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Ohio Sea Grant

IMPACT OF FLOOD & EROSION DAMAGE ON THE NORTHERN OHIO ECONOMY, 1972-1976

Technical Bulletin
OHSG-TB-024

Leroy Hushak
Dept. of Agr. Econ. and Rural Soc.
The Ohio State University

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June 1988

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Leroy Hushak

Ohio Sea Grant Program
The Ohio State University
1314 Kinnear Road Columbus, Ohio 43212
614/292-8949

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The Ohio Sea Grant Program is administered by the Center for Lake Erie Area Research (CLEAR) within the College of Biological Sciences at The Ohio State University. CLEAR also administers Franz Theodore Stone Laboratory.

Funding Support

This publication is a result of work from research project R/ME-4. Ohio Sea Grant Program is partially supported through grant NA84AA-DD-00079 from the National Sea Grant Program of the National Oceanic and Atmospheric Administration (NOAA), U.S Department of Commerce, and funds from the State of Ohio, Ohio Board of Regents and The Ohio State University.

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IMPACT OF FLOOD AND EROSION DAMAGE ON THE NORTHERN OHIO ECONOMY, 1972-1976

Introduction

One hundred and ninety miles of Lake Erie's shoreline fall under the jurisdiction of Ohio. This area is particularly valuable to the state as a center of industry, commerce, agriculture, and recreation. It is also a densely populated region. However, much of the land is susceptible to periodic flood and erosion damages from the Lake associated with high winds and storms. With the Lake Erie water levels in the mid-1980s breaking the record high water levels of the early 1970s [Monthly Water Level Bulletin, 1986], Ohio's Lake Erie coastline was again highly susceptible to flood and erosion damage from storms.

...in the mid-1980's...,Ohio's Lake Erie coastline was again highly susceptible to flood and erosion damage from storms.

In the early 1970s, the lower Great Lakes were especially hard hit by storms that caused extensive property damage. In November 1972, in March 1973 and again in April 1974, several counties in northern Ohio were declared federal disaster areas due to the severity of the storm-related damage they sustained. Each of these storm events occurred with water levels far above the historic mean water level of Lake Erie (Carter, 1973). Between 1861 and 1976, 12 of 15 severe storm events occurred with Lake Erie water levels above the long-term average (USDC-NOAA, No date).

In 1976, the U.S. Army Corps of Engineers was charged with conducting an extensive survey of private property owners along the entire U.S. Great Lakes shoreline in order to assess the extent and nature of damages occurring during that period and the expenditures made to protect their properties (Bedford et al., 1978, U.S. Army Corps of Engineers, 1981). In this study we utilize the damage and cost of protection estimates generated by the Corps study for private property in the state of Ohio. Public property damages were not estimated in the Corps' study. Using an input-output model of the northern Ohio regional economy (Hushak et al., 1984), we estimate the economic resources

Table 1. Classification of Ohio's Lake Erie Shoreline by Land Type

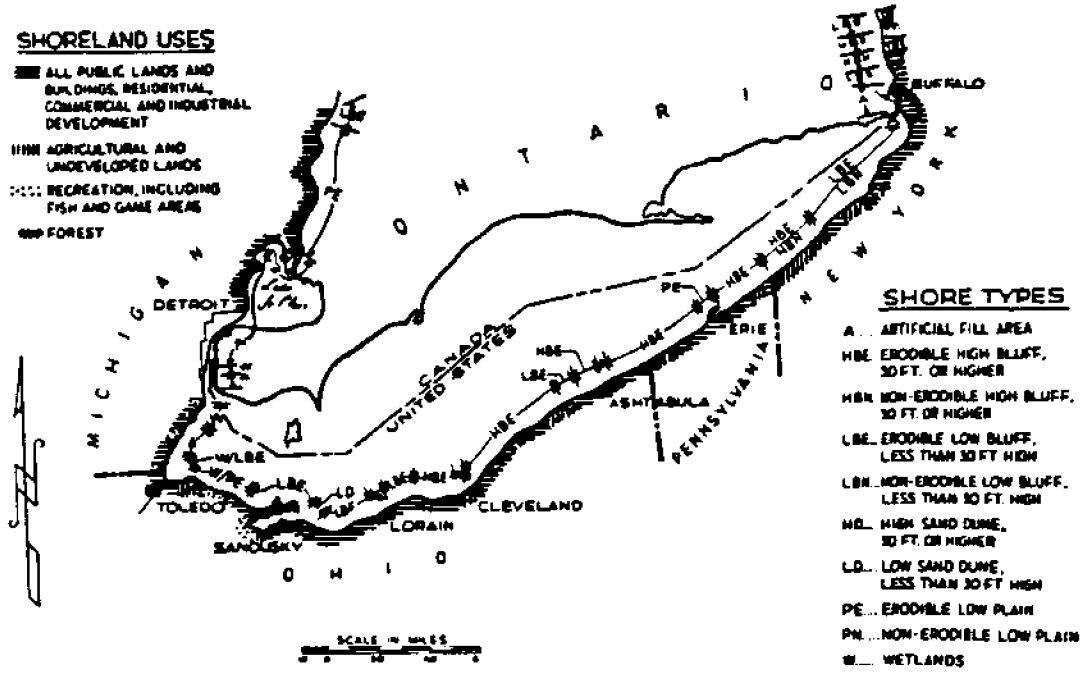
Land Type	Miles	%
Erodible		
Erodible High Bluff	72.7	38
Erodible Low Bluff	55.1	29
Erodible Low Plain	19.9	10
Wetlands/Erodible Plain	3.5	2
Total	151.2	79
Non-Erodible		
Artificial Fill Areas	15.1	8
Low Sand Dune	12.4	7
Non-Erodible Low Bluff	5.5	3
Wetlands	4.1	2
Non-Erodible High Bluff	2.0	1
Total	39.1	21
Total	190.3	100

Source: $GLBC_b$, 1976.

within the region that were used for the restoration, replacement and/or protection of private property instead of for production of the usual goods and services during this four-year period. These estimates of total economic resource costs are then converted into expected annual costs of storm damage using information on linkages between storm events and Lake Erie water levels (USDC-NOAA, No date).

These annual expected cost estimates provide guidelines against which the costs of protective strategies, such as the construction of protective devices or the design of shoreline development zoning policies, can be compared. Even though we are examining damages to private property, public strategies are needed. Private property owners, as individuals, cannot deal efficiently with protection strategies such as large protective devices or zoning policies because of the necessity that many persons reach a joint decision. Local public and often state programs or policies are necessary. However, the choice of who can most effectively administer alternative policies and of how they should be financed is beyond the scope of this study.

Figure 1. Characteristics of the Lake Erie Shoreline.



Source: $GLBC_b$, 1976.

Characteristics of Lake Erie and Its Shoreline

The state of Ohio includes over 190 miles or about 56 percent of the U.S. Lake Erie shoreline ($GLBC_b$, 1976). Generally the land bordering the western basin is low-lying and at one time contained extensive wetlands. Today, although much of the original marshland has been drained, some areas of northwestern Ohio remain flood-prone.

