	P80169	P80170	P80171	P80172	P80173	P80181	P80182	P80183	P80184	P80185
351816094321001	35 18 16	94 32 10	13 - 318.0	20031006	1425	21.5	99	81	1	1	2	16	43	54	62	74	90	100		1	1	1	1	1
351821094313201	35 18 21	94 31 32	13 - 317.0	20031006	1415	21.4	98	86	2	0	0	1	11	29	41	58	75	97	100					
351821094320901	35 18 21	94 32 09	13 - 318.0 L	20031006	1435		100	84	0	0	1	12	28	53	74	83	86	95	100					
351829094325701	35 18 29	94 32 57	13 - 319.0	20031006	1445	21.5	100	74	0	0	0	3	28	42	51	62	74	82	100					
351907094301901	35 19 07	94 30 19	13 - 316.0	20031006	1410	21.5	100	75	0	0	0	2	6	22	55	68	79	94	100					
351947094294701	35 19 47	94 29 47	13 - 315.0	20031006	1345	21.2	99	85	1	0	0	0	6	27	38	67	90	100						
352021094294601	35 20 21	94 29 46	13 - 314.5	20031006	1335	21.3	100	78	0	0	0	0	1	17	52	79	90	100						
352031094294501	35 20 31	94 29 45	13 - 314.3	20031006	1325	21.3	100	78	0	0	0	0	2	26	62	87	97	100						
352040094294401	35 20 40	94 29 44	13 - 314.0 R	20031006	1315		100	82	0	0	0	4	23	55	83	93	97	100						
352101094180301	35 21 01	94 18 03	13 - 292.9 LA	20031006	1155	21.5	99	73	1	2	2	4	26	72	94	99	100			1	1	1	1	1
352128094294201	35 21 28	94 29 42	13 - 313.0	20031006	1305	21.1	99	79	1	0	0	0	12	46	74	92	100							
352207094291601	35 22 07	94 29 16	13 - 312.0	20031006	1250	21.2	100	70	0	0	0	0	3	51	83	94	99	100						
352242094272001	35 22 42	94 27 20	13 - 310.0 R	20031006	1235		100	75	0	0	1	3	54	95	100									

