CLEAR TECHNICAL REPORT NO. 290

Assessment of the Impacts to the Lake Erie Fishery from Proposed Expansion of Sand and Gravel Dredging on the Northwest Bar (Norfolk Moraine), Pennsylvania

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INTRODUCTION

The Erie Sand Steamship Company presently holds a permit from the U.S. Army Corps of Engineers (No. 80-476-6) to annually dredge sand and gravel in Area "C" on the Norfolk Moriane in Lake Erie. This 12 square mile area is located approximately 7 miles off Presque Isle in Erie, Pennsylvania (Figure 1) in water approximately 50 to 70 feet deep. The moraine is a submerged, glacially-deposited ridge which separates the central and eastern basins of Lake Erie (Figures 2 and 3).

On 13 January 1984, the Erie Sand Steamship Company applied for a revised permit (Appendix A) which would enlarge the dredging area by 7.6 square miles in order to obtain more favorable grades of sand for construction purposes. Of the 19.6 square miles requested in the application, 7.6 square miles are within existing Area "C" and 12 square miles are in a new area located to the north and west (see illustrations in Appendix A).

The Buffalo District, Corps of Engineers has received a number of letters from agencies and concerned citizens relating to the potential impact of the proposed area expansion (originally proposed to be 100, then 40 square miles) on the fisheries resources of the moraine, particularly in regard to spawning and nursery use of the area by important recreational and commercial species such as lake trout, lake whitefish, yellow perch, and walleye. In regard to the application for the 7.6 square miles expansion, the Corps of Engineers has requested, by 9 March 1984, comments from key state and federal agencies.

The purpose of the following report is to summarize the available reports and other documentation which bears on the question of fish utilization of this region of Lake Erie. An assessment of the potential impact of sand and gravel dredging on these fishery resources from the proposed expansion is also presented.

NORFOLK MORAINE

The Norfolk Moraine, or Pennsylvania Ridge as it is called by some authors, extends from the base of Long Point, Ontario on the north to Presque Isle, Pennsylvania on the south (Figure 3). This submerged sand and gravel bar forms the natural divide for the central and eastern basins of Lake Erie (Figure 4). Pegrum (1929) was one of the first investigators to map the distribution of bottom sediments in eastern Lake Erie (Figure 5) and describe the bar. He speculated that the irregular distribution of sand and gravel on the ridge indicated a glacial origin, possibly a ground moraine. Hough (1963), Wall (1968), and Sly (1976) concluded that during the maximum readvance of the Port Huron ice (approximately 13,000 years before the present), a terminal moraine was deposited across the Lake Erie basin from the base of Long Point to the vicinity of Erie, Pennsylvania (Figure 6).

Lewis, et al. (1966) referred to this feature as the Long Point - Erie Ridge and described it as a broad rise 27-64 miles (17-40 km) wide, the western surface of which is mainly dense glacial till veneered with sand at depths below 59 feet (18 m), and the eastern surface of which is sand-covered at depths as shallow as 46 feet (14m). They found the western part of the ridge to be a wave-eroded clay till surface, veneered with a thin, rippled, sandy lag concentrate which sloped gently southwestward from the 59- to 60-foot (18 to 20 m) depth contour (Figure 7). Immediately east of this area and lying at shallower depths, between 46-59 feet (14-18 m), the ridge is composed of sand with thicknesses approaching 15-20 feet (5-6 m) (Williams and Meisburger 1980).

Lewis et al. (1966) postulated that the existence of the Long Point-Erie sand deposit can best be explained as a relict beach deposit built in the past by a lake some 66 feet (20 m) lower than present Lake Erie. In this "low-level" lake, the largest storm waves likely came from the west because the prevailing wind and greatest fetch both lay in that direction. These waves pounded against the western flank of the ridge where they cut a terrace in the moraine across which the eroded sand was transported and finally laid down as a beach deposit along the ridge crest at lake level (Figures 7 and 8). Lewis et al. (1966) also believed that the sand may have been further heaped up into dunes by wind action.

More recent studies by Boyce et al. (1980) appear to support the theory that the sand deposit was formed under a different energy regime than is now present over the ridge. Current measurements (Figure 9) indicate bottom velocities well under 5 cm/sec on the ridge and generally less than 10 cm/sec in the Pennsylvania Channel (Figure 10) which is located between the ridge and Presque Isle. Current velocities of these magnitudes are too weak to erode sand and gravel. Herdendorf (1975) found that velocities of 20 cm/sec are required to erode and transport sand in the 0.1 to 1.0 mm size range at Cedar Point on Lake Erie. Boyce et al. (1980) also found that the crest of the moraine projects well above the thermocline during summer stratification (Figures 11,12, 13, and 14).

Assuming a depth of 66 feet (20 m) as the lower boundary of the Norfolk Moraine, it occupies an area of approximately 185 square miles (478 sq km) in Lake Erie (Figure 15). Of this total, 92 square miles (237 sq km) are located in Pennsylvania waters with the remainder in Ontario.

LAKE TROUT (*Salvelinus namaycush*)

Status

Trautman (1957) indicated that early studies showed a moderately large population of lake trout in the deeper waters of eastern Lake Erie before 1900. Between 1925-30 fair catches were made occasionally in the lake waters of Ashtabula County, Ohio with gill nets. After 1930, a decrease in abundance became apparent and since 1940, relatively few have been taken. Trautman states that the few individuals he has taken in the last 40 years were greatly emaciated, having thin bodies, sharply-ridged backs, and bulky heads, all factors usually associated with submarginal conditions. Distribution maps (Scott and Crossman 1973 and Trautman 1981) indicate that Lake Erie constitutes the extreme southern range of this species in eastern North America. Trautman (1981) reported the decline in the population size of lake trout in Lake Erie, apparent since 1850, continued to the point where by 1975 it appeared to be very rare, or possibly extirpated. Goodyear et al.(1982) concluded that the population declined due to over-exploitation (an opinion different than the environmental reasons eluded to by Trautman) and that the native stocks are now extinct. Lake trout have been planted in Pennsylvania waters of Lake Erie since 1969 and in New York waters since 1975. The U.S. Fish and Wildlife Service (Bur 1982) reported that a few stocked fish have been recovered in healthy condition over a year after release, but reproductive success has yet to be determined.

Habitat Preference

When abundant, lake trout were primarily confined to the deeper waters of the eastern half of Lake Erie, although they ventured into shallower waters in late fall to spawn and to feed in the vicinity of the rocky and gravelly reefs and returned to the deeper waters in early spring (Trautman 1981). Scott and Crossman (1973) found that lake trout spawning most often occurs over a large boulder or rubble bottom in Canadian lakes at depths of less than 40 feet (12m) and sometimes as shallow as one foot; in the upper Great Lakes, however, spawning has been reported as deep as 120 feet (37m). For Wisconsin lakes, Becker (1983) reported the optimum water temperature for lake trout spawning ranges from 46° to 52°F (7.8°-11.1°C). In Lake Superior, Eschmeyer (1955) recorded egg production ranging from about 2,500 to 17,000 per female.

In Ontario lakes, Martin (1957 and 1960) found that lake trout disperse through the lake and may move over 100 miles (160 km) away. The eggs remain in their rocky or gravelly incubator for several weeks, In Algonquin Park, Martin observed that spawning took place in October and November and that hatching occurred in February and March, and the incubation was a period of 15-21 weeks. The optimum temperature of hatching was 32.5° to 33.8°F (0.3°-1.0°C).

Goodyear et al. (1982) reported that Greeley (1929) observed the young-of-the-year lake trout to be pelagic (referring to the open-water region not directly influenced by the shore or bottom) in Lake Erie. The young usually seek deeper water after the yolk sac is absorbed, normally within a month after hatching (Scott and Crossman 1973).

In Canadian lakes, adult lake trout often occur in surface waters immediately after breakup of ice in the spring. As the surface waters warm, lake trout retire to the cooler waters, eventually returning to the hypolimnion below the thermocline during the summer months. Lake trout do make feeding excursions above the thermocline despite the unfavorably warm temperatures. In general they prefer temperatures about 50 F (10 C). Although lake trout are more abundant in some localities than in others, in lakes where they occur, they seldom if ever form compact schools. Even the young are scattered and seem to have more or less solitary habitats (Eschmeyer 1957).

LAKE WHITEFISH (*Coregonus clupeaformis*)

Status

Presumably, like the lake trout, the lake whitefish has been present in Lake Erie since early post-glacial times. Also like the lake trout, Lake Erie is at the southern limit of the distribution of lake whitefish in North America and thermal conditions are somewhat marginal for them (Hartman 1973). The population of this species has also declined dramatically in the past 100 years. Lake whitefish successfully spawned in the Detroit River and Maumee Bay of western Lake Erie until about 1890 (Trautman 1957), but by 1900 the runs into the Detroit River had apparently been stopped by pollution and by 1918 the Maumee Bay spawning beds had been smothered by silt leaving only the lake-spawning populations to support the fishery (Hartman 1973). Progressive decrease in the dissolved oxygen in the bottom waters of central Lake Erie has been documented for the period 1930 to 1974 (Herdendorf 1983a and b). As early as the 1950s the hypolimnion in the central basin experienced anoxia by the end of summer stratification. Hartman (1973) concluded that this situation reduced oversummering habitat for cold, stenothermal fish species. Eventually the last major remnants of the Lake Erie population were confined to the deep eastern basin (Regier et al.1969). The annual commercial production of lake whitefish from 1915 to 1965 is shown on Figure 16.

Habitat Preference

When this species was abundant in Lake Erie, throughout the warmer months the whitefish chiefly inhabited water of 40 feet (12 m) or more in depth, and the bulk of the populaton was in the eastern half of the lake (Trautman 1981). In fall an inshore and/or western migration began, its speed of advance depending on the rapidity of water temperature decline. Trautman (1957) observed that spawning began in earnest after the water temperature had dropped below 45 F (7.2 C) and lasted from late October to mid-December. By mid-March most of the lake whitefish had left the shallow western areas for the deeper water of the eastern end of the lake. Trautman (1981) reports that Koelz (1929) observed a secondary movement of whitefish from eastern Lake Erie into the shoals, individuals remaining on the shoals until June, after which they remained in deep waters until fall.

Goodyear et al. (1982) reported that spawning occurred in the eastern end of the lake from mid-November to mid-December and that historically (Moore 1894) lake whitefish spawned along the Pennsylvania shore (Figure 17). They also reported unpublished observations that suggest "Northwest Sand Bar" (42 19' Lat., 80 20' Long.) is probably a spawning area for lake whitefish. This location is approximately 5 miles (8 km) southwest of the existing commercial sand and gravel dredging area "C" on the Norfolk Moraine. They describe the area as an unstable sand bottom with no vegetation ranging from 44 to 46 feet (13-14 m) deep. In the late fall, lake whitefish are believed to concentrate in the area (males with running milt and gravid females have been collected here in mid-November) and spawning probably occurs in water less than 60 feet (18 m) deep (Kenyon, personal communication)

Observations in Wisconsin lakes (Becker 1983), indicate that lake whitefish spawn from early through late November at water temperatures of 40 to 43 F (4.4 - 6.1 C). Like the lake trout, spawning occurs at night. It is accompanied by considerable jumping; as the fish rise to the surface, the female emits spawn and the male simultaneously discharges milt. The eggs are broadcast and settle to the bottom. Eggs receive no parental care. Egg production ranges from 25,000 to 130,000 per female. The eggs hatch during late March or early April, requiring about 130 days of incubation at a water temperature of 35 F (1.7 C). A heavy natural mortality occurs among the developing eggs, probably less than 15% survive to the fry stage.

Scott and Crossman (1973) reported that lake whitefish spawning usually occurs in shallow water at depths of less than 25 feet (7.6 m), but in the upper Great Lakes, Koelz (1929) found spawning in deeper water. Spawning normally takes place over hard or stony bottom but sometimes over sand. Lawler (1961) calculated that lake whitefish produce about 16,000 eggs per pound of fish and Van Oosten (1939) reported that in Lake Erie, females lose approximately 11% of their weight at spawning.

The lake whitefish is a cold water species, as indicated by the temperature required for successful incubation of its eggs. Like the lake trout, it descends into the cooler waters of the hypolimnion during the summer months. Whitefish are usually regarded as schooling fishes, although Faber (1970) did not find the aggregation of larvae great enough to fall within the accepted definitions of schooling proposed by Keenleyside (1955).

YELLOW PERCH (*Perca flavescens*)

Status

Yellow perch populations in Lake Erie declined during the late 1960s and have generally remained at lower levels in the 1970s and early 1980s. The Ohio Division of Wildlife (1983) attributes these lower abundance levels to poor young-of-the-year recruitment and excessive exploitation of adult yellow perch, especially in the central basin. The sizes and age composition of yellow perch taken by the ODW in the fall of 1982 indicate that western basin perch grow slower than central basin stocks. The faster growing central basin perch are harvested at an earlier age with few fish older than age 3 remaining in the population, thereby reducing their reproduction potential. In spite of this situation, yellow perch was the most common fish taken by sport anglers (approximately 3 million fish) and commercial fishermen (nearly 1 million fish) in the central basin in 1982.

Habitat Preference

Trautman (1981) observed that yellow perch occur in greatest numbers in shallow, clear, static water where there is abundant rooted aquatic plants and bottoms of muck, organic debris, sand, or gravel; its numbers decrease with increased turbidity and siltation and loss of aquatic plants. Yellow perch spawns in the spring usually from mid-April to mid-May at water temperatures from 44 - 54 F (8.9 - 12.2 C) (Scott and Crossman 1973).

In the spring adults move shoreward where spawning takes place during the night or early morning, usually near rooted vegetation, submerged brush, or fallen trees, but at times over sand and gravel. Egg production ranges from about 35,000 to 10,000 per female. The eggs are extruded in a transparent, gelatinous, accordion-folded string which adheres to submerged vegetation or, at times to the bottom. No protection is given to the eggs or the young by the parents. Scott and Crossman (1973) reported that hatching usually takes 8-10 days, but as long as 27 days in water at 47 F (8.3 C). After hatching the 5 mm long young are inactive for about 5 days during the absorption of the yolk sac.

Larval fish studies (Figure 18) by Mizera (1981) and Cooper et al. (1982 and 1983) showed that yellow perch larvae in central Lake Erie are at their greatest density between mid-May and mid-July (Figure 19). The average basin-wide density of yellow perch larvae for this period in 1978 was 1.25 individuals per 100 cubic meters and the highest density was 6.2 larvae per cubic meters on June 19. Figures 20 and 21 show that the greatest numbers of larvae and pro-larvae were found at the inshore stations and that densities of yellow perch dropped off dramatically at the offshore stations. The decrease in a lakeward direction is particularly evident at the eastern end of the central basin in the vicinity of Ashtabula and Conneaut (Stations 9 and 10 on Figures 20 and 21).

In their survey of fish spawning and nursery areas in the Great Lakes, Goodyear et al. (1982) noted that yellow perch young-of-the-year are abundant from Erie, Pennsylvania to Vermilion, Ohio in the central basin of Lake Erie. They also reported that Fish (1932) found that larvae of this species were abundant from June to August, usually in shallow inshore areas. No specific spawning areas were identified for Pennsylvania or New York, but general locations are shown on Figure 22.

Yellow perch are usually considered shallow water fish and are normally not taken below 30 feet (10 m). Adults and young are gregarious, often moving in loose aggregations of 50-200 individuals. The young, in shallower, nearshore water than the adults, are often in mixed schools with spottail shiners (Scott and Crossman 1973). Becher (1983), however, pointed out that many lone yellow perch have been captured in gill nets, suggesting that this species is not strictly a schooling fish. Yellow perch are inactive at night and rest on the bottom. They are active all winter under ice or in deeper water.

WALLEYE (*Stizostedion v. vitreum*)

Status

The abundance of walleye in western Lake Erie increased dramatically throughout the 1970s and the population in the central basin is beginning to show increases in the 1980s. During the 1960s and early 1970s, the "fishable" population of walleye (fish of age 2 or older) was estimated at or below two million fish in western Lake Erie. In 1982, the fishable population present was approximately 25 million walleye (Ohio Division of Wildlife 1983). The increased walleye population has been attributed to good young-of-the-year recruitment and international management approaches to control sport and commercial harvests. The increases in the central basin population is thought to be due to the eastward movement of western basin stocks (Carl Baker, ODW, personal communication 1984).

The eastern basin walleye population has been found to be distinct from the western basin stocks (Wolfert and Van Meter 1978). Only 2% of the walleyes tagged in New York waters were recovered in the central basin. The eastern basin population has also increased in recent decades, but the upward trend started earlier, in the late 1950s and 1960s.

Habitat Preference

In Lake Erie, walleye is an inhabitant of the shallow waters, occurring in the greatest abundance over bedrock, gravel and other types of firm bottoms, where the turbidity is the least; the rock-bottomed reefs of the islands region has the greatest concentration (Trautman 1981). Spawning occurs in spring (late March to mid-May) when the ice breaks up and the water temperature approaches 44 F (6.7 C). Spawning grounds are rocky areas or boulder to coarse-gravel shoals in the lake (Scott and Crossman 1973). Goodyear et al.(1982) reported that walleye exhibit a homing tendency, therefore, each reef may support its own discrete spawning population. Spawning takes place at night in small groups. The eggs are broadcast and fall into crevices in the substrate. They are sticky at first but harden after they adhere to the rock. As many as 600,000 eggs per female have been observed (Scott and Crossman 1973).

Eggs hatch in 12-18 days, usually in April or May when the water temperature nears 50 F (10 C). The yolk sac is absorbed rapidly and by 10-15 days after hatching the young larvae have dispersed into the upper levels of the open water. Young-of-the-year walleye remain near the spawning areas, or in areas slightly closer to shore, throughout the summer (Goodyear et al. 1982).

Walleye spawn along the shoreline throughout the eastern part of the lake from the Ohio-Pennsylvania border to Angola, New York (Figure 23). The spawning grounds are rocky and usually in water 3-12 feet (1-4 m) deep. There are few reefs in this area, and spawning probably takes place wherever rocky areas exist (Goodyear et al. 1982). Wolfert (1978) has documented the isolation of this population from stocks in the western and central basins (Figure 24).

In Pennsylvania waters, young-of-the-year walleye have been taken in August on rocky areas, usually inshore of the 36 feet (11 m) depth contour. The gravel bars of the mouths of Raccoon Creek and east of Crooked Creek as well as the inner portion of Presque Isle Bay and the nearshore reach near the New York-Pennsylvania border have been reported as walleye spawning and nursery areas (Goodyear et al. 1982).

OTHER SPECIES

Cooper et al. (1983) presented a table (Figure 25) which documents the density and peak period of abundance of larval fish in the central basin of Lake Erie. Because samples were taken in the vicinity of the Ohio-Pennsylvania border, this table is useful in assessing the relative abundance of fish which might be expected on the Norfolk Moriane. Typically the densities of larvae were greatest at the inshore stations and decline dramatically offshore. Therefore values presented in Figure 25 can generally be considered as maximum densities.

Of the 25 fish taxa collected, the forage species including alewife, gizzard shad, emerald shiner (Figure 26), and spottail shiner (Figure 27) comprised 82.4% of the larval fish captured. Freshwater drum (Figure 28) amounted to 4.2% of the total. Rainbow smelt (Figure 29), one of the few species that showed an increased density offshore, particularly west of Cleveland (Figure 30, station 1-4), accounted for 3.7% of the larval fish. Yellow perch contributed 1.3% to the total population, walleye and lake whitefish accounted for less than 1% each, and no lake trout were collected. The thermal preference of these species during summer stratification is shown on Figure 31. Spawning and habitat characteristics of common Lake Erie fish are shown on Table 1.

TABLE 1

SPAWNING AND HABITAT CHARACTERISTICS OF COMMON LAKE ERIE FISH

TAXON	REPRODUCTIVE CHARACTERISTICS						HABITAT CHARACTERISTICS (42,45)												
	Maturity	Spawning	Fecundity		Spawning	Longevity	Spawning Location		Water Depth		Water Clarity		Bottom Type				Rooted Aquatic Plants		
Family and Species	Age Class	Temperature (°C)	Female Age or Size	Egg Production/Female	Season	Years	Tributaries	Nearshore	Shallow	Deep	Clear	Turbid	Mud	Sand	Rocky	Organic	Absent	Moderate	Abundant
ACIPENSERIDAE																			
Acipenser fulvescens Lake sturgeon	XX(38)	12–19°C(22)	13,608–17,690g 48,535–52,617g	181,720–188,800(50) 652,904–682,640(50)	May–June(45)	80+(38)	X		X		X			X	X		X		
CLUPEIDAE																			
Alosa pseudoharengus Alewife	M–II F–III(26)	22°C(13)	178 mm	10,000–12,000(26)	June–July(45)	9+(26)	X	X	X	X	X		X	X	X	X			
Dorosoma cepedianum Gizzard shad	II(24)	19.5°C(6)	282–297 mm 434–452 mm	23,405–96,560(24) 267,216–350,288(24)	June–July(6)	9+(24)	X	X	X	X	X	X	X	X	X	X			
SALMONIDAE																			
Coregonous artedii Cisco	II–III(24)	1.1–5.0°C(16)	II III	16,000–42,500 (24) 14,000–38,600(24)	Nov.–Dec.(16)	13(24)		X	X	X	X		X		X		X		
Salvelinus namaycush Lake trout	XIII–XVII(24)			6,000 (24)	Sept.–Nov.(19)	41(24)		X	X	X	X		X		X		X		
OSMERIDAE																			
Osmerus mordax Rainbow smelt	II–III(24)	10°C(13)	241 mm 185–195 mm	57,910 (33) 25,102 (30)	May (13)	6(24)	X	X		X	X		X		X		X		
ESOCIDAE																			
Esox lucius Northern pike	M–II–III F–II(12)	8°C(1)	431–480 mm 597 mm	22,000 (49) 48,950 (31)	Feb.–March(45)	24(24)	X	X	X	X	X			X	X	X			X
Esox masquinongy Muskellunge	M–III F–III–IV(24)	4.5–10°C(45)	900–1170 mm	22,092–164,112 (25)	April(45)	30(24)	X	X	X	X	X		X			X			X
CYPRINIDAE																			
Carassius auratus Goldfish	100–185 mm(32)			1400(28)		4(24)	X	X	X		X	X	X	X	X	X			X
Cyprinus carpio Carp	M–II–IV F–III–V(5)	25.2°C(40)	1225–1905g	72,000–347,000(44)	April June(24)	16(24)	X	X	X		X	X	X	X	X	X		X	
Notemigonus crysoleucas Golden shiner	I–II(8)	16–27°C(8)			May–August(14)	8(15)	X		X		X			X		X			X
Notropis atherinoides Emerald shiner	M–II–III F–III–IV(48)	23°C(47)	III–IV(48)	500–1,500(est.)	June–August(24)	5(48)		X	X		X		X	X	X	X	X		
Notropis hudsonius Spottail shiner	59–84 mm(48)	20°C(13)	87–127 mm	1769–4380(48)	June (13)	5(48)		X	X	X	X			X	X				
Notropis spilopterus Spotfin shiner	I–II(43)		61–82 mm	316–1,155(43)	June–late August (43)	5(43)	X		X			X	X					X	
Pimephales promelas Fathead minnow	<I(10)	15.6°C(10)		800,1,000(10)	May–August(10)	1(10)	X		X			X	X				X	X	
Pimephales notatus Bluntnose minnow	<I(10)	>21°C(10)		200–500 (10)	April–Sept.(10)	3(10)	X		X		X	X	X	X	X	X			
CATOSTOMIDAE																			
Carpiodes cyprinus Quillback	1800–2700g(42)			4,000–15,000(45)	April–May(45)	3(24)	X	X	X	X	X			X	X				
Catostomus commersoni White sucker	M–III–VII(17) F–III–IX	10°C(47)	406–510 mm	36,000–139,000(43)	March–April(24)	12(24)	X		X	X	X	X	X	X	X	X	X	X	X

TABLE 1 (Con't.)

