4 Ecological Characteristics

4.1 Overview

This chapter provides a description of the historical and current ecological characteristics of the Lower Fox River valley and Green Bay, with an emphasis on habitat and specific animals that are present in the area, as well as how they have been affected by both area development and environmental degradation. This information is used in the RA and the assessment of risks posed by historical discharge of PCBs and other pollutants into this system.

In September 1998, Exponent completed the *Habitat Characterization for the Lower Fox River and Green Bay Assessment Area* (Exponent, 1998) on behalf of the FRG. The assessment area began at the outlet of Lake Winnebago and extended to just north of the Oconto Marsh, on the west side of the bay, and Little Sturgeon Bay, on the east side (Exponent, 1998). Much of the information referenced in this section for the Lower Fox River was obtained from this document.

In addition to the Exponent (1998) report, a number of other data sources were utilized for this section. These sources largely consisted of electronic data files compiled by the ESRI ArcView™ (version 3.2) geographic information system (GIS), which was used to develop the maps for this section. Other sources included the USFWS fish and bird injury reports (Stratus, 1999b and 1999c), discussions with USFWS personnel, USGS reports, and specific texts concerning select species.

These data, and the resulting maps, have been used to develop an understanding of the Lower Fox River and Green Bay system. The data sources are listed below and included on the appropriate figures, which will also be used in the RA.

Lower Fox River GIS Data Sources

Habitat Data	Description	Source
Physical and habitat features (bridge, riffles)	in-water polygon shapes	OSI/Exponent, 1999
Shoreline (bulkhead, riprap)	linear colors only along the shoreline	OSI/Exponent, 1999
Wetlands	Green areas along shore and upland	WDNR, 1999d. USFWS, 1993
Bald eagle nesting sites	yellow triangles, discrete points	Stratus, 1999c. Stubenvoll, 1998.
Threatened or endangered resources	TRS1/4S polygons	Natural Heritage Inventory (NHI), 2000
Basemap generated from TIGER census data and ESRI data and maps in ARCVIEW GIS version 3.2, WTM projection.		

Green Bay GIS Data Sources

Habitat Data	Description	Source
Physical and habitat features (bridge, riffles)	in-water polygon shapes	OSI/Exponent, 1999
Wetlands	Green areas along shore and upland	WDNR, 1999d. Minc and Albert, 1998. USFWS, 1981 and 1993.
Bald eagle nesting sites	yellow triangles, discrete points	Stratus, 1999c. Stubenvoll, 1998.
Threatened or endangered resources	Colored Squares by nearest Township, Range, and Section	NHI, 2000 Natural heritage Inventory (NHI), 2000
Fish Distribution	in-water polygons	NOAA, 1997c.
Bird Distribution	in-water polygons	NOAA, 1997c.
Fish Locations	discrete points in Michigan	Great Lakes Commission, 2000.
Bird Locations	discrete points in Michigan	Great Lakes Commission, 2000.
Fish Spawning grounds	in-water polygons	UWSGI, 1980
Basemap generated from TIGER census data and ESRI data and maps in ARCVIEW GIS version 3.2, WTM projection.		

4.1.1Habitats

The abundance and type of wildlife populating an area depends on the presence of suitable habitat, including the availability and distribution of food and water, protective cover, and appropriate breeding and nesting grounds. The Lower Fox River and Green Bay system varies considerably in its potential to provide and support different kinds of habitat and this variability affects the wildlife diversity and populations.

The two major types of habitat present are terrestrial (on-land) and aquatic (within or near the water). The two main terrestrial habitats within the Lower Fox River and Green Bay area are open land and woodland. Aquatic habitats within the area include wetland, riverine, and lacustrine. Cities and villages represent an urban environment that most wildlife typically avoid, except certain passerines that nest almost anywhere (i.e., select species of wrens, swallows, and sparrows, robins, blackbirds, etc.,) and scavengers (i.e., raccoons, squirrels, vermin, etc.).

