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Using a Numerical Model to Evaluate Dredging Options

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Abstract

A study was conducted to address a shoaling problem in the vicinity of the Cubits Gap distributary on the lower Mississippi River. Upstream from Cubits Gap the river is relatively deep, but the channel depth decreases as it approaches the distributary, where frequent dredging is required. A one-dimensional numerical model was used to evaluate alternative dredging operations and to forecast sediment accumulation. The numerical model was also used to forecast sediment accumulation based on 30-day flow projections. This information can be used to help determine when to initiate dredging fleet mobilization.

Introduction

The purpose of this investigation was to evaluate proposals to improve dredging operations in the vicinity of Cubits Gap, located at river mile 3.0 in the Mississippi River delta. Cubits Gap is 3 miles upstream from Head of Passes where three major distributaries, Pass a Loutre, South Pass, and Southwest Pass, disseminate (Figure 1). The existing navigation channel is maintained at a minimum depth of 45 ft and width of 750 ft. The channel is dredged to el -48.0 ft referred to the National Geodetic Vertical Datum (NGVD) which provides 3 ft of overdredging. One alternative evaluated was advance maintenance, which would increase the overdredging depth from 3 to 5 ft. A 1000-ft-wide sediment trap, dredged to el -50.0, adjacent to the navigation channel between miles 0.0 and 4.0 was also evaluated. A third alternative was to reduce the outflow through Cubits Gap by some structural means. Flow redistribution quantities were uncertain at the time of this investigation, so an arbitrary 50 percent reduction in the discharge through Cubits Gap was assigned to evaluate the relative merits of this alternative. The effect of the three alternatives on dredging operations in both the Cubits Gap reach and Head of Passes was evaluated by comparing total annual sediment

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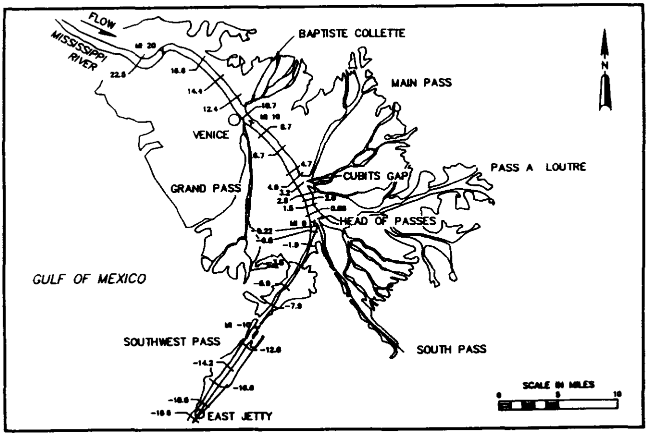

Figure 1. Location Map

accumulations and the number of days that project depth was lost with designated dredging capacities.

Model Description

The TABS-1 one-dimensional sedimentation program, which is a research version of the US Army Corps of Engineer Hydrologic Engineering Center (1991) HEC-6 program, was used to develop the numerical model for this study. The numerical model extended from Tarbert Landing at mile 304 to East Jetty at mile -19.6, and is described in detail in Copeland (1990). Numerical model reliability was tested by comparing calculated and reported dredging in the vicinity of Cubits Gap and Head of Passes for the October 1988-May 1989 hydrograph. The combined calculated dredging in the Cubits Gap reach and Head of Passes was within 2 percent of reported dredging.

Calculated Sediment Accumulation

Geometries for the proposed alternatives were incorporated into the numerical model and run using 11 different annual hydrographs. In these tests, dredging was simulated at the end of the water year.

Both the advance maintenance and sediment trap alternatives resulted in more combined sediment accumulation. The extra storage capacity provided by these two alternatives has the disadvantage of reducing sediment transport potential and thus increasing sediment accumulation rates. Reducing flow through Cubits Gap by 50 percent, however, resulted in a combined reduction in total annual dredging. Sand concentrations in the distributary are lower than upstream in the Mississippi River. This causes a higher sand concentration in the river downstream from Cubits Gap, and coupled with the decrease in discharge, results in a reduced sediment transport capacity. The shoaling potential is reduced when flow through the distributary is reduced. Average annual sediment accumulations for the 11 years are shown in the following tabulation.