Approximately 79 percent of Ohio's Lake Erie coastline is classified as being susceptible to erosion (Table 1). As shown in Figure 1, erodible lands of the western basin are of the low bluff and low plain types whereas erodible high bluffs dominate the southeastern shore. Although erosion is an ongoing, natural process along Lake Erie, it is exacerbated during periods of high water and during storms.

Approximately 79 percent of Ohio's Lake Erie coastline is classified as being susceptible to erosion.

Ohio's Lake Erie shoreline is highly developed and densely populated. In 1970, only 14 percent of the shoreline was undeveloped or devoted to agriculture. Another two percent was forest and woodland whereas over one-half was classified as residential ($GLBC_e$, 1976).

In that year, publicly owned land made up nearly 20 percent of the total, including fairly large state and federal wildlife refuges and parks just east of Toledo and county and municipal recreational land elsewhere along the coast. Eight percent of the land was held by industrial firms; much of it concentrated in the east around Conneaut, Ashtabula, Painesville, Fairport Harbor, Cleveland and Lorain, and at the extreme western end of the state in Toledo.

Lake Erie is the shallowest of the Great Lakes with an average depth of only 62 feet. From the shallows at the western end where water depths average 25 to 30 feet, the Lake drops to a maximum depth of 212 feet in the east ($GLBC_a$, 1976).

Lake Erie is situated so that its long axis is oriented in a general southwest-northeast direction along the path of the prevailing southwest winds. It is characterized by low-lands at its western end and bluffs of over 30 feet in height along much of the length of its central and eastern basins. It is this unique

combination of factors which makes Lake Erie especially susceptible to storm damage.

High winds accompanying low pressure systems originating from the northeast can push water to the western end of the Lake. Here it gradually builds up since subsurface flows are restricted by the shallowness of the Lake. If such weather disturbances are of sufficient duration, water can inundate low-lying areas causing flood, erosion and wave damage to property and structures. Although the high bluff shoreline areas of the central basin are susceptible to erosion, during the period covered in this study, erosion-related damages tended to be concentrated in the western basin.

...Lake levels may rise and remain significantly above their long-term averages for long periods of time. The potential for storm-related damage is greater under these conditions...

Lake Erie Water Levels

Lake Erie water levels vary seasonally. Peak volumes are reached during the summer months and lows occur in the winter. Although a number of factors--freezing, snow and ice melt, evaporation, ground water flows and crustal movements--contribute to these seasonal variations, the most significant determining factor is precipitation which adds to the Lake's volume directly and also indirectly through the run-off carried by streams and rivers within the Lake's natural drainage basin.

With their large areas, the Great Lakes can usually handle short-term excesses of precipitation although the capacities of the rivers connecting and draining them are limited. Thus, if precipitation is abnormally high over time as during the period covered in this report, Lake levels may rise and remain significantly above their long-term averages for long periods of time. The potential for storm-related damage is greater under these conditions since deeper water allows waves to achieve greater heights and to break with greater force closer to the shore. In addition, high water levels change the effect of waves on the shoreline in that natural beaches are submerged and waves can act directly on the more susceptible backshore, accelerating the normal erosion process.

The 1972-1974 Storm Events

Historically there have been a number of damaging northeast storms on Lake Erie, most of which occurred when water levels were high (Figure 2). Data in Figure 3 indicate that prior to and during the study period (September 1972 to September 1976), average annual precipitation over the entire Great Lakes basin and within the Lake Erie basin itself was greater than the long-term average. It was the severity, destructiveness and close spacing of the storms that made the early to mid 1970s a unique period for Lake Erie's shore communities.

The Storm of November 13 and 14, 1972

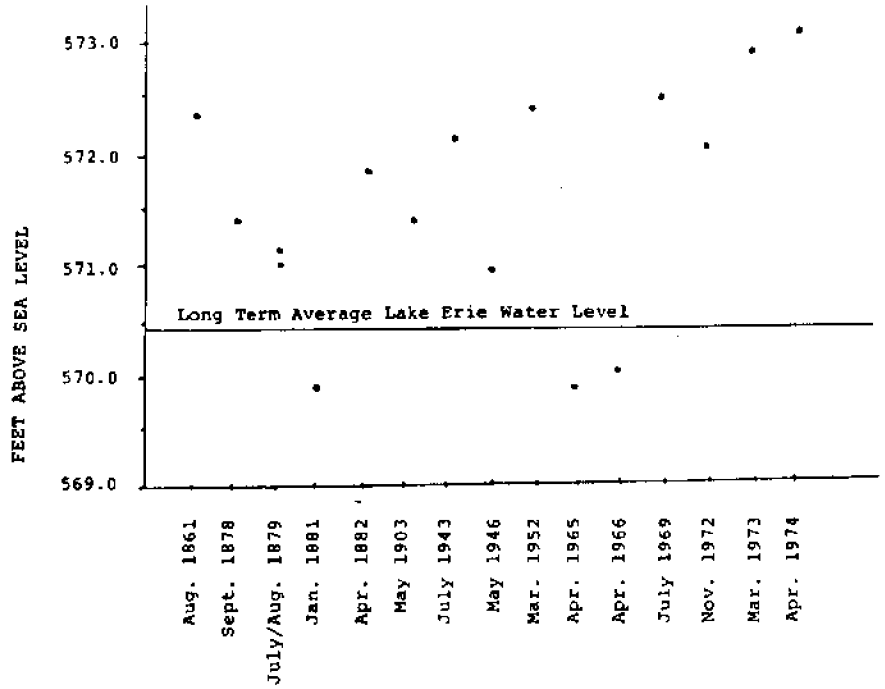
The storm of November 13 and 14, 1972 is considered one of the worst natural disasters in Ohio's history,...

The storm of November 13 and 14, 1972 is considered one of the worst natural disasters in Ohio's history (Carter, 1973). It occurred when Lake Erie was about two feet above its long-term November average. A northeast wind began early on November 13 and continued until late on the 15th, eventually reaching speeds up to 45 miles per hour (Carter, 1973). The strong winds forced water to pile up against and then inundate extensive areas of the southwest shore. At one point, water levels reached a height at Toledo of more than six feet above the long-term November average, and waves of up to 12 feet were generated (Carter, 1973).

Residents from Huron, Ohio to Monroe, Michigan were forced to evacuate their homes because of flooding and waves. Many homes, roads and protective structures such as seawalls, dikes, beaches and dunes were damaged or destroyed. Flooding occurred where waves breached dikes and other protective structures surrounding low-lying areas. Because some of the land in north west Ohio contains high levels of clay, flood water could not readily percolate downward, and in some places, the ground was covered with water for several days.

