ENVIRONMENTAL SENSITIVITY INDEX — LAKE MICHIGAN, EASTERN SHORE

SHORELINE TYPES

The eastern shoreline of Lake Michigan was classified during a low-altitude, fixed-wing aerial survey undertaken in June 1984. The list below, presented in order of increasing sensitivity to spilled oil, provides a summary of all shoreline types common to the Great Lakes region. As noted, four shorelines are not found within the study area. Wetland environments (ESI = 10A and 10B) are the most sensitive and deserve priority protection.

Sensitivity ↓

1. Exposed bedrock bluffs (not present).
2. Exposed bluffs.
3. Shelving bedrock shores (not present).
4. Sand beaches.
5. Mixed sand and gravel shores.
6. Gravel beaches.
7. Riprap structures.
8. Sheltered bluffs (not present).
9. Low banks subject to flooding (not present).

10A. Fringing wetlands.

10B. Extensive wetlands.

Unranked harbor structures (concrete, steel bulkheads, etc.)

BIOLOGICAL RESOURCES

The biological resources found within the study area were collected and compiled by University of Michigan researchers from the literature and from direct contact with scientists knowledgeable about local species occurrence. After compilation, preliminary resource maps were reviewed by several federal and state of Michigan agencies. During a spill-response incident, areas having noted resources should receive special consideration in order to mitigate the potentially detrimental effects of oiling or cleanup. Wetlands which support both these resources and their food (fish, frogs, insects) are colored on the maps. Symbols for specific organisms are as follows:

MAMMALS

Coastal species	Habitats and feeding areas

BIRDS

Shorebirds	Habitats and feeding areas
Wading birds	Habitats and feeding areas
Diving birds	Habitats and feeding areas
Waterfowl	Overwintering and feeding areas
Raptors	Habitats and feeding areas

FISHES

Forage fish	Population concentrations
Salmonids	Population concentrations
Other gamefish	Population concentrations

VEGETATION

Rare coastal species	Population locations

SOCIOECONOMIC FEATURES

The following information is provided to highlight those areas having socioeconomic importance in order to assist or direct the spill-response effort. The field survey report by Perrone et al. (1984; see references) contains a detailed list of marinas within the study area.

Parks and preserves
(1-19: state game areas, parks and national lakeshores)
(a-h: protected natural areas)

Marinas

Recreational beaches

Water intakes

Power plants

WATER INTAKES

FACILITY	STATION	FATHOMS	FEET
Ludington W.W.	530025	8	48
Muskegon W.W.	610054	10	60
Muskegon Heights W.W.	610266	9	54
Grand Rapids W.W.	700028	8	48
Grand Haven W.W.	-	-	-
Wyoming W.W.	700301	9	54
Holland W.W.	700062	8	48
South Haven W.W.	800020	7	42
Benton Harbor W.W.	110041	7	42
St. Joseph W.W.	110104	8	48
Lake Twp. Berrien Count W.W.	110381	5	30
Bridgeman W.W.	110040	4	24
New Buffalo W.W.	110378	9	54
Grand Beach W.W.	110379	7	42
Michiana W.W.	110380	7	42

PROTECTED NATURAL AREAS

a. Tower Nature Preserve, Manistee County, The Nature Conservancy
b. Nordhouse Dunes (proposed wilderness area), Mason County, U.S. Forest Service
c. Hoffmaster Wild Area, Muskegon and Ottawa County Michigan DNR - Parks Division
d. Ketchel Dune Preserve, Ottawa County, The Nature Conservancy
e. Central Michigan University Dune Preserve, Ottawa County, Central Michigan University
f. Grand Mere Nature Preserve, Berrien County, Kalamazoo Nature Center
g. Warrsen Dune Nature Study Area, Berrien County, Michigan DNR — Parks Division
h. Pepperidge Dunes Plant Preserve, Berrien County, Michigan Nature Association

PARKS AND PRESERVES

1. Betsie River State Game Area
2. Manistee River State Game Area
3. Pere Marquette State Game Area
4. Pentwater State Game Area
5. Muskegon State Game Area
6. Grand Haven State Game Area
7. Orchard Beach State Park
8. Ludington State Park
9. Charles Mears State Park
10. Silver Lake State Park
11. Duck Lake State Park
12. Muskegon State Park
13. P.J. Hoffmaster State Park
14. Grand Haven State Park
15. Holland State Park
16. Van Buren State Park
17. Warren Dunes State Park
18. Sleeping Bear Dunes National Lakeshore
19. Indiana Dunes National Lakeshore

SPILL-RESPONSE INFORMATION

The symbols below are used to indicate primary locations for the positioning of booms and open-water skimmers. Boat ramps to enable equipment access to the river are also indicated.