Within the Lower Fox River valley, the terrestrial habitats are generally located adjacent to the river from a point downstream of Kaukauna to just upstream of De Pere. In the vicinity of the Fox Cities MSA and Green Bay MSA, much of the river shoreline and associated former wildlife habitat has been developed (Figures 1-3 through 1-6). Natural habitats have retreated from the river and exist only in less developed areas such as lands cultivated for agriculture, open meadows, or small, localized woodlands. The aquatic habitat is wetland and riverine, and it is comprised of and confined to the Lower Fox River and its tributaries.

Green Bay represents a lacustrine habitat and the other habitats, listed above, are found in the area surrounding the bay. The land surrounding Green Bay is much less developed than the Lower Fox River valley, as detailed in Section 3.1.2. Open, agricultural land and forests/woodlands comprise between 65 percent and 94 percent of the land use outside of Brown County, while residential and commercial/industrial land use is less than 5 percent. Wetlands also account for up to 20 percent of county land use in these areas (Table 3-1). The communities located along the shores of Green Bay are much smaller and less populated than the cities of the Lower Fox River valley. Excluding the city of Green Bay (as well as the Lower Fox River watershed), approximately 289,000 people inhabit the Green Bay area (Table 3-7). While individual residences or structures may be located along the shores of Green Bay, shoreline development is much less concentrated than in the Lower Fox River valley and extensive open land or forested tracts may be present along or in close proximity to the shore.

4.1.2 Wildlife Groups

The significant groups of wildlife found within the Lower Fox River and Green Bay habitats are summarized below.

- Both pelagic and benthic aquatic invertebrates species form the primary prey in the food webs of the river and bay. Species of oligochaetes and chironomids (worms and midges) are typically most abundant and are found throughout the Lower Fox River and Green Bay. Amphipods, crayfish, snails, and mussels are also present in the river and bay. Zebra mussels, an exotic species, are present throughout the river and bay (Szymanski, 2000). Due to their aggressive nature, the presence of zebra mussels in the system will present problems for the native macroinvertebrates that cannot adequately compete with these mussels for food or habitat.

- Fish of the region include salmon, trout, game fish such as walleye, yellow perch, and northern pike, and pelagic and benthic non-game fish. Fish species included within uptake modeling and analysis are discussed in detail in this section.

- Birds of the region include raptors, gulls, terns, diving birds, migratory waterfowl, passerines, shorebirds, and wading birds. These animals are found nesting, feeding, and living in both terrestrial and aquatic habitat environments.

- Mammals of the region include large and small game animals that generally live in open or wooded habitat, as well as fur-bearing animals that may forage or live within or near aquatic environments. Game animals include rabbits, squirrels, bear, and deer. The fur-bearing animals include beaver, red fox, mink, raccoon, muskrat, and otter. Additionally, bats feed on insects in the vicinity of Lake Winnebago and along the Lower Fox River near the Fox Cities. Few of the mammals are discussed in detail within this document. Mink are the principal species that are discussed in the RA report.

- Reptiles and amphibians, including snakes, turtles, frogs, and toads are present in the region (Exponent, 1998). Frogs and toads that dwell in wetlands or nearshore areas are fed upon by wading birds of the region. These include the leopard frog, wood frog, green frog, chorus frog, and Eastern grey-tree frog as well as the American toad (Nikolai, 2000a). Typically, the frogs and turtles confine themselves to the wetland and near shore areas while snakes of many different species and toads are found in association with both terrestrial and aquatic habitats. Salamanders confine themselves to forested wetlands and the Blandings turtle is listed as a threatened species in Wisconsin (Nikolai, 2000a). Many egg laying sites have been eliminated due to development along the Lower Fox River (Nikolai, 2000a).

4.2 Wildlife Habitat

4.2.1 Open Lands

Open land habitat in the Lower Fox River and Green Bay area is largely agricultural and characterized as cropland, orchards, pastures, and meadows with grasses, herbaceous shrubs, and vines. The Fox Cities and Brown County land use maps (East Central Wisconsin Regional Planning Commission, 1996 and Brown County Planning Commission, 1990, respectively) and the habitat characterization report (Exponent, 1998) indicate that this is the largest habitat present within 0.8 km (0.5 mi) of the Lower Fox River.