SPAWNING AND HABITAT CHARACTERISTICS OF COMMON LAKE ERIE FISH

TAXON	REPRODUCTIVE CHARACTERISTICS						HABITAT CHARACTERISTICS (42,45)												
	Maturity	Spawning	Fecundity		Spawning	Longevity	Spawning Location		Water Depth		Water Clarity		Bottom Type				Rooted Aquatic Plants		
Family and Species	Age Class	Temperature(°C)	Female Age or Size	Egg Production/Female	Season	Years	Tributaries	Nearshore	Shallow	Deep	Clear	Turbid	Mud	Sand	Rocky	Organic	Absent	Moderate	Abundant
ICTALURIDAE																			
Ictalurus melas Black bullhead	III(3)	15.6–23.9°C(45)	183–224 mm	168–6,820(11)	May–June(45)	9(35)	X	X	X			X	X					X	
Ictalurus natalis Yellow bullhead	II–III(42)	15.6–23.9°C(45)	170–680g	1,652–6,660(46)	May–June(45)	5(41)	X	X	X		X			X	X	X			X
Ictalurus nebulosus Brown bullhead	F–III(42)	15.6–23.9°C(45)	203–330 mm	2,400–13,800(18,34,49)	May–June(45)	6(37)	X	X		X	X			X	X	X		X	
Ictalurus punctatus Channel catfish	IV–VI(29)	27°C(47)	406–508 mm	4,200–106,000(34)	April–August(45)	8(36)	X		X	X	X			X	X		X		
PERCICHTHYIDAE																			
Morone chrysops White bass	III(36)	19°C(47)		242,000–933,000(42)	April–May(45)	7(36)	X		X		X			X	X				
CENTRARCHIDAE																			
Lepomis gibbosus Pumpkinseed	II(23)	18–21°C(8)	61–92 mm	600–2,923(46)	April–May(45)	8–10(42)		X	X		X			X		X			X
Lepomis macrochirus Bluegill	II–III(32)	19–27°C(8)		2,360–47,400(8)	May–August(4)	8–10(42)		X	X		X			X	X	X		X	
Pomoxis annularis White crappie	II–III(21)	18°C(47)		5,000–30,000(45)	May–June(45)	8(21)		X	X		X	X	X	X	X	X		X	
Pomoxis nigromaculatus Black crappie	II–III(27)	14–18°C(2)		11,000–188,000(8)	March–May(2)	8–10(42)		X	X		X			X		X			X
Micropterus dolomieui Smallmouth bass	III–VI(32)	13–18°C(8)		2,000–10,000(2)	May–July(42)	15(42)		X	X		X				X			X	
Micropterus salmoides Largemouth bass	II(4)	18–22°C(4)		2,000–25,000(10)	May–July(4)	15(42)	X	X	X		X			X	X	X			X
PERCIDAE																			
Perca flavescens Yellow perch	M–II F–III(48)	16°C(40)	246 mm	44,000(48)	Mid-April–May(45)	8(48)		X	X	X	X			X		X			X
Stizostedion canadense Sauger	M–23.7mm F–26.2mm(9)	8.2°C(45)	305–311 mm	43,000–48,500(9)	April–May(45)	10(9)	X	X	X			X	X				X	X	
Stizostedion v. vitreum Walleye	M–II–III F–III– V(48)	4.5–11.1°C(45)		48,000–614,000(48)	March–May(45)	13(39)	X	X	X		X			X	X		X		
SCIAENIDAE																			
Aplodinotus grunniens Freshwater drum	M–III–VII F–V–VI(7)	21.0°C(47)		100,000–500,000(45)	Spring(45)	9(7)		X	X	X	X				X				

DATA SOURCE: HARTLEY & HERDENDORF (1977)

DREDGING

Overview

Dredging in the Great Lakes is the process by which sediments are removed from the bed of the lakes and harbors, and disposed of elsewhere in a manner that is compatible with the dredging purpose and requirements. The common purposes for dredging include:

1) maintain, improve, or extend navigable waterways;
2) create, maintain, or improve harbor facilities;
3) remove undesirable material (pollutants, debris, etc.) from aqueous environments; and
4) extract resource minerals (sand and gravel, shells, etc.) for construction materials, beach nourishment, and create new land.

Dredging for all purposes within both the Canadian and United States portions of the Great Lakes (Figure 32) averages 12.5 million cubic yards per year (Walker 1975 and International Joint Commission 1982). The United States dredging activities consist of 79% of the total. By far the greatest amount of dredging is undertaken in Lake Erie which accounts for 65% of all United States Great Lakes navigational and mining dredging. Over 89% of all dredging in undertaken in support of navigation at the many harbors and in the connecting channels throughout the lakes. Sand and gravel mining from the lake beds account for the remaining 11% of total United States dredging in the lakes (Walker 1975). The distribution of navigational and mining dredging in Lake Erie is shown in Figure 33.

Sand and Gravel Dredging

Dredging for sand and gravel on the Norfolk Moraine, as it is presently done and as is planned for the new area, consists of removing surficial sediment with a trailing-arm, suction dredge. In 1983, approximately 193,000 cubic yards of commercial sand were recovered from Area "C". A royalty of $0.15 per cubic yard of sand is collected by the Pennsylvania Fish Commission for their fishery enhancement programs. In 1983, the Erie Sand Steamship Company paid $28,986 in royalties to the Fish Commission.

The Erie Sand Steamship Company presently operates two dredging vessels on Lake Erie which extract material from Area "C" of the Norfolk Moraine. (Table 2). The method of sand and gravel dredging on Lake Erie has been described by Hartley (1960) and Herdendorf (1974). Buoys are placed where the desired materials are found in order that the dredges may return to the same area. A trailing arm hydraulic boom containing a hose is lowered to the bottom. The bottom sediments are pumped through the hard rubber hose, 12 to 20 inches in diameter, the end of which is equipped with a steel shoe covered with a large open grid or screen. The shoe is permitted to drag or troll along the bottom. The materials pass through a centrifugal pump with rubber bladed impellers into a materials drop through the screens into the bin of the vessel and the unwanted material is washed back into the lake. The sand and gravel is delivered to ports in New York, Ohio, and Pennsylvania and is unloaded at dockside by cranes.

TABLE 2. CHARACTERISTICS OF ERIE SAND STEAMSHIP COMPANY DREDGES

Vessel Characteristics	Lakewood	J.S. St. John
Vessel Type	Trailing-arm suction dredge	Trailing-arm suction dredge
Length (ft)	390	120
Capacity		
a. cubic yards	3,450	550
b. cubic meters	2,622	418
Length of hydraulic boom (ft)	65	65
Dredging time to fill hold (hrs)	13	4
Pumping rate (approx.):		
a. Total (gallons/min.)	4,600	2,300
b. Sand (cubic yds/hr)	270	135
c. Water:		
1) cubic yds/hr	1,080	540
2) cubic meters/hr	830	415

The pumping characteristics of each dredge are listen on Table 2. Essentially, the Lakewood also has 6.3 times the capacity and twice the pumpimg rate of the J.S. St. John. The mode of operation and length of the trailing-arm hydraulic boom (65 feet) are the same for the dredges, which permits both vessels to work similar areas of the Norfolk Moraine.

The Lakewood and the J.S. St. John pump a mixture of water and sand for a total volume of 4,600 gpm of this quantity 20% is solids (sand, gravel and finer sediments). Approximately 22% of the material lifted from the lake bottom (sediment and water) is retained in the vessel (Robert Boorum, Erie Sand Steamship Company, Personal Communication, March 1984).

The depth of the individual trenches left by the trailing arm shoes may vary from a few inches to a foot due to some bouncing as it moves over the irregular sand and gravel bottom. Fathograms made by Herdendorf and Cooper (1975) in western Lake Erie show excavations of similar magnitude for the dredge R.W. Holst, a vessel comparable to the J.S. St. John. Figure 34 shows the difference in configuration of a dredged and undisturbed sand deposit in the Maumee River Estuary of western Lake Erie. Dredging had been active in this area for approximately 40 years prior to the soundings.

The normal operating season for these vessels is from 25 April to 15 December. Although the Erie Sand Steamship Company began operation in 1888, Area "C" on the Norfolk Moraine was not established until 1940.

The quantity of sand and gravel dredged from Area "C" between 1955 and 1983 is shown in Figure 35 and listed in Table 3. Over this period of record, a total of 12.2 million cubic yards of material has been extracted. If evenly distributed over the entire 12 square miles of Area "C", this 29 years of dredging would be equivalent to the removal of bottom sediment to a depth of 11.8 inches. Therefore, on an annual basis the equivalent of 0.4 inches of sediment is removed from the bottom of Area "C". If the average annual extraction rate from 1955 to 1983 is projected back to 1940 when Area "C" was established, an equivalent of 1.5 feet of sand and gravel has been extracted from this portion of the Norfolk Moraine. Table 4 shows that the rate of extraction is not uniform throughout the dredging season. April, November and December are periods of low yields while May through August are peak production months.

TABLE 3. ANNUAL QUANTITIES OF SAND AND GRAVEL DREDGED FROM AREA "C" OF THE NORFOLK MORAINE--1955 TO 1983

Year	Cubic Yards of Sand Dredged
1955	510,000
1956	575,430
1957	683,998
1958	525,000
1959	650,000
1960	518,350
1961	500,000
1962	450,000
1963	452,000
1964	513,450
1965	524,750
1966	588,425
1967	625,285
1968	571,405
1969	506,280
1970	465,020*
1971	439,495*
1972	372,005*
1973	312,730*
1974	252,585*
1975	434,780*
1976	339,815*
1977	190,570*
1978	254,372*
1979	230,880*
1980	184,875*
1981	191,395*
1982	169,465*
1983	193,240*
TOTAL	12,225,600
ANNUAL MEAN	421,572

* Total of $604,684 in royalties paid to the Pennsylvania Fish Commission (1970-1983).

TABLE 4. MONTHLY QUANTITIES OF SAND AND GRAVEL DREDGED FROM AREA "C" OF THE NORFOLK MORAINE--1976 to 1980

Month ---	1976	1977	1978	1979	1980
April	45,485	6,600	13,250	9,525	5,925
May	67,110	29,845	47,440	29,425	31,225
June	56,510	29,550	41,300	44,825	18,875
July	43,355	35,000	33,000	32,125	33,650
August	39,000	22,025	33,840	38,020	20,895
September	26,080	18,435	29,037	25,725	19,975
October	43,755	23,820	27,150	28,735	25,425
November	16,820	21,685	22,080	17,800	19,505
December	1,700	3,610	6,975	4,700	9,400
TOTALS:	339,815	190,570	254,372	230,880	184,875

ASSESSMENT OF DREDGING IMPACTS

The proposed enlargement of dredging Area "C" on the Norfolk Moraine to obtain sand and gravel for commercial purposed raises a number of question in regard to potential environmental impacts. Broadly considered, these questions concern water quality modifications and possible adverse effects on the biota of the lake, principally the fishery resources. the following sections of this report address these issues.

Water Quality

The Great Lakes Laboratory of the New York State University College at Buffalo (Sweeney 1970) conducted a study of ecological impacts of sand dredging on Lake Erie for the Erie Sand Steamship Company. The study was performed on a submerged sand bar (Norfolk Moraine) north of Presque Isle spit. The study was designed to measure how much, if any, nutrients (phosphorus and nitrogen)are added to the upper waters of the lake through sand dredging and if dredging operation add or remove oxygen from the water. Sweeney concluded that because of only slight changes, both in amount and duration, which were noted in the oxygen saturation and temperature profile values, sand dredging has neither a negative nor positive effect on the water in the dredging area. The over flow from the dredge did contain higher amounts of nutrients than the surface or bottom waters. However, the amount of soluble phosphorus (form in which it is available for algal production) was lower than that in the surrounding surface water. The rapid decrease in turbidity following dredging indicated the suspended material settled quickly, carrying with it adsorbed phosphates. Nitrates and ammonia in the overflow were above the ambient levels in the lake. This could stimulate increased algal production within the dredging area but the increase would probably persist for only a short period due to the reduction of phosphorus which would limit growth. The dredging overflow had no significant impact on biochemical oxygen demand; chemical oxygen demand increased as much as two-fold in the overflow. Sweeney stated that this was not expected to be a problem because of the high oxygen values at the surface. In summary, the study found, "the effect of dredging on the ecology of Lake Erie is negligible at most," and that, "no modifications in dredging operation are believed necessary."

In a similar, but more comprehensive study in western Lake Erie (Herdendorf and Cooper 1975 and Herdendorf 1978) demonstrated that commercial sand and gravel dredging had only temporary impacts on water quality. The most significant impact was a localized increase in turbidity in the vicinity of the dredge discharge pipe. Although planktonic and benthic organisms were assumed to be eliminated as they passed through the pump system, nektonic fish appeared to be uneffected by the dredging operation. In summary, the assessment concluded that that long-term adverse impacts to the Maumee River - Maumee Bay ecosystems of continued dredging activities would be negligible.

Fishery Resources

The only significant species of fish which now may spawn, or are likely to spawn in the future, on the proposed dredging area include lake trout and lake whitefish. As discussed earlier these species are fall spawners, with eggs hatching in the early spring. In assessing the potential impact of dredging it is necessary to know the density of eggs and larvae over the spawning beds and the volume of water that passes through the pump system during normal dredging operations.

The annual production of sand and gravel from Area "C" during the past 10 years has averaged about 234,000 cubic yards (Table 2). As pointed out earlier in this report, the pumping ratio of water to sand is approximately 4:1 during the dredging operation. Therefore, the production of234,000 cubic yards of sand requires 936.000 cubic yards (716,000 cubic meters) of water to pass through the pumps.

Reports from scientific literature indicate that lake trout or lake whitefish prefer shallower spawning beds than those available on Norfolk Moraine (Scott and Crossman 1973). Studies have shown that the larval density of these species in the shallower nearshore regions of the lake is less than one individual per 100 cubic meters (Figure 25). In order to estimate the mortality of dredging on these species it is also necessary to know the amount of dredging activity during the spawning and nursery period (November - April). Table 4 shows that less than 23% of the dredging activity occurs during these months. This is equivalent to about 160,000 cubic meters of water pumped during this critical period. If 10 individuals per 100 cubic meters is used as a possible population density (several times higher than actually measured for these species) and if total mortality is assumed, the estimated loss of larval fish would be 16,000 individuals. To place this number in perspective, one adult lake trout lays up to 17,000 eggs each year (Eschmeyer 1955), while lake whitefish egg production per female has been reported as high as 9 times this number (Becker 1983).

As a worst case estimate, the highest combined density of al species found in the central basin of Lake Erie was used to calculate potential larval fish mortality. Cooper et al. (1983) found the highest density to be somewhat less than 10 individuals per 10 cubic meters of water near the Ohio - Pennsylvania line (Figure 25). If this high density were to persist throughout the entire dredging season, the total larval mortality to all species would be 716,300 individuals, When compared with the fecundity of most fish species resident in the lake (Table 2) this number represents the egg production of only a few adult females.

CONCLUSIONS

1. The Erie Sand Steamship Company (ESSC) has proposed the expansion of Norfolk Moraine Area "C" from 12 to 19.6 square miles, an increase of 7.6 square miles (Appendix A). ESSC has requested the additional area in order to obtain different grades of sand than are available in the present Area "C". The future annual production is expected to be approximately the same as has been in the past 10 years (Sidney E. Smith, President, ESSC, personal communication, February 1984). Therefore, if the expanded area is approved, the net impact on the Norfolk Moraine is <u>not</u> expected to be significantly different than it has been for the past 40 years.

2. The annual rate of sand and gravel removal from the Norfolk Moraine is approximately 0.4 inches projected over the present Area "C". If the area is expanded from 12 to 19.6 square miles, the removal will decrease to less than 0.3 inches per year. Typically permits are issued for a five year period. Given this period, a total of 1.5 inches will be removed. Realistically, only about 50% of the area may contain high quality material which would result in about 3 inches of material being removed over a 5-year period. Based on the reserves of sand and gravel available (15 feet maximum thickness and 6 feet mean thickness). The expanded Area "C" would provide material for an estimated 120 years at the present rate of extraction. It should also been noted that the expanded Area "C" accounts for about 22% of the surface area of the Norfolk Moraine in Pennsylvania or about 11% of the entire moraine in both United States' and Canadian waters.

3. A review of the literature available for Lake Erie and other lakes in the Great Lake region does <u>not</u> support the contention that the Norfolk Moraine serves as a significant spawning and nursery area for lake trout, lake whitefish, yellow perch, walleye, and other important fish species. Documentation contained earlier in this report shows that yellow perch and walleye are shallow water, inshore spawners. Although the data is sparser for lake trout and lake whitefish, water shallower than that available on the Norfolk Moraine is preferred for spawning. As restoration efforts for the latter two species continue, it is possible (particularly for the lake trout) that some future utilization of the moraine will take place. Because spawning takes place in the late fall when dredging is at a minimum or has already ended for the season, it is anticipated that the impact will be minimal. Worst case estimates of fish larvae mortality due to entrainment by the dredges show this to be an insignificant problem.

4. Studies sponsored by the U.S. Environmental Protection Agency (Herdendorf 1979 and Cooper et al. 1982) and U.S. Department of Energy (1982) have shown that the inshore waters of the far eastern end of the central basin are the preferred spawning and nursery areas for Lake Erie fish species. These studies concluded that total larval densities were highest nearshore, and decreased with increasing distance from shore. These findings are consistent with literature citation for other lakes in the Great Lakes region. Based on these data and the deep water (48-66 ft) found over the Norfolk Moraine, it is unlikely that significant spawning of lake trout, lake whitefish, yellow perch, walleye, or other important

species takes place on the moraine.

5. Studies by the Canada Centre for Inland Waters (Boyce et al. 1980) demonstrated that the Norfolk Moraine (Pennsylvania Ridge) projects above the thermoclines of the central and eastern basins (Figure). Lake trout and lake whitefish are primarily hypolimnion dwellers during the summer months, therefore dredging activities on the moraine should not be a significant disturbance to these species during the period of summer stratification.

6. Based on the above considerations, the proposed expansion of sand and gravel dredging Area "C" by 7.6 square miles will have only negligible impact on the ecology of Norfolk Moraine and the fishery resources of this portion of Lake Erie. The evidence presented in the report demonstrates that an exhaustive environmental assessment, such as the one recommended by the U.S. Army Corps of Engineers, Buffalo District (Appendix B) is unwarranted.

REFERENCES CITED

Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison. 1052 pp.

Boyce, F.M., F. Chiocchio, B. Eid, F. Penicka, and F. Rosa. 1980. Hypolimnion flow between the central and eastern basins of Lake Erie during 1977. Jour. Great Lakes Res. 6(4): 290-306.

Bur, M.T. 1982. Appraisal of lake trout restoration effort. In Progress of fishery research 1981. U.S. Fish and Wildlife Service, Great Lakes Fishery Laboratory, Ann Arbor, Michigan. 27 pp.

Cooper, C.L., C.E. Herdendorf, J.J. Mizera, and A.M. White. 1983. Limnetic larval fish in the nearshore zone of the south shore of the central basin of Lake Erie. Ohio Jour. Sci 83(3):138-140.

Eschmeyer, P.H. 1955. The reproduction of lake trout in southern Lake Superior. Trans. Am. Fish Soc. 84:47-74.

Eschmeyer, P.H. 1957. The lake trout (Salvelinus Namaycush). U.S. Fish. Wild. Serv. Fish. Leaflet No. 441. 11 pp.

Faber, D.J. 1970. Ecological observation on newly hatched lake whitefish in South Bay, Lake Huron. In Biology of coregonid fishes. University of Manitoba Press, Winnipeg. 560 pp.

Fish, M.P. 1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters. Bull. U.S. Bur. Fish. 10(47):293-398.

Goodyear, C.D., T.A. Edsall, D.M.O. Dempsey, G.D. Moss, and P.E. Polanski. 1982. Atlas of the spawning and nursery areas of the Great Lakes, Volume IX, Lake Erie. U.S. Fish and Wildlife Service, Washington, D.C. 193 pp.

Greeley, J.R. 1929. Fishes of the Erie-Niagara watershed. In A biological survey of the Erie-Niagara system. N.Y. Conserv. Dept., Supl. 18th Annual Rept. p.150-180.

Hartley, R.P. 1960. Sand dredging areas in Lake Erie. Ohio Dept. Natural Resources, Div. Shore Erosion Tech. Rept. 5. 79 pp.

Hartley, R.P. 1961. Bottom deposits in the Ohio waters of central Lake Erie. Ohio Dept. Natural Resources, Div. Shore Erosion Tech. Rept. 6. 14 pp.

Hartley, R.P. and C.E. Herdendorf. 1965. Sedimentology of the southeastern central basin of Lake Erie. Ohio Dept. Natural Resources, Div. Shore Erosion 67 pp.

Hartley, S.M. and C.E. Herdendorf. 1977. Spawning ecology of Lake Erie fish species. The Ohio State University, Center for Lake Erie Area Research Tech. Rept. 62. 10 pp.

Hartman, W.L. 1973. Effects of exploitation, environmental changes, and new species on the fish habitats and resources of Lake Erie, Great Lakes Fish. Comm. Tech. Rept. 22. 43 pp.

Herdendorf, C.E. 1974. Methods of sediment dredging and disposal in the Great Lakes. The Ohio State University, Center for Lake Erie Area Research Tech. Rept. 28. 34 pp.

Herdendorf, C.E. 1975. Shoreline change of lakes Erie and Ontario, with special reference to currents, sediment transport and shore erosion. Bull. Buffalo Soc. Nat. Sci. 25(3):43-76.

Herdendorf, C.E. 1976. Sedimentology of Lake Erie. In Limnology of lakes and embayments. Great Lakes Basin Commission Framework Study, App. 4. p. 338-345.

Herdendorf, C.E. 1978. Environmental impact assessment:an aquatic biologist's point of view. Ohio Jour. Sci. 78(4):229-234.

Herdendorf, C.E. 1979. Dates of first and last occurrence and maximum density of fish eggs and larvae in central Lake Erie. The Ohio State University, Center for Lake Erie Area Research Tech. Rept. No. 131. 12 pp.

Herdendorf, C.E. 1983a. Lake Erie water quality 1970-1982. The Ohio State University, Center for Lake Erie Area Research Tech. Rept.No. 279. 139 pp.

Herdendorf, C.E. 1983b. Our changing fish species history. Inland Seas 39(4):276-286.

Herdendorf, C.E. 1984. Guide to fishing in central Lake Erie. Ohio Sea Grant Guide Series No. 8. 1 map.

Herdendorf, C.E. and C.L. Cooper. 1975. Environmental impact assessment of commercial sand and gravel dredging in Maumee River and Maumee Bay of Lake Erie. The Ohio State University, Center for Lake Erie Area Research Tech. Rept. No. 41. 380 pp.

Hough, J.L. 1963. The prehistoric Great Lakes of North America. Am. Scientist 51:84-109.

Hubbs, C.L. and K.F. Lagler. 1964. Fishes of the Great Lakes region. University of Michigan Press, Ann Arbor. 213 pp.

International Joint Commission. 1982. Guidelines and register for evaluating Great Lakes dredging projects. IJC, Great Lakes Water Quality Board. 365 pp.

Keenleyside, M.H.A. 1955. Some aspects of the schooling behavior of fish. Behaviour 8(2,3):183-248.

Koelz, W. 1929. Coregonid fishes of the Great Lakes. Bull. U.S. Bur. Fish. 43(2):297-643.

Lawler, G.H. 1961. Egg counts of Lake Erie whitefish. Jour. Fisheries Research Board Canada 18(2):293-294.

Lewis, C.F.M., T.W. Anderson, and A.A. Berti. 1966. Geological and palynological studies of early Lake Erie deposits. University of Michigan, Great Lakes Res. Div. Publ. 15:176-191.

Martin, N.V. 1957. Reproduction of lake trout in Algonquin Park, Ontario. Trans. Amer. Fish. Soc. 86:231-244.

Martin, N.V. 1960. Homing behavior in spawning lake trout. Canada Fish Cult. 26:3-6.

Mizera, J.J. 1981. Distribution and entrainment of larval fishes in western and central Lake Erie. Ohio State University, Center for Lake Erie Area Research Technical Rept. 215. 225 pp.

Moore, H.F. 1894. Report upon condition and regulation of the fisheries of Lake Erie. Resume of observations. Joint Fisheries Commission.

Nagel, W. and P. Knuth. 1981. Commercial dredging in the Pennsylvania waters of Lake Erie. Coastal Research Associates, Inc. 23 pp.

Ohio Divisison of Wildlife. 1983. Status of Ohio's Lake Erie fisheries. Ohio Dept. Nat. Res., Div. Wildlife, Lake Erie Fisheries Unit, Sandusky, Ohio. 21 pp.

Pegrum, R.H. 1928. Topography of Lake Erie basin. Bull. Buffalo Soc. Nat. Sci. 14(3):17-24.

Regier, H.A., V.C. Applegate, R.A. Ryder, J.V. Manz, F.G. Ferguson, H.D. Van Meter, and D.R. Wolfert. 1969. The ecology and management of the walleye in western Lake Erie. Great Lakes Fish. Comm. Tech. Rept. No. 15. 101 pp.

Robbins, E.A., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1980. A list of common and scientific names of fishes from the United States and Canada. 4th Ed. Amer. Fish. Soc. Spec. Publ. No. 12. 176 pp.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada. Bull. 184. 966 pp.

Sly, P.G. 1976. Lake Erie and its basin. Jour. Fisheries Research Board of Canada. 33(3):355-370.

Sweeney, R.A. 1970. Evaluation of the ecological impact of sand dredging on Lake Erie. New York State University College at Buffalo, Great Lakes Laboratory. 11 pp.

Trautman, M.B. 1957. Fishes of Ohio. Ohio State University Press, Columbus. 683 pp.

Trautman, M.B. 1981. Fishes of Ohio. 2nd Ed. Ohio State University Press, Columbus. 782 pp.

U.S. Department of Energy. 1982. 30-KV international submarine transmission line-Erie, Pennsylvania to Nanticoke, Ontario, Canada General Public Utilities Corporation. Environmental Impact Statement. USDOE, Office of Emergency Operations, DOE/EIS-0079. Final

Van Oosten, J. 1939. The age, growth, sexual maturity, and sex ratio of the common whitefish, Coregonus clupeaformis (Mitchill). of Lake Huron. Paper Michigan Acad. Sci. Arts Lett. 24(2):195-221.

Walker, R.L. (ed.). 1975. Abatement and control of pollution from dredging activities. International Joint Commission, Work Group on Dredging Activities. 227 pp.

Wall, R.E. 1968. A sub-bottom reflection survey in the central basin of Lake Erie. Bull. Geol. Soc. Am.79:91-106.

Williams, S.J. and E.P. Meisburger. 1980. Sand and gravel resources offshore Presque Isle, Pennsylvania, U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, VA. Draft Rept. 67 pp.

Wolfert D.R. and H.D. VanMeter. 1978. Movements of walleyes tagged in eastern Lake Erie. New York Fish and Game Jour. 25(1):16-22.