Average Annual Sediment Accumulation
Million Cubic Yards (Percent Increase)

	Existing Conditions	Advance Maintenance	Sediment Trap	50% Flow Reduction Cubits Gap
Cubits Gap	1.30	1.48 (14)	2.44 (88)	0.25 (-81)
Head of Passes	3.74	3.87 (4)	3.08 (-18)	3.46 (-8)
Total	5.04	5.35 (6)	5.52 (10)	3.71 (-26)

Maintenance of Project Depth

Percent of time that the navigation channel could be maintained at project depth with different alternatives and dredging capacities was determined using the 11 annual hydrographs. The model was used to calculate progressive bed elevation and sediment accumulation rates in the navigation channel. For example, maximum calculated bed elevation changes in the Cubits Gap reach for existing conditions and for the alternatives during the 1989 hydrograph, are shown in Figure 2. As the numerical simulation progressed, accumulated volume in each reach was reduced by a specified dredging rate to obtain a net maximum bed elevation. When the calculated bed elevation exceeded -45.0 ft, the project depth was considered to be lost. It remained lost until it could be restored by dredging and reduced sediment accumulation rates. Dredging capacities of 25,000 and 50,000 yd^3/day in both the Cubits Gap reach and in Head of Passes were tested. A summary of the number of days project depth is lost for each annual hydrograph is shown in Table 1. Also shown is the percent of time that project depth would be maintained over the entire 11 years.

The greatest benefits from the advance maintenance alternative are realized during years with slightly above average runoff (1974, 1975, 1989), when the extra storage capacity is significant compared to the annual volume of sediment accumulation. With the 11 annual hydrographs, project depth was maintained 94 percent of the time in the Cubits Gap reach and 84 percent of the time in Head of Passes with the advance maintenance alternative and a dredging capacity of 25,000 yd^3 per day. This is an improvement over existing conditions, which provide for project depth 93 percent of the time in the Cubits Gap reach and 81 percent of the time in Head of Passes. With a dredging capacity of 50,000 yd^3 per day, project depth can be maintained 98 percent of the time in the Cubits Gap

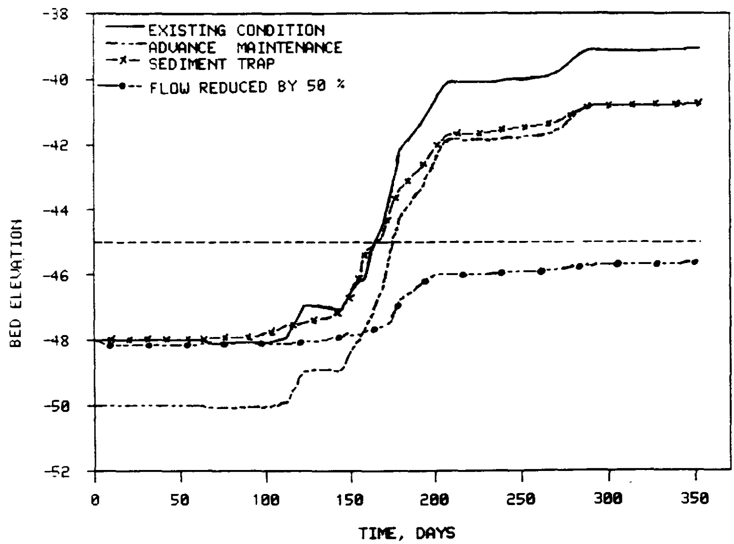

Figure 2. Minimum Calculated Bed Elevation Changes in Cubits Gap Reach During 1989 Hydrograph

reach and 95 percent of the time in Head of Passes, which is the same as for existing conditions.

With the sediment trap alternative, maintaining project depth in the Cubits Gap reach would be more difficult. With a dredging capacity of 25,000 yd^3 per day, project depth was maintained 86 percent of the time with the sediment trap alternative. In Head of Passes, project depth was maintained 88 percent of the time. With a dredging capacity of 50,000 yd^3 per day, project depth was maintained 95 percent of the time in the Cubits Gap reach and 97 percent of the time in Head of Passes.

Reducing the outflow through Cubits Gap by 50 percent provided improved navigation conditions in the Cubits Gap reach for all hydrographs tested. This included both high- and low-runoff years. In the Cubits Gap reach, with a dredging capacity of 25,000 yd^3 per day, project depth was maintained 100 percent of the time. The shoal downstream from Cubits Gap is caused by reduced transport potential created by the distributary. Reducing the impact of the distributary by reducing its outflow also reduces the shoaling problem downstream. In Head of Passes, project depth was maintained 80 percent of the time with a dredging capacity of 25,000 yd^3 per day, and 96 percent of the time with a dredging capacity of 50,000 yd^3 per day. In some relatively low runoff years (1980 and 1982), conditions appeared to be worse at Head of Passes with this alternative because there are more days without project depth than with existing conditions. This condition is created because the shoal at Cubits Gap is scoured at high flows, which causes increased sediment accumulation temporarily in Head of Passes. This condition is eventually overcome; and for years with slightly above average runoff, the increased sediment transport potential provides benefits in Head of Passes as well as in the Cubits Gap reach.