Along the east side of Green Bay, from the Fox River mouth to Little Sturgeon Bay, open land is the predominant habitat (Exponent, 1998). Use of the land for agricultural purposes is responsible for the presence of this habitat along the east shore of Green Bay. Although the Exponent habitat characterization ended at Little Sturgeon Bay, review of Door County SCS (1978) soil survey maps and land use information (Section 3.1.2) indicates that open land habitat is prevalent throughout the Door Peninsula. Approximately 50 percent and 70 percent of the land use in Door and Kewaunee Counties, respectively, is classified as agricultural.

Extensive tracts of agricultural and open land are also present in Brown and Oconto counties. More than 60 percent and 42 percent of the land in Brown and Oconto counties, respectively, is classified as agricultural or open (Section 3.1.2). However, the percentage of agricultural and open land decreases moving north. Agricultural and open land in Marinette, Menominee, and Delta counties ranges between approximately 13 percent and 21 percent, with forested land comprising the majority of the remaining land use (Table 3-1).

Typical open land vegetative cover includes grasses and legumes such as fescue, bromegrass, vetch, and birdsfoot trefoil. Native vegetation consisting of wild herbaceous plants such as goldenrod, asters, beggar-ticks, violets, and various other spring herbs occur on open landscapes. Grasses and prairie grasses such as wheatgrass, big and little bluestem, indiangrass, switchgrass, and sideoats grama exist in limited areas along the bluffs and open areas with prairie forbs consisting of round-headed bush-cover, New England aster, rigid goldenrod, and prairie blazingstar. Cultivated vegetation in the area includes clover, oats, sorghum, soybeans, alfalfa, and hay. This vegetation, both wild and cultivated, provides food and protective cover for wildlife that populates this habitat.

Animals which are frequently observed in open land areas are waterfowl (at rest or feeding), Hungarian partridge, pheasant, songbirds (meadowlark, field sparrows, horned lark, etc.), white-tailed deer, rabbits, red fox, coyote, and various livestock, including Holstein and Brown Swiss cattle.

Although open lands are prevalent along the Lower Fox River and east side of Green Bay, pressure from individuals and developers to convert farmland and other open areas into residential housing or urban uses may reduce the acreage of this habitat. The Brown County Year 2020 Land Use and Transportation Plan (HNTB, 1996) expects the county population to increase by about 32 percent, from 194,500 in 1990 to around 257,700 in 2020. The recommended land use plan map indicates that residential housing is intended for large areas along the east shore of Green Bay. Due to the presence of the wetlands and the large tracts of state-owned land along the west side of the bay, residential housing developments in this area will be more limited. However, development of these areas is still expected to impact the nearby habitats.

Increases in housing and population are also expected in Door County. The Door County Development Plan expects that the year-around population will increase by about 5.4 percent (1,380 people) between 1990 and 2015 (Olejniczak and Florence, 1995). Again, much of this growth is expected to decrease open land areas as well as other habitats.

4.2.2Woodlands

Woodland habitat is characterized as hardwood and conifer forest land and wood lots with an associated understory of grasses, legumes, and wild herbaceous plants. Woodland habitat originally covered a vast majority of the land in eastern Wisconsin and Michigan's UP. Due to development and growth of urban areas and agricultural activities in the Lower Fox River valley, few significant tracts (40 acres or more) of woodland habitat are present within a mile of either bank of the Lower Fox River. Those areas that are present are usually thin, elongated areas which border roads or farm fields.

Agricultural activities have dominated the historical development of northeastern Wisconsin and significant losses of woodlands have occurred in this area. However, large tracts of woodlands and forests remain in the UP. Moving north along the shores of the bay, the acreage of wooded land increases. This is especially true where the growth of agricultural areas has slowed and replanted forests have matured since the trees were logged during the 1800s and early 1900s. Review of the aerial photos used for the SCS soil maps for the counties surrounding Green Bay (1972, 1978, 1988, 1989, 1991, and 1994) indicates that the size of the tracts of woodlands increases moving north. Less than 6.7 percent of the land within Brown County was described as forested compared to 51 percent to 76 percent in Oconto, Marinette, Menominee, and Delta counties (Table 3-1). Over 625,000 hectares (1.54 million acres) of forests are present in Marinette, Menominee, and Delta counties (Table 3-1). Forested land comprises between 22 percent and 34 percent of land use in Door and Kewaunee counties (Table 3-1).