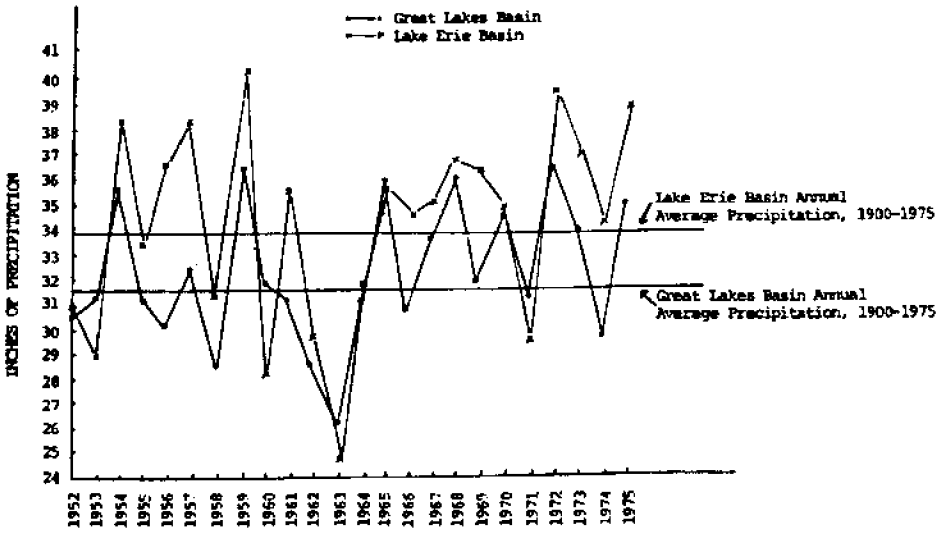
Following the storm, seven Ohio counties (Lucas, Ottawa, Erie, Sandusky, Lorain, Cuyahoga and Lake) and nine Michigan counties were declared a major disaster area by the Small Business Administration. This made flood victims eligible for low-interest loans to restore and/or replace damaged or lost property

Figure 2. Average Monthly Lake Erie Water Levels During the Months in Which Severe Northeast Storms Occurred.



Source: Carter, 1973, pg. 4.

Figure 3. Annual Precipitation Within the Lake Erie and Great Lakes Basins, 1952-1975.



Source: U.S. Army-Detroit, 1977.

and structures. Eventually northern Ohio was declared a major disaster area by President Nixon which made federal funds available for direct relief and for the repair and restoration of public facilities.

In making his request for federal aid, Ohio's Governor Gilligan estimated that more than $22 million of damage had been sustained in Ohio (Toledo Blade, November 24, 1972). A preliminary survey showed damages of $12 million to 2000 homes and $500 thousand to 24 businesses in Lucas, Ottawa and Sandusky counties alone (Toledo Blade, November 18, 1972). Eventually as a result of this storm, certain Ohio cities and townships within the disaster counties and the Ohio Departments of Natural Resources and of Transportation were granted a total of $615,862 of direct federal aid (Deborah Patchen, 1984).

Operation Foresight,.... authorized the U.S. Army Corps of Engineers to conduct studies to determine sites along the Great Lakes shoreline where temporary flood emergency operations would be practical....

Operation Foresight

The Detroit District, U.S. Army Corps of Engineers publishes monthly estimates of anticipated water levels for the Great Lakes which are then extended for the next six months. During the second half of 1972 when above-average levels of precipitation fell within the Great Lakes drainage basin, forecasters predicted that the spring, 1973 water levels would approach or exceed the last extreme high of 1952 and possibly cause severe flooding around the Great Lakes except Lake Superior. In view of these predictions, Operation Foresight was activated and authorized on December 15, 1972. Ohio's governor responded to the announcement on January 30, 1973.

Operation Foresight, a program initiated under the provisions of PL84-99, authorized the U.S. Army Corps of Engineers to conduct studies to determine sites along the Great Lakes shoreline where temporary flood emergency operations would be practical (erosion control was not specifically provided for under Operation Foresight). Among the criteria set out in the law were that flood protection measures must exceed the capabilities of state or local resources, be justified from an economic and engineering standpoint, be of a temporary nature, be designed to handle the anticipated high water levels and be completed in time to

be of use. As outlined in the laws, maintenance and removal of protective structures were local responsibilities. In some cases where a project was not approved, materials were offered on a self-help basis to communities that agreed to supply voluntary labor.

Fifty-nine communities in seven states received $26.8 million of assistance through Operation Foresight.

Fifty-nine communities in seven states received $26.8 million of assistance through Operation Foresight (Table 2). Eighty-four percent ($22.3 million) went for contract projects and the rest was spent on self-help materials, mainly sandbags. Among the protective structures built under contract were earth dikes, riprap, sand and rock-filled cribs and stone-filled gabions.[1] The target date for completion of the projects was fall 1973 to early spring 1974.

Table 2. Operation Foresight Costs and Estimates of Damage Prevented to the Great Lakes Shoreline, 1973-1974

	Costs[1]		Estimated Damages Prevented	
	$ million	(percent)	$ million	(percent)
Contract Projects[2]				
Ohio	8.621	(39)	22.126	(18)
Other States[3]	14.192	(61)	97.859	(82)
Total	22.318	(100)	119.985	(100)
Self-Help Projects				
Ohio	0.175	(4)	0.477	(6)
Other States[3]	4.257	(96)	11.800	(94)
Total	4.432	(100)	12.277	(100)
Total				
Ohio	8.796	(33)	22.603	(17)
Other States[3]	18.017	(67)	109.659	(83)
Total	26.813	(100)	132.262	(100)

1 Includes materials and administration costs.
2 Contracts were awarded to local firms by the U.S Army Corps of Engineers.
3 Other states included Wisconsin, Illinois, Indiana, Michigan, New York and Pennsylvania.

Source: U.S. Army-Detroit, 1977.

[1] Gabions are offshore breakwaters designed to protect beaches. Riprap consists of a layer, facing or pretective mound of stones randomly placed to prevent erosion. Cribs are large crate-like structures built against slopes and filled with rock or sand to lend support and protect the slopes from erosion (U.S. Army-NCD, 1978, Army-LCSP, 1978).

Eight of the communities that received contract assistance were in Ohio.[2] Altogether they received $8.6 million or 40 percent of the total contract project award made to the seven states. Ohio's share of the self-help funds amounted to $175 thousand or four percent of the self-help total. Overall, the state of Ohio received nearly $8.8 million of Operation Foresight funds: 33 percent of the total allocated to the seven states.

The March, 1973 and April, 1974 Storms

Much less detail is available on the other two major storms. However, a similar sequence of events occurred in March, 1973 as with the November, 1972 storm. The April, 1974 storm was associated with a weather disturbance that caused the Xenia tornado.

Eight of the communities that received contract assistance were in Ohio.

In the aftermath of the March, 1973 storm, eight northern Ohio counties were declared a major disaster area by the President and by the Small Business Administration. After the April, 1974 storm, three Ohio counties (Lucas, Ottawa and Sandusky) were designated as a disaster area. Flooding associated with both of these storms was worse than that which occurred in 1972 because of higher water levels (Figure 4).

In 1973, $1.418 million in federal aid went to cities, villages and townships within the eight county disaster area as well as to the Ohio Department of Natural Resources and to Camp Perry, a National Guard installation (Deborah Patchen, 1984). In 1974, certain cities, towns, villages and conservancy districts within the three county disaster area and the Ohio Departments of Natural Resources and of Transportation received federal grants totaling $859 thousand (Deborah Patchen, 1984).

