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BENEFIT-COST ANALYSIS OF HARBOR DREDGING ON THE GREAT LAKES

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ABSTRACT: *Commercial harbors on the Great Lakes have to be maintained through dredging. The US Army Corps of Engineers maintains the Federal harbors on the Great Lakes. The Buffalo District of the Corps periodically conducts an economic evaluation of dredging for the harbors it dredges. This economic evaluation uses benefit-cost analysis to ascertain (1) whether dredging of the harbor is economically justified and (2) the economic optimum channel depth(s) to be maintained. The analysis is based on a comparison of total (land and water) transportation costs under the "with project" and "without project" conditions.*

INTRODUCTION

This is a case study in the application of benefit-cost analysis as practiced by the US Army Corps of Engineers (USACE) in evaluating water resources projects. It is a synthesis of a report prepared by the author for the Buffalo District, USACE (Waxmonsky, 1996). The Buffalo District conducts an economic evaluation of dredging on a schedule of about once every five years for each of the thirteen commercial harbors it maintains on Lakes Erie and Ontario. Huron Harbor is located on the southern shore of Lake Erie. It is located about half way between Toledo Harbor and Cleveland Harbor.

Waterborne traffic on the Great Lakes is dominantly based on movement of relatively low valued, bulky commodities. The four principal commodities moving across the Great Lakes are iron ore, limestone, coal, and grain (Waxmonsky, 1992). Waterborne traffic at Huron is primarily based on receipts of iron ore and limestone, and shipments of minor amounts of grain. No coal is handled at Huron Harbor.

The Geography of Huron Harbor

The Federal project at Huron Harbor consists of two piers, three channels and a turning basin. The two piers provide a sheltered area behind which vessels can safely enter the harbor. The turning basin is no longer used for commercial navigation and it is not maintained. The three channels are the: Lake Approach, the Entrance and the River channels (Figure 1).

A brief explanation of LWD - Low Water Datum - is necessary in order to understand channel depths on the Great Lakes. LWD is the theoretical water surface elevation of a Great Lake, in the case of Huron Harbor of Lake Erie, from which channel depths are measured. Approximately 95% of the time, the elevation of the lake's surface exceeds LWD. On Lake Erie, the lake's water surface elevation generally is one to two feet above LWD about 90% of the time.

As its name implies, the Lake Approach Channel is the Federal channel that extends out into Lake Erie and allows vessels to approach the harbor proper.

The Entrance channel is the trapezoid shaped channel situated between the Lake Approach channel and the River channel. The latter is the channelized downstream portion of the Huron River. The upstream limit of the Entrance channel is the turning basin.

Huron Harbor contains a Confined Disposal Facility (CDF) which has been used to hold sediments that in the past were deemed polluted and could not be deposited in the open waters of Lake Erie. Currently, sediments dredged from the channels are suitable for open lake disposal and current policy is to deposit all sediments dredged from Federal channels at the harbor in an open lake site. This analysis assumes continuation of open lake disposal.