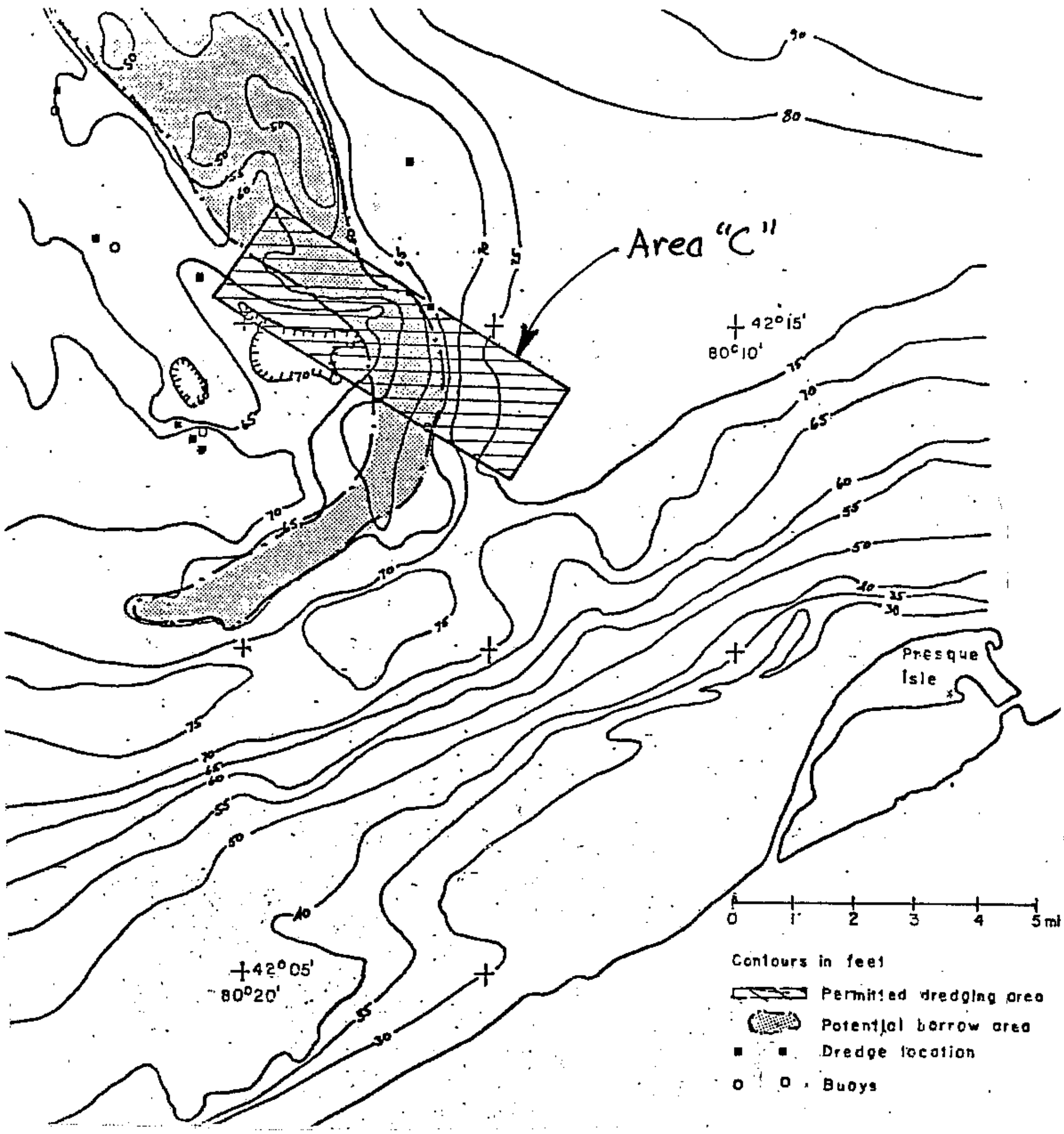


FIGURE 1. BATHYMETRY OF THE NORFOLK MORAINE SHOWING DREDGING AREA "C" (CROSS-HATCHED) AND SAND AND GRAVEL DEPOSITS (STIPPLED) (WILLIAMS AND MEISBERGER 1980)

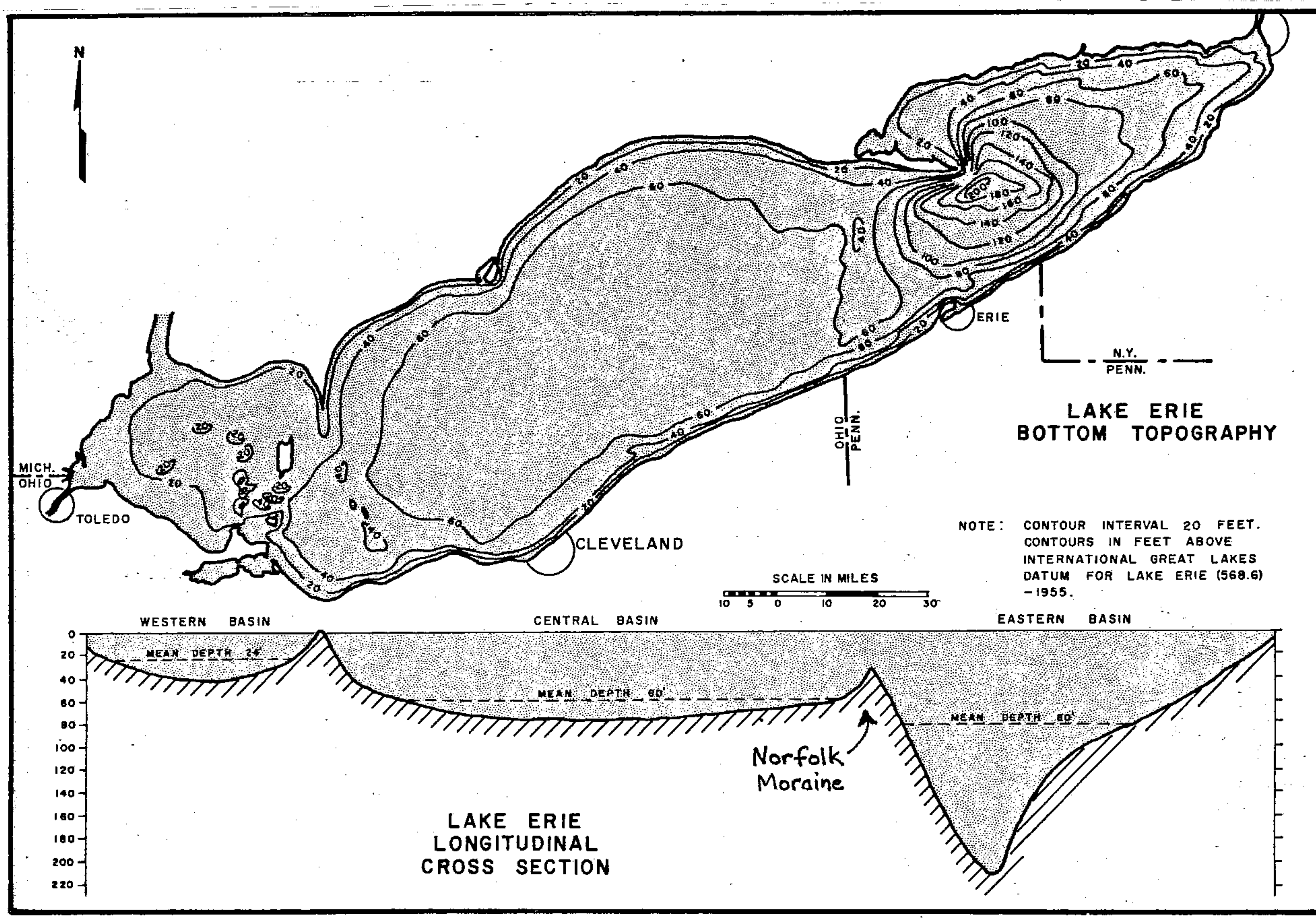


FIGURE 2. LAKE ERIE BOTTOM TOPOGRAPHY AND CROSS-SECTION (HERDENDORF 1976)

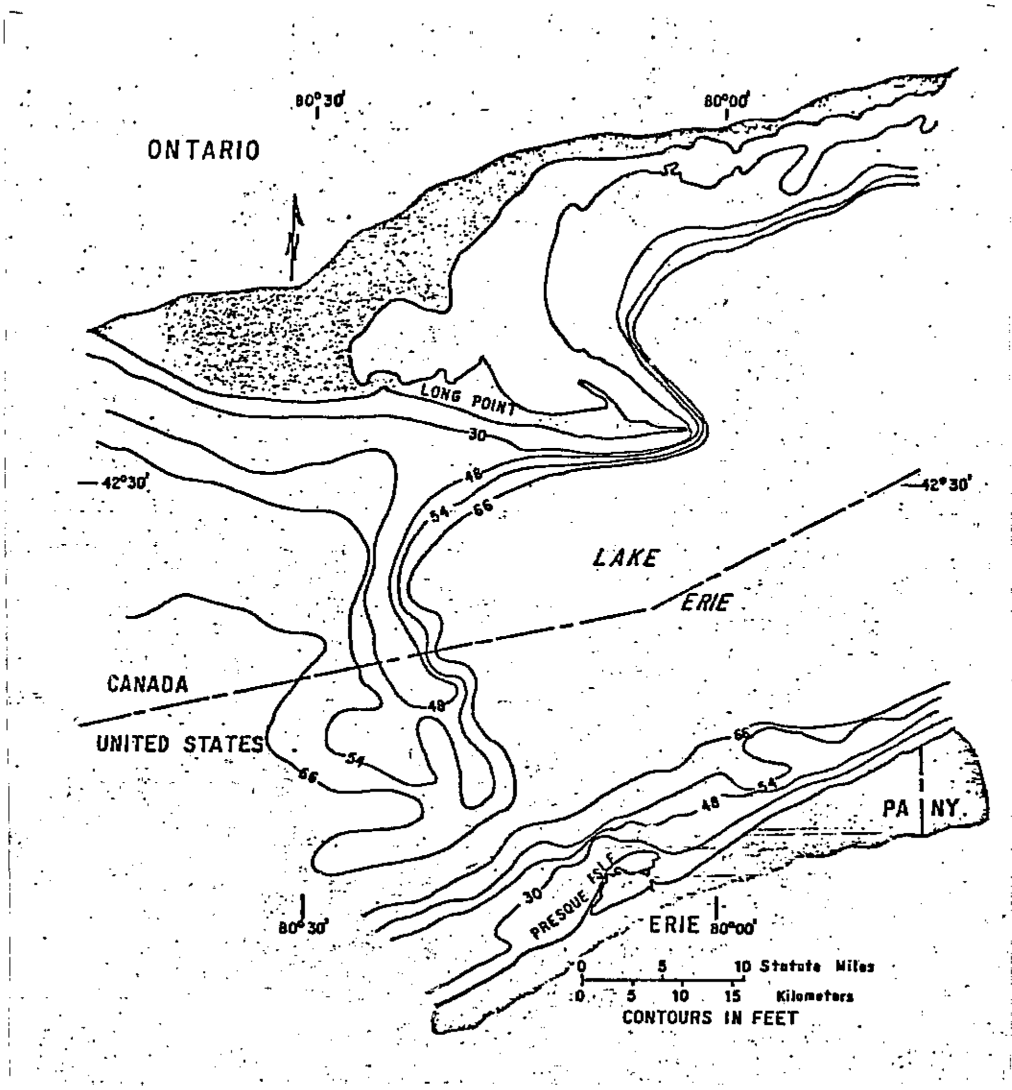


FIGURE 3. BATHYMETRY OF THE NORFOLK MORAINE BETWEEN LONG POINT, ONTARIO AND PRESQUE ISLE, PENNSYLVANIA (WILLIAMS AND MEISBURGER 1980)

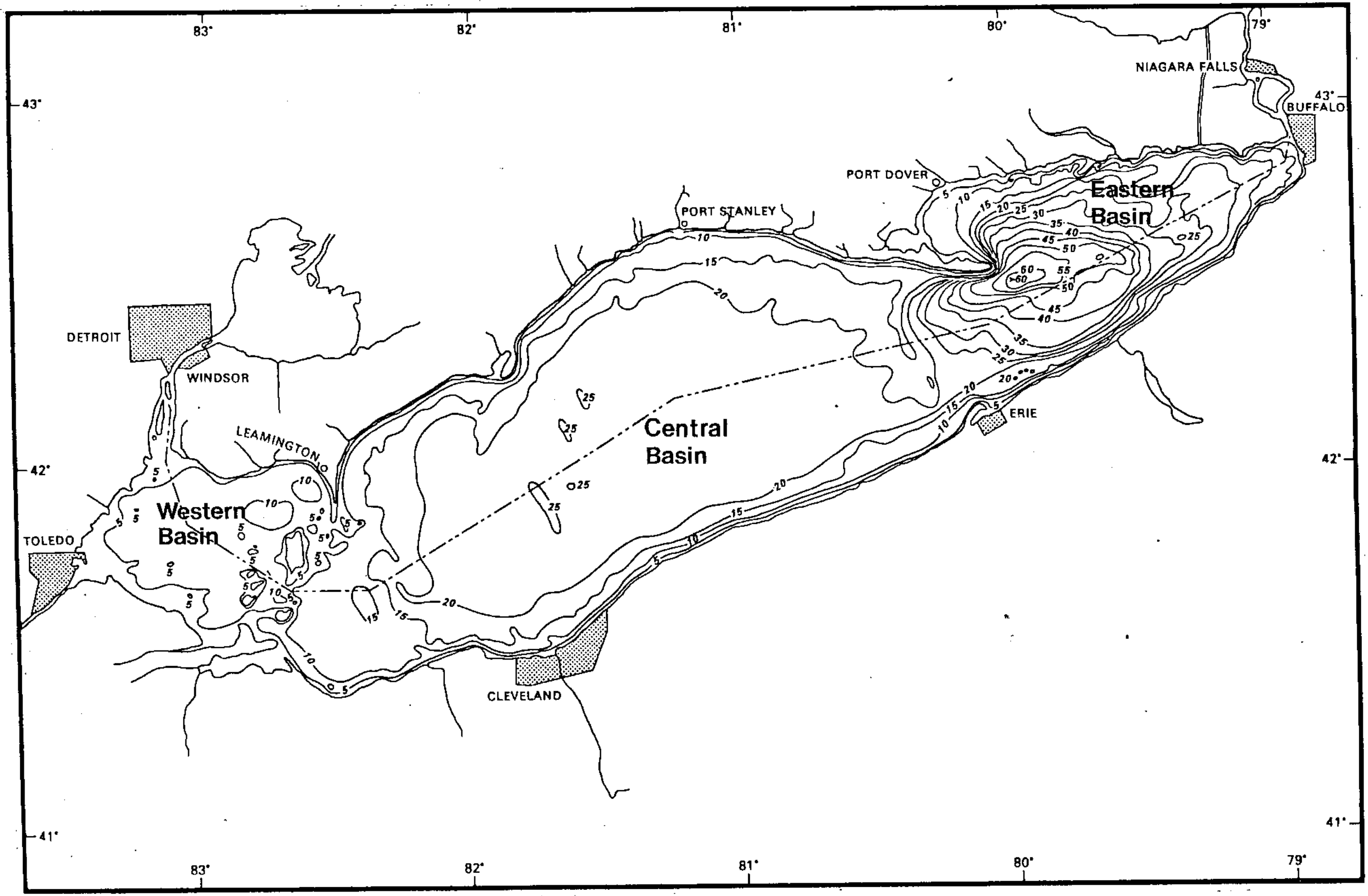


FIGURE 4. LAKE ERIE BATHYMETRY WITH DEPTH CONTOURS IN METERS (SLY 1976)

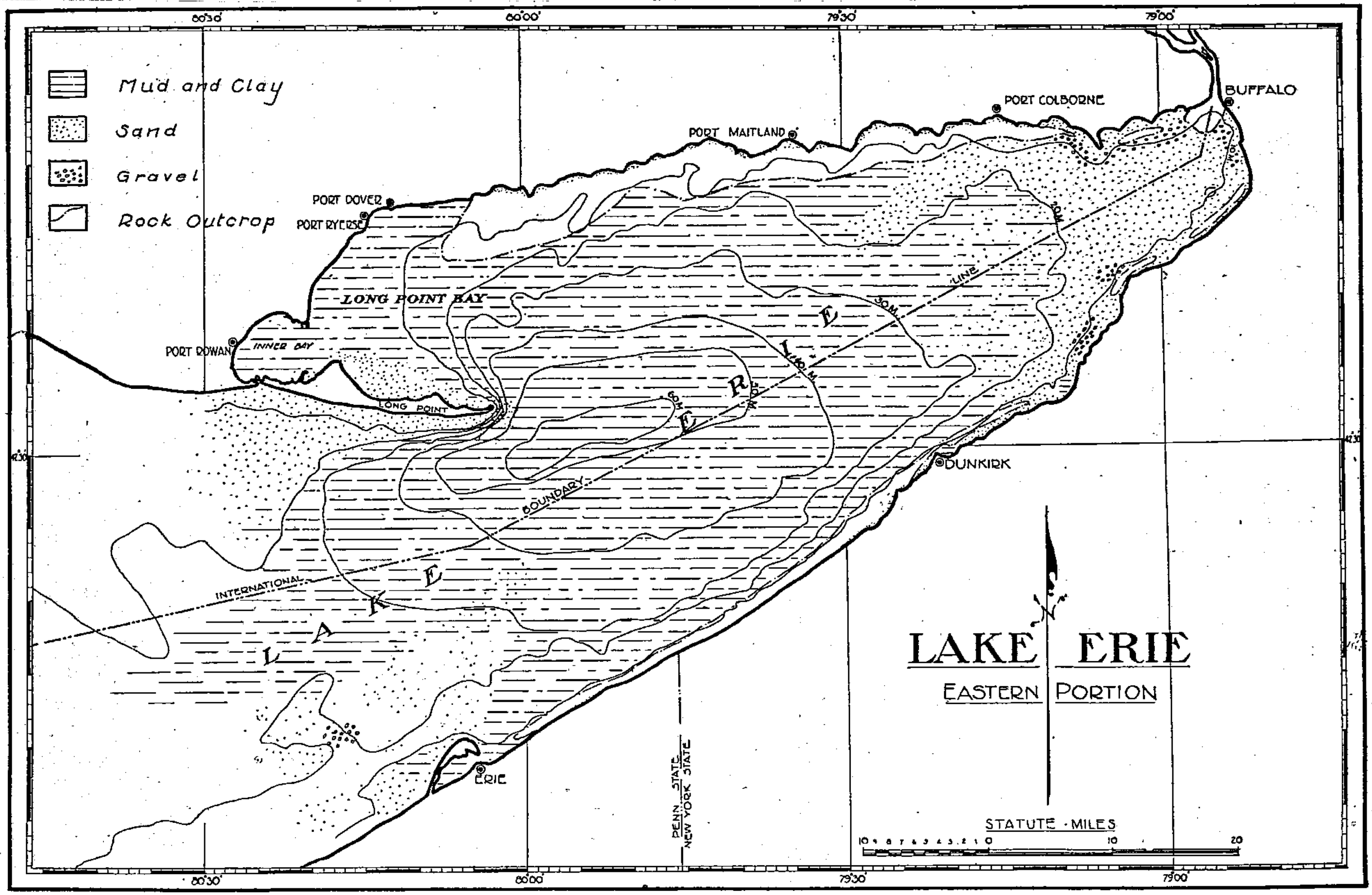


FIGURE 5. BOTTOM DEPOSITS OF EASTERN LAKE ERIE (PEGRUM 1929)

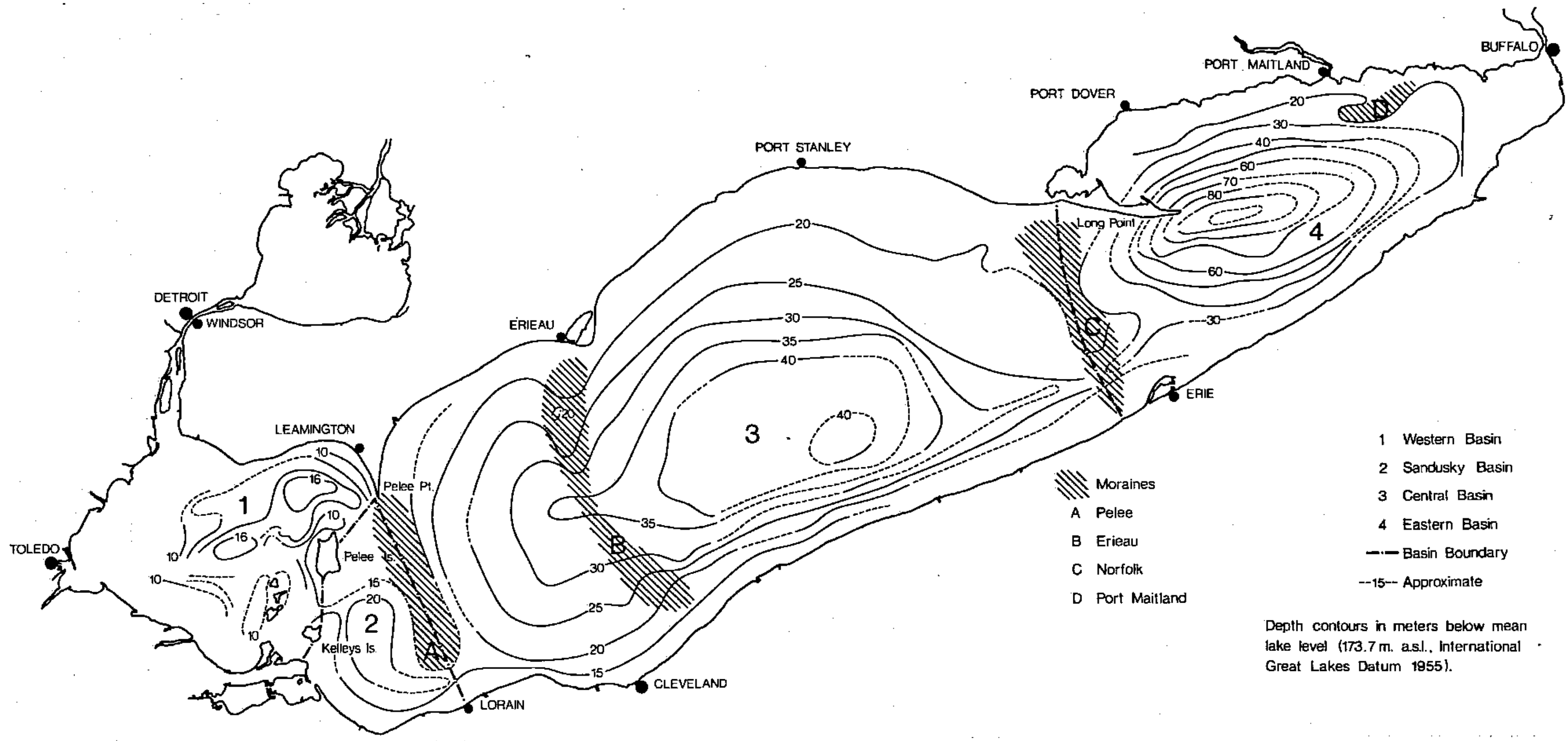


FIGURE 6. CONTOURS ON UPPER SURFACE OF LAKE ERIE GLACIAL DEPOSITS, SHOWING TERMINAL MORAINES, RELATIVE TO PRESENT LAKE LEVEL (SLY 1976)

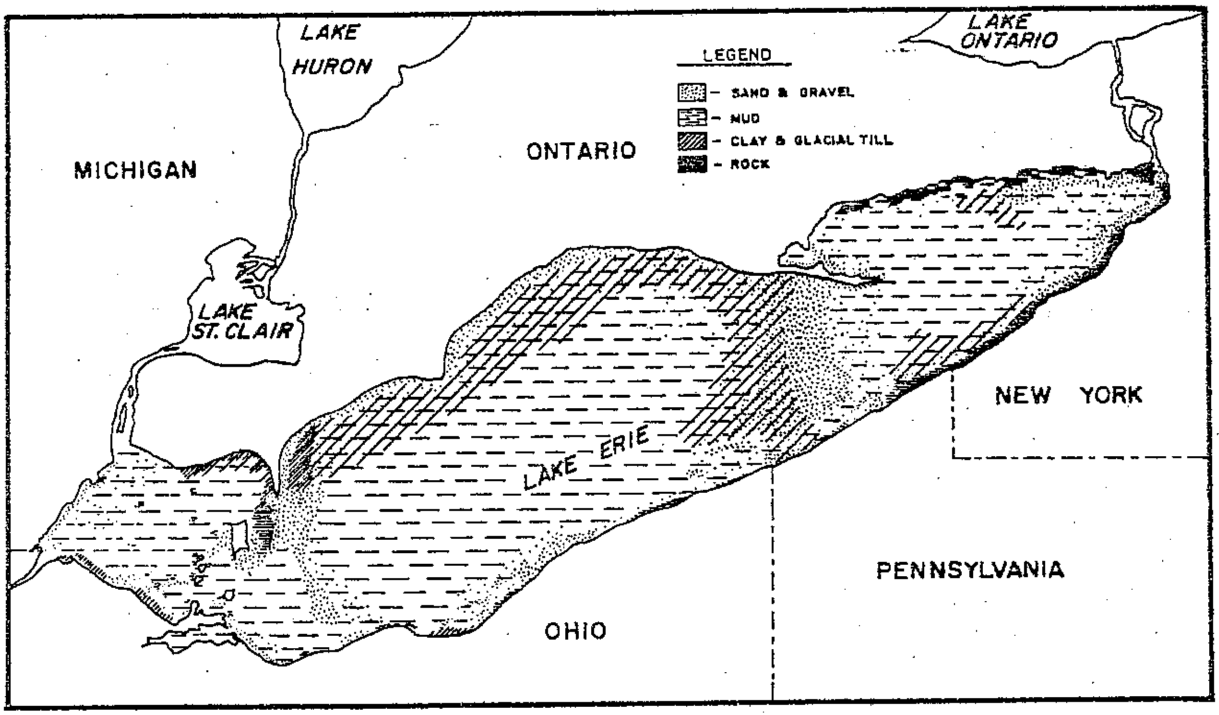


FIGURE 7. DISTRIBUTION OF BOTTOM SEDIMENTS IN LAKE ERIE (HERDENDORF 1976)