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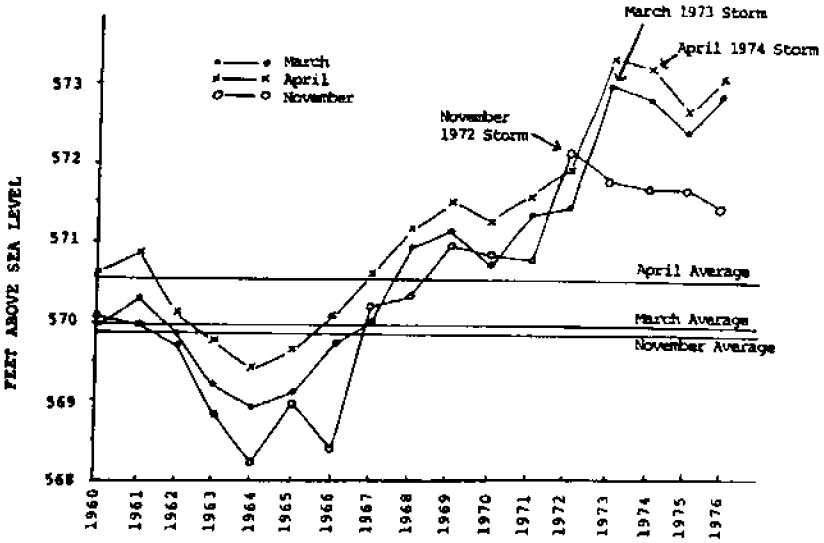
[2] The eight project sites were Point Place in Toledo, Reno Beach/Howard Farms, Bay Township, Whites Landing, Bayview, Eastlake, Conneaut Water Intake and Crystal Rock. Forty-five other sites in Ohio were considered and then rejected because they failed to meet one or more of the Operation Foresight guidelines.

The eight Ohio Operation Foresight contract projects were completed between April and November 1973 so they were not in place until after two of the three major storms of the study period. The U.S. Army Corps of Engineers estimated that in Ohio, Operation Foresight projects prevented more than $22.6 million of damage through 1974.[3]

.... Operation Foresight projects prevented more than $22.6 million of damage through 1974.

The Corps of Engineers inspected the eight contract project sites in 1976 and found them all functional. The 1976 status report referred to additional flooding in the fall and winter of 1973, March 1974 and the spring of 1975. A newspaper account mentioned that three windstorms in 1973 were associated with some shoreline flooding (Sandusky Register, 1974).

Figure 4. Average Monthly Lake Erie Water Levels: March, April and November, 1960-1975.



Source: USDC-NOAA, No date, pg. 47.

[3] Field crews visited each site to determine at what water levels zero, intermediate and maximum amounts of flooding would occur. Using average property and structure value assessments for the area and applying water level projects that were termed "most probable," the Corps of Engineers derived their estimates of damages prevented. Because of time constraints, their calculations were necessarily rough.

Damage Estimation

As a result of the unusual amount of damage sustained by the lower Great Lakes states in the early 1970s, the U.S. Army Corps of Engineers funded studies to assess the extent of damage to private property along the Lakes from Labor Day 1972 to Labor Day 1976 (Bedford, et al., 1978, U.S. Army Corps of Engineers, 1981). The Corps of Engineers report did not contain estimates of damages to public property. In this study we use the results for the state of Ohio within the analytical framework of an input-output model for northern Ohio to estimate the total economic damages from these storm events between 1972 and 1976.

The study area for Ohio was defined as the 100-year open coast flood level....

Data from the Corps of Engineers Study

The study area for Ohio was defined as the 100-year open coast flood level and included properties both inland and along the Lake in eight northern Ohio counties: Lucas, Ottawa, Sandusky, Erie, Lorain, Cuyahoga, Lake and Ashtabula. The study area was then divided into subreaches based upon the susceptibility of the land to erosion and/or flood damage, certain demographic characteristics and proximity to the shore.

Field teams were sent to the eight county seats and information about each property was collected. Mailing lists were generated according to land use. The land use categories were: residential, commercial, industrial, transportation, utilities and agriculture/forestry (Data on public property were not collected for this report). Due to the large number of residential properties, a sample based on assessed property values was selected statistically and, through linear extrapolation the sample results were later expanded to reflect the total population. All property owners in other land-use categories were sent questionnaires and the survey results were linearly extrapolated to account for non-responses.

Lake Erie's commercial sector at the time of the study was made up of diverse firms. Nearly 60 percent of the commercial firms were identified by private names only and could not be categorized. Of the commercial firms which could be categorized 30 percent were marina/

boat sales operations, 12 percent were recreation-oriented such as sports clubs and camps, 9 percent were categorized as retail and 8 percent each were associated with real estate or chemicals. Other commercial properties along Lake Erie were components of sectors such as finance, construction, electricity, eating/-drinking establishments, wholesale, water transportation, commercial fishing, communications and machinery.

Thirty-nine land parcels were owned by industrial firms from the following sectors: paper and allied products, stone, clay and glass, chemicals and primary non-ferrous metals. In the Corps of Engineers study, commercial and industrial firms were grouped together.

Flood damages were concentrated in the western basin counties, especially Lucas and Ottawa....

Firms in the transportation category were railroads and a docking company, and several different power companies operating along the shoreline were classed as utilities. Residences and agricultural/forest land were owned by individuals and there were no data to enable any characterization of these properties.

Western basin counties suffered nearly two thirds of the erosion damages.....

Estimates of Damage and Protection Costs

Corps of Engineers questionnaires were designed to collect detailed information from survey respondents on the amount and type of erosion and flood damage done to private property during the four-year study period. Data were also collected on the costs incurred by property owners for shore and property protection.

Damages

The distribution of flood and erosion damages by county is summarized in Table 3. Flood damages were concentrated in the western basin counties, especially Lucas and Ottawa which together accounted for 81 percent of the total. Central basin counties, in contrast, sustained only four percent of the flood damages. Western basin counties suffered nearly two thirds of the erosion damages over the study period. Among the hardest hit counties were Erie with 36 percent of the total and Ottawa with 26 percent. Damages to the four central basin counties were nearly equal.

Table 4 summarizes the extent of flooding and erosion damage to private property by sector during the period 1972 to 1976. Overall, flooding and erosion damages were nearly equal; both were over $32 million. An examination of Table 4 reveals that residential property owners suffered the greatest losses of the five sectors: 92 percent of the flood damages and 90 percent of the erosion damages. Commercial/industrial property owners sustained three percent of the flood and nine percent of the erosion damages whereas owners of agricultural/forest lands accounted for five percent of flood-related damages and less than one percent of erosion damages. Utility and transportation properties were virtually untouched by floods and each sustained less than one percent of the erosion damages.

.....residential property owners suffered the greatest losses of the five sectors: 92 percent of the flood damages and 90 percent of the erosion damages.

Table 5 lists for each sector and for each damage category examples of the types of damage as reported on respective sample questionnaires. However, it was beyond the scope of this study to review all individual questionnaires. Instead, a sample of questionnaires for each land-use category was examined and a general idea about the nature of damages was gained.