Booms

Boat Ramps

Open-water skimmers

KEY TO SPECIES

MAMMALS

1	Beaver	*Castor canadensis*
2	Meadow vole	*Microtus pennsylvanicus*
3	Muskrat	*Ondatra zibethicus*
4	Red fox	*Vulpes vulpes*
5	Raccoon	*Procyon lotor*
6	Mink	*Mustela vison*
7	Striped skunk	*Mephitis mephitis*
8	Long tailed weasel	*Mustela frenata*
9	River otter	*Lutra canadensis*

BIRDS

A	Any of the following waterfowl: #16-28.	
B	Any of the following hawks: #29-36.	
1	Piping plover[2]	*Charadrius melodius*
2	Common snipe	*Capella gallinago*
3	American woodcock	*Philohala minor*
4	Great blue heron	*Ardea herodius*
5	Green heron	*Butorides virescens*
6	Virginia rail	*Rallus limicola*
7	Sora rail	*Porzana carolina*
8	Sandhill crane[3]	*Grus canadensis*
9	Black-crowned night heron[3]	*Nycticorax nycticorax*
10	American bittern[3]	*Botarurus lentiginosus*
11	Belted kingfisher	*Megaceryle alcyon*
12	Black tern	*Chlidonias niger*
13	Double-crested cormorant[2]	*Phalacrocorax auritus*
14	Caspian tern[3]	*Hydroprogne caspia*
15	Common loon[2]	*Gavia immer*
16	Mute swan	*Cygnus olor*
17	Canada goose	*Branta canadensus*
18	Mallard	*Anas platyrhynchos*
19	Black duck	*Anas rubripes*
20	Green-winged teal	*Anas crecca*
21	Blue-winged teal	*Anas discors*
22	Wood duck	*Aix sponsa*
23	Ring-necked duck	*Aythya collaris*
24	Redhead	*Aythya americana*
25	Greater scaup	*Aythya marila*
26	Common goldeneye	*Bucephala clangula*
27	Bufflehead	*Bucephala albeola*
28	Common merganser	*Mergus merganser*
29	Bald eagle[2]	*Haliaeetus leucocephalus*
30	Marsh hawk[2]	*Circus cyaneus*
31	Osprey[2]	*Pandion haliaetus*
32	Peregrine falcon[1]	*Falco peregrinus*
33	Red shouldered hawk[2]	*Buteo lineatus*
34	Sharp skinned hawk[3]	*Accipiter striatus*
35	Pigeon hawk[3]	*Falco columbarius*
36	Coopers hawk[2]	*Accipiter cooperii*
37	Barred owl[2]	*Strix varia*

1 Endangered species in Michigan and Indiana.
2 Threatened species in Michigan.
3 Rare species in Michigan.

RARE PLANTS

1	Pitcher's thistle[1,2]	*Cirsium pitcheri*
2	Broom-rape[1]	*Orobanche fasciculata*
3	Smartweed[1]	*Polygonum careyi*
4	Spurge[1]	*Euphorbia polygonifolia*
5	Rock sandwort[1]	*Arenaria stricta*
6	Bald-rush[1]	*Psilocarys scirpoides*
7	Clubmoss[1]	*Lycopodium appressum*
8	Rose mallow	*Hibiscus palustris*
9	Wild bean	*Strophostyles helvola*
10	Sea rocket[1]	*Cakile edentula*
11	Ginseng[1]	*Panax quinquefolius*
12	Sedge[1]	*Carex platphylla*