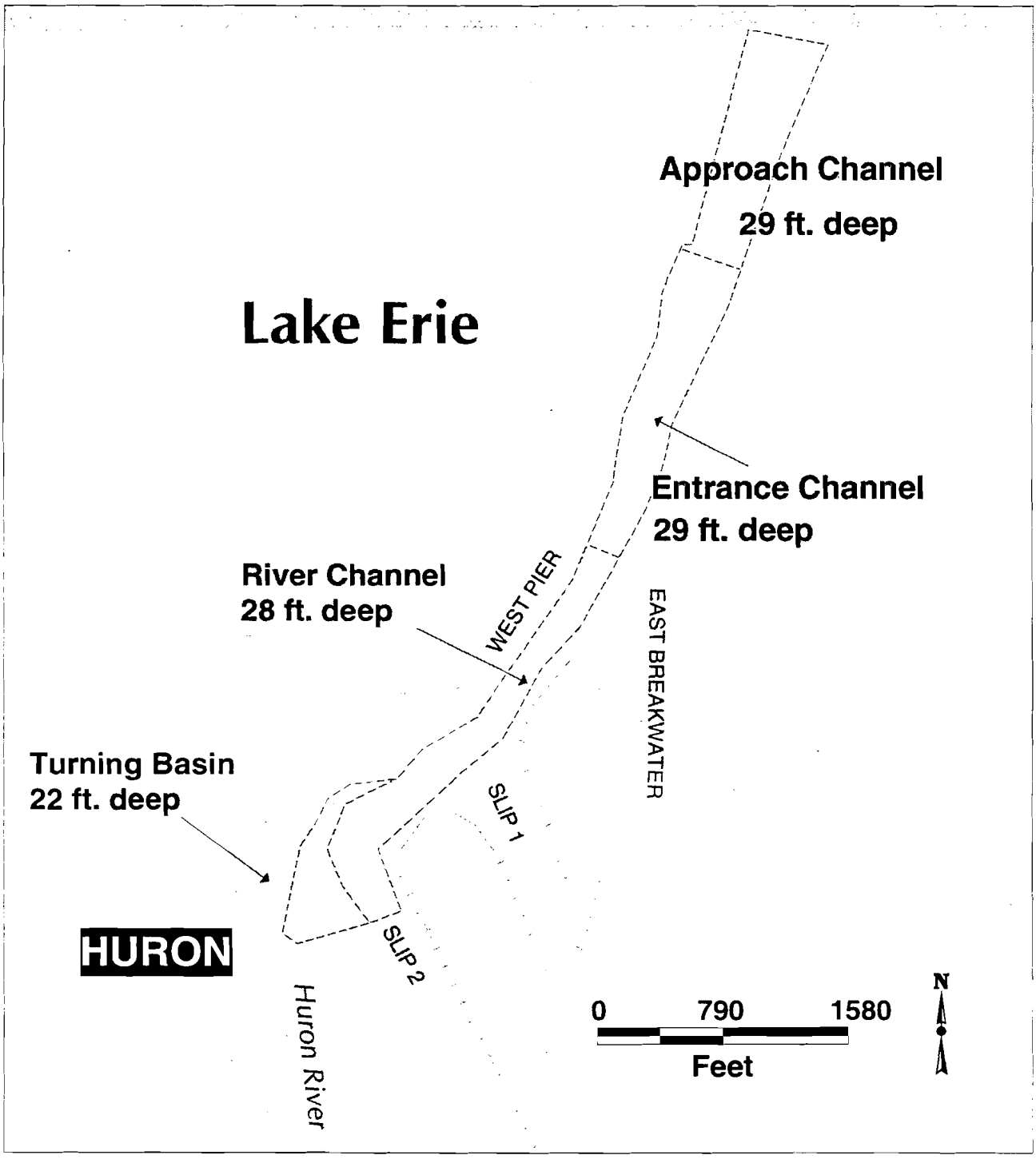

Figure 1. Huron Harbor, Huron, OH.

Channel Depths

"Authorized depth" is the channel depth specified in a project's initial congressional authorizing legislation. The initial project involves establishment of Federal channels to the authorized depth. The authorized depth of the Lake Approach and Entrance channels is 29 ft.; the authorized depth of the River channel is 28 ft. As all vessels entering the harbor must pass through the Lake Approach and Entrance channels, it is their depth that is most critical.

"Maintenance depth" is the channel depth currently provided by periodic dredging. While it is accurate to define the maintenance depth of a channel to be the channel depth provided by periodic dredging, it is somewhat misleading because of shoaling, which is the deposition of sediments in the channel (and elsewhere). The shoaling rate at Huron Harbor is about one foot per year in both the Lake Approach and Entrance channels.

As Huron Harbor is dredged to its authorized depth plus one foot of "overdepth", a 28 ft. channel depth is usually available in the Lake Approach and Entrance channels at the end of the second year of the dredging cycle ((29.0 + 1.0 - (2 X 1.0)). Since all traffic entering the harbor must pass through these two channels, the current maintenance depth at Huron Harbor is said to be 28 ft. below LWD.

Commercial Traffic

Three bulk commodities - iron ore, limestone and grain are the principal commodities moving to\from Huron Harbor via water. Approximately 220,000 tons of iron ore, 450,000 tons of limestone and about 100,000 tons of grain move to or from the harbor via water each year. Iron ore is a receipt at Huron Harbor; all iron ore received at the harbor is shipped out via rail to a steel mill situated on the banks of the Ohio River at Steubenville, OH.

Limestone is also a receipt at Huron Harbor. The limestone received at Huron Harbor is destined for a lime processing plant situated on the east bank of the Huron River at the mouth of the river. Huron Limes processes the limestone and ships it out via rail to integrated steel mills located throughout the Midwest.

Grain is both a receipt and a shipment at or from Huron Harbor. Wheat and oats are received at one grain elevator in Huron Harbor from Thunder Bay, Ontario. The grain elevator at Huron in turn exports grain out of the country via the St. Lawrence Seaway.