As noted previously, the residential sector accounted for over 90 percent of the $64.6 million of erosion and flood-related damages. Thirty-one percent of that total ($20 million) occurred in the residential "structures and contents" category which included residences and furnishings, detached garages and other outbuildings on residential properties. Another 31 percent was incurred by residential "grounds and improvements" such as docks, boat ramps, boathouses, stairways, septic systems and landscaping. The remaining expenditures made by the residential sector were for clean-up, loss of rental or business income and "other costs" which could not be characterized due to lack of data. Flood and erosion damages for all other sectors were minimal when compared to those of the residential sector.

Table 3. Percentage Distribution of Flood and Erosion Damage to the Study Region by County, 1972-1976

	Damage	
	Flood	Erosion
	(percent)	
Western Basin		
Lucas	32	2
Ottawa	49	26
Sandusky	2	1
Erie	13	36
Total	96	65
Central Basin		
Lorain	<1	6
Cuyahoga	2	11
Lake	1	8
Ashtabula	<1	10
Total	4	35

Source: Bedford, et al., 1978.

Table 6. Percentage Distribution of Flood and Erosion Protection Costs for the Study Region, by County, 1972-1976

	Costs of Protection	
	Flood	Erosion
	(percent)	
Western Basin		
Lucas	17	1
Ottawa	53	18
Sandusky	7	1
Erie	10	26
Total	87	46
Central Basin		
Lorain	3	17
Cuyahoga	6	13
Lake	3	11
Ashtabula	1	13
Total	13	54

Source: Bedford, et al., 1978.

Table 4. Flood and Erosion Damages to the Study Region by Sector, 1972-1976, in Millions of Dollars ($M)

	Structure & Contents	Grounds & Improvements	Clean Up	Emergency Evacuation	Financial Loss	Other Damages	Total Damages	
Flood								
Residential	14.276	7.107	1.198	0.0	2.756	4.235	29.572	(92)
Commercial/Industrial	0.263	0.413	0.121	0.011	0.199	0.026	1.033	(3)
Transportation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(0)
Utilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(0)
Agriculture/Forestry	0.0	0.0	0.0	0.0	0.0	1.613	1.613	(5)
Total	14.539	7.520	1.319	0.011	2.955	5.874	32.218	(100)
Erosion								
Residential	5.578	13.177	1.357	0.0	1.861	7.180	29.153	(90)
Commercial/Industrial	0.881	1.492	0.0	0.0	0.013	0.724	3.110	(9)
Transportation	0.0	0.0	0.0	0.0	0.0	0.036	0.036	(<1)
Utilities	0.0	0.0	0.0	0.0	0.0	0.008	0.008	(<1)
Agriculture/Forestry	0.0	0.0	0.0	0.0	0.0	0.084	0.084	(<1)
Total	6.459	14.669	1.357	0.0	1.874	8.032	32.391	(100)

Source: Bedford, et al., 1978.

Table 5. Flood and Erosion Damages of Private Property Owners by Sector and by Type, and Percent of Total Damages Sustained by Category, 1972-1976[1]

Residential		
Structure & Contents	31%	residential buildings contents, detached garages, non-residential buildings
Grounds & Improvements	31%	docks, ramps, boathouses, stairways, lawns, trees, landscaping, septic systems
Clean Up	4%	clean up
Financial Loss	7%	loss of rental and business income
Other Damages	18%	---[2]
Commercial/Industrial		
Structure & Contents	2%	foundation, walls, merchandise, equipment, records, contents, stock redecoration, painting
Grounds & Improvements	3%	parking lots, walls, signs, lawns, shrubs, docks, wharves, boat and beach houses
Clean Up	<1%	clean up
Emergency Evacuation	1%	evacuation and reoccupation (moving goods, temporary leasing space)
Financial Loss	1%	loss of business income and employee wages
Other Damages	1%	---[2]
Transportation		
Structure & Contents[3]		bluff repairs, repairs of rights of way, foundations, pavements surfaces, equipment
Financial Loss[3]		loss of business and employee wages
Other Damages	<1%	temporary rerouting costs, increased operating costs
Utilities		
Structure & Contents[3]		machinery, furniture and fixtures mains, lines, cables, meters
Grounds & Improvements[3]		roads, storage areas
Clean Up[3]		clean up of equipment, grounds and structures
Financial Loss[3]		loss of business income and employee wages
Other Damages	<1%	---[2]
Agriculture/Forestry		
Other Damages	3%	livestock, crops, farm equipment fences

[1] Percentages are based on total flood and erosion damages: $64,609 million. Percentages total >100 percent due to rounding.

[2] No information on the nature of these damages was provided on the questionnaire.

[3] No expenses reported but examples of expenses given.

Source: Bedford, et al., 1978.

Table 7. Flood and Erosion Protection Costs Within the Study Region by Sector, 1972-1976

	Relocations ($ Mil.)	Protective Structures ($ Mil.)	Other Costs ($ Mil.)	Total Costs $ Mil.	(%)
Flood					
Residential	1.012	9.921	1.773	12.706	(76)
Commercial/Industrial	0.0	0.115	0.400	0.515	(3)
Transportation	0.0	0.0	0.0	0.0	(0)
Utilities	0.0	0.002	0.0	0.002	(<1)
Agriculture/Forestry	0.000	0.000	3.596	3.596	(21)
Total	1.012	10.038	5.769	16.819	(100)
Erosion					
Residential	0.295	18.726	0.739	19.760	(92)
Commercial/Industrial	0.013	0.589	0.227	0.829	4)
Transportation	0.0	0.075	0.0	0.075	(<1)
Utilities	0.150	0.008	0.0	0.158	(1)
Agriculture/Forestry	0.000	0.000	0.696	0.696	(3)
Total	0.458	19.398	1.662	21.518	(100)

Source: Bedford, et al., 1978.

Table 8. Cost of Protection by Sector and by Type and Percent of Protection Costs Spent by Category, 1972-1976[1]

Residential		
Relocations	3%	relocation of home/cottage (materials and labor)
Protective Structures	75%	revetments, sea walls groins
Other Costs	7%	---[2]
Commercial/Industrial		
Relocations	<1%	relocation of facilities and roads
Protective Structures	2%	jetties, groans, revetments, dikes, levees, seawalls, flood-proofing, costs of temporary shore-up structures
Other Costs	2%	---[2]
Transportation		
Relocations[3]		relocation of RR lines, roads, and bridges
Protective Structures	<1%	permanent protection to prevent damage to RR lines, roads, bridges
Utilities		
Relocations	<1%	relocation of facilities
Protective Structures	<1%	emergency and permanent protection
Agriculture/Forestry		
Relocations		relocation of structures
Other Costs	11%	flood-proofing, terracing fences, irrigation lines, drainage tiles, planting of ground cover

1 Percentages are based on total flood and erosion protection expenditure of $38.337 million.

2 No information on the nature of these damages was provided on the questionnaire.

3 No expenses reported but examples of expenses given.

Source: Bedford, et al., 1978.