1 Threatened species in Michigan.
2 Candidate for federal endangered species list.

KEY TO SPECIES

FISH

1	Alewife	*Alosa pseudoharengus*
2	Rainbow smelt	*Osmerus mordax*
3	Spottail shiner	*Notropis hudsonius*
4	River redhorse[1]	*Moxostoma cirinatum*
5	Lake trout	*Salvelinus namaycush*
6	Brown trout	*Salmo trutta*
7	Rainbow trout	*Salmo gairdneri*
8	Lake whitefish	*Coregonus clupeaformis*
9	Chinook salmon	*Oncorhynchus tshawytscha*
10	Coho salmon	*Oncorhynchus kisutch*
11	Atlantic salmon	*Salmo salar*
12	Lake sturgeon[1]	*Acipenser fulvescens*
13	Northern pike	*Esox lucius*
14	Bluegill	*Lepomis macrochirus*
15	White crappie	*Pomoxis annularis*
16	Black crappie	*Pomoxis nigromaculatus*
17	Yellow perch	*Perca flavescens*
18	Largemouth bass	*Micropterus salmoides*
19	Smallmouth bass	*Micropterus dolomieui*
20	Rock bass	*Ambloplites rupestris*
21	Pumpkinseed	*Lepomis gibbosus*
22	Walleye	*Stizostedion vitreum vitreum*
23	White bass	*Morone chrysops*
24	Tiger musky	*Esox amentus*
25	Muskellunge	*Esox masquinongy*
26	Channel catfish	*Ictalurus punctatus*

[1] Threatened species in Michigan.

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Description of Shoreline Types

EXPOSED BEDROCK BLUFFS — ESI = 1

- Not present in study area

EXPOSED BLUFFS — ESI = 2

- Very common in the study area
- Composed of soft, unconsolidated sediments (glacial or lacustrine)
- Commonly 30 or more feet high
- Beaches in front of the bluffs are narrow or absent
- Biological activity is low

Predicted Oil Impact

- Incoming oil will form a band along the high-tide swash line
- Oil persistence is limited to days or weeks, due to wave activity

Recommended Response Activity

- In most areas, cleanup is not necessary due to the short residence time of the oil
- Oil can usually be scraped off the surface of the sediment using manual labor
- Removal of sediment should be avoided
- Mechanical cleanup may be very difficult due to the steep slope of the bluff

SHELVING BEDROCK SHORES — ESI = 3

- Not present in the study area

SAND BEACHES — ESI = 4

- Most common shoreline type
- Commonly fronts a hill or dune region
- Very important for recreation
- Usually have a moderate-to-steep slope
- Generally contain low species density and diversity
- Birds such as plovers, sandpipers, and gulls are common along the beaches; rainbow smelt and the larval stages of several species utilize the intertidal areas during early spring and summer
- Many rare plants occur on dunes behind the beaches

Predicted Oil Impact

- Commonly, oil will be deposited on and become mixed into the sand along the high-tide swash zone
- Oil may become deeply buried into the beach sands; up to 30 cm in coarser-grained beaches
- Organisms resident in the beach are likely to be killed under moderate oil concentrations

Recommended Response Activity

- Cleanup may be difficult because of relatively soft sediments
- Cleanup should concentrate on oil removal from the upper swash zone
- Sand removal should be minimal to avoid erosion problems
- Activity through the oiled sand should be limited to prevent grinding oil deeper into the beach
- Use of heavy equipment for oil/sand removal may result in the removal of excessive amounts of sand; manual cleanup may be more efficient

MIXED SAND AND GRAVEL BEACHES — ESI = 5

- Common along short segments of shore where sediments are available from behind the beaches
- Beach access is generally good

Predicted Oil Impact

- Oil will be deposited primarily along the high-tide swash zone
- Under very heavy accumulations, oil may spread across the entire beach face
- Oil percolation into the beach may be up to 60 cm in well-sorted material
- Burial may be very deep along the berm
- Biota present may be killed by the oil, either by smothering or by lethal concentrations in the water column

Recommended Response Activity

- Remove oil primarily from the upper swash lines
- Removal of sediment should be limited
- Mechanical reworking of the sediment into the wave zone and/or high-pressure water spraying can effectively remove the oil; sorbent boom may be necessary to capture oil outflow