Forecasting with the Numerical Model

It is possible to use the numerical model to forecast sediment accumulation rates and dredging requirements. A 5-week forecasting period between 10 January 1990 and 12 February 1990 was simulated with the model. Results were available within hours after receiving the forecasted hydrograph. Calculated results could not be confirmed, however, because the actual dredging operation was completely different from the simulated dredging operation. Forecasting is only as reliable as the forecasted hydrograph, forecasted sediment inflow, and availability of initial bed elevations for the navigation channel. The model can be useful to dredging management by assisting the Operations Division to anticipate problem periods earlier, thus allowing for more orderly scheduling of dredging operations on a routine rather than emergency basis.

Acknowledgement

The tests described and resulting data presented herein, unless otherwise noted, were obtained from research conducted for the US Army Engineer District, New Orleans, by the US Army Engineer Waterways Experiment Station. Permission was granted by the Chief of Engineers to publish this information.

APPENDIX I. Conversion Factors from U.S. Customary to SI Units

To convert	To	Multiply by
Cubic yard (yd^3)	Cubic meter (m^3)	0.76
Foot (ft)	Meter (m)	0.31
Mile (mi)	Kilometer (km)	1.61

APPENDIX II. REFERENCES

Copeland, Ronald R. (1990). "Dredging alternatives study - Cubits Gap, Lower Mississippi River, Report 1, TABS-1 numerical model investigation." *Technical Report HL-90-20*, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

US Army Engineer Hydrologic Engineer Center. (1991). "HEC-6: Scour and deposition in rivers and reservoirs, users manual." Davis, CA.

TABLE 1. Days Without Project Depth with Dredging Capacity of 25,000 (50,000) yd^3/day

		Existing Conditions	Advanced Maintenance	Sediment Trap	50% Flow Reduction Cubits Gap
1974	Cubits Gap	41 (15)	18 (5)	82 (28)	0 (0)
	Head of Passes	118 (19)	94 (26)	63 (11)	115 (15)
1975	Cubits Gap	12 (0)	6 (0)	76 (13)	0 (0)
	Head of Passes	102 (0)	79 (0)	61 (0)	93 (0)
1976	Cubits Gap	0 (0)	0 (0)	0 (0)	0 (0)
	Head of Passes	0 (0)	0 (0)	0 (0)	0 (0)
1977	Cubits Gap	0 (0)	0 (0)	0 (0)	0 (0)
	Head of Passes	0 (0)	0 (0)	0 (0)	0 (0)
1978	Cubits Gap	0 (0)	0 (0)	0 (0)	0 (0)
	Head of Passes	17 (0)	0 (0)	0 (0)	17 (0)
1979	Cubits Gap	76 (11)	92 (21)	138 (63)	0 (0)
	Head of Passes	225 (86)	204 (83)	169 (60)	223 (63)
1980	Cubits Gap	2 (0)	0 (0)	0 (0)	0 (0)
	Head of Passes	19 (0)	0 (0)	0 (0)	31 (0)
1981	Cubits Gap	0 (0)	0 (0)	0 (0)	0 (0)
	Head of Passes	0 (0)	0 (0)	0 (0)	0 (0)
1982	Cubits Gap	5 (0)	0 (0)	0 (0)	0 (0)
	Head of Passes	0 (0)	0 (0)	0 (0)	9 (5)
1983	Cubits Gap	116 (48)	108 (47)	190 (75)	0 (0)
	Head of Passes	214 (85)	189 (79)	152 (65)	226 (75)
1989	Cubits Gap	21 (0)	13 (0)	61 (15)	0 (0)
	Head of Passes	81 (11)	55 (11)	52 (0)	81 (0)
11 Year Total					
	Cubits Gap	273 (74)	237 (73)	547 (194)	0 (0)
	Head of Passes	776 (201)	621 (199)	497 (136)	795 (158)
Percent of Time Project Maintained					
	Cubits Gap	93 (98)	94 (98)	86 (95)	100 (100)
	Head of Passes	81 (95)	84 (95)	88 (97)	80 (96)