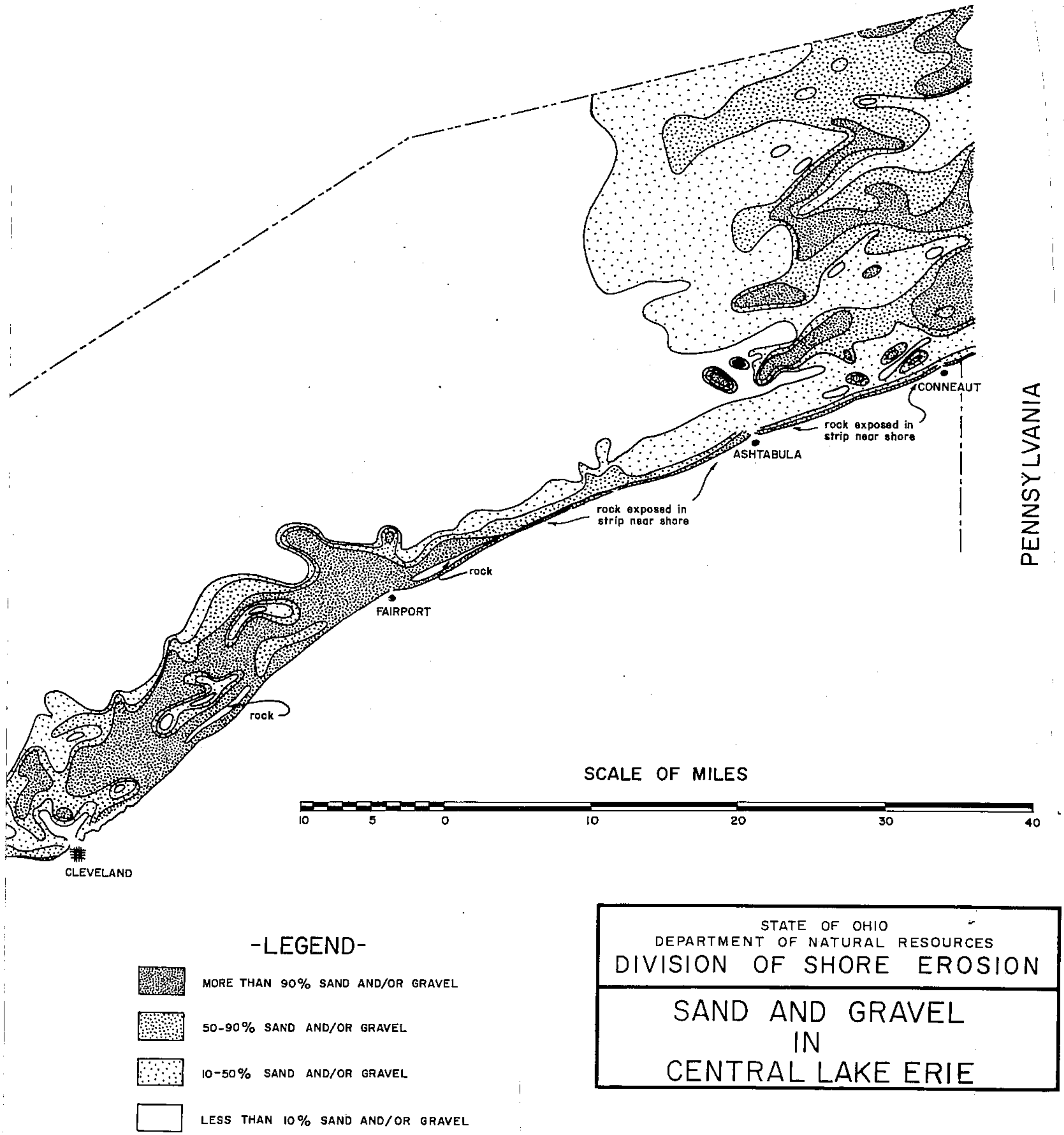


FIGURE 8. DISTRIBUTION OF SAND AND GRAVEL DEPOSITS IN CENTRAL LAKE ERIE (HARTLEY 1977)

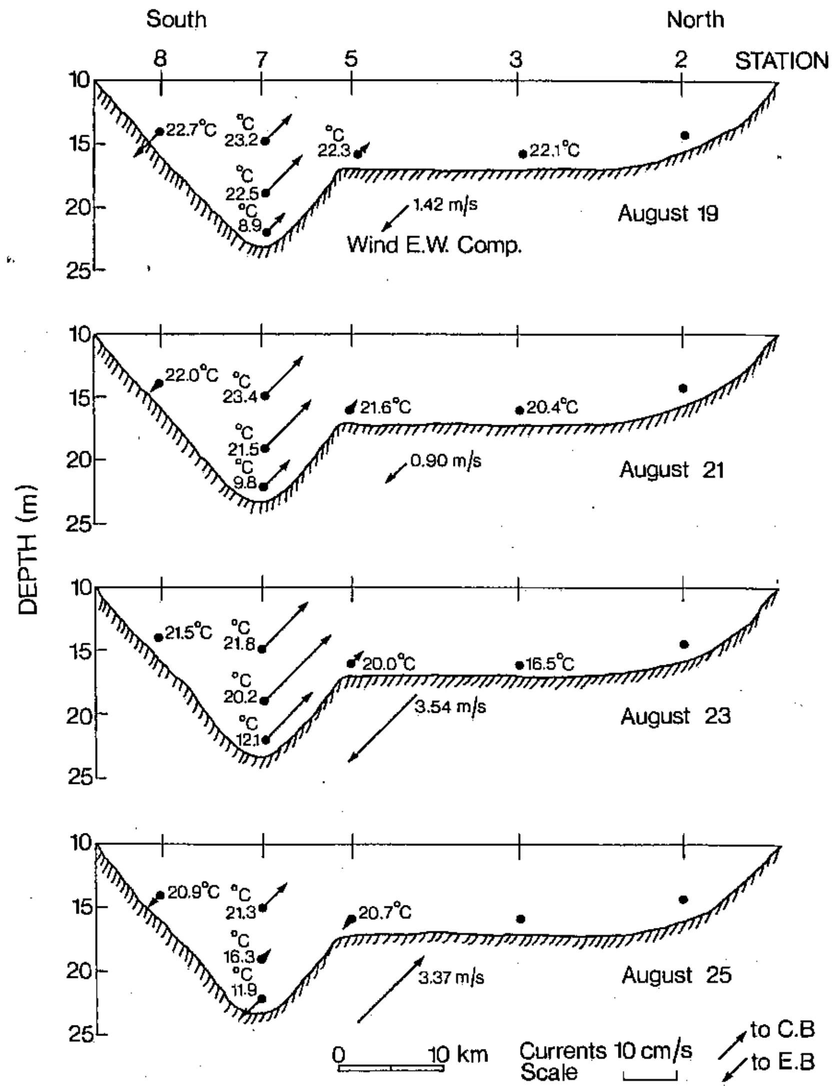


FIGURE 9. CURRENT VELOCITIES IN THE PENNSYLVANIA CHANNEL AND OVER THE NORFOLK MORAINE (BOYCE ET AL. 1980)

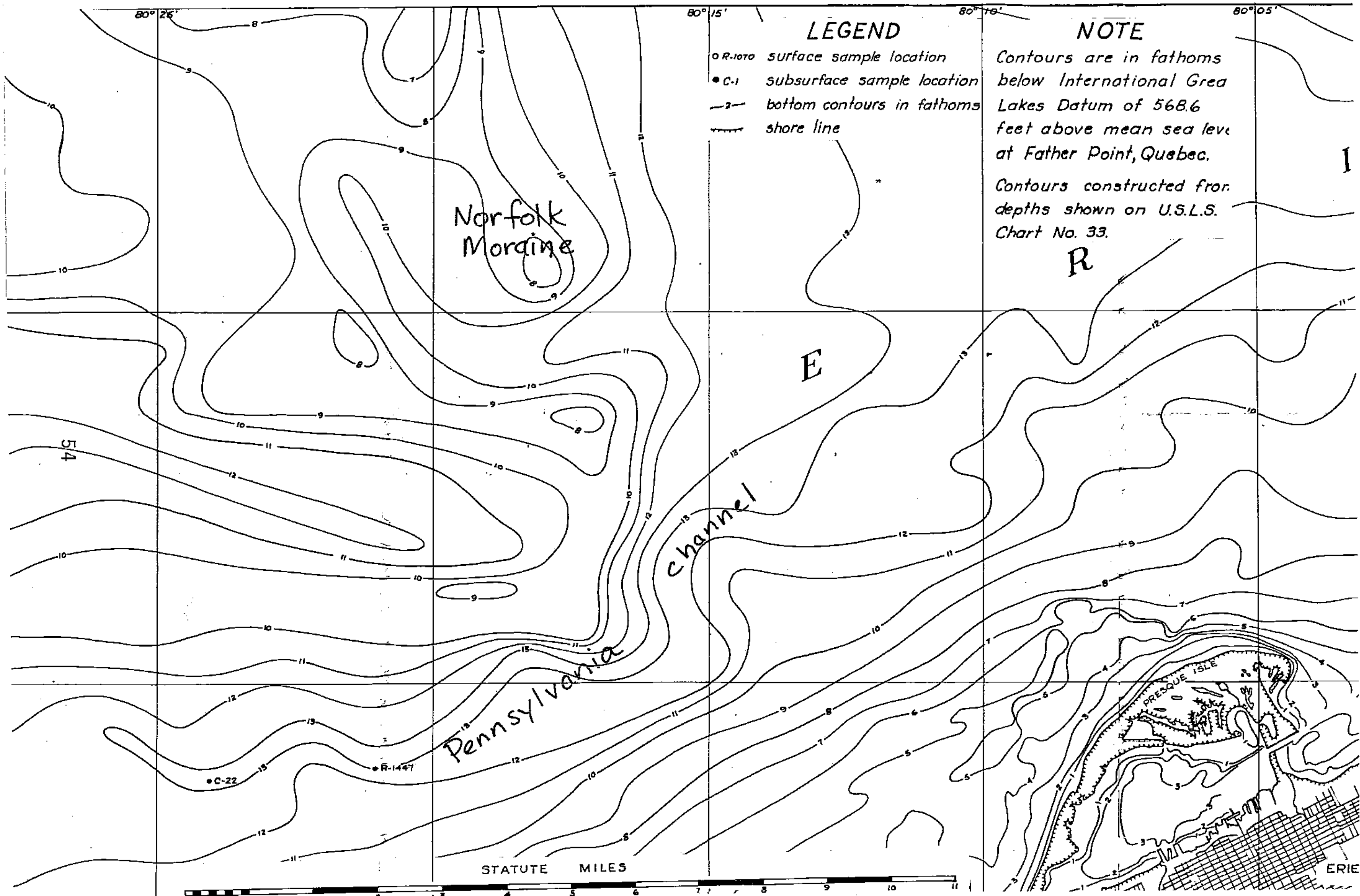


FIGURE 10. BATHYMETRY OF THE SOUTHERN END OF THE NORFOLK MORAINE (HARTLEY AND HERDENDORF 1965)

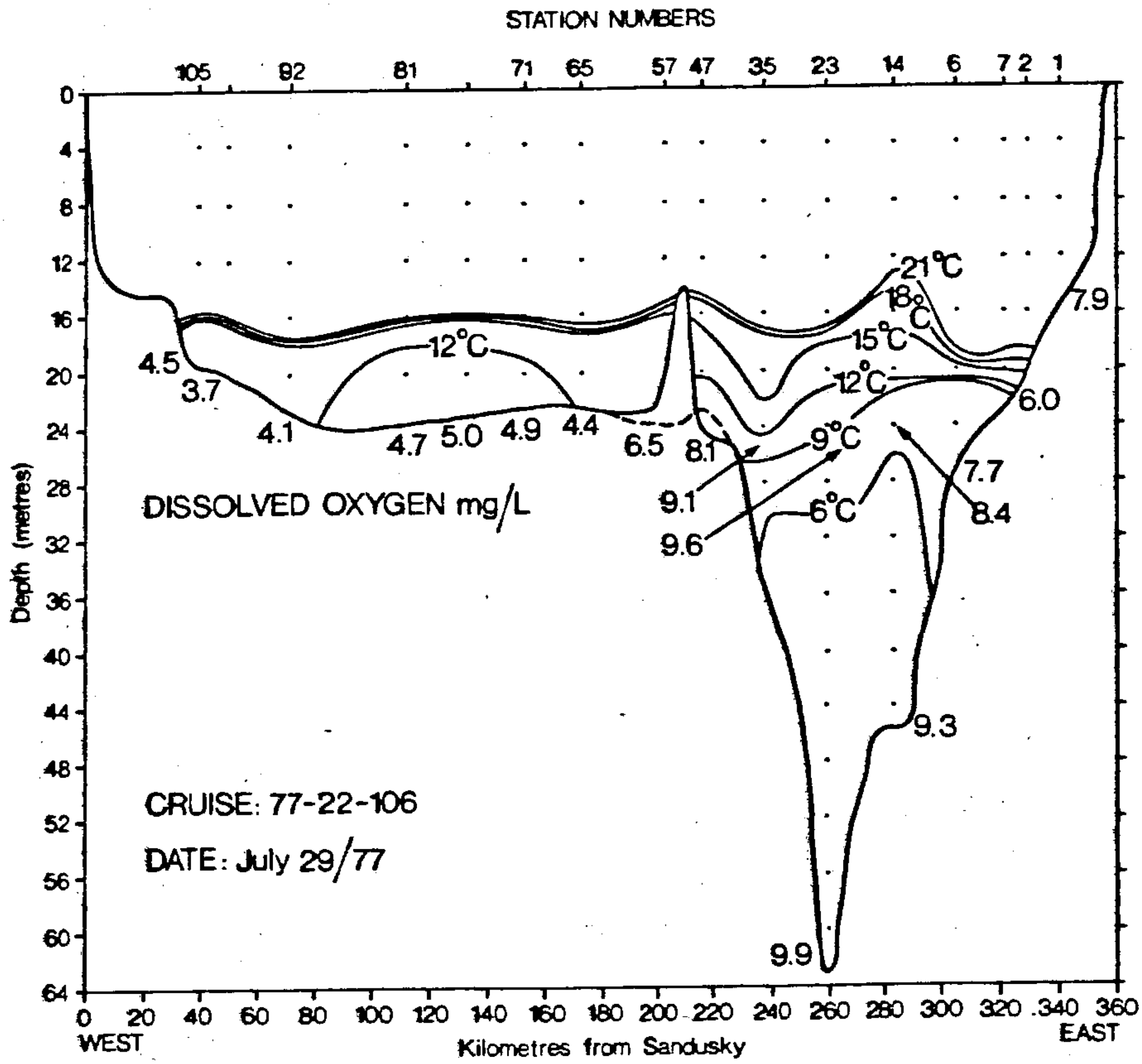


FIGURE 11. THERMAL STRUCTURE OF LAKE ERIE IN THE VICINITY OF THE NORFOLK MORAINE--JULY 1977 (BOYCE ET AL. 1980)

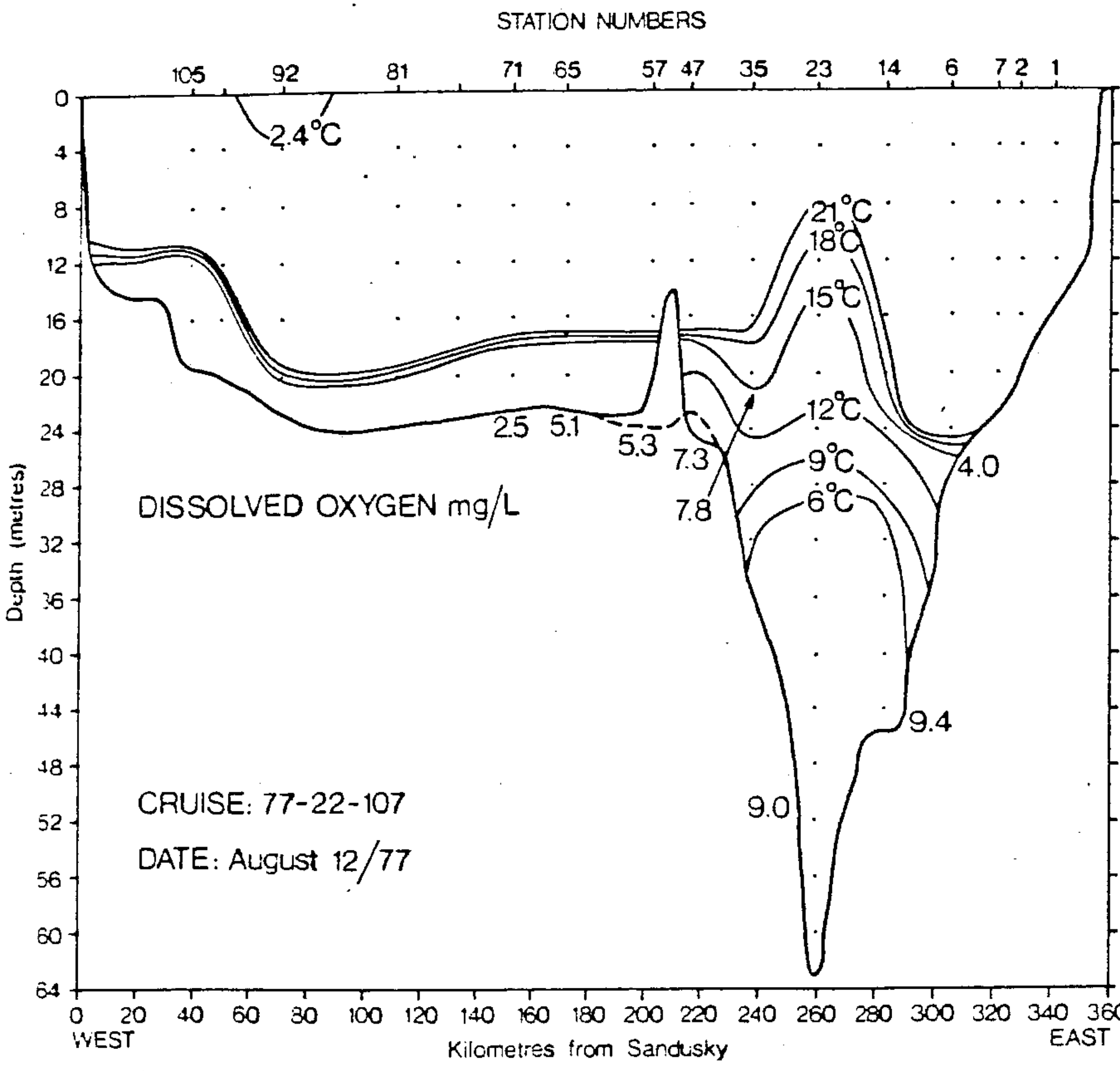


FIGURE 12. THERMAL STRUCTURE OF LAKE ERIE IN THE VICINITY OF THE NORFOLK MORAINE--AUGUST 1977 (BOYCE ET AL. 1980)

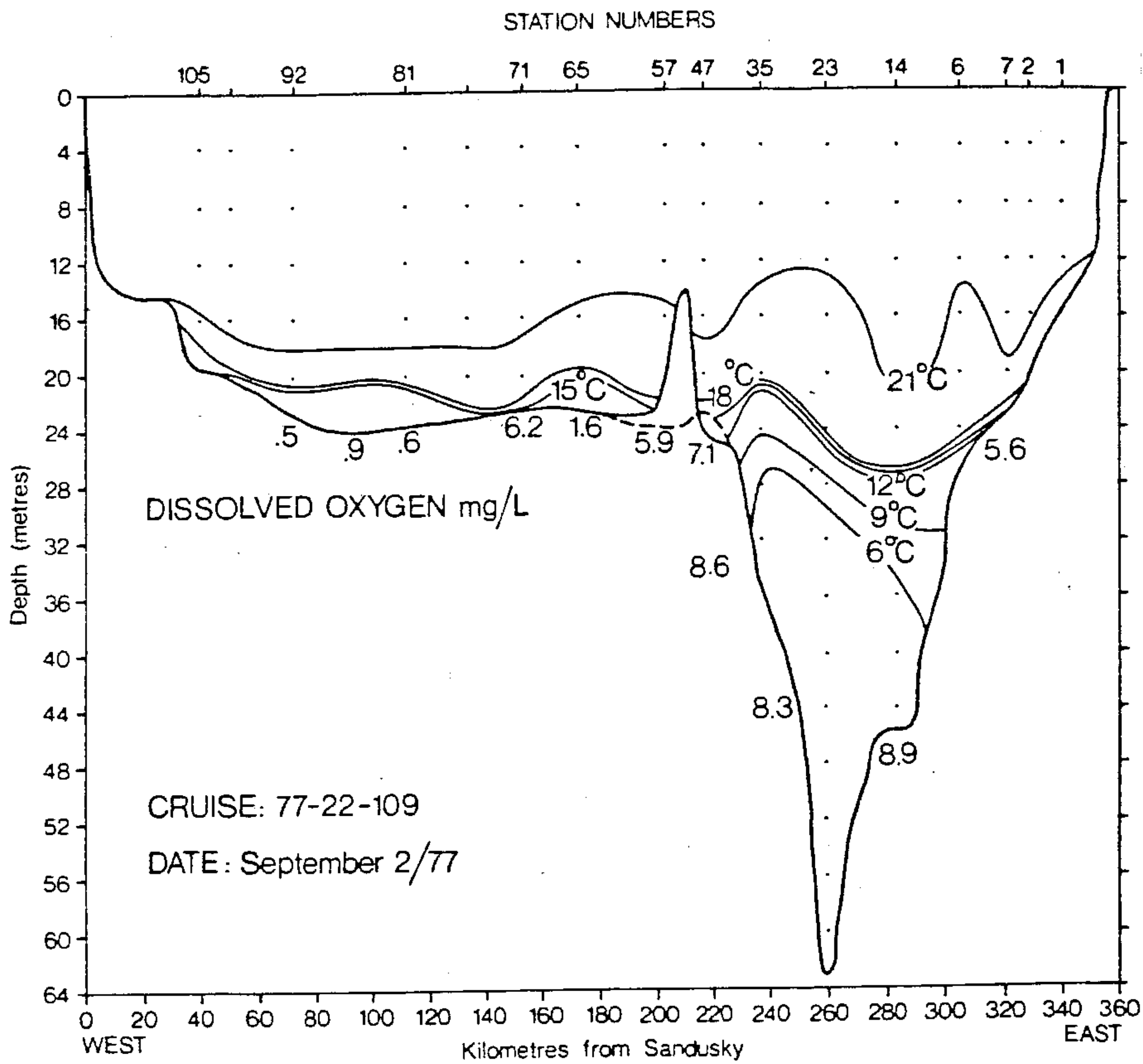


FIGURE 13. THERMAL STRUCTURE OF LAKE ERIE IN THE VICINITY OF THE NORFOLK MORAINE--SEPTEMBER 1977

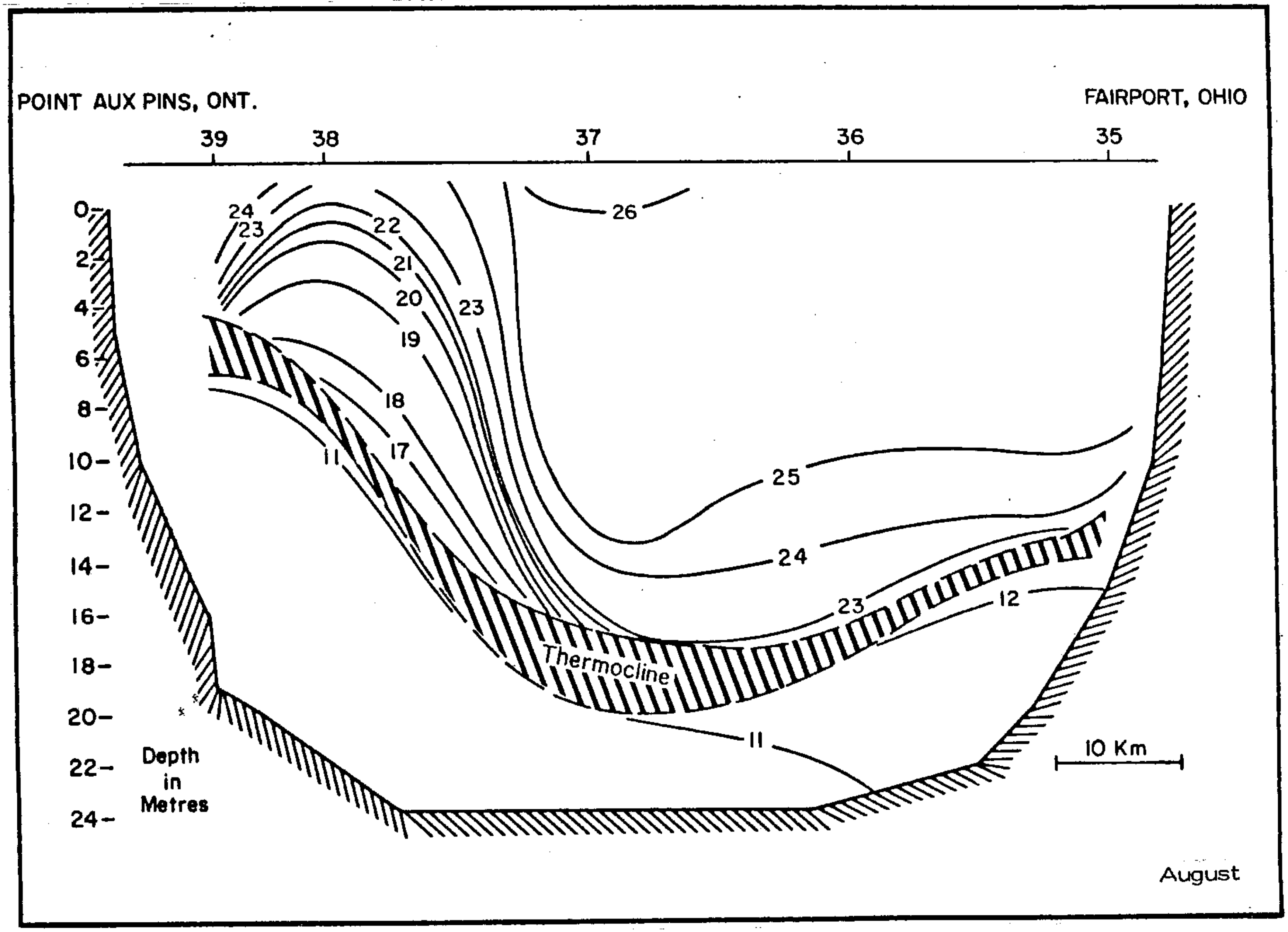


FIGURE 14. THERMAL STRUCTURE OF CENTRAL LAKE ERIE IN AUGUST 1974 (HERDENDORF 1984)