Typical vegetative cover includes oak, maple, poplar, cherry, apple, hawthorn, dogwood, hickory, blackberry, hazelnut, viburnum, and blueberry. Conifers include pine, spruce, cedar, juniper, fir and tamarack. Birds and wildlife eat the nuts, fruits, buds, catkins, twigs, bark and foliage that the vegetation provides, as well as use the vegetation for nesting sites and protective cover from predators. Woodlands are inhabited by upland game birds and passerines, small and large game, as well as other non-game animals that include the invertebrates, insects, reptiles, and amphibians typical of the upper Midwest. Dominant species in these areas include whitetail deer, squirrel, raccoon, ruffed grouse, songbirds, thrushes, and woodpeckers. Many of the species that utilize the open land habitats will seek food and protection within woodlands when necessary.

Historical development in northeast Wisconsin and Michigan's Upper Peninsula (UP) have reduced the forests, which were originally the dominant habitat in the region. Logging activities, for lumber and to supply raw material to the paper mills in the Fox Valley greatly reduced the woodland acreage. Following logging, these areas were typically cultivated, especially within the Lower Fox River valley and along the southern half of Green Bay. With this lost forested land, the animal populations utilizing this habitat also decreased and changed.

Within the state of Michigan, significant tracts of woodlands and forests are designated as state or federal lands. Parcels of the Escanaba River State Forest stretch from just north of the city of Menominee to just outside the city of Escanaba, a distance of approximately 45 km (28 mi). Some of this land is located on the shores of the bay but most of it is inland about 1.2 to 2.4 km (0.75 to 1.5 mi). Smaller tracts of the Escanaba River State Forest are located along the shores of Little Bay de Noc north of Gladstone and throughout Delta County. All together, the Escanaba River State Forest comprises 168,350 hectares (416,000 acres) of land. The Hiawatha National Forest is located in the central portion of the UP, running from the north end of Big Bay de Noc to the shores of Lake Superior and comprises 348,000 hectares (860,000 acres). Large tracts of land within the Stonington Peninsula are designated as part of the Hiawatha National Forest. Finally, the Lake Superior State Forest comprises over 404,700 hectares (1 million acres) of forested land in the central and eastern UP. The northern portion and eastern side of the Garden Peninsula, as well as much of Summer Island are designated as Lake Superior State Forest land. In addition to these state and federal forests, the J. W. Wells State Park and Beach is located along the west shore of Green Bay between Menominee and Escanaba. Fayette State Park is located on the west side of the Garden Peninsula, just off of Sand Bay on the east shore of Big Bay de Noc.

There is no state or federally designated forest land located along the shores of Green Bay in Wisconsin. However, three forested Wisconsin State Parks are located along the east shore of Green Bay on the Door Peninsula. The largest of these is Peninsula State Park, which comprises about 1,520 hectares (3,760 acres) of forest and includes about 32 km (20 mi) of shoreline along the east side of Green Bay. Potawatomi State Park is located on the south side of Sturgeon Bay and comprises about 456 hectares (1,127 acres). Finally, Rock Island is a designated state park and comprises approximately 510 hectares (1,260 acres).

4.2.3Wetlands

4.2.3.1 Wetland Areas and Types

Wetlands are critical habitat for many wildlife groups within the Lower Fox River and Green Bay area. Wetlands provide nesting and feeding areas for many migratory birds, including waterfowl, shorebirds, wading birds, and passerines. Many of these birds feed in or over wetlands. Dominant species include geese and mallards, blue-winged teal, wood ducks, scaup, golden eye, common and hooded mergansers, bald eagles, osprey, and great blue and black crowned night herons. Some species of fish seek out wetlands for spawning or foraging purposes, including northern pike, bass, sunfish, yellow perch, carp, alewife, rainbow smelt, and shiners (Exponent, 1998). Small game and fur-bearing mammals, including muskrat, mink, otter, and bats utilize wetlands habitat for nesting, feeding, and protective cover (Exponent, 1998). Numerous insects, amphibians, snakes, turtles, and invertebrates live within wetlands.