Costs of Protection

The distribution of protection costs by county summarized in Table 6 reveals that 87 percent of flood protection expenditures were made by property owners in the western basin. Over 50 percent of flood protection costs were borne by property owners in Ottawa County. Erosion protection expenditures on the other hand were more evenly distributed between the western and central basins. Expenditures were minimal in Lucas and Sandusky counties but Erie and Ottawa counties together accounted for 44 percent of the total. Property owners in the central basin incurred 54 percent of the total costs of erosion protection. Those expenditures were spread fairly evenly among the four counties.

....residential property owners spent the most: 76 percent of flood protection expenditures and 92 percent of outlays for erosion protection.

Cost of protection data, by sector, appear in Table 7. As expected, residential property owners spent the most: 76 percent of flood protection expenditures and 92 percent of outlays for erosion protection. Property owners of the agriculture/forestry sector accounted for 21 percent of the total spent on flood protection. Protection costs for all other sectors were less than five percent.

Seventy-five percent of total protection costs was spent by residents for protective structures like seawalls, revetments and groins (Table 8).[4] Another three percent was spent on materials and labor for relocation of residences and seven percent was categorized as "other costs." The only other significant expenditures occurred in the agriculture/-forestry sector under the category "other costs." Eleven percent of the total was spent by private property owners in this sector for flood proofing, ground covers, fences, drainage tiles and irrigation lines. Expenditures for protection were minimal in the other sectors.

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[4] Revetments and groins are stone or concrete shore protection structures. The former are designed to protect embankments from erosion and the latter are built perpendicular to the shore to retard beach erosion (U.S. Army-NCD, 1978, U.S. Army-LCSP, 1978).

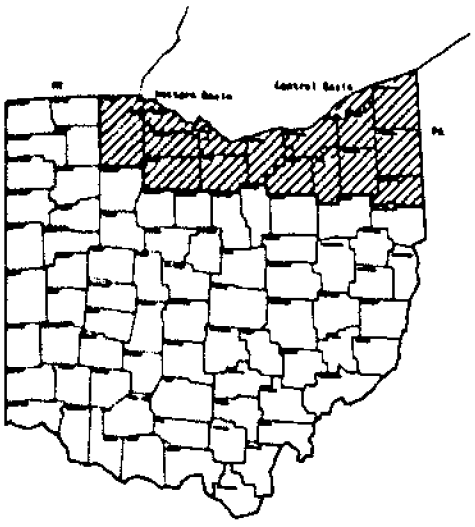
The Input-Output Model

A change in one sector of an economy leads to changes in its other sectors. To measure the total impact of a change in one economic activity on the whole economy, it is necessary to trace out the indirect effects on all other economic sectors in addition to the direct impact. To accomplish this, it is necessary to know how the various economic sectors relate to each other. One method that does this is input-output (I/O) analysis.

In I/O analysis, all economic activity is categorized into either endogenous or exogenous sectors. Firms within a given endogenous sector produce a set of similar goods and services for sale to other endogenous sectors or to the exogenous or final demand sectors of exports and household consumption. The flow table of an I/O model describes the demand and supply relationships of an economy in equilibrium by showing final demand for goods and services and the inter industry transactions required to satisfy the demand. Coefficients which measure the direct and indirect effects of changes in output in each sector resulting from a $1.00 change in final demand for a given processing sector are derived from the flow tables. I/O models also permit calculations of the impact on regional output, income and employment caused by changes in final demand for a given sector.

....expenditures to mitigate flood and erosion damage do not contribute new output, income and employment to an economy,...

Figure 5 Study Region Covered by the I/O Model.



In this study, a 43-sector, open, static I/O model was used to assess the impact of erosion and flooding on the northern Ohio regional economy from Labor Day, 1972 to Labor Day, 1976 (Hushak, et al., 1984). The study region covered by the model is shown in Figure 5 and includes not only the eight counties which border the Lake, but nine others in northern Ohio that are directly affected by economic activities relating to Lake Erie.

The usual application of an I/O model allows one to trace the impact of expenditures made by a particular sector on the rest of the economy, since spending by that sector generates new output, income and employment under the assumption of unemployed resources in the region. However, expenditures to mitigate flood and erosion damage do not contribute new output, income and employment to an economy,

but rather reduce the output, income and employment in other sectors or parts of the economy because resources must be transferred from these sectors to flood and erosion damage mitigation.

In this report, we use the I/O model to estimate the quantity of regional output, income and employment resources diverted from the usual production of goods and services to the restoration, replacement or protection of private property because of real or anticipated storm-related damages. If regional resources are fully employed, then resources which are used to replace or restore property or to invest in shore protection must be obtained from other sectors of the economy. If there are unemployed labor or capital resources in the region, the employment of these resources reduces the total impacts of storm and erosion damage, i.e., resources which have zero or low opportunity costs are used rather than resources which were fully employed producing other goods and services. The estimates of damage costs that we present use the assumption that the resources used for flood and erosion damage mitigation were previously fully employed in the region. In this respect, our estimates are upper bound estimates of these costs. On the other hand, since damages to public property and the loss from the washing out or the loss of square footage of lakefront property are not estimated in the Corps' study, our estimates are low.

Estimates of Total Impact

Ideally, to determine the impact of storm-related floods and erosion on the northern Ohio regional economy, the sectors from which purchases were made to restore, replace and/or protect private property should be identified. However, because detailed information was not available, the descriptive data in Tables 5 and 8 were used to allocate the purchases to the appropriate sectors.

Although a number of sectors were probably affected, it is likely that the construction sector was most affected since the largest share of the damage and protection costs occurred in the "structures and contents," "grounds and improvements," and "protective

....we assumed that all damage repair and protection expenditures were made by the construction sector.

structures" categories. Listed in Table 9 are the impact coefficients for construction and some of the other sectors probably affected, based upon the descriptive detail found in the sample questionnaires. The average of the output multiplier and total income and employment effects for these sectors are similar to those of the construction sector. For these reasons, we assumed that all damage repair and protection expenditures were made by the construction sector.

Table 9. Impact Coefficients of Sectors Potentially Affected by Erosion and Flood-Related Damages, and Protection Costs, 1972-1976

Sector	Output Multiplier[1]	Total Income Effect[1]	Total Employment Effect[2]
Construction	1.72	.26	19.70
Furniture/Fixtures	1.94	.44	24.67
Misc. Machinery	1.81	.27	17.70
Stone, Clay, Glass	1.76	.33	20.50
Electricity, Gas, Sanitary	1.63	.10	8.75
Wood/Lumber	1.50	.20	15.50
Average	1.72	.32	17.80

1 Dollars per dollar of final demand.
2 Man-years per million dollars of final demand.
Source: Hushak, Morse and Apraku, 1984.

Private Expenditures

Column 1 of the "Private Expenditures" section of Table 10 lists total damage and protection costs relating to floods and erosion from Tables 4 and 7. It was assumed that all of these expenditures were made within the study region. We have no estimate of the amount of damage which was prevented by the expenditures on costs of protection of $38 million.