POOL 15

BED SEDIMENT SAMPLES

				Date as yyyy-mm-dd	Sample time	# P00010 Temperature, water, degrees Celsius	# P00540 Residue, fixed nonfilterable, as %	# P00530 Residue, total nonfilterable, as %	# P00535 Loss on ignition, from nonfilterable residue, as %	# P70342 Suspended sediment, fall diameter (deionized water), percent smaller than 0.063 millimeters	# P70343 Suspended sediment, fall diameter (deionized water), percent smaller than 0.125 millimeters	# P70344 Suspended sediment, fall diameter (deionized water), percent smaller than 0.25 millimeters	# P70345 Suspended sediment, fall diameter (deionized water), percent smaller than 0.5 millimeters	# P80164 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.063 millimeters	# P80165 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.125 millimeters	# P80166 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.25 millimeters	# P80167 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.5 millimeters	# P80168 Bed sediment, dry sieved, sieve diameter, percent smaller than 1 millimeter	# P80169 Bed sediment, dry sieved, sieve diameter, percent smaller than 2 millimeters	# P80170 Bed sediment, dry sieved, sieve diameter, percent smaller than 4 millimeters	# P80171 Bed sediment, dry sieved, sieve diameter, percent smaller than 8 millimeters	# P80172 Bed sediment, dry sieved, sieve diameter, percent smaller than 16 millimeters	# P80181 Total sediment, fall diameter (deionized water), percent smaller than 0.002 millimeters	# P80182 Total sediment, fall diameter (deionized water), percent smaller than 0.004 millimeters	# P80183 Total sediment, fall diameter (deionized water), percent smaller than 0.008 millimeters	# P80184 Total sediment, fall diameter (deionized water), percent smaller than 0.016 millimeters	# P80185 Total sediment, fall diameter (deionized water), percent smaller than 0.031 millimeters
Station Number	Latitude	Longitude	Pool # & River Mile	DATES	TIMES	P00010	P00540	P00530	P00535	P70342	P70343	P70344	P70345	P80164	P80165	P80166	P80167	P80168	P80169	P80170	P80171	P80172	P80181	P80182	P80183	P80184	P80185
351521094580601	35 15 21	95 58 06	SBC - 9.0	20031001	1800	21	94	44	6					100									40	51	65	81	96
351540094580901	35 15 40	94 58 09	SBC - 7.6	20031001	0930	20.1	No Sample Collected																				
351617094575301	35 16 17	94 57 53	SBC - 7.2	20031001	0925	20.1	No Sample Collected																				
351625094573601	35 16 25	94 57 36	SBC - 7.0	20031001	0920	20.6	71	68	29	100													34	42	49	67	92
351629094572801	35 16 29	94 57 28	SBC - 6.8	20031001	0915	20.6	No Sample Collected																				
351638094571001	35 16 38	94 57 10	SBC - 6.4	20031001	0905	20.6	67	65	33	100													29	37	47	61	85
351647094570301	35 16 47	94 57 03	SBC - 6.0	20031001	0835	20.9	No Sample Collected																				
352356094561601	35 23 56	94 56 16	15 - 348.0	20031001	1010	20.8	98	71	2					9	15	21	58	93	99	100			4	4	4	5	7
352405094564601	35 24 05	94 56 46	15 - 348.5	20031001	1035	20.7	100	70	0					1	8	96	100										
352414094571801	35 24 14	94 57 18	15 - 349.0	20031001	1050	20.8	99	17	1					2	5	70	90	99	100								
352432094592601	35 24 32	94 59 26	15 - 351.0	20031001	1105	21	99	77	1					1	5	76	92	97	100								
352508095011401	35 25 08	95 01 14	15 - 352.0	20031001	1125	21.1	95	37	5					15	21	57	95	99	100				6	7	8	9	11
352626095012301	35 26 26	95 01 23	15 - 353.0	20031001	1220	21.5	99	57	1					3	12	40	92	99	100								
352633095011801	35 26 33	95 01 18	15 - 353.4	20031001	1235	21.5	100	76	0					2	11	38	91	97	99	100							
352639095011801	35 26 39	95 01 18	15 - 354.0	20031001	1245	21.5	98	74	2					9	31	78	96	99	100								
352718095024801	35 27 18	95 02 48	15 - 356.0	20031001	1320	21.9	100	81	0					1	1	5	30	57	76	90	98	100					
352722095035201	35 27 22	95 03 52	15 - 357.0	20031001	1420	22.7	99	72	1					1	1	2	36	78	93	98	100						
352724095021301	35 27 24	95 02 13	15 - 355.6	20031001	1310	21.9	100	77	0					2	4	45	96	98	100								
352725095014001	35 27 25	95 01 40	15 - 355.0	20031001	1250	21.5	100	78	0					1	1	4	65	94	99	100							
352735095050801	35 27 35	95 05 08	15 - 358.2	20031001	1430	22.7	100	76	0					0	1	2	48	91	95	99	100						
352805095051801	35 28 05	95 05 18	15 - 358.8	20031001	1440	22.7	99	71	1					1	1	3	23	57	77	91	100						
352858095053601	35 28 58	95 05 36	15 - 360.0	20031001	1450	22.7	98	57	2					28	75	98	99	100					7	8	9	11	14
352928095060601	35 29 28	95 06 06	15 - 360.7	20031001	1510	22.7	98	70	2					16	35	56	74	83	88	92	97	100	5	5	6	7	9
352945095063101	35 29 45	95 06 31	15 - 361.3	20031001	1520	22.9	99	78	1					0	1	4	22	43	60	80	92	100					
353010095070601	35 30 10	95 07 06	15 - 362.0	20031001	1530	22.9	99	76	1					1	1	4	25	43	64	84	96	100					
353028095071401	35 30 28	95 07 14	15 - 362.5	20031001	1535	22.8	98	65	2					36	83	97	99	99	100				14	15	16	18	22
353149095080301	35 31 49	95 08 03	15 - 364.0	20031001	1550	22.5	98	59	2	83	94	97	100										25	28	30	38	52
353208095080101	35 32 08	95 08 01	15 - 364.7	20031001	1605	22.5	96	65	4	66	80	88	93					97	98	100			28	31	32	38	50
353247095093401	35 32 47	95 09 34	15 - 365.8	20031001	1615	22	100	79	0					17	57	82	88	92	94	96	100		4	4	4	5	7