ECONOMIC EVALUATION

The purpose of this evaluation is to identify the economic benefits and costs of maintaining alternative channel depths at Huron Harbor. Each channel depth evaluated is considered to be a "plan". The range of channel depths evaluated includes a depth that would accommodate all vessels serving the harbor in the study's base years (1993-94). The evaluation provides estimated benefits, costs, net benefits and associated B\C ratio for each channel depth evaluated and it identifies the economic optimum channel depth - the one with maximum net benefits.

The economic evaluation of alternative plans (channel depths to be maintained) consists of a comparison of the difference in the average annual value of the waterborne transportation bill to the difference in the average annual value of dredging costs. The basis of the comparison consists of the "without plan" project condition minus the "with plan" project condition. These two project conditions are frequently referred to as "without plan" and "with plan" conditions. Definition of the two project conditions are critical to the economic evaluation and are elaborated on below.

Project Conditions

The "with plan" project condition is the level of maintenance dredging that is projected to occur in the future. Since there are alternative channel depths that can be maintained, there are alternative "with plan" conditions. There can be a "with plan" project condition for every channel depth that could be maintained. Since it is difficult to dredge to a level elevation, it is customary to limit "with plan" conditions to integer values - 28 ft., 27 ft., 26 ft., etc. below LWD.

The "without plan" project condition is the reduced (lesser) channel depth at which waterborne commercial navigation traffic in a specified harbor would switch to an alternative transportation mode and/or alternative harbor. As used in this context, "switch to" means that the entities serving as the originator of a traffic flow to the port, or as a destination of a traffic flow from the port, would elect to utilize an alternative land transportation mode or would elect to divert their waterborne traffic to an alternative harbor, or a combination of the two. The switch is made when the total transportation bill at the alternative port or mode becomes less than the total transportation bill at the

subject harbor. "Total transportation bill" refers to the combined rail and water transportation bill.

The determination of the "without plan" project condition at a specific harbor is an intricate process. The depth at which a particular commodity flow would switch from a subject harbor to another mode or harbor varies with the commodity. At Huron Harbor there are three significant commodities that move to or from the harbor - iron ore, limestone and grain. For each commodity there is an alternative harbor or land transportation mode and associated channel depth that has lower total transportation costs than does Huron Harbor.

An analysis has been conducted that identified the alternative harbor and the without plan condition (channel depth) at Huron Harbor for each of the three commodities. For iron ore the alternative harbor is Ashtabula, OH; for limestone it is Sandusky, OH.; and for grain it is Toledo, OH. For iron ore the "without plan" condition (channel depth) is 22 ft. below LWD; for limestone it is 18 ft. below LWD; and for grain it is 25 ft. below LWD.

The Waterborne Transportation Bill

The waterborne transportation bill associated with each "with plan" project condition (channel depth in feet below LWD) has been calculated using historic 1993 /94 data on receipts to and shipments from Huron Harbor and two computer programs developed by the Buffalo District, USACE.

Table 1 presents the annual waterborne transportation bills for channel depths of 17 to 28 ft. in one foot increments. The dollar values presented in the table for each commodity, as well as for the sum of the three commodities, are the estimated total waterborne transportation bills that would be incurred **IF** the 1993/ 94 volume of each commodity were transported by water to or from Huron Harbor at the specified channel depths.

As can be seen in Table 1, as the channel depth initially decreases from 28.0 to 27.0 ft., the increase in the total transportation bill is very minor - $2,000 ($5,306,000 at 27.0 ft. - $5,304,000 at 28.0 ft.). As the channel depth diminishes, the increase in the total transportation bill becomes substantial. At the end of the range of channel depths evaluated, from 18.0 to 17.0 ft., the change amounts to $661,000 ($8,442,000 - $7,781,000 = $661,000).

The reason for the above is that Great Lake boats have large fixed costs and as a result the waterborne transportation bill increases as channel depths decrease. A less deep channel mandates use of a physically smaller boat with less capacity. With lesser capacity, the smaller vessels require an increase in the number of trips in order to transport a given volume of a commodity. The larger number of trips produces a higher (greater) total waterborne transportation bill.