Column 2 summarizes the total sales or resources required to restore or replace those destroyed resources. The estimates were calculated by multiplying Column 1 (direct spending) by the output multiplier of the construction sector (1.72). The results indicated that direct spending associated with erosion and flood-related damage required more than $111

million of regional resources during the four-year period. Similarly, the more than $38 million of protection-related expenditures required almost $66 million in total resources including the $38 million which could have been used by other sectors to produce other goods and services.

Columns 3 and 4 of Table 10 show the effects of damage and protection expenditures on regional income and employment. These estimates were derived by multiplying direct spending by the total income and employment effects of the construction sector: .26 and 19.7, respectively. Income transferred from other activities to repair flood and erosion damages within the region totaled $16.8 million. Protection expenditures transferred nearly $10 million of income. Approximately 1273 man-years of employment were required for damage replacement expenditures and another 755 man-years of employment were required for protection-related expenditures. In total and under the assumption that all regional resources were fully employed, the $102.95 million of direct costs of damage to and protection of private property reduced other regional activity by $177 million of output, $27 million of income and 2028 man-years of employment from 1972 to 1976.

....the $102.95 million of direct costs of damage to and protection of private property reduced other regional activity by $177 million of output, $27 million of income and 2028 man-years of employment from 1972 to 1976.

Table 10.
Impact of Private Expenditures on the Northern Ohio Economy, 1972-1976

	Direct Spending ($ mil.)	Output ($ mil.)	Income ($ mil.)	Employment (man-years)
Private Expenditure				
Damage				
Flooding	32.22	55.42	8.38	634.7
Erosion	32.39	55.71	8.42	638.1
Total	64.61	111.13	16.80	1272.8
Costs of Protection				
Flooding	16.82	28.93	4.37	331.4
Erosion	21.52	37.01	5.59	423.9
Total	38.34	65.94	9.96	755.3
Total	102.95	177.07	26.76	2028.1
Public Expenditures				
Operation Foresight	8.80	8.80	1.23	78.3
Net Impact of Storms on the Regional Economy[1]	94.15	168.27	25.53	1949.8

[1] Net impact = Total Private Expenditures - Public Expenditures

Source: Bedford, et al., 1978.

Operation Foresight projects were estimated to have prevented $22 million of damage to selected Ohio shoreline sites through 1974. If this damage estimate is accurate, total flood and erosion damages would have been 21 percent greater than they were with the protective devices in place. Resource use in terms of output, employment and income would also have increased by 21 percent.

Net Impact of Storms on the Regional Economy

Protection-related expenditures made through Operation Foresight amounted to $8.8 million. Since these resources were used largely to protect private property at selected sites along Lake Erie, they offset private expenditures for protection as reported in the Corps of Engineers study. In other words, the Operation Foresight revenue was a net increase in regional resources because these revenues came from Federal Sources. This $8.8 million of outside resources offset only $8.8 million of output, the secondary effect of $6.3 million still had to be generated from local resources. The $8.8 million Operation Foresight revenue generated potential new regional income of $1.23 million and 78 man-years of potential new employment if unemployed resources were available.

The last section of Table 10 summarizes the net impact of storms on the regional economy from 1972 to 1976 when regional costs are reduced by the injection of outside resources. More than $94 million in regional expenditures were incurred to restore, replace and protect private property during that period, which required $168 million of output, $25.5 million of income and 1950 man-years of employment resources from the economy.

Table 11 contains information on the impact of federal aid spent for restoration, replacement and protection of public property on regional output, income and employment. Federal aid represents new resources to the region, similar to Operation Foresight revenues. However, we do not have data on damage to public property and cannot estimate the resources needed to restore public facilities. Assuming that the grants were given in cash, only the secondary or indirect effects on

output, income and employment would divert resources from the usual production of goods and services. Therefore, the $2.9 million of federal aid granted to disaster counties which generated nearly $5 million of output required $2 million ($4.99-$2.90 million) of regional resources. Diversions of income and employment resources also occurred but they were small compared to those resulting from private damage and protection-related expenses.

Table 11.
Impact of Public Expenditures on the Northern Ohio Economy, 1972-1976

	Direct Spending ($ mil.)	Output ($ mil.)	Income ($ mil.)	Employment (man-years)
Disaster Relief				
November 1972 Storm	.62	1.07	.16	12.21
March 1973 Storm	1.42	2.44	.37	27.97
April 1974 Storm	.86	1.48	.22	16.94
Total	2.90	4.99	.75	57.12

Source: Deborah Patchen, Personal Communication, 1984.

Annual and Per Storm Estimates of Impact on Northern Ohio

In the previous section, we estimated the economic impacts of the three storms during the four-year period, 1972-76. For policy purposes, however, expected annual costs are more useful. In this section, we converted the four-year impacts to per year and per storm bases, and then generated an annual expected impact of storms estimate.

On a per-storm basis,...direct spending amounted to $34.3 million which required $59 million of output, 8.9 million of income and 676 man-years of employmen

Average annual private damage and protection costs for the four-year period were $25.7 million which required $44.3 million of output, $6.7 million of income and 507 man-years of resources annually from the study region (Table 12). On a per-storm basis, over the three storms direct spending amounted to $34.3 million which required $59 million of output, $8.9 million of income and 676 man-years of employment from the regional economy.

Table 12. Annual, Per Storm and Expected Annual Impact of Private Expenditures on the Northern Ohio Economy, 1972-1976

	Direct Spending ($ mil.)	Output ($ mil.)	Income ($ mil.)	Employment (man-years)
Per Year, 1972-76				
Damage	16.15	27.78	4.29	318.20
Cost of Protection	9.59	16.49	2.49	188.83
Total	25.74	44.27	6.69	507.03
Per Storm, 1972-76				
Damage	21.54	37.04	5.60	424.27
Cost of Protection	12.78	21.98	3.32	251.77
Total	34.32	59.02	8.92	676.04
Expected Annual, 1861-1976				
High Water Year[1]				
Damage	4.52	7.78	1.18	89.10
Cost of Protection	2.68	4.62	.70	52.87
Total	7.20	12.40	1.88	141.97
Low Water Year[2]				
Damage	1.08	1.85	.28	21.21
Cost of Protection	.64	1.10	.17	12.59
Total	1.72	2.95	.45	33.80
Expected Annual, 1986 Dollars				
High Water Year	16.01	27.56	4.18	141.97
Low Water Year	3.82	6.56	1.00	33.80

1 Calculated by multiplying per storm estimates by 21 percent, the probability of a storm occurring in a high water year.

2 Calculated by multiplying per storm estimates by five percent, the probability of a storm occurring in a low water year.

Source: Calculated from Table 10.

Estimates of Expected Annual Resource Diversions Due to Storms

Historic data indicate that between 1861 and 1976 there were 12 severe northeast storms occurring when Lake Erie water levels were above their long-term average (including the three covered in this report) and three storms occurring when the levels were below average (Figure 2). Since 1861, Lake Erie water levels have been above average one-half of the time. Therefore, in any future year when Lake Erie levels are above average, the estimated probability that a severe storm will occur is 12/58 or 21 percent. During a future year when the Lake level falls below its long-term average, the probability of a severe storm occurring is 3/58 or five percent.

...in high water years, the annual expected storm-related costs to the region are $7.2 million.... In low water years, the annual expected storm-related costs are $1.7 million....