POOL 16

BED SEDIMENT SAMPLES

				Date as yyyy-mm-dd	Sample time	# P00010 Temperature, water, degrees Celsius	# P00540 Residue, fixed nonfilterable, as %	# P00530 Residue, total nonfilterable, as %	# P00535 Loss on ignition, from nonfilterable residue, as %	# P80164 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.063 millimeters	# P80165 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.125 millimeters	# P80166 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.25 millimeters	# P80167 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.5 millimeters	# P80168 Bed sediment, dry sieved, sieve diameter, percent smaller than 1 millimeter	# P80169 Bed sediment, dry sieved, sieve diameter, percent smaller than 2 millimeters	# P80170 Bed sediment, dry sieved, sieve diameter, percent smaller than 4 millimeters	# P80171 Bed sediment, dry sieved, sieve diameter, percent smaller than 8 millimeters	# P80172 Bed sediment, dry sieved, sieve diameter, percent smaller than 16 millimeters	# P80173 Bed sediment, dry sieved, sieve diameter, percent smaller than 32 millimeters	# P80181 Total sediment, fall diameter (deionized water), percent smaller than 0.002 millimeters	# P80182 Total sediment, fall diameter (deionized water), percent smaller than 0.004 millimeters	# P80183 Total sediment, fall diameter (deionized water), percent smaller than 0.008 millimeters	# P80184 Total sediment, fall diameter (deionized water), percent smaller than 0.016 millimeters	# P80185 Total sediment, fall diameter (deionized water), percent smaller than 0.031 millimeters
Station number	Latitude	Longitude	Pool # & River Mile	DATES	TIMES	P00010	P00540	P00530	P00535	P80164	P80165	P80166	P80167	P80168	P80169	P80170	P80171	P80172	P80173	P80181	P80182	P80183	P80184	P80185
354540095175801	35 45 40	95 17 58	16 - 392.0	20030930	1425	20.5	99	55	1	6	10	30	72	90	97	100				2	2	2	2	3.4
354616095175601	35 46 16	95 17 56	16 - 392.6	20030930	1435	19.8	100	78	0	3	5	38	76	96	99	100				1	1	1	1	1.6
354606095175401	35 46 06	95 17 54	16 - 393.0	20030930	1445	20.0	100	70	0	1	2	56	88	98	99	100				0	0	0	0	0.3
354651095175201	35 46 51	95 17 52	16 - 393.3	20030930	1450	19.8	100	75	0	6	13	43	85	92	98	100				1	1	2	2	3.1
354737095174601	35 47 37	95 17 46	16 - 394.2	20030930	1510	18.6	100	78	0	1	2	7	60	90	98	100								
354753095180401	35 47 53	95 18 04	16 - 394.5	20030930	1520	19.0	100	77	0	1	3	13	59	89	97	100				0	0	0	0	0.3
354756095181701	35 47 56	95 18 17	16 - 394.8	20030930	1530	19.5	100	75	0	0	3	11	64	88	96	100								
354759095182501	35 47 59	95 18 25	16 - 394.9	20030930	1540	20.6	100	74	0	5	10	35	97	100						1	1	1	2	2.6
354820095185601	35 48 20	95 18 56	16 - 395.5	20030930	1550	22.3	99	74	1	2	3	36	98	99	100					1	1	1	1	1.5
354834095141501	35 48 34	95 14 15	16 - 396.0	20030930	1600	22.4	99	71	1	0	1	35	93	94	94	94	94	94	100					
354923095193101	35 49 23	95 19 31	16 - 397.0	20030930	1610	22.5	99	74	1	0	1	19	97	99	100									
355018095192301	35 50 18	95 19 23	16 - 398.0	20030930	1620	22.4	98	73	2	1	1	40	99	100						0	0	0	0	0
355052095193901	35 50 52	95 19 39	16 - 398.6	20030930	1630	22.2	99	71	1	1	2	42	97	99	99	100				0	0	0	0	1
355057095200301	35 50 57	95 20 03	16 - 399.0	20030930	1645	22.2	98	77	2	1	2	19	90	97	99	99	100			0	0	1	1	1