Both the USFWS (1979) and the Michigan Natural Features Inventory (MNFI) (Minc and Albert, 1998) have developed wetland classifications. The classifications used by Exponent (1998) in the Lower Fox River and the southern portion of the Green Bay are, more or less, those of the USFWS (1979), while many of the descriptions for Green Bay are those of the MNFI. Therefore, an effort has been made to identify the wetlands in Green Bay using both classification systems in order to facilitate an understanding of the habitat.

According to the MNFI, there are six types of coastal wetlands found within the Great Lakes, including Green Bay, based on floristic variability (Minc and Albert, 1998). Moving from deeper water to the shore, these wetland types include the following:

1) Submergent marsh: contains submerged aquatic vegetation (SAV) and/or floating vegetation.

2) Emergent marsh: characterized by shallow water or saturated soils with rushes, cattails, and other emergent species

3) Shoreline (or strand) zone: located at or just above the water line and are typically thin zones, usually dominated by herbs

4) Wet meadow (herbaceous): characterized by saturated or periodically flooded soils dominated by sedges, grasses, and other herbs

5) Shrub swamp & 6) Swamp forest: characterized by periods of standing water and are dominated by woody species adapted to a variety of flooding regimes, including dogwood, cottonwood, tamarack, and spruce

These are general wetland types and not all types are found within each wetland or wetland complex (Minc and Albert, 1998). These can also be lacustrine, riverine, palustrine, and lacustrine/freshwater estuaries. The wetlands located within Green Bay are primarily lacustrine followed by palustrine, and then riverine. The wetland descriptions used by Exponent (1998) are presented below, as well as information pertaining to the typical flora of each wetland type.

Wetlands are characterized by seasonally flooded basins and swales, as well as open, marshy, swampy, or shallow water areas with water-tolerant vegetation. Lower Fox River and Green Bay wetland types observed by Exponent (1998) included the following:

- **Emergent/Wet Meadow Wetlands:** These wetlands/wetland complexes are typically present along the west shore and tributary mouths of Green Bay, as well as in the backwater covers of LLBdM and the Lower Fox River. These wetland areas are a combination of the emergent, shoreline, and wet meadow types defined by MNFI (above). Typical emergent vegetation in these wetlands include cattails, bulrush, arrowhead, assorted rushes, sedges and reeds. Smartweed, wild millet, wild rice, saltgrass, purple loosestrife, cordgrass, reed canary grass, phragmites, and sagittaria are also common within these wetland complexes. The submergent and floating aquatic vegetation within these marshes primarily consists of water-milfoil, coontail, wild celery, pondweeds, and water lilies (Exponent, 1998).

- **Scrub/Shrub wetlands:** These wetlands are often found in conjunction with emergent/wet meadow wetland complexes in the Lower Fox River and the southern portion of Green Bay. Typical vegetation in these wetlands include shrub willows, small cottonwoods, dogwoods, and small ash, as well as elderberry and buttonbush. These wetlands are located primarily along the west shore of Green Bay, in association with the emergent/wet meadow wetlands located near tributary deltas, shallows, reefs, and spits. Small and large game utilize the wetlands, as do waterfowl, passerines, and select herons species (Exponent, 1998).

- **Forested wetlands:** These wetlands occur along the banks of the Lower Fox River and the shorelines of Green Bay throughout the area that Exponent characterized (1998). These wetlands are forested with numerous deciduous species, including elm, cottonwood, willow, ash, maples, box elder, dogwood, and sumac. Red and white oaks and large cottonwood typically dominate the canopy of more mature forested areas while white oak, maple and ash usually dominate the canopy of upland wetland complexes (Exponent, 1998).

Areas identified and mapped as wetlands by the WDNR along the Lower Fox River are shown on Figures 4-1 through 4-4. Wetland areas along Green Bay, which were identified and mapped by USFWS (1981 and 1993) are shown on Figures 4-5 and 4-6.