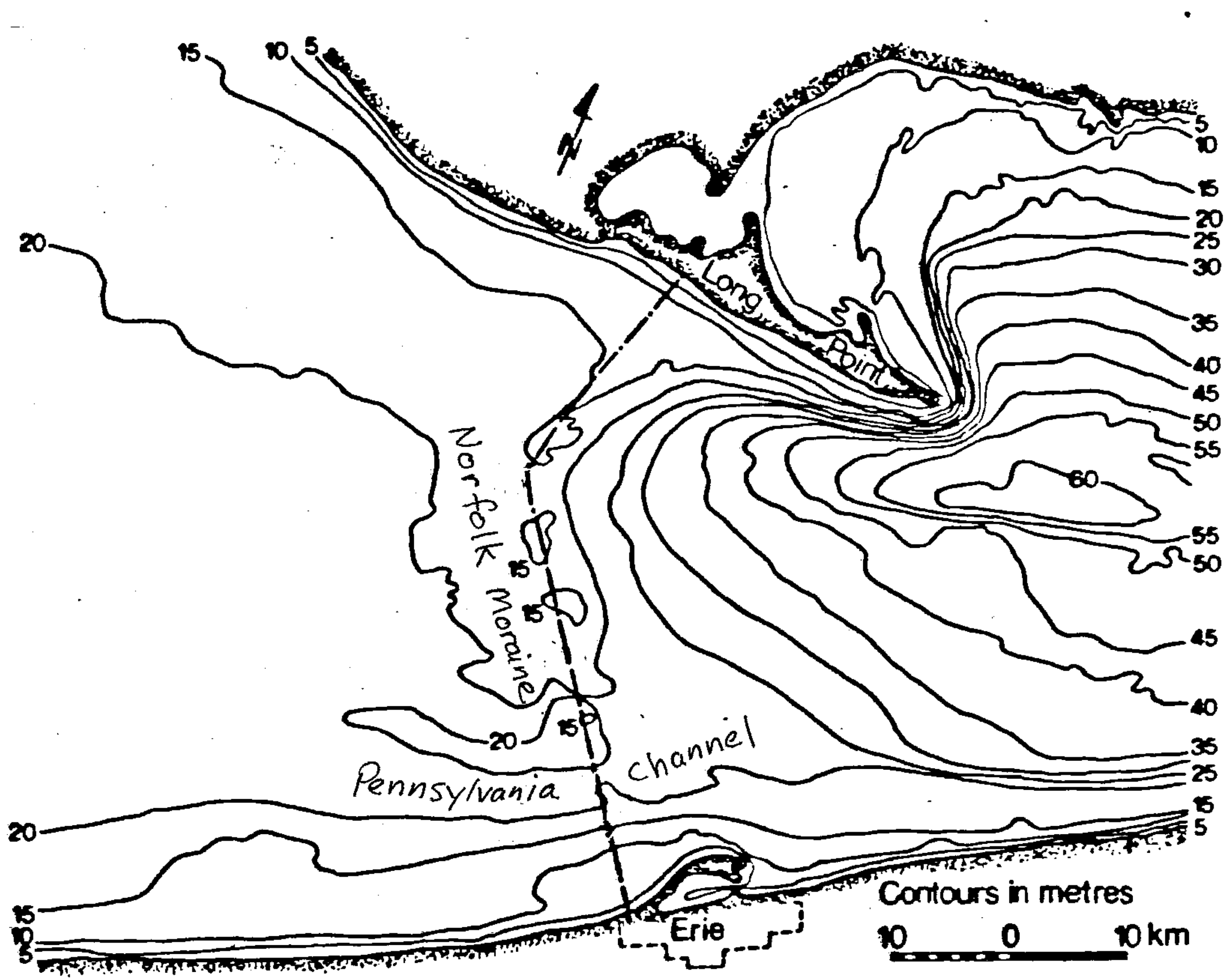


FIGURE 15. BATHYMETRY OF THE NORFOLK MORAINE (PENNSYLVANIA RIDGE) (BOYCE ET AL. 1980)

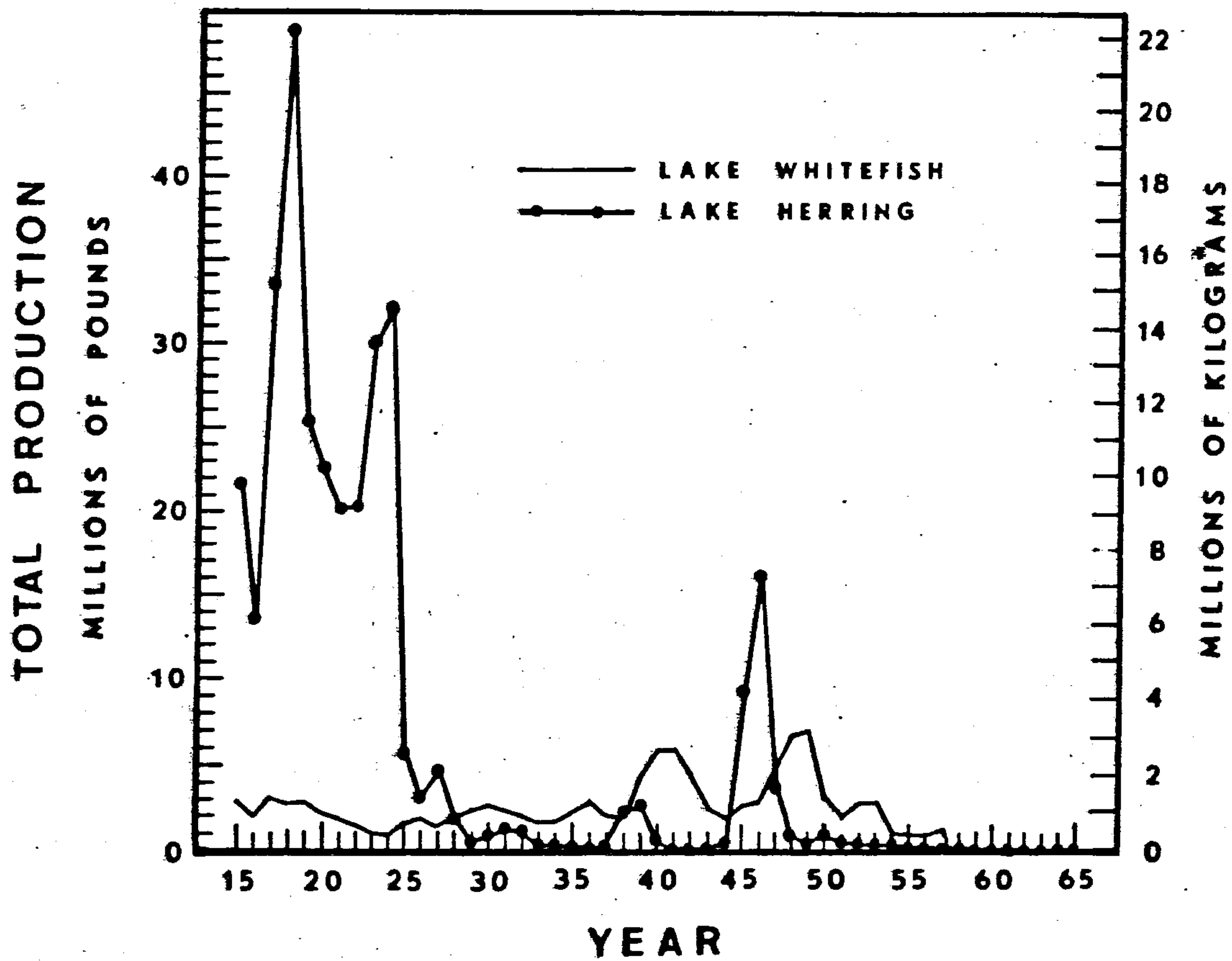


FIGURE 16. COMMERCIAL PRODUCTION OF LAKE WHITEFISH AND LAKE HERRING FROM LAKE ERIE--1915 TO 1965 (HARTMAN 1973)

LAKE WHITEFISH

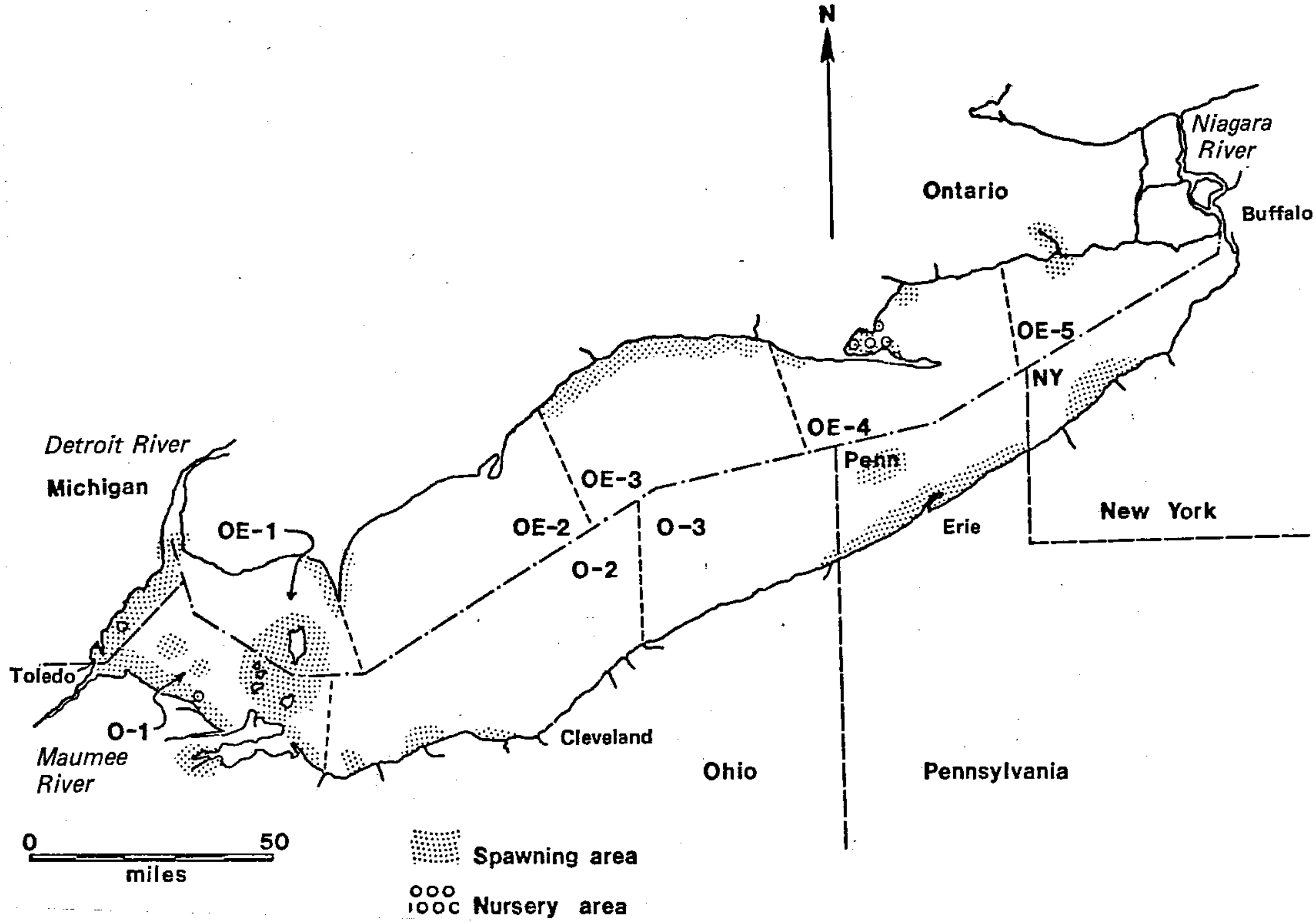


FIGURE 17. SPAWNING AND NURSERY AREAS FOR LAKE WHITEFISH (<u>Coregonus clupeaformis</u>) IN LAKE ERIE (GOODYEAR ET AL. 1982)

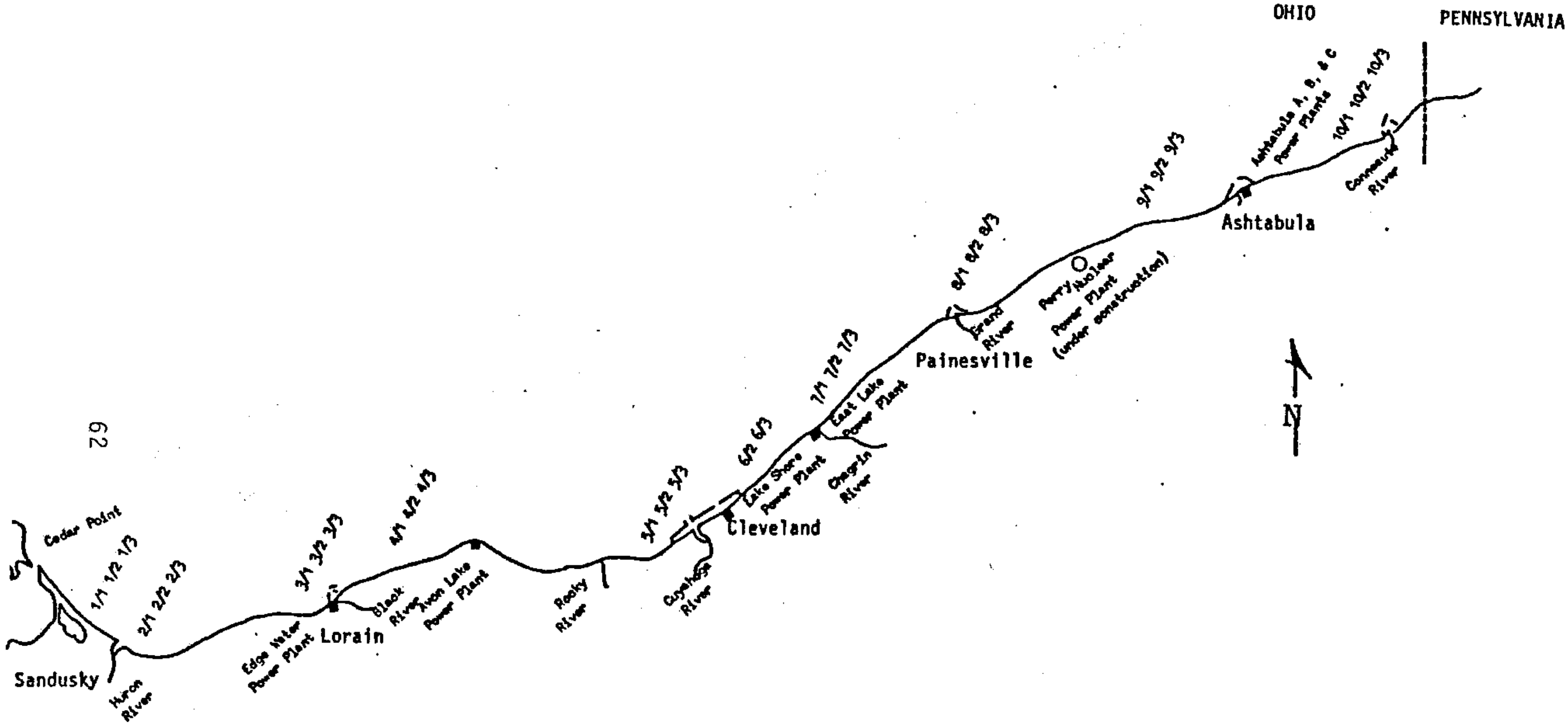


FIGURE 18. SAMPLING STATIONS FOR LARVAL FISH DENSITIES SHOWN IN FIGURES 19,20, 21 AND 30 (MIZERA 1981)

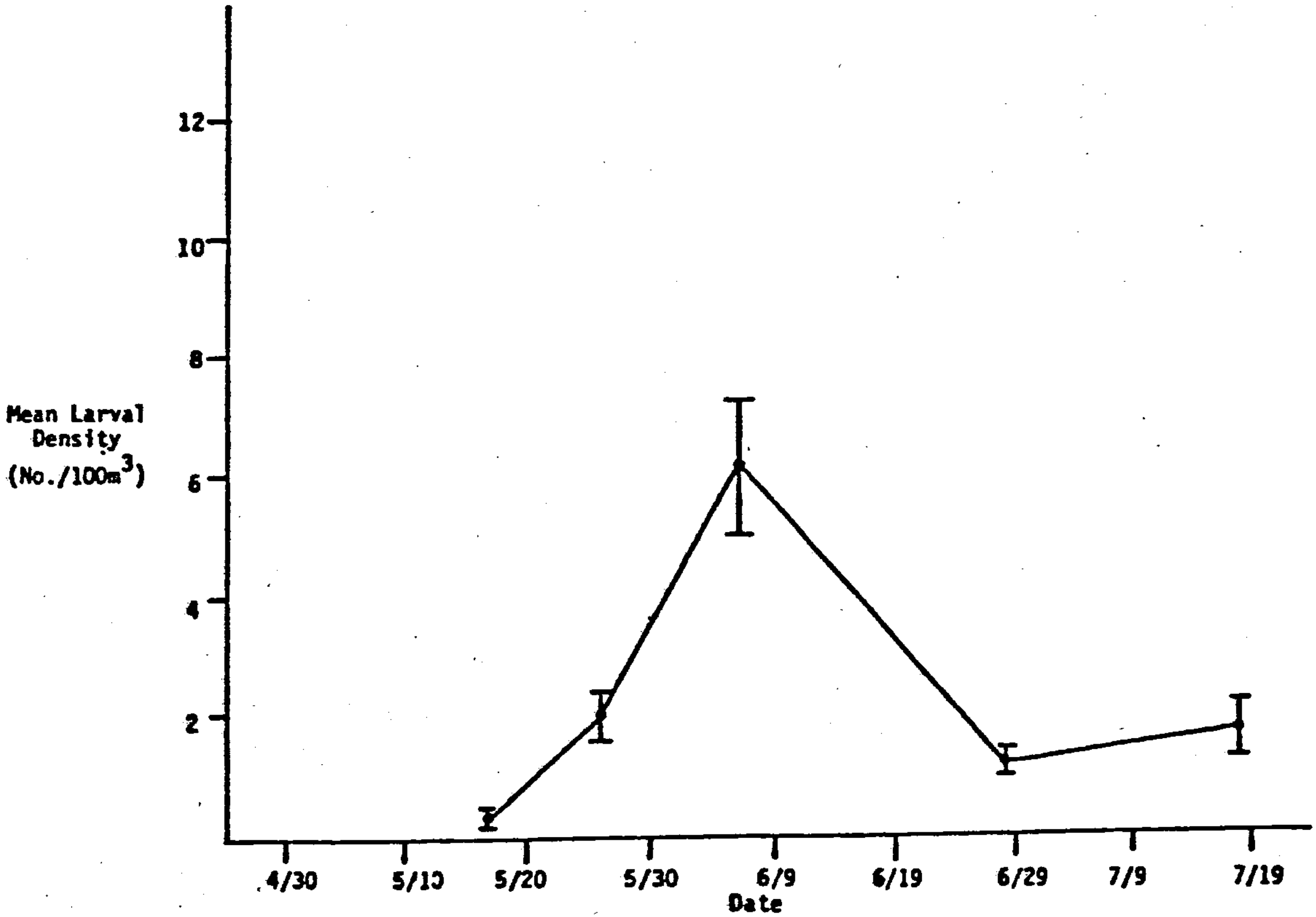


FIGURE 19. MEAN DENSITY OF YELLOW PERCH LARVAE (<u>Perca flavescens</u>) IN CENTRAL LAKE ERIE FROM MAY TO JULY 1978 (MIZERA 1981)

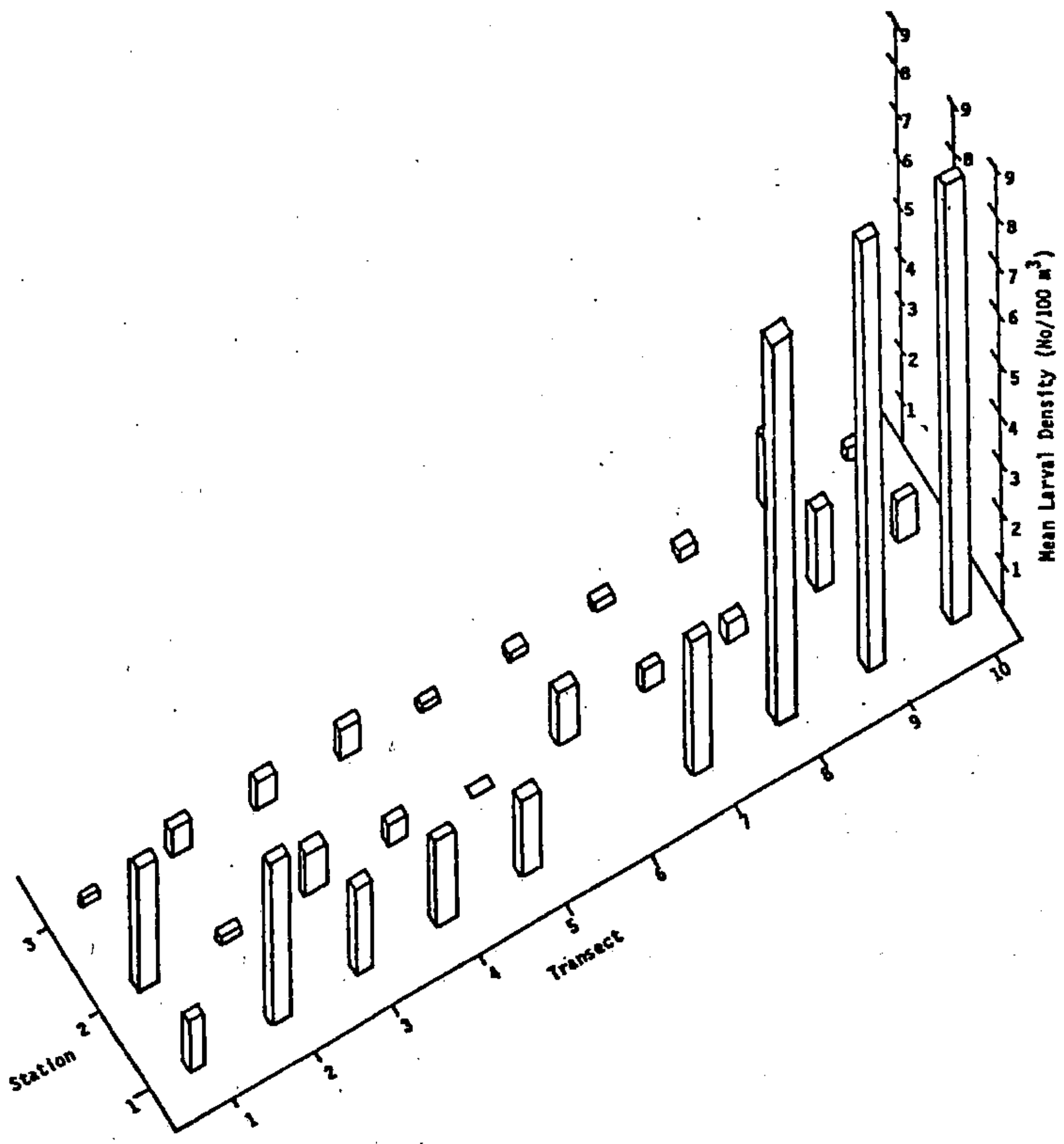


FIGURE 20. MEAN DENSITY OF YELLOW PERCH LARVAE (*Perca flavescens*) IN CENTRAL LAKE ERIE DURING 1978 (MIZERA 1981)