POOL 18

BED SEDIMENT SAMPLES

				Date as yyyy-mm-dd	Sample time	# P00010 Temperature, water, degrees Celsius	# P00540 Residue, fixed nonfilterable, as %	# P00530 Residue, total nonfilterable, as %	# P00535 Loss on ignition, from nonfilterable residue, as %	# P80164 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.063 millimeters	# P80165 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.125 millimeters	# P80166 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.25 millimeters	# P80167 Bed sediment, dry sieved, sieve diameter, percent smaller than 0.5 millimeters	# P80168 Bed sediment, dry sieved, sieve diameter, percent smaller than 1 millimeter	# P80169 Bed sediment, dry sieved, sieve diameter, percent smaller than 2 millimeters	# P80170 Bed sediment, dry sieved, sieve diameter, percent smaller than 4 millimeters	# P80171 Bed sediment, dry sieved, sieve diameter, percent smaller than 8 millimeters	# P80172 Bed sediment, dry sieved, sieve diameter, percent smaller than 16 millimeters	# P80181 Total sediment, fall diameter (deionized water), percent smaller than 0.002 millimeters	# P80182 Total sediment, fall diameter (deionized water), percent smaller than 0.004 millimeters	# P80183 Total sediment, fall diameter (deionized water), percent smaller than 0.008 millimeters	# P80184 Total sediment, fall diameter (deionized water), percent smaller than 0.016 millimeters	# P80185 Total sediment, fall diameter (deionized water), percent smaller than 0.031 millimeters
Station Number	Latitude	Longitude	Pool # & River Mile	DATES	TIMES	P00010	P00540	P00530	P00535	P80164	P80165	P80166	P80167	P80168	P80169	P80170	P80171	P80172	P80181	P80182	P80183	P80184	P80185
361235095425301	36 12 35	95 42 53	18 - 443.7	20030930	0800	20.5	97	69	3	1	7	56	92	96	98	100							
361243095430201	36 12 43	95 43 02	18 - 444.0	20030930	0810	21	98	62	2	1	4	55	95	98	100								
361255095431201	36 12 55	95 43 12	18 - 444.2	20030930	0818	21	91	64	9	24	28	62	93	97	99	100			8	9	10	12	18
361301095431901	36 13 01	95 43 19	18 - 444.5	20030930	0825	21	98	74	2	15	33	73	90	96	99	99	100		4	5	5	6	9
361314095433101	36 13 14	95 43 31	18 - 444.7	20030930	0840	21	99	75	1	1	4	42	92	97	98	99	99	100					
361328095433701	36 13 28	95 43 37	18 - 445.0	20030930	0853	21.2	86	61	14	1	4	36	84	94	98	99	100						

Summation of Grain Size USGS Analysis

		Percent Finer /Sediment Size		
	N.M.	d10	d50	d90
		mm	mm	mm
POOL #3				
	50.3	0.270	0.440	0.800
	55.5	0.260	0.360	0.550
	58	0.250	0.350	0.480
	61	0.220	0.350	0.570
	61.2	0.240	0.350	0.500
	61.5	0.240	0.370	0.670
	62.5	0.250	0.370	0.660
	64.2	0.290	0.420	0.820
	65.2	0.280	0.430	1.200
	65.6	0.140	0.280	0.440
POOL #4				
	66.2	0.000	0.140	0.220
	70.4	0.110	0.170	0.250
	79	0.270	0.380	0.630
	79.2	0.280	0.470	1.070
	79.4	0.300	0.460	1.000
	79.6	0.280	0.450	0.810
	79.8	0.270	0.390	0.730
	80	0.270	0.370	0.650
	81	0.270	0.410	1.000
	83	0.250	0.345	0.460
	84	0.280	0.385	0.660
	85	0.275	0.380	0.630
	85.9	0.160	0.290	0.450
POOL #5				
	86.5	0.150	2.700	12.000
	91.3	0.300	0.520	0.960
	94.7	0.220	0.340	0.480
	95	0.230	0.350	0.560
	95.7	0.230	0.340	0.480
	96.2	0.270	0.450	0.810
	96.3	0.270	0.360	0.530
	96.6	0.270	0.380	0.640
	96.7	0.280	0.480	1.000
	96.9	0.280	0.500	1.000
	97.4	0.260	0.420	0.820
	98.1	0.270	0.420	0.780
	99.2	0.290	0.430	0.860