To estimate the expected annual impact in terms of output, income and employment on northern Ohio due to storm-related damage and costs of protection, the per storm estimates from Table 12 are multiplied by the respective above and below-average storm probabilities. The results, summarized in Table 12, indicate that in high water years, the annual expected storm-related costs to the region are $7.2 million which utilizes $12.4 million of output, $1.9 million of income and 142 man-years of employment. In low water years, the annual expected storm-related costs are $1.7 million which divert $3 million of output, $450 thousand of income and 34 man-years of employment from the production of regular goods and services of the region.

Expected Annual Diversions in 1986 Prices

The cost data presented in the analysis were in the prices of the 1972-76 period. Since substantial inflation has occurred since 1976, the expected annual damages in current dollars are much higher than in 1972-76 dollars. The last section of Table 12 presents expected annual damages in 1986 dollars where the 1861-1976 expected annual damages are adjusted by the ratio of the consumer price index in 1986 to that in 1974, or 328.4/147.7 = 2.223. Total inflation over the 12-year period was 222 percent. Other data can be adjusted from 1972-76 prices to 1986 prices through multiplication by the same constant equal to 2.22.

Conclusions and Implications

Summary

In November 1972, April 1973 and March 1974, Ohio's Lake Erie shoreline counties experienced severe storms that caused extensive erosion and flood damage to both public and private property. As a result of those storms, the U.S. Army Corps of Engineers conducted surveys of private property owners along the Lake to gather information about the amount and types of damages sustained by the region and costs associated with shoreline protection from Labor Day, 1972 to Labor Day, 1976. The study results showed that most of the $64 million of flood and erosion damages occurred to residential properties in the four western Ohio counties bordering Lake Erie. Most of the $38 million of flood and erosion protection costs were also spent by owners of residential properties in the western basin counties, although expenditures on erosion protection were more evenly spread among the eight shoreline counties. Federal disaster grants to northern Ohio counties over the study period amounted to $2.9 million and the value of Operation Foresight projects completed in Ohio exceeded $8.8 million.

....the expected annual cost of storm damage and protection in northern Ohio is $16.01 million in a high water year and $3.82 million in a low water year in 1986 dollars.

To determine the impact on the northern Ohio regional economy of erosion and flood-related damages and protection costs, the output multiplier and total income and employment effects of the construction sector were used. The results showed that the $103 million of storm damage and related shore protection costs required $177 million of output, $27 million of income and 2028 man-years of employment resources from the region over the four-year study period which was offset somewhat by the influx of federal funds in the form of Operation Foresight resources totaling over $8.8 million. The net impact on northern Ohio of the more than $94 million of flood and erosion-related expenditures was a diversion of $168 million of output, $25.5 million of output and 1950 man-years of employment from production of the usual set of goods and services.

Using historical data, the expected annual cost of storm damage and protection in northern

Ohio is $7.2 million in a high water year and $1.72 million in a low water year in 1972-76 dollars, or $16.01 million and $3.82 million, respectively, in 1986 dollars. The output, income and employment resources required to satisfy these costs in 1986 dollars would be $27.5 million, $4.2 million and 142 man-years, respectively, in a high water year and $6.6 million, $1.0 million and 34 man-years, respectively, in a low water year.

Study Limitations

Because certain information was inaccessible, it was impossible to identify the sectors in northern Ohio from which private property owners made purchases for the restoration and protection of their properties. The data limitation also prohibited an accurate determination of the share of public and private expenditures that went to each of those sectors. Although assigning all expenditures made during the four-year period to the construction sector is reasonable, at best it provides only a rough estimate of the impact that floods and erosion had on the northern Ohio regional economy from 1972 to 1976.

The magnitude of public funds spent within the region over the study period is almost certainly understated....

The magnitude of public funds spent within the region over the study period is almost certainly understated in this report since federal disasters are declared only when "local and state resources have been exhausted." The report also does not include estimates of public funding for the routine repair and/or protection of state parks and beaches, highways and other public properties along the shore. Although state and county officials were contacted and asked for information concerning such expenditures, they could not provide it because the data did not exist or because the figures were not readily accessible. Corps of Engineers personnel contacted in the course of assembling background data for this report indicated that Section 14 or "small projects" funds were spent on certain local emergency shore protection projects along Ohio's Lake Erie shoreline during the study period (exclusive of Operation Foresight projects). However, those data were not available either.

This report focused on flood and erosion damages and protective measures attributable to

the three major storms of the study period. Although all flood damage and protection costs can reasonably be attributed to storms, erosion is a continual process on the Lake which is worsened under high water conditions and which can become severe during storms. To the extent that erosion damages and protection costs were made to eliminate or reduce that baseline type of erosion, estimates of annual and per-storm expenditures are somewhat high.

Although questionnaires distributed by the Corps of Engineers solicited information from respondents about physical losses of their beach and bluff property through erosion, an economic value was not assigned to these losses. Therefore, the final damage estimates may be understated, especially in the central basin counties where reported losses of beach area and bluff volumes were nearly twice those of western basin counties. (Data on beach and bluff loss from the tables accompanying the Corps of Engineers report were provided by study respondents. These estimates were not extrapolated to the whole population so it was impossible to ascertain the actual magnitude of beach and bluff losses).

....Lake Erie's Ohio shoreline is the most urbanized of the Great Lakes' shorelines, an important reason why recent erosion and flooding have been so costly to the region.

The three storms of this study period were atypical in that they occurred so closely in time, yet there is no evidence that these storms were any more or less severe than those of the past. To the extent that they may have been more severe than normal, per-storm estimates of future damage in a high water year (Table 12) are overstated.

Implications

Prior to the storms discussed in this report, the last one of comparable magnitude and destructiveness occurred in 1952. Since that time, Ohio's Lake Erie coastline has undergone unprecedented growth and development. In fact today, Lake Erie's Ohio shoreline is the most urbanized of the Great Lakes' shorelines, an important reason why recent erosion and flooding have been so costly to the region ($GLBC_d$, 1976). The Great Lakes Basin Framework Study in 1976 projected that growth and development along the shore would continue and that urban areas would gain primarily at the expense of cropland (which is largely found in the

western basin, the area suffering the most damage from recent storms and where construction of the Lake-based recreation facilities such as marinas has grown fastest). Federal aid granted to selected northern Ohio communities in the aftermath of the storms came only after local resources were exhausted and it was designated for replacement or restoration of public property. Since shore development has continued into the 1980s and shore properties were at the highest risk ever in 1986-1987 with Lake Erie at record water levels, it is important that policies be designed to seek optimal protection of shoreline property and optimal restrictions on further investment in high risk areas.

The estimates of the expected annual diversion of regional resources from the regional economy for storm-related restoration and protection of property (output in 1986 prices from Table 12 of $16.0 million in high water years and $3.8 million in low water years) serve as bench marks for investment in shore protection. Since the early 1970s Lake Erie water levels have remained above the long-term average, and since there is no indication that water levels will decline to below average levels in the near future, it is reasonable to conclude that the $16.0 million estimate is the better investment bench mark figure.

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