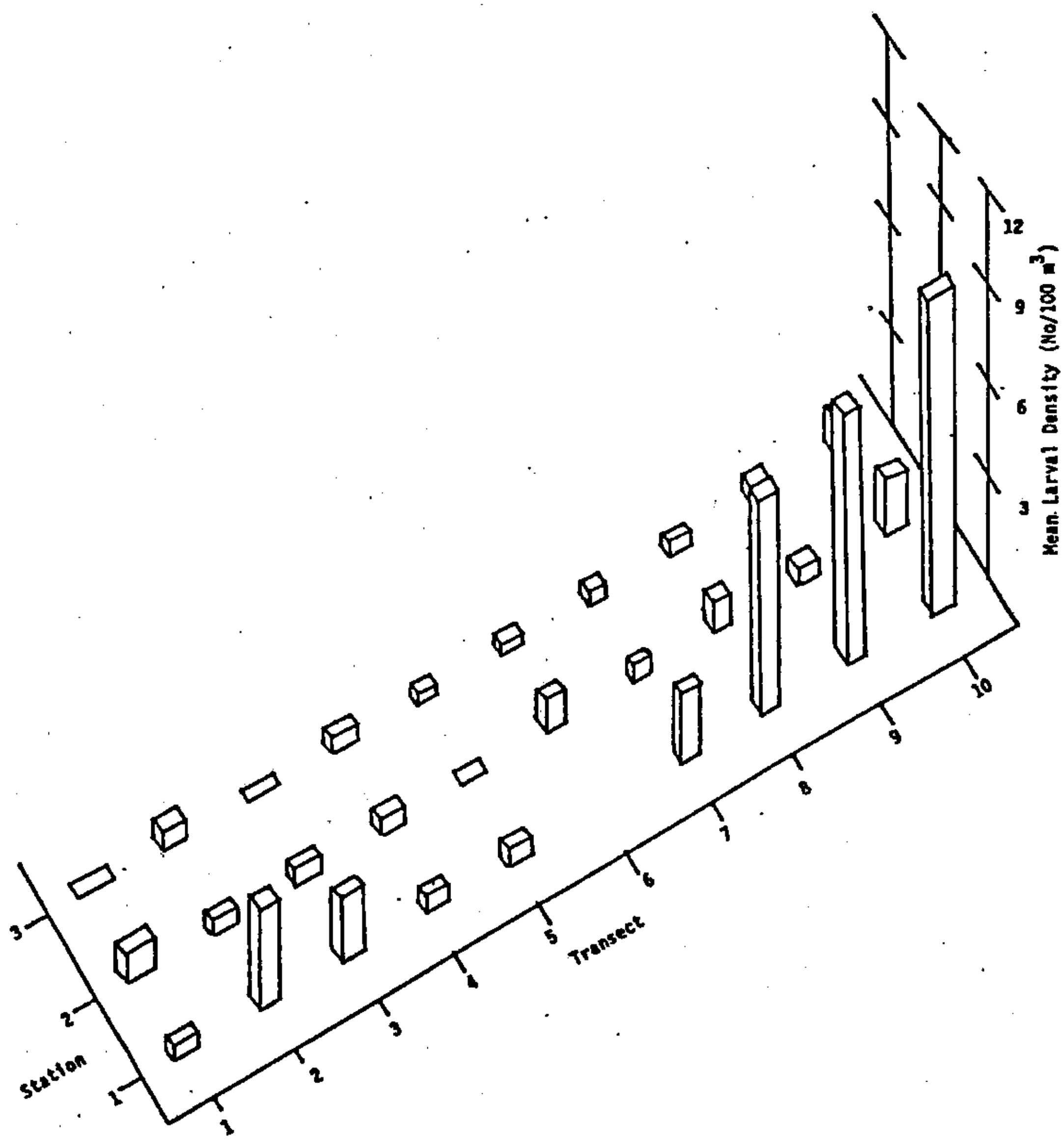


FIGURE 21. MEAN DENSITY OF YELLOW PERCH PRO- LARVAE (<u>Perca flavescens</u>) IN CENTRAL LAKE ERIE DURING 1978 (MIZERA 1981)

YELLOW PERCH

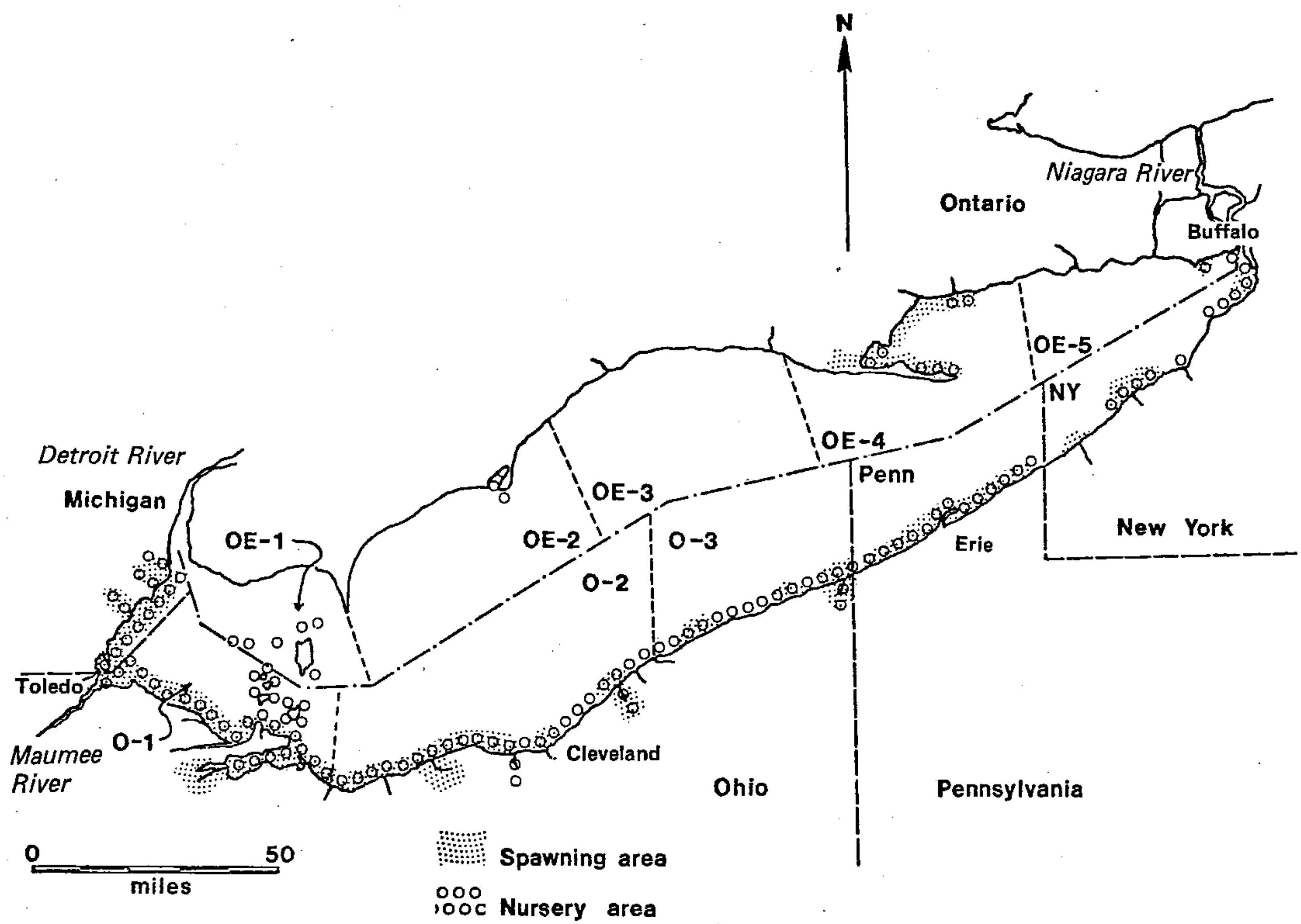


FIGURE 22. SPAWNING AND NURSERY AREAS FOR YELLOW PERCH (Perca flavescens) IN LAKE ERIE (GOODYEAR ET AL. 1982)

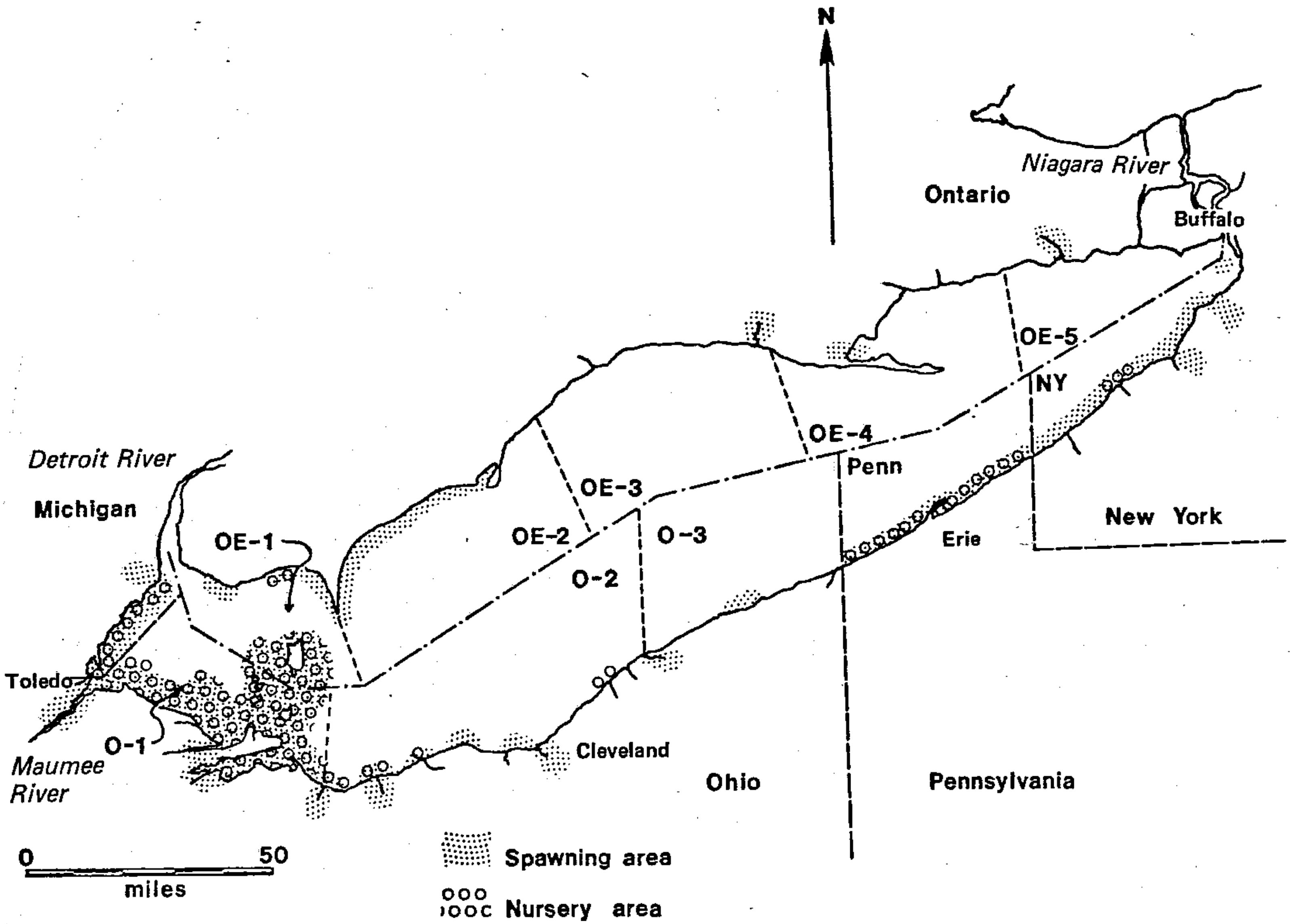


FIGURE 23. SPAWNING AND NURSERY AREAS FOR WALLEYE (*Stizostedion v. vitreum*) IN LAKE ERIE (GOODYEAR ET AL. 1982)

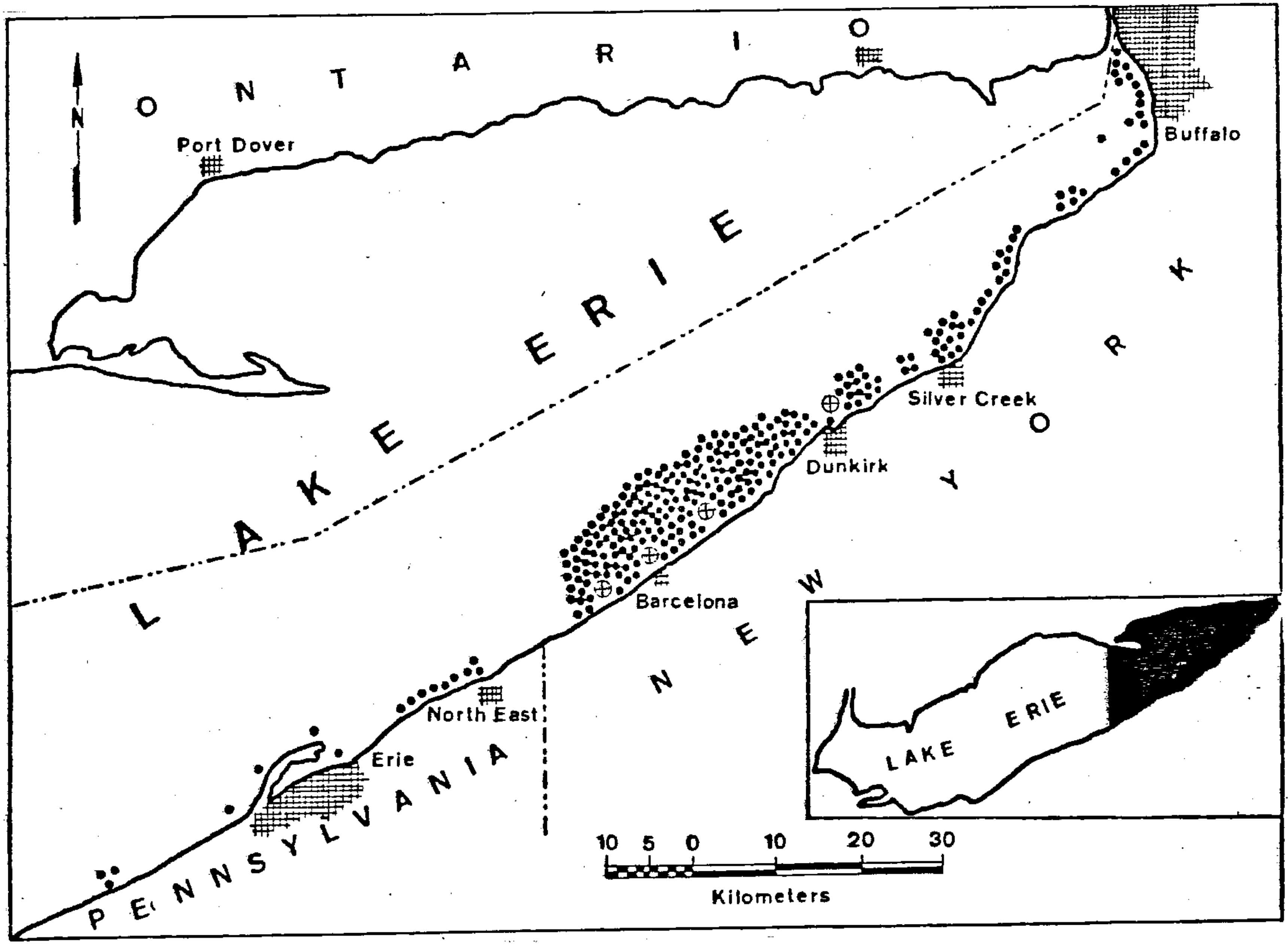


FIGURE 24. LOCATIONS OF RELEASED (CIRCLED CROSS) AND RECOVERED (SOLID CIRCLE) TAGGED WALLEYES IN EASTERN LAKE ERIE (WOLFERT AND VAN METER 1978)

Species*	First Capture	Last Capture	Period of Peak Abundance	Relative Abundance %	Avg. Density No./100 cu. m Prolarvae	Avg. Density No./100 cu. m Total Larvae
Dorosoma cepedianum/ *Alosa pseudoharengus*	17 May	5 August	Mid-June-early July	30.5	6.2	30.4
Coregonus clupeaformis	26 June	26 June	26 June	< 0.1	< 0.01	< 0.1
Osmerus mordax	14 May	6 August	Early-mid-June	3.7	0.2	5.2
Carpiodes cyprinus	21 May	16 June	Late May-early June	< 0.1	< 0.1	< 0.1
Moxostoma spp.	31 May	31 May	31 May	< 0.1	0.0	0.1
Catostomus commersoni	10 May	2 June	Mid-May	< 0.1	< 0.1	< 0.1
Cyprinus carpio/ *Carassius auratus*	22 May	6 August	Late June-early July	3.0	1.5	3.5
Notropis Atherinoides	31 May	6 August	Late June-early July	34.3	32.3	43.8
N. chrysocephalus	21 May	16 June	Late May-early June	< 0.1	< 0.1	< 0.1
N. hudsonius	21 May	4 August	Mid-June-mid-July	17.6	7.7	19.5
Lota lota	10 May	10 May	10 May	< 0.1	< 0.1	< 0.1
Percopsis omiscomaycus	10 May	4 July	Late May-mid-June	1.0	1.1	1.5
Morone chrysops	16 June	19 July	Mid-July	< 0.1	0.0	< 0.1
Pomoxis spp.	2 June	5 July	Mid-late June	< 0.1	< 0.1	< 0.1
Ambloplites rupestris	17 June	6 July	Late June-early July	< 0.1	< 0.1	< 0.1
Micropterus dolomieui	16 June	16 June	16 June	< 0.1	< 0.0	< 0.1
Lepomis spp.	17 May	4 August	Late June-mid-July	< 0.1	< 0.1	< 0.1
Stizostedion canadense	21 May	31 May	Late May	< 0.1	< 0.1	< 0.1
S. vitreum vitreum	10 May	6 July	Mid-May	< 0.1	< 0.1	< 0.1
Perca flavescens	17 May	16 July	Early-mid-June	1.3	1.6	1.8
Percina caprodes	17 May	6 August	Mid-late June	0.8	0.3	0.8
Etheostoma nigrum	1 June	30 July	Late June-early July	0.8	0.9	1.0
E. blennioides	1 June	5 June	5 June	< 0.1	< 0.1	< 0.1
Aplodinotus grunniens	5 June	4 August	Late June	4.2	1.5	1.6
Cottus spp.	21 May	2 June	Late May	0.5	0.12	0.59

*Scientific names assigned according to Robins et al. (1980)

FIGURE 25. LIMNETIC LARVAL FISH COLLECTED IN THE OHIO WATERS OF CENTRAL LAKE ERIE DURING 1978 (COOPER ET AL. 1983)

EMERALD SHINER

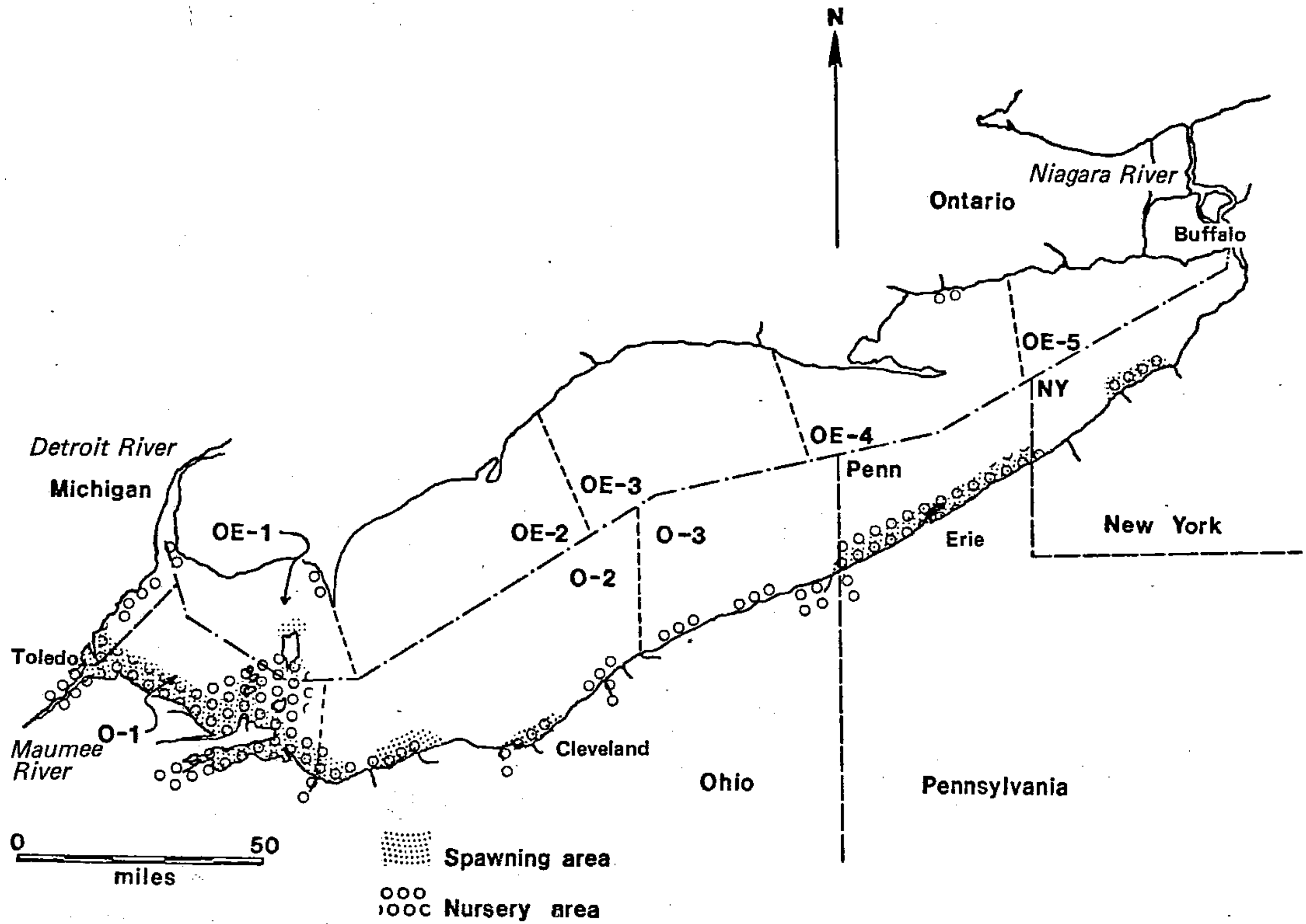


FIGURE 26. SPAWNING AND NURSERY AREAS FOR EMERALD SHINER (<u>Notropis</u> <u>atherinoides</u>) IN LAKE ERIE (GOODYEAR ET AL. 1982)

SPOTTAIL SHINER

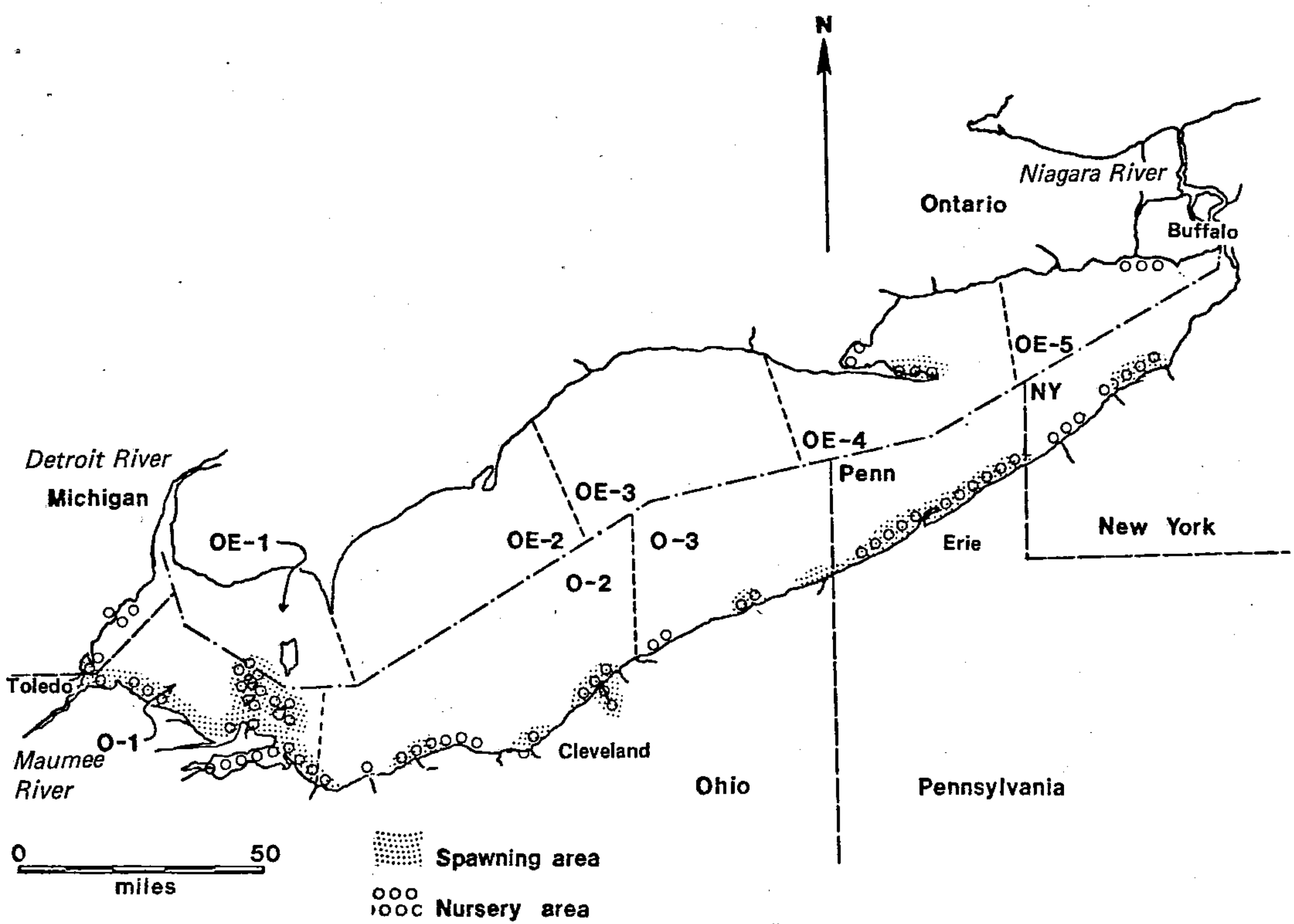


FIGURE 27. SPAWNING AND NURSERY AREAS FOR SPOTTAIL SHINER (Notropis hudsonius) IN LAKE ERIE (GOODYEAR ET AL. 1982)