	100	0.280	0.410	0.750
	101	0.280	0.480	2.500
	101.5	0.280	0.420	0.890
	101.7	0.270	0.390	0.780
	102	0.250	0.450	4.000
	103	0.280	0.450	0.900
	103	0.220	0.340	0.470
	105.7	0.300	0.800	11.800
	106.7	0.360	0.670	1.220
	107	0.300	0.700	2.000
	107.75	0.150	0.650	2.000
POOL #6				
	124.9			
POOL #7				
	125.5	0.260	0.350	0.460
	126.7	0.100	0.200	3.800
	126.7	0.200	0.340	0.520
	128.1	0.270	0.420	0.960
	128.8	0.210	0.330	0.450
	130	0.270	0.370	0.560
	130.7	0.280	0.390	0.830
	131.8	0.270	0.380	0.680
	133.5	0.250	0.360	0.540
	134.5	0.100	0.170	0.300
	135.1	0.300	0.500	2.700
	135.3	0.280	0.380	0.600
	136.5	0.280	0.420	1.000
	137.6	0.290	0.420	0.780
	138.2	0.580	0.850	1.600
	138.8	0.300	0.440	1.140
	140.5	0.300	0.500	1.450
	142	0.130	0.260	0.440
	142.6	0.280	0.410	0.840
	142.9	0.280	0.400	0.770
	145	0.350	0.710	1.950
	145.3	0.380	0.690	1.350
	145.8	0.450	1.000	3.600
	146	0.350	0.800	9.200
	146.2	0.400	0.670	1.100
	146.7	0.350	0.670	1.300
	147	0.320	0.640	1.260
	147.5	0.330	0.680	1.880
	150	0.280	0.400	0.770
	150.5	0.220	0.335	0.450
	152	0.190	0.350	0.820
	152.5	0.300	0.520	1.000

	154	0.140	0.210	0.390
	154.1	0.490	0.900	2.600
	154.5	0.400	0.680	1.040
	155.35	0.510	0.760	1.400
POOL# 8				
	155.95	0.300	5.300	26.100
	164.6	0.300	0.800	13.800
	164.8	0.300	0.530	1.020
	165	0.820	0.410	0.830
	165.9	0.310	0.560	0.960
	166	0.300	0.500	0.870
	167	0.430	0.750	3.050
	169	0.300	0.510	2.800
	169.5	0.300	0.520	1.020
	170	0.350	0.620	1.180
	170.8	0.290	0.460	0.850
	171	0.180	0.320	0.460
	171.5	0.450	1.050	2.600
	171.8	0.330	0.640	1.700
	172.5	0.350	0.750	2.900
	174	0.320	0.590	1.650
	175	0.380	0.730	3.000
	175.2	0.320	0.600	1.080
	175.7	0.380	1.300	8.000
	176.35	0.600	3.100	12.800
POOL #9				
	177	0.250	0.750	6.000
	181	0.310	0.700	4.700
	181.4	0.300	0.700	5.400
	181.7	0.470	0.860	1.820
	182.2	0.410	0.800	9.500
	182.4	0.520	0.890	2.750
	182.8	0.350	0.700	11.000
	183	0.400	0.750	2.220
	183.2	0.210	0.600	10.700
	184	0.390	0.730	1.560
	184.5	0.300	0.700	6.400
	185	0.340	0.630	1.070
	185.2	0.350	0.660	1.080
	186.4	0.600	1.100	2.610
	186.9	0.430	0.700	1.350
	187	0.500	0.900	19.200
	188	0.400	1.200	22.500
	188.5	0.700	6.000	24.000
	188.7	0.350	0.600	1.090
	189.5	0.550	1.380	11.100