Emergent/wet meadow wetland complexes account for 43 percent of all wetlands observed in the Lower Fox River and southern Green Bay assessment area. Shrub/scrub wetlands comprise approximately 27 percent of the wetlands and are located mainly along the west shore of Green Bay. Forested wetlands account for 25 percent of the area and are predominantly located in the northern portion of this assessment area. Open water within designated wetland areas account for 2 percent of the total area and aquatic beds, excavated ponds, and wetlands smaller than 0.8 hectares (2 acres) in size comprise the remaining 3 percent of the assessed area (Exponent, 1998).

Only 135 hectares (334 acres) of wetlands within 0.4 km (0.25 mi) of the shore were identified within the Lower Fox River valley (Exponent, 1998). Of these identified wetlands, 119 hectares (294 acres) or 88 percent were located between LLBdM and the De Pere dam (Figures 4-1 through 4-3). The wetlands in this part of the river were predominately forested wetland (68.9 hectares or 170 acres) and emergent/wet meadow wetlands (32 hectares or 81 acres) (Exponent, 1998). The largest wetland areas are associated with the Stroebe Island Marsh and backwater areas in LLBdM, the Thousand Islands wetlands (adjacent to

Kaukauna/mouth of Kankapot Creek), and the Little Rapids dam, and account for approximately 87 percent of the wetlands upstream of the De Pere dam (Exponent, 1998). Only 16 hectares (40 acres) of wetlands were identified in the De Pere to Green Bay Reach (Green Bay Zone 1), and these were predominantly emergent/wet meadow and forested wetlands (Figure 4-4). Approximately 60 percent of these wetlands (9.5 hectares or 23.4 acres) are associated with marsh at the mouth of the Lower Fox River (Exponent, 1998).

In addition to the wetland analysis, Exponent (1998) documented the presence and areal extent of SAV within each portion of the Lower Fox River. However, it appears that Exponent (1998) did not classify these areas as wetlands. Approximately 350 hectares (865 acres) of SAV are present in the Lower Fox, with only about 8 hectares (20 acres) located downstream of the De Pere dam. Approximately 260 hectares (642 acres) of SAV are present within LLBdM and are likely associated with the Stroebe Island Marsh and the other backwater wetlands of LLBdM; however, SAV is also associated with smaller wetlands, both within LLBdM and other areas of the river. Another 62 hectares (153 acres) of SAV are present in the same part of the river as the Thousand Islands wetlands; therefore, it is assumed that the SAV is again associated with these wetlands. Only 26 hectares (64 acres) of SAV are present in the river downstream of the Rapide Croche dam (Exponent, 1998). This is likely due to the fact that the river is narrower with faster stream flow velocities; conditions that are not favorable (1978) or the establishment of SAV. In addition, water clarity and depth are also other limiting factors which effect the presence or absence of SAV in a given location (Szymanski, 2000).

The USFWS completed a study of the fish and wildlife resources of the Great Lakes coastal wetlands in 1981. This study found that there are at least 17,098 hectares (42,250 acres) of wetlands located along the shores of Green Bay (Table 4-1). The wetland/wetland complexes identified on Table 4-1 include those over 40.5 hectares (100 acres) in size, which is the MNFI study size criterion (Albert, 2000). Although there are a number of fully functioning wetlands under 20.2 hectares (50 acres) along the shores of Green Bay, physical constraints generally inhibit these wetland areas from expanding (Albert, 2000). Therefore, controlling losses in larger wetland complexes is important for maintaining the overall wetland habitat of the region (Albert, 2000). However, the functional value or benefit of smaller wetland areas cannot be discounted. The 40.5 hectare (100 acre) size criteria is only used to focus the discussion below.

Approximately 42 percent of wetland areas larger than 40.5 hectares are located in Wisconsin while about 58 percent are located in Michigan. Both the bathymetry and the physical environment of the bay have a significant influence on the size and location of coastal wetlands. Based on these factors, the distribution of wetlands along the east shore of Green Bay is very limited compared to the west shore of the bay and in both Big Bay de Noc and Little Bay de Noc (Table 4-1; Figures 4-5 and 4-6).