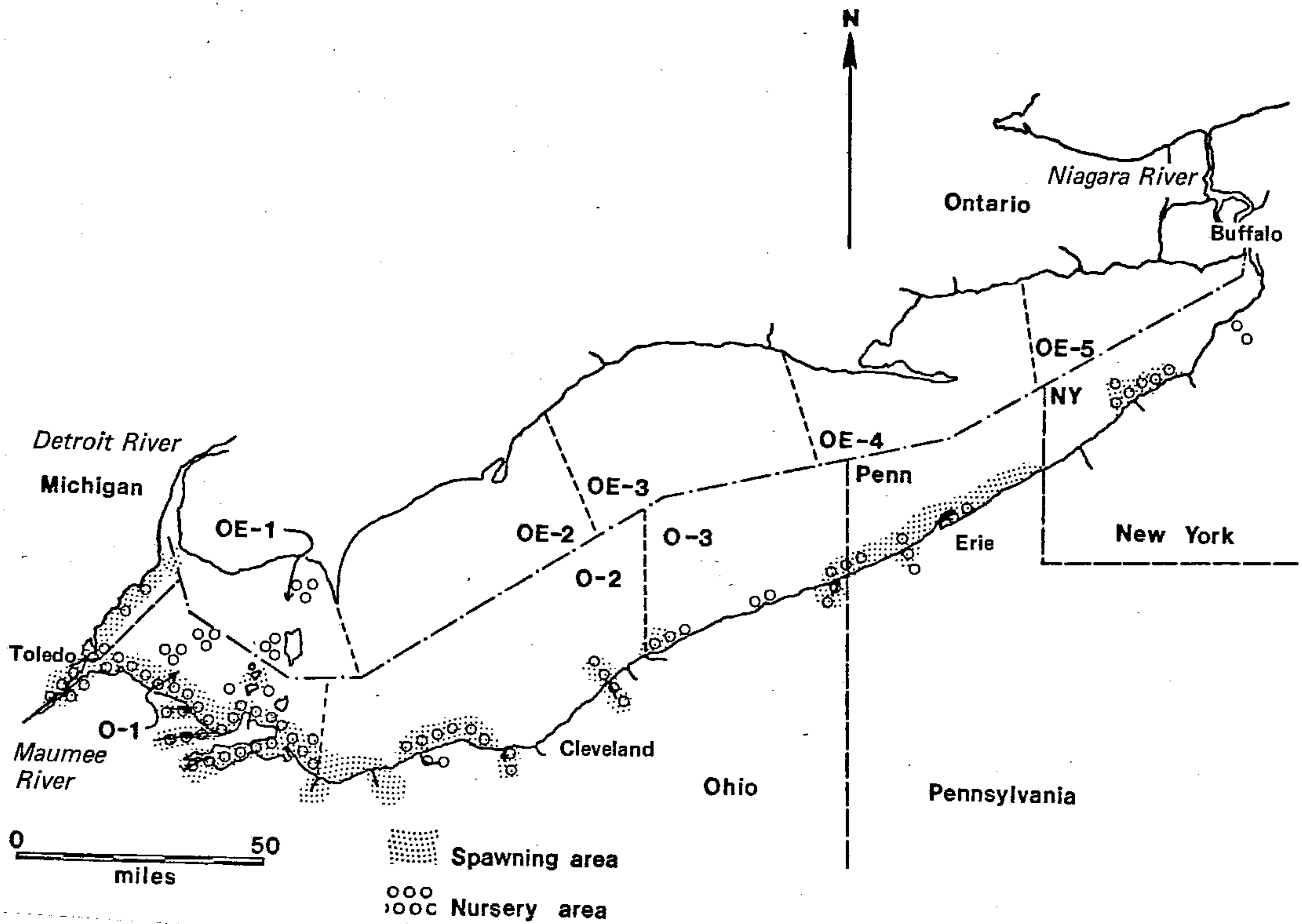


FIGURE 28. SPAWNING AND NURSERY AREAS FOR FRESHWATER DRUM (*Aplodinotus grunniens*) IN LAKE ERIE (GOODYEAR ET AL. 1982)

RAINBOW SMELT

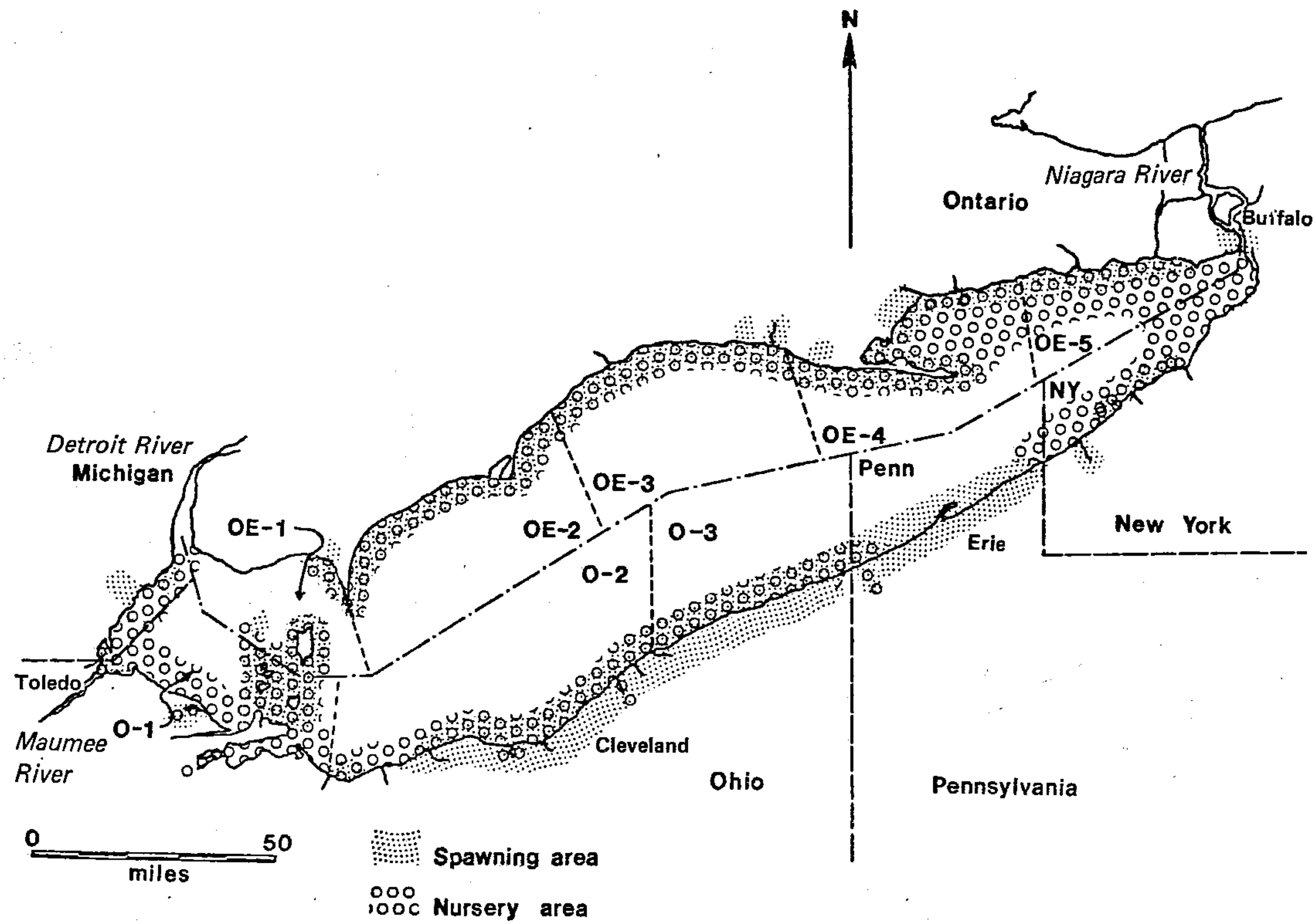


FIGURE 29. SPAWNING AND NURSERY AREAS FOR RAINBOW SMELT (Osmerus mordax) IN LAKE ERIE (GOODYEAR ET AL. 1982)

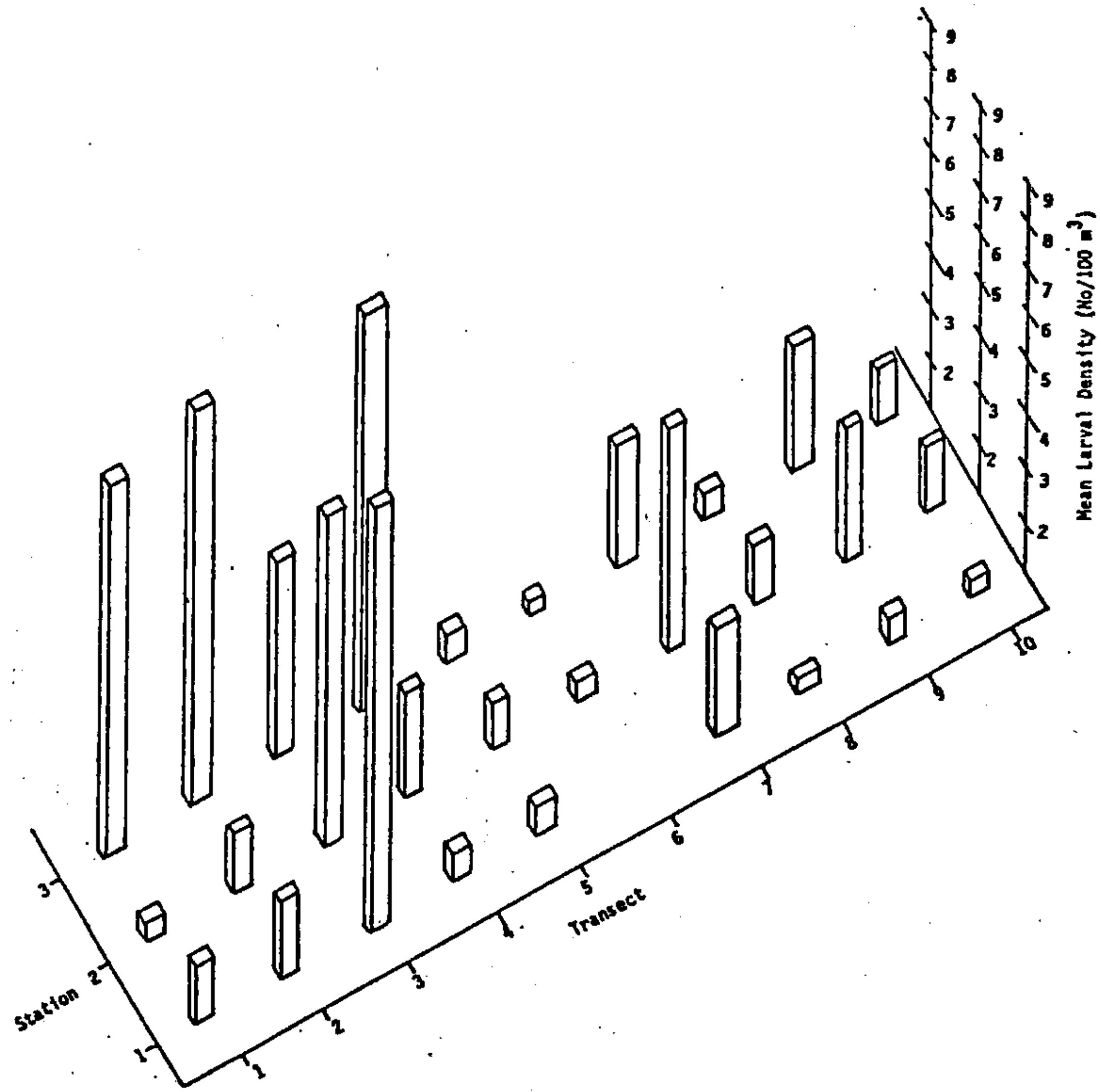


FIGURE 30. MEAN DENSITY OF RAINBOW SMELT LARVAE (Osmerus mordax) IN CENTRAL LAKE ERIE DURING 1978 (MIZERA 1981)

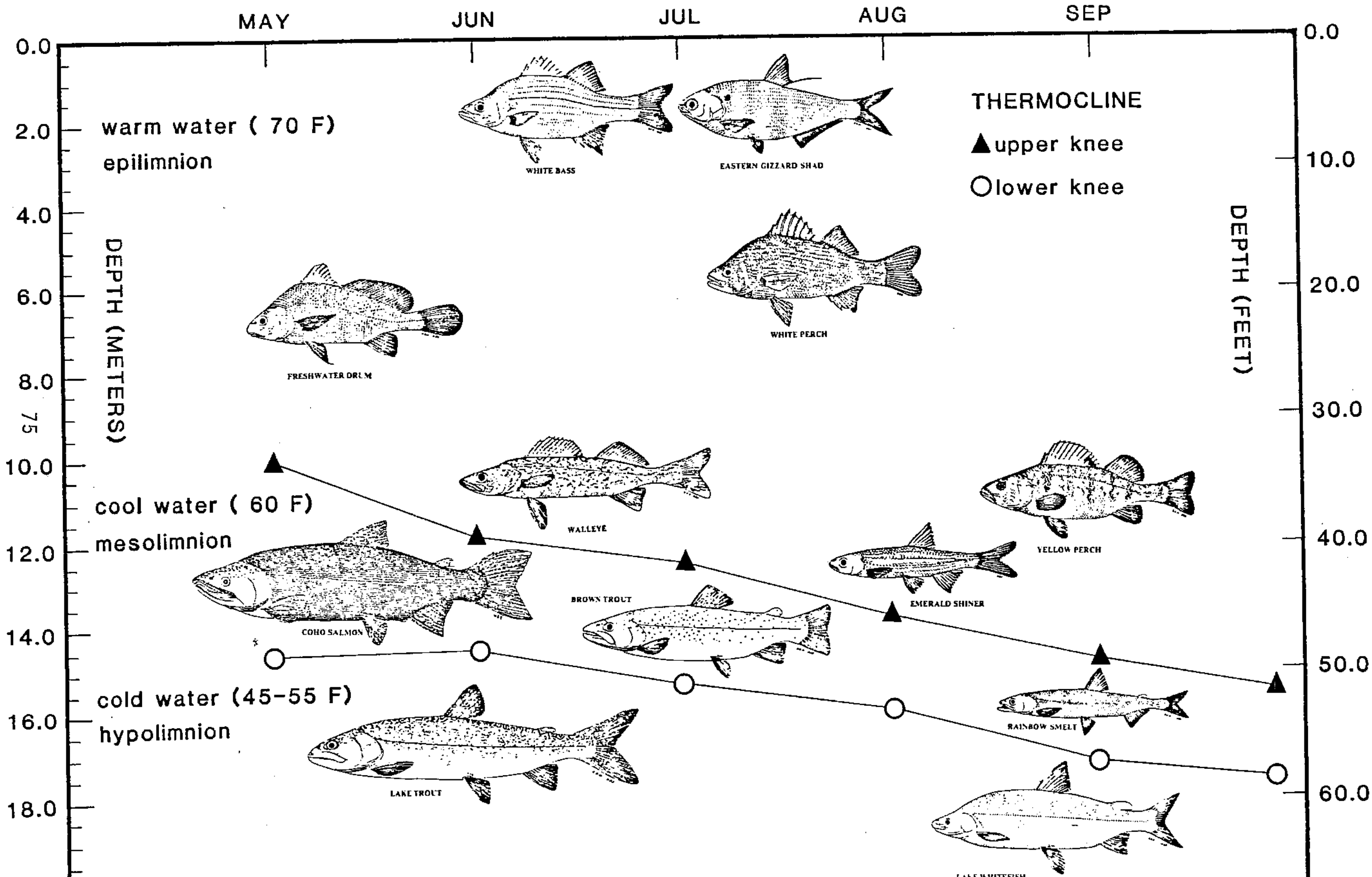


FIGURE 31. THERMAL PREFERENCE OF FISH IN CENTRAL LAKE ERIE (HERDENDORF 1984)

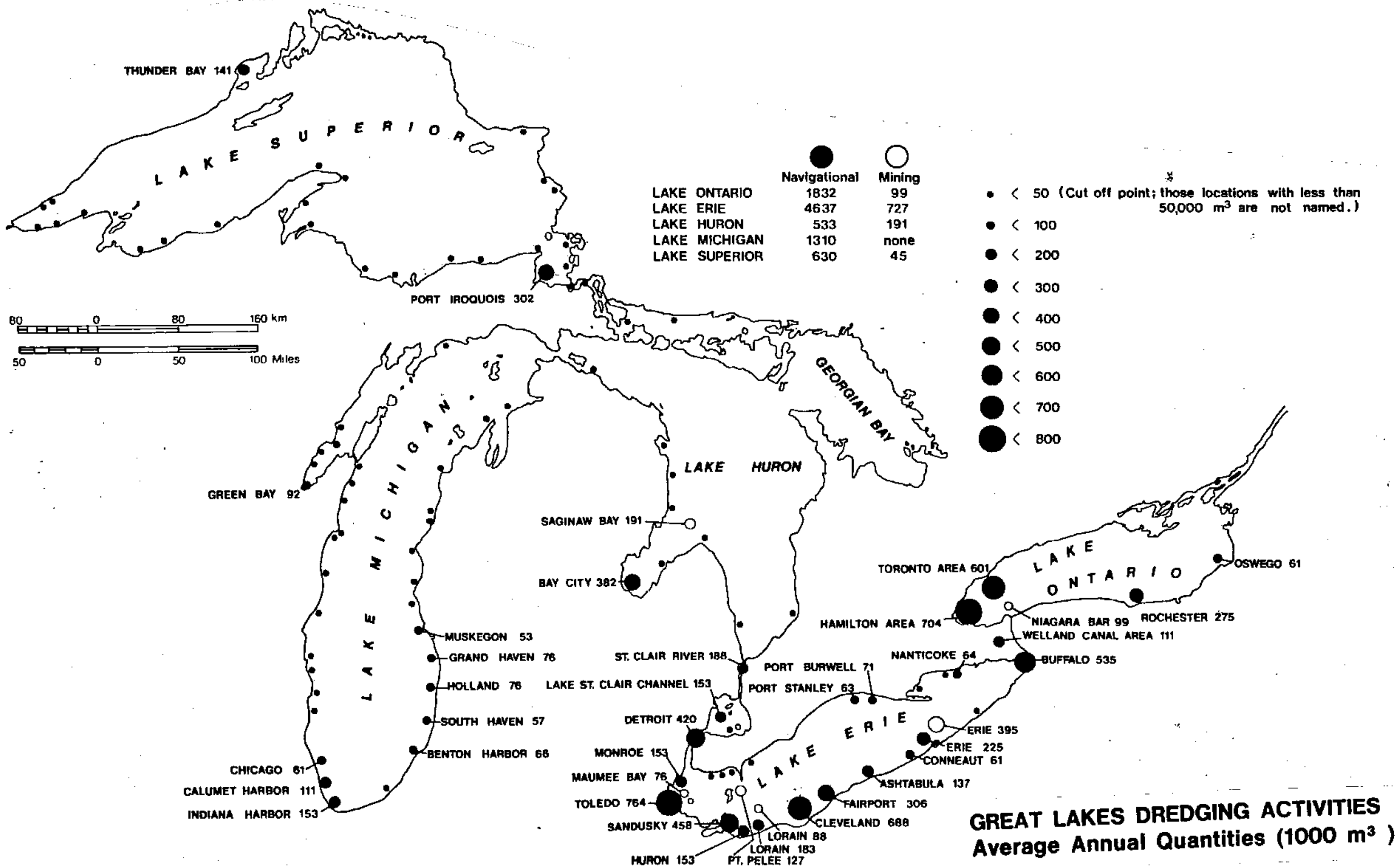


FIGURE 32. GREAT LAKES DREDGING ACTIVITIES (IJC 1982)

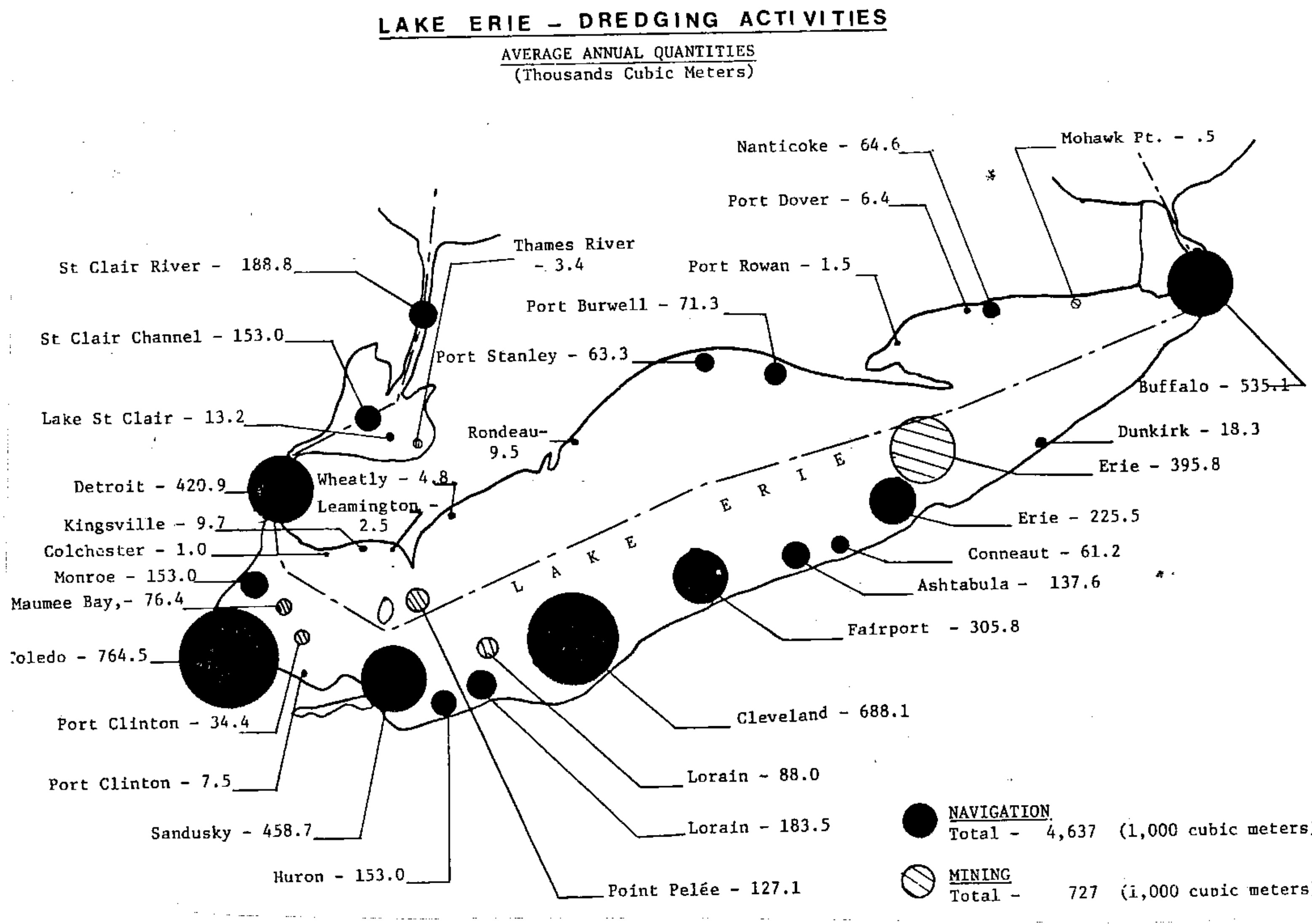


FIGURE 33. LAKE ERIE DREDGING ACTIVITIES (WALKER 1975)