GRAVEL BEACHES — ESI = 6

- Not common within the study site
- Present along some lakes and riverfront areas; rocks have apparently been placed for shore protection
- Fish may occupy space between very coarse gravels

Predicted Oil Impact

- The primary problem with oil pollution in this environment is related to the deep penetration of oil into the gravel beach
- If oil is left uncleaned, it may become asphalt-like
- Resident fauna and flora may be killed by the oil

Recommended Response Activity

- Removal of sediment should be restricted
- The use of high-pressure water spraying may be effective at removing oil while it is still fresh
- Sorbent booms or pads should be used to capture oil outflowing during the cleansing process

RIPRAP STRUCTURES — ESI = 7

- Scattered throughout the region, primarily for shore protection and breakwaters
- Composed of cobble- to boulder-sized material
- Rock and concrete riprap are often used in breakwaters at the entrances to harbors
- Biota along the upper structures are sparse, although gulls may be common
- Some fish, including yellow perch, darters, and sculpins, occupy portions of riprap structures
- Riprap is an important substrate for fish-food organisms such as crayfish and for the spawning of spottail shiners, rainbow smelt, and sculpins, among others

Predicted Oil Impact

- Oil would percolate easily between the gravel and boulders of riprap structures
- Biota would be damaged or killed under heavy accumulations

Recommended Response Activity

- Along exposed structures, cleanup may not be necessary
- May require high-pressure spraying:
  - -to remove oil
  - -to prepare substrate for recolonization of barnacle and oyster communities
  - -for aesthetic reasons
- Since riprap is often associated with developed, recreational beaches, cleanup would be advisable to minimize chronic leaching of oil trapped in the rocks

SHELTERED BLUFFS — ESI = 8

- Not present in the study area

LOW BANKS SUBJECT TO FLOODING — ESI = 9

- Not present in the study area

NARROW WETLANDS — ESI = 10A

BROAD WETLANDS — ESI = 10B

- Very common within the sheltered river or lake areas
- Not present along the outer Lake Michigan shoreline
- Relatively sheltered from wave activity
- Narrow areas are less than 5 m wide; broad areas cover extensive, upstream lake areas
- Composed of emergent or floating aquatic vegetation
- Wetlands are the most important wildlife habitat in the area, providing a nesting area for ducks, geese, herons, rails, kingfishers, some shorebirds, muskrats, and turtles; as well as a major nursery and spawning grounds for many species of sport and forage fish
- Several rare plants are also found

Predicted Oil Impact

- Oil in heavy accumulations may persist for decades
- Small quantities of oil will be deposited primarily along the outer wetland fringe or along the upper wrack (debris) swash line
- Resident biota, including bird life, are likely to be oiled and possibly killed

Recommended Response Activity

- Under light oiling, the best practice is to let the wetland recover naturally
- During winter months, surface ice commonly offers shoreline protection
- Cutting of oiled grasses and low-pressure water spraying are effective, especially during the early part of the spring growing season
- Heavy oil accumulations on the wetland surface should be removed manually; access across the wetland should be greatly restricted
- Cleanup activities should be carefully supervised to avoid excessive damage to the area

HARBOR STRUCTURES — (NOT RANKED)

- Common for shoreline protection, particularly in harbor areas
- Composed of solid concrete, wooden, or metal bulkheads, and wooden pilings
- May also be used at the base of bluffs for stabilization
- Concrete structures are commonly used for harbor entrances and jetties
- Fish may occupy nooks and crannies of the structures
- Birds may be common along upper portions of the structure

Predicted Oil Impact

- Oil tends to coat the solid structure
- Oil persistence is minimal along the structures in Lake Michigan exposed to wave action; persistence is long term in sheltered areas
- Biota would be damaged or killed under heavy accumulations

Recommended Response Activity

- Along exposed structures, cleanup may not be necessary
- High-pressure spraying or sandblasting is effective, especially for fresh oils
- Cleanup is usually necessary in recreational beach areas; sorbent materials should be used to capture the oil as it leaches out