Almost 570 hectares (1,400 acres) of wetlands are located along the east shore of Green Bay. This represents just over 3 percent of all the wetlands larger than 40.5 hectares (100 acres) in the bay (Table 4-1). Wetlands along the east side of Green Bay are generally classified as palustrine (marsh or swamp) (USFWS, 1981). Palustrine wetlands generally lack flowing water and have water depths less than 1.8 m (6 feet) deep. Based on the Exponent (1998) and USFWS (1981) descriptions, many of the wetlands along the east shore of Green Bay are emergent/wet meadow wetlands.

About 8,000 hectares (19,770 acres) of wetlands are present along the west shore of Green Bay, from the Fox River mouth to the city of Escanaba, Michigan, (Table 4-1). This is approximately 47 percent of the Green Bay wetlands greater than 40.5 hectares. Between the Fox River mouth and the city of Oconto, Exponent (1998) classified slightly more than 50 percent of the wetlands as emergent/wet meadow, while approximately 31 percent were shrub/scrub wetlands. The information provided by USFWS (1981) and Minc and Albert (1998) suggest that wetlands further north of the city of Oconto are similar (Table 4-1). The USFWS (1981) primarily classified all the west shore wetlands as lacustrine systems (Table 4-1), although smaller palustrine systems were typically associated with these wetlands. The west shore wetlands are affected by littoral currents, storm driven wave action, wind action, and ice scour, which the primary causes of shoreline sediment deposition and erosion (Minc and Albert, 1998). These lacustrine systems have developed in the shallows of the bay and many of them are associated with the Green Bay tributary spits or deltas. Only wetlands associated with river deltas are classified as riverine systems (Table 4-1). These include select portions of the Atkinson Marsh (Duck Creek), Oconto Marsh (Oconto River), Peshtigo River Wetland, Cedar River Wetland Complex, and Ford River Wetland Complex (Table 4-1). Other riverine wetlands are associated with the other tributaries; however, these wetlands are usually very small and are not included on Table 4-1.

Wetlands found in both Little Bay de Noc and Big Bay de Noc are predominantly lacustrine systems and are generally similar to the west shore wetlands. Approximately 8,527 hectares (21,070 acres) of wetlands are located in these two bays. This is just under 50 percent of the Green Bay wetlands larger than 40.5 hectares (Table 4-1). These wetlands have extensive emergent vegetation development (Minc and Albert, 1998). Also, the wet meadow complexes, shrub swamp, swamp forest wetlands in the UP are typically larger and more a readily extensive than further south in Green Bay. This is primarily due to less development in this region of the bay compared with areas further south.

Due to the fact that the west and north shore wetlands developed on gently sloping lake or outwash plains, these wetlands are considered to be "pulse stable" systems (USFWS, 1981; MDNR, 1998). Periodic, short-term and long-term water level fluctuations are very important to the maintenance and productivity of pulse stable wetlands. High water levels in the mid-1970s and mid-1990s reduced the areal extent of these wetlands, flooded areas of emergent vegetation, and may adversely effect wet meadow or shrub/scrub plant species that may not be able to tolerate flooded conditions for extended periods of time. Conversely, periods of low water levels allow expansion of wetland areas, decomposition of accumulated organic material, and new wetland plants to germinate (MDNR, 1998). Emergent plant species will colonize shallow water areas as the area of wet meadow and shrub/scrub plant species increases lakeward.

The state of Wisconsin has a number of designated wetlands/wildlife areas located in the Green Bay area. The largest of these is the Green Bay West Shores State Wildlife Area (SWA), which comprises 11 separate wetland units. The 11 units are listed below, starting near the Fox River mouth and moving north along the west shore. The status of an area as either a designated SWA or national wildlife refuge (NWR) is also indicated.