Benefits and Costs

The benefits associated with each plan are the difference in the average annual equivalent value of the total transportation bill under the "without plan" project condition over the duration of the 20 year evaluation period minus the average annual equivalent value of the same transportation bill under the "with plan" project condition over the same evaluation period. The "without plan" condition is the channel depth at which waterborne traffic at the specified harbor (Huron Harbor) would switch to an alternative harbor and\or land transportation mode because the alternative would provide lower total transportation costs. The use of the term "equivalent" indicates that a time stream of monetary values is to be discounted to its "present value" at year one of the time stream. The evaluation period used in this analysis is 20 years.

Since the depth at which a commodity movement would "switch" from Huron Harbor to an alternative harbor, transportation mode, or combination of the two, varies with the commodity, benefits have to be calculated for each significant commodity moving through the harbor. The benefit accruing to each commodity is an amount equal to the average annual equivalent waterborne transportation bill for movement of the commodity in question to Huron Harbor at the "without plan" condition channel depth minus the average annual equivalent waterborne transportation bill for the same commodity flow under the "with plan" project condition channel depth of 28.0 ft. below LWD. For iron ore, which has a with plan projection condition of 22 ft., the resulting maximum average annual benefit amounts to $230,100 at a channel depth of 28 ft.

Table 2 presents the calculation of average annual equivalent transportation benefits under the "without plan" project and "with plan" project conditions for iron ore, limestone, grain, and the total for all three commodities. Note that the average annual transportation cost (column 3) are "equivalent" values that involve financial "discounting." For this reason they differ from the undiscounted annual transportation bills presented in Table 1.

Table 1. Huron Harbor: Waterborne Annual Transportation Bill ($000).

Channel Depth (ft)	Iron Ore	Limestone	Grain	All Commodities
17	3,289	3,439	1,714	8,442
18	2,995	3,162	1,624	7,781
19	2,752	2,993	1,548	7,233
20	2,548	2,740	1,484	6,772
21	2,373	2,578	1,428	6,379
22	2,222	2,439	1,381	6,042
23	2,093	2,340	1,339	5,772
24	1,983	2,257	1,305	5,545
25	1,903	2,208	1,285	5,396
26	1,862	2,186	1,278	5,326
27	1,850	2,181	1,275	5,306
28	1,849	2,180	1,275	5,304

The maximum average annual equivalent total transportation benefit that accrues to movement of all three commodities to or from Huron Harbor amounts to $678,700; it accrues to provision of the 28 ft. channel, (the channel depth currently provided by dredging).

Dredging Costs

Huron Harbor is dredged every other year; it is projected that this frequency of dredging will continue throughout the 20 year evaluation period. The dredging costs associated with each alternative "with plan" condition (channel depth to be maintained) are the average annual equivalent costs incurred in dredging to the specified channel depth (ft. below LWD) over the duration of the 20 year evaluation period. These are the total costs inclusive of S&A (supervision and administration) and E&D (engineering and design) costs associated with maintaining the specified channel depth over the duration of the evaluation period. They do include cost of disposing of dredged sediments in the open waters of Lake Erie.

The Physical Support Branch of the Buffalo District estimated that the 1996 dredging event would remove 200,000 cu. yds. of sediment and that thereafter the harbor would continue to be dredged on an every other year scenario. It projected that the dredging costs would amount to $600,000 ($3.00 per cu. yd.). The total cost of the 1996 dredging event was projected to be $685,000.

Table 3 presents the resulting average annual equivalent dredging costs associated with each "with plan" project condition (channel depth to be maintained) over the 20 year evaluation period. The table presents the "present worth (PW)" of dredging costs over the 20 year evaluation period that are associated with each "with plan" condition, the relevant "partial payment factor" (PPF) at an interest rate of 7.75% and a 20 year evaluation period, and the resulting average annual equivalent dredging cost associated with each channel depth (plan). As expected, average annual equivalent dredging costs are a maximum for the 28 ft. channel ($335,300) and they are a minimum for the 18 ft. channel ($113,200).

Table 3. Huron Harbor: Average Annual Equivalent Dredging Costs.

Channel Depth	PW of Dredging Costs	PPF at 7.75% for 20 years	Avg. Annual Dredging Costs
28 ft.	$3,354,000	0.09996	$335,300
26 ft.	$2918,300	0.09996	$289,000
24 ft.	$2,370,700	0.09996	$234,800
22 ft.	$1,899,100	0.09996	$189,100
20 ft.	$1,493,000	0.09996	$147,900
18 ft.	$1,143,000	0.09996	$113,200

A note about the "interest rate" used throughout this analysis. The interest rate is the official "water resources" interest rate annually determined by the Federal government that is used in the evaluation of all Federal water resources projects in the Fiscal Year the analysis is conducted. This evaluation was completed in Fiscal Year 1996 when the Federal water resource interest rate was 7.75%.