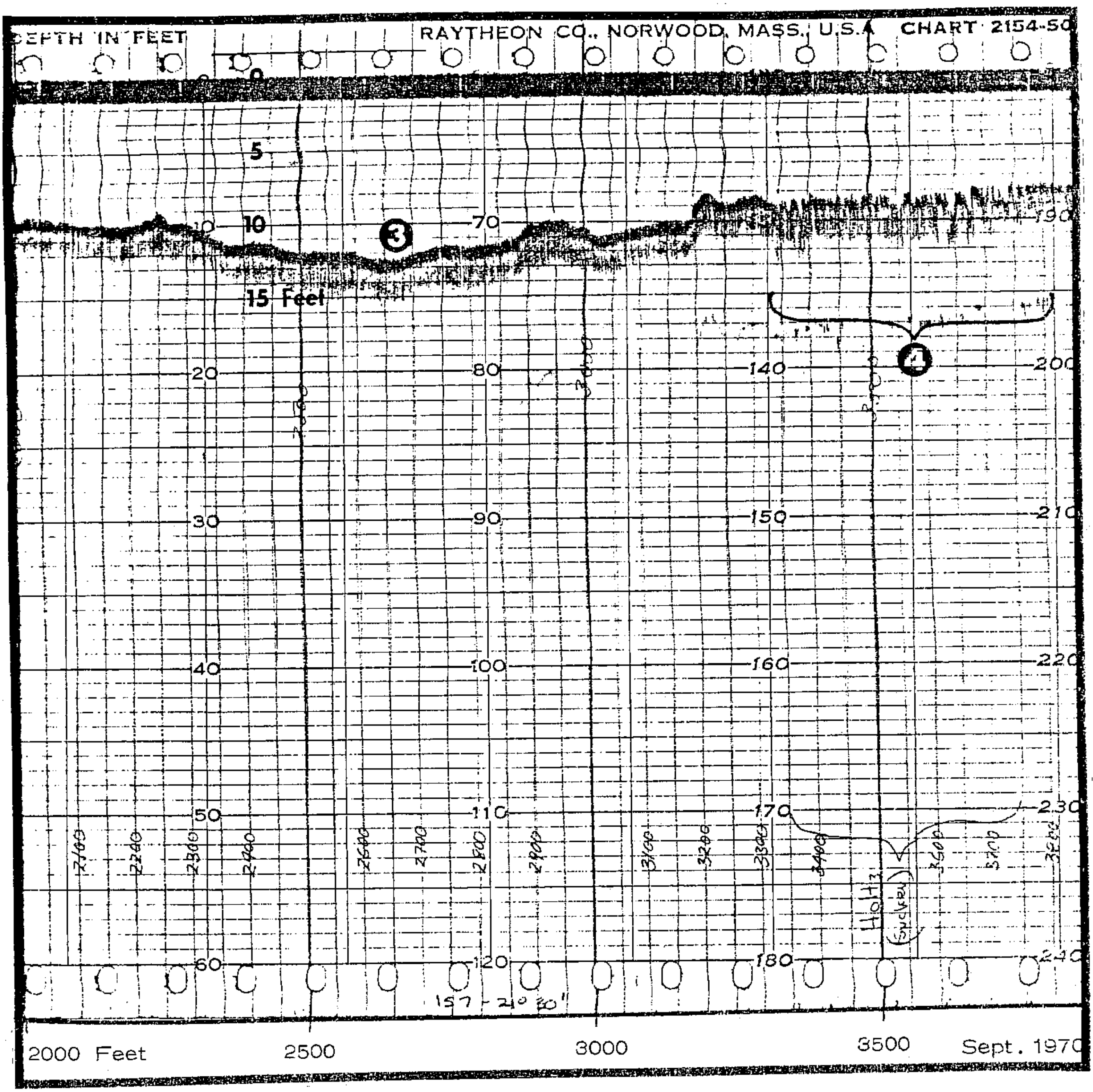


FIGURE 34. FATHOGRAM OF AN EXCAVATION PRODUCED BY A TRAILING ARM SUCTION DREDGE (4) AND THE NATURAL BOTTOM OF THE MAUMEE RIVER ESTUARY (3) IN WESTERN LAKE ERIE (HERDENDORF AND COOPER 1975)

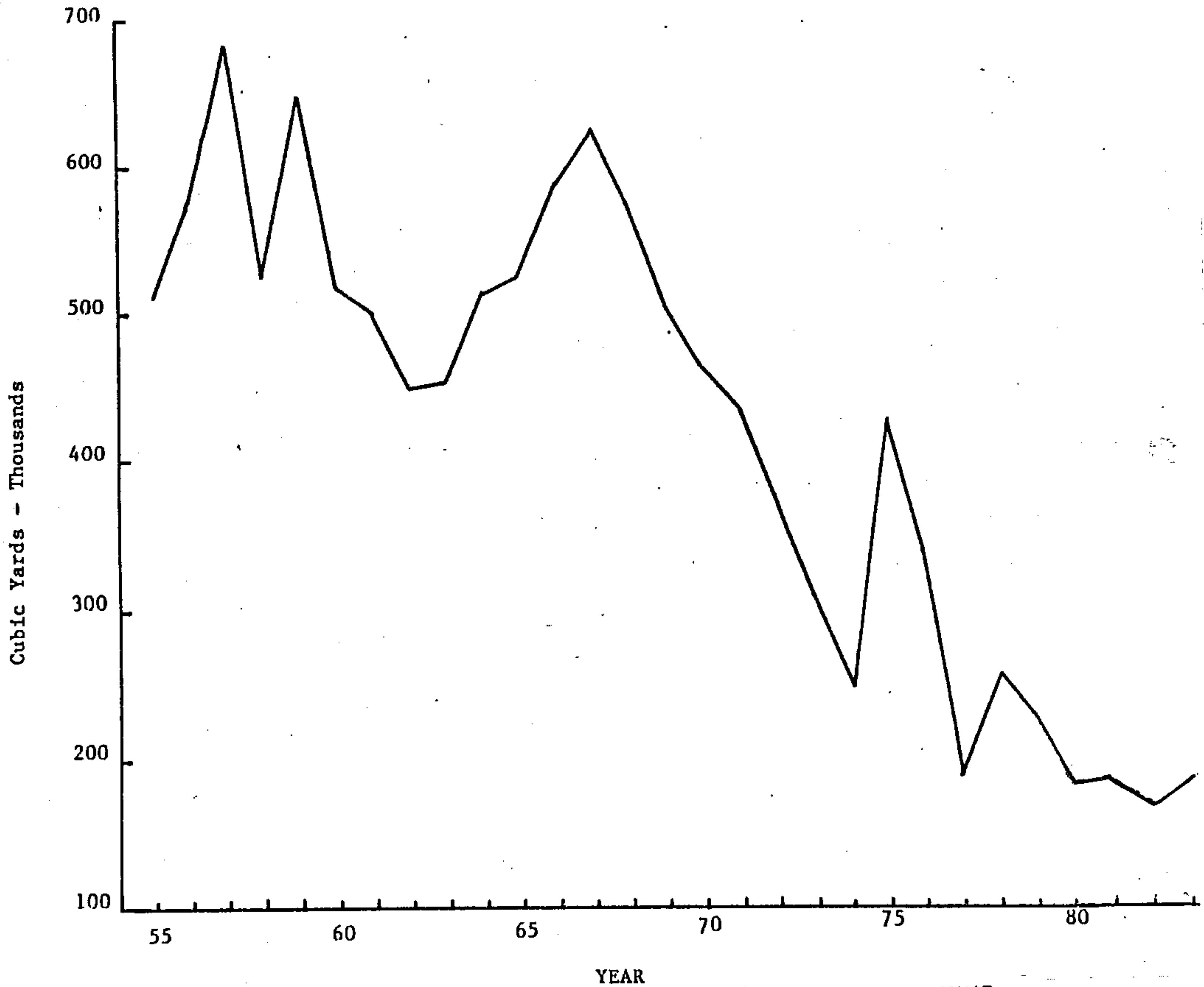


FIGURE 35. SAND AND GRAVEL DREDGED BY THE ERIE SAND STEAMSHIP COMPANY FROM THE NORFOLK MORAINE--1955 TO 1983 (UPDATED FROM NAGEL AND KNUTH 1981)

APPENDIX A

S. E. SMITH JR.
PRESIDENT

ERIE SAND STEAMSHIP CO.

A Subsidiary of Koppers Co., Inc.

LAKE TRANSPORTATION

PRODUCERS OF LAKE SAND AND GRAVEL

FOOT OF SASSAFRAS STREET

ERIE, PENNA

January 13, 1984

District Engineer, Buffalo District
Corps of Engineers
Department of the Army
1776 Niagara Street
Buffalo, New York 14207

Attention Mr. Art Marks, Regulatory Branch

PRE APPLICATION FOR EXPANDING THE COMMERCIAL SAND AND GRAVEL DREDGING OPERATION IN AREA "C" OFF THE SHORE OF PRESQUE ISLE

We appreciated the opportunity of meeting with you on Thursday, January 5, 1984 and as a result of this meeting we are submitting additional comments and drawings relative to our Pre-Application for a dredging permit.

The drawing enclosed shows the approximate 40 square mile area we requested on a revision in 1983. The broken area shows our existing permit of 12 square miles and the hatched area shows the area of approximately 19.6 square miles we would like to have under permit. We have not shown co-ordinates as they are on the drawings left with you at our meeting. The outline of the ridge or morain is shown in relation to the requested area. We will be presenting this sand drawing to the Department of Environmental Resources in Harrisburg, Pa. for their review and comments prior to a formal presentation.

In our discussion we threw out a number of figures and I want to confirm that the economic impact on the local economy through our operations are a payroll of approximately $3,000,000 and employment of approximately 140 people. The operation of GAF Corporation and Superior Concrete Pipe – – –

S. E. SMITH JR.
PRESIDENT

ERIE SAND STEAMSHIP CO.

A Subsidiary of Koppers Co., Inc.

LAKE TRANSPORTATION

PRODUCERS OF LAKE SAND AND GRAVEL

FOOT OF SASSAFRAS STREET
ERIE, PENNA

January 13, 1984

Company with approximately 175 jobs is also dependent on our supplying them with raw materials dredged from the lake. In addition, we supply the local ready mix concrete and block plants and these same industries in Fairport, Cleveland, Lorain, Sandusky and Toledo, Ohio. These are industries located adjacent to water facilities.

On our 1978 Corps of Engineers dredging permit we eliminated voluntarily an inner 1 x 2 mile southerly end of the existing dredging area. This was done after consultation with the local Pennsylvania Fish Commission and to satisfy their concerns. We therefore are now requesting an additional 5.6 square miles and a shifting of the 2 square mile area given up in 1978 to the northerly end of the existing area. It might also be pointed out that we will not be dredging the entire 19.6 square miles, as we do not the present 12 square miles, but only the areas, within the boundaries, that contain the commercial grade material we require. We would estimate this to be approximately 10 to 12 square miles. The type and location of the material needed is shown in the Coastal Engineering Research Center Report entitled "Sand andGravel Resources Offshore Presque Isle, Pennsylvania" dated March 1980. It might also be pointed out that we are requesting approximately 5-6% more of the ridge, over and above the 14% authorized prior to 1978.

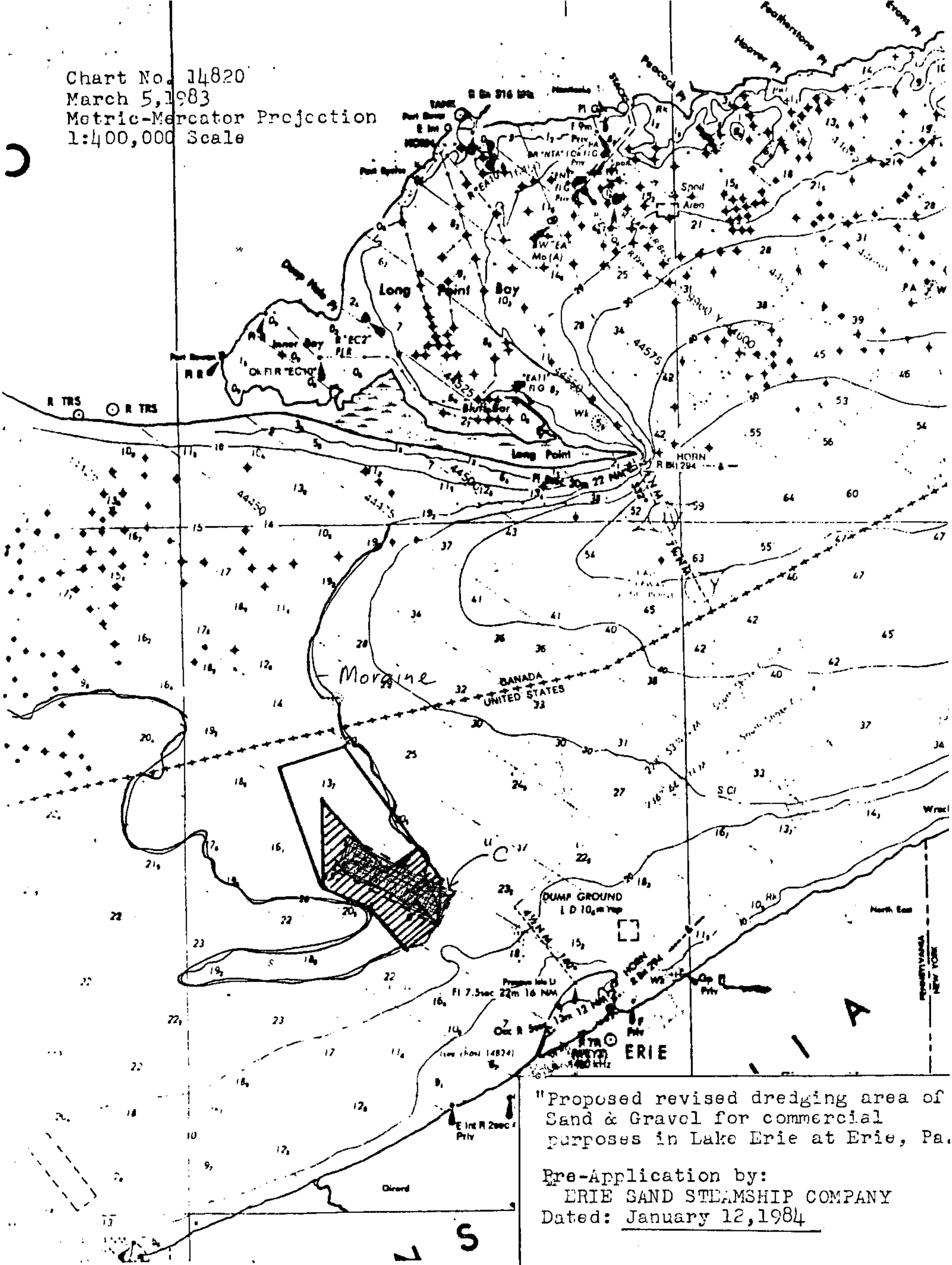
We dredged 193,240 cubic yards of commercial sand from "Area C" in 1983 which means we paid directly to the Pennsylvania Fish Commission a royalty of $28,986 for their sole use. With this yardage you can understand why we cannot justify the expenditure of the funds required to complete a worst case study of the magnitude set forth in your letter of 14 September 1983. You must also consider that both State and Federal Permits are for five (5) year duration and the areas are not Permitted for our exclusive use.

It would be appreciated if you would run this by the various people and Agencies for their comments. We can then meet at a later date for a review before submitting a formal application.

Harry K. Goodman

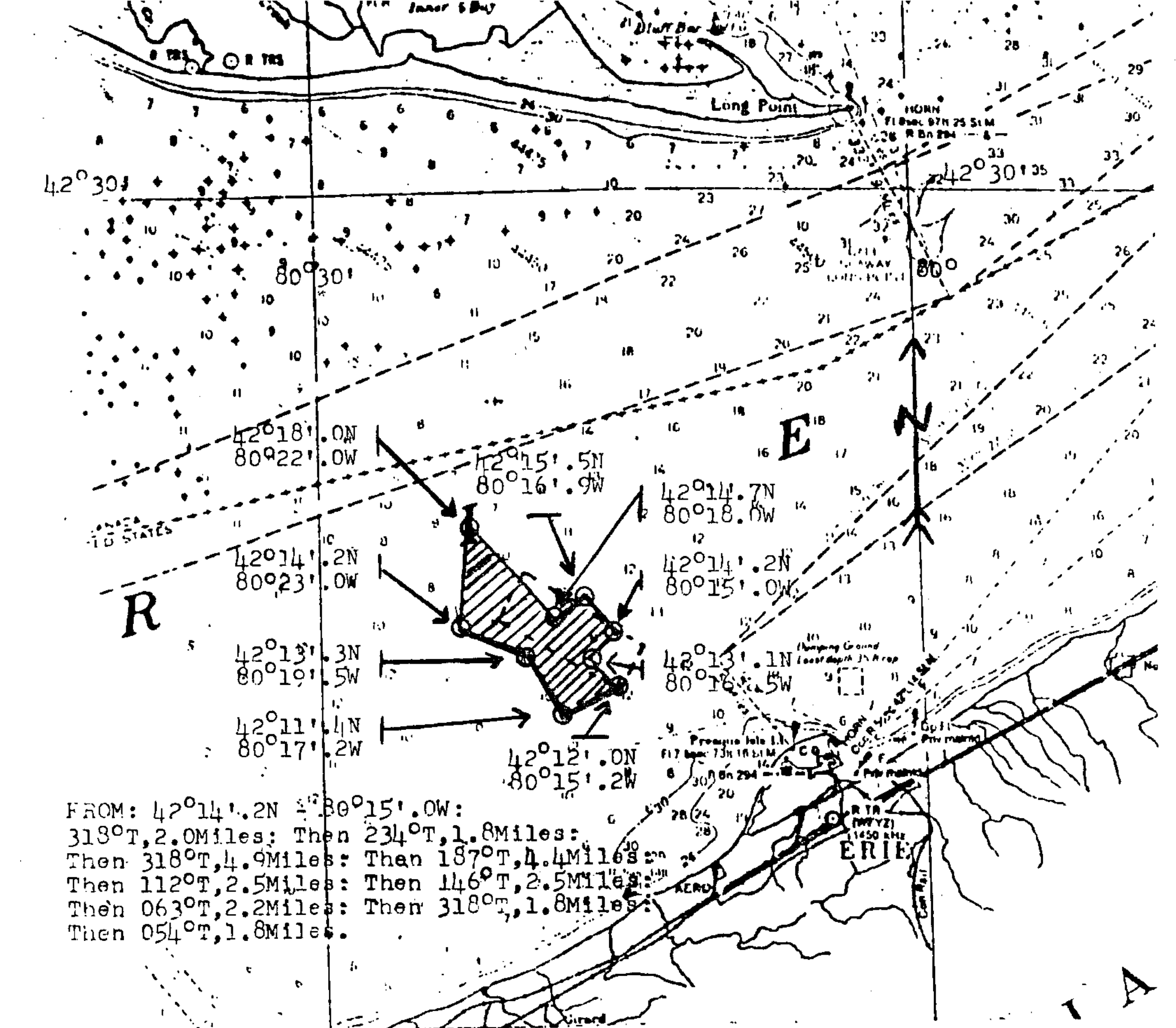
HARRY K. GOODMAN, MARINE MANAGER

Chart No. 14820
March 5, 1983
Metric-Mercator Projection
1:400,000 Scale



"Proposed revised dredging area of Sand & Gravel for commercial purposes in Lake Erie at Erie, Pa.

Pre-Application by:
ERIE SAND STEAMSHIP COMPANY
Dated: January 12, 1984



Coordinates for "Proposed revised dredging area of Sand & Gravel for Commercial purposes in lake Erie at Erie, Pa."

Pre-Application by: ERIE SAND STEAMSHIP COMPANY

Dated: January 12,1984

APPENDIX B

CERTI..IED MAIL - RETURN RECEIPT REQUE...ED C

DEPARTMENT OF THE ARMY

BUFFALO DISTRICT, CORPS OF ENGINEERS

1776 NIAGARA STREET

BUFFALO, NEW YORK 14207

NCBCO-S

14 September 1983

SUBJECT: Application for Department of the Army Permit No. 83-476-1 by Erie Sand Steamship Company, Dated 2 May 1983

Erie Sand Steamship Company
Foot of Sassafras Street
P.O. Box 153
Erie, PA 16512

Gentlemen:

This is in regard to your application for a Department of the Army permit under Section 10 of the River and Harbor Act of 1899 and Section 404 of the Clean Water Act to expand the size of the commercial sand and gravel dredging area in Lake Erie off shore of Presque Isle, Pennsylvania. Your original application included expansion of the area from approximately 12 square miles which is currently authorized, to about 100 square miles. This proposal was advertised by public notice dated 11 July 1983. By letter dated 26 August 1983, you requested that your application be revised to show an expansion of the dredging area to about 40 square miles rather than the originally proposed 100 square miles.

We have reviewed and evaluated comments that were received on the public notice advertising the original proposal and have reviewed the revised proposal. During the public interest review period, significant concerns were raised by the general public, the U.S. Fish and Wildlife Service, and the Pennsylvania Fish Commission in regard to the impact of expanding the commercial sand and gravel dredging area over the Norfolk Morain. This area has been identified as a potentially critical spawning and nursery area for fish such as lake trout, yellow perch, walleye, whitefish and possibly other species. A review of the revised proposal shows that while the size of the area has been reduced, nevertheless, it occupies a large portion of the Moraine. Telephone conversations between this office and the Pennsylvania Department of Environmental Resources indicate that they are also concerned about the impact on the lake fishery resource. A preliminary review by the Permits Evaluation Section, Regulatory Branch, U.S. Army Corps of Engineers, Buffalo District also indicated that the work would occur in a potentially critical area in regard to fisheries. It is also apparent that there is insufficient baseline data needed to thoroughly assess the impact of the expansion on the lake fishery resource.

Accordingly, you will be required to perform baseline fishery studies and prepare an environmental report concerning the effects, including long-term and cumulative effects of the expansion of the dredging area on the fishery resource. The baseline studies should be directed at the assessment of effects on:

a. fish spawning
b. nursery use of the area
c. food chain and aquatic ecosystem (species diversity and density, species composition, relative abundance, populations, communities, species interrelationships, food supply, habitat, etc.)
d. fish migration
e. year class strengths and recruitment
f. feeding and shelter areas.

The baseline studies should include a minimum of one years' collection effort designed to demonstrate the temporal and spatial distribution of fisheries including ichthyoplankton and ichthyoplankton densities. Such studies shall be designed to provide the information needed to adequately assess the effects listed in paragraph three and shall include surface, mid-depth and bottom collections of fish eggs, yolk-sac larvae, post larvae and juveniles. Ichthyoplankton collections shall include diurnal sampling. The number of sampling stations and the frequency of sampling shall be sufficient enough to determine the spawning and nursery use of the expansion area and some of the stations shall be within the existing dredging area. Depending on the results of the initial years' sampling, additional collections may be required.

Sampling and identification shall include all species collected although particular attention should be given to those species mentioned in paragraph two and important forage species such as rainbow smelt, spottail shiners, emerald shiners, troutperch, etc. Studies relative to food chain impacts shall include fish stomach content analysis.

Based on the results of the baseline studies, an environmental report shall be prepared addressing the effects of the dredging within the expansion area as listed in paragraph three. Since any permit granted for the expansion area would set a precedent and essentially open the area to additional applications from other commercial sand and gravel dredging companies, the analysis of impacts shall be a worst case analysis and shall include long-term and cumulative impacts. The environmental report shall consider the effects on habitat and organisms from physical disruption by suction pipe, entrainment of aquatic organisms with the wash water using an assumption of 100 percent mortality, covering of benthic organisms and fish eggs through sediment disturbance and resettling, effects of the discharge of liquid phase dredged material, and the effects of discharging colder bottom waters to warm surface waters. The environmental report, based on the impact analysis and baseline studies shall address measures that would avoid or minimize impacts on the aquatic ecosystem. Such measures could include dredging logistics (e.g. avoiding sensitive spawning or nursery areas, timing of the operation to avoid certain areas at certain times of the year, etc.), feasible or practicable changes in dredging methodology such as alternatives to the circular dredging patterns, and any other measures that would be practicable and minimize or avoid adverse impacts.

The baseline studies shall be appended to the environmental report and shall include a description of the sampling gear used, sampling and identification methods, and quality control methods used. The locations of all sampling stations shall be shown on maps of adequate scale. Water temperature and dissolved oxygen measurements shall be included in the baseline study.

Final analysis of the baseline data and the environmental report will be performed by the Buffalo District Corps of Engineers and will be coordinated with the U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, Pennsylvania Department of Environmental Resources, and the Pennsylvania Fish Commission.

Please be advised that the information requested in this letter is needed to make a decision on your permit application and that the performance of the studies does not assure that favorable action will ultimately be taken on the application. No further action will be taken on your application until the requested information is provided.

Correspondence pertaining to this matter shall be addressed to the District Engineer, U.S. Army Engineer District, Buffalo, 1776 Niagara Street, Buffalo, NY 14207, ATTN: Mr. Arthur K. Marks. You may also contact Mr. Marks by calling (716) 876-5454, extension 2329.

Sincerely,

FOR ROBERT R. HARDIMAN
Colonel, Corps of Engineers
District Engineer

CF: Mr. Kervin Smith
PA Department of Environmental Resources

Mr. Charles Kulp
USF&WS - State College, PA

Mr. Peter Yeager
PA Department of Environmental Resources
Meadville, PA

Mr. Ron Tibbott
PA Fish Commission
Belefonte, PA

USEPA - Wetland Review Section
Philadelphia, PA