Green Bay West Shore Wildlife Area Units

Unit	Hectares (Acres)	Unit	Hectares (Acres)
Peats Lake/South Shore	163.6 (404.3)	Pensaukee W.A.	164.1 (405.6)
Long Tail Point NWR.	52.3 (129.3)	Pecor Point	35.3 (87.1)
Sensiba W.A.	317.8 (785.4)	Oconto Marsh	362.7(896.2)
Little Tail	86.0 (212.4)	Rush Point	74.2 (183.3)
Tibbet-Suamico	106.7 (263.6)	Peshtigo Harbor W.A.	1,609.4 (3,976.9)
Charles Point	43.7 (108.0)	**Total Area**	**3,015.8 (7,452.1)**

Currently, just over 3,015 hectares (7,450 acres) are designated as part of the Green Bay West Shores SWA. However, the WDNR desires to expand this area to a total of 5,639 hectares (13,933 acres) in the future (WDNR, 2000b).

Along the east side of the bay, the Gardener Swamp SWA covers 478 hectares (1,181 acres) in Door County (WDNR, 2000b). Gardener Swamp SWA is located just south of Little Sturgeon Bay, approximately 2.4 km (1.5 mi) from the bay. The WDNR is also currently planning to establish the Red Banks Glades

SWA in Brown County. This planned SWA would cover approximately 204 hectares (503 acres) and be located just inland from the bay, similar to the Gardener Swamp SWA (WDNR, 2000b).

The city of Green Bay owns and operates the Bay Beach Wildlife Sanctuary, which is located approximately 1.9 km (1.2 mi) east of the Fox River mouth. The sanctuary is approximately 283 hectares (700 acres), of which 24.3 hectares (60 acres) are standing water and lagoon. Wet meadow, emergent, and shrub/scrub wetland areas are all present in the sanctuary (Baumann, 2000).

4.2.3.2 Wetland Losses

Wetlands, similar to woodlands, were historically more prevalent than they are today. While wetland losses can be attributed to both human and natural processes, those associated with human activities are generally more permanent. Filling of lowland and marshy areas was historically considered advantageous, as these areas were of little recognized use or importance and the resulting land could be developed for numerous purposes. This was probably more predominant along the banks of the Lower Fox River than along the shores of Green Bay, but it has occurred throughout the region (Burridge, 1997; Exponent, 1998). Due to the cities and large areas of developed land located along the banks of Lower Fox River, it is likely that wetland losses along the river resulting from human activities have been more significant than along the shores of the bay. Additionally, water level fluctuations within the bay play an important role in the amount of wetland present immediately adjacent to the shore and extending into the bay during any given time period.

In the Lower Fox River, the only wetland exceeding 8.1 hectares (20 acres) is associated with the Thousand Islands Nature Preserve (Exponent, 1998). Wetland losses in the Lower Fox River were generally associated with filling and development activities, including construction of the locks and dams. Although not directly documented, it is likely that construction of the locks and dams of the Lower Fox River, along with the dredging activities which occurred up through the 1960s (as listed on Table 3-13) likely had long-term detrimental impacts on the riverine wetlands. Exponent (1998) documented development of the Lower Fox River shoreline and these results are discussed below in riverine habitat section.

Green Bay shoreline development has also resulted in wetland habitat loss, some of which has been documented. The Bay Port Industrial Park and CDF is a 243 hectare (600 acre) facility located along the west shore of Green Bay about 3.2 km (2 mi) from the Fox River mouth. This facility was constructed between Interstate 43 and the bay, largely over Atkinson Marsh. In the early 1960s, the

Bay Port Industrial Park was envisioned as a facility to enlarge, enhance, and modernize the Port of Green Bay. In order to fill the incorporated wetlands of Atkinson Marsh and the other low areas, the city of Green Bay offered the site to the USACE as a CDF for placement of sediments dredged from the navigation channel and other harbor work. The USACE began disposing of dredge spoils at Bay Port in 1966 and approximately 7.24 million m^3 (9.47 million yd^3) have been placed in the CDF through the end of 1999 (Table 3-13).

Wetland losses along the west shore of Green Bay from the Fox River mouth to the city of Marinette, Wisconsin were studied in the mid-1970s (Bosley, 1976 and 1978). Using land survey information from 1834