Net Benefits and B\C

Net benefits for a specified plan are the average annual equivalent transportation benefit associated with

Table 2. Huron Harbor: Waterborne average annual transportation benefits.

Without Project					Alternative With Project Condition							
Average Annual Channel Depth (ft < LWD)	Avg Annual Transportation Cost				Annual Equivalent Transportation Cost				Average Transportation Benefit			
	Iron Ore	Limestone	Grain	Total	Iron Ore	Limestone	Grain	Total	Iron Ore	Limestone	Grain	Total
28	$2,079,100	$2,620,900	$1,282,700	$5,982,700	$1,849,000	$2,180,000	$1,275,000	$5,304,000	$230,100	$440,900	$7,700	$678,700
27	$2,079,100	$2,620,900	$1,282,700	$5,982,700	$1,849,900	$2,180,900	$1,275,000	$5,305,800	$229,200	$440,900	$7,000	$676,900
26	$2,079,100	$2,620,900	$1,282,700	$5,982,700	$1,859,800	$2,185,000	$1,277,500	$5,322,300	$219,300	$435,900	$5,200	$660,400
25	$2,079,100	$2,620,900	$1,282,700	$5,982,700	$1,890,200	$2,201,400	$1,282,700	$5,374,300	$188,900	$419,500	$0	$608,400
24	$2,079,100	$2,620,900	$1,282,700	$5,982,700	$1,943,800	$2,234,200	$1,282,700	$5,460,700	$135,300	$386,700	$0	$522,000
23	$2,079,100	$2,620,900	$1,282,700	$5,982,700	$2,009,900	$2,284,000	$1,282,700	$5,576,600	$69,200	$336,900	$0	$406,100
22	$2,079,100	$2,620,900	$1,282,700	$5,982,700	$2,079,100	$2,338,200	$1,282,700	$5,699,000	$0	$283,700	$0	$283,700
21	$2,079,100	$2,620,900	$1,282,700	$5,982,700	$2,079,100	$2,403,600	$1,282,700	$5,765,400	$0	$217,300	$0	$217,300
20	$2,079,100	$2,620,900	$1,282,700	$5,982,700	$2,079,100	$2,472,100	$1,282,700	$5,833,900	$0	$148,800	$0	$148,800
19	$2,079,100	$2,620,900	$1,282,700	$5,982,700	$2,079,100	$2,566,100	$1,282,700	$5,927,900	$0	$54,800	$0	$54,800
18	$2,079,100	$2,620,900	$1,282,700	$5,982,700	$2,079,100	$2,620,900	$1,282,700	$5,982,700	$0	$0	$0	$0

each "without plan" project condition (channel depth in feet below LWD) minus the average annual equivalent dredging cost associated with the "with plan" condition (channel depth in feet below LWD). The B\C (benefit to cost) ratio is the average annual equivalent benefit associated with each "with plan" project condition divided by the average annual equivalent dredging cost associated with the same "with plan" project condition.

Table 4. Average Annual Benefits, Dredging Cost, Net Benefits and B\C for Alternative Without Plan Condition Channel Depths.

Channel Depth (ft.<LWD)	Avg. Annual Dredging Costs	Avg. Annual Dredging Benefits	Avg. Annual Net Benefits	B\C
28	$335,300	$678,700	$333,400	1.99
26	289,000	660,400	371,400	2.28
24	234,800	522,000	287,200	2.22
22	188,100	283,700	95,600	1.51
20	147,800	148,800	1,000	1.01
18	113,200	0	-113,200	0.00

Table 4 presents the average annual equivalent benefits, average annual equivalent costs, average annual net benefits, and the benefit\cost (B\C) ratio for each alternative "with plan" project condition (channel depth in feet below LWD that could be maintained by dredging) in increments of 2.0 feet. The 2.0 ft. interval corresponds to dredging every other year with an annual shoaling rate of 1.0 ft. per year.

CONCLUSION

Huron Harbor is economically justified as there are positive net benefits associated with maintenance channel depths of 20 to 28 ft.below LWD. Dredging of Huron Harbor to the current 28 ft. maintenance depth is economically justified as there are positive net benefits associated with that maintenance depth. However, the optimum maintenance depth for the harbor is 26 ft. below LWD as that is the channel depth that accrues maximum average annual benefits, $371,400 an amount that exceeds the corresponding net benefits associated with the 28 ft. channel by an additional $38,000.

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