	189.6	0.160	0.261	0.420
	190	0.330	1.400	4.320
	190.5	0.550	1.050	2.700
	190.8	0.470	0.700	1.050
	191.8	0.220	0.790	1.600
	192.8	0.500	0.760	1.470
	193.7	0.400	1.500	26.000
	194	0.460	0.710	1.150
	194	0.260	0.460	1.080
	195	0.500	1.000	25.200
	196.1	0.350	1.000	5.800
	197.5	0.400	1.500	26.100
	198	0.790	4.000	11.000
	199	0.400	1.400	23.500
	200	0.400	1.800	7.650
	201	0.400	1.000	18.000
	201.3	0.400	4.600	14.000
	202	0.500	3.000	12.200
	203	0.600	8.000	27.000
	204	0.380	0.700	9.900
	204.6	0.450	1.200	9.700
	204.8	0.600	2.410	17.100
Dardanelle				
	205.6			
	221.8			
	222.8			
	223	0.135	0.175	0.232
	224			
	225			
	228	0.200	0.350	0.820
	229.8	0.245	0.349	0.560
	230	0.300	0.175	0.230
	230	0.250	0.430	1.300
	231	0.140	0.400	0.900
	232.3			
	233.9	0.210	0.360	0.690
	234	0.220	0.381	0.835
	235	0.250	0.410	2.000
	236	0.160	0.310	0.440
	236.1	0.270	0.500	2.500
	236.3	0.260	0.390	0.870
	237	0.270	0.470	0.920
	237.6	0.380	0.710	1.470
	238	0.400	0.780	1.800
	238.9	0.400	1.050	9.100
	239	0.210	0.720	1.410

	240.5	0.390	0.900	7.300
	240.8	0.200	0.660	1.900
	241	0.250	0.700	11.500
	241.9	0.275	0.430	0.820
	243	0.350	0.950	6.100
	244	0.560	0.780	1.350
	245	0.300	0.700	2.900
	245.7	0.200	1.150	12.000
	246.1	0.280	0.600	9.700
	247	0.200	0.820	9.300
	248	0.100	0.600	9.300
	248	0.390	1.600	11.500
	249	0.300	3.000	13.000
	249.6	0.200	2.800	10.200
	249.8	0.200	3.200	16.300
	251	0.120	0.290	3.200
	252	0.250	0.600	7.100
	253			
	253.7	0.210	0.420	6.100
	254	0.200	0.300	19.500
	255	0.200	0.300	13.000
	256	0.400	1.900	14.300
	256.2	0.300	4.500	13.100
Ozark				
	256.9		0.150	3.500
	271.7	0.280	0.450	1.000
	272.5	0.280	0.400	1.550
	275.4	0.400	0.800	13.500
	276	0.280	0.430	1.050
	277	0.279	0.385	0.730
	278	0.300	0.500	1.400
	278.7	0.280	0.380	0.730
	279.4		0.110	0.220
	279.7	0.300	0.400	4.000
	280	0.340	0.700	1.870
	280.3	0.510	1.500	3.200
	281	0.500	1.200	9.500
	282	0.280	0.450	0.850
	282.7	0.290	0.450	1.450
	283	0.300	0.500	2.350
	283	0.060	0.140	0.222
	283.7	0.280	0.410	0.920
	284	0.280	0.450	0.950
	284.5	0.300	0.460	1.600
	285.3	0.300	0.500	1.130
	285.8	0.200	0.450	1.650

	286.5	0.300	0.500	0.920
	288.6	0.290	0.430	1.550
	289.5	0.275	0.375	0.650
	290.3	0.290	0.440	0.790
	290.5	0.220	1.100	16.000
	291.5	0.330	0.610	1.480
	292	0.280	0.400	8.200
	292.3	0.390	1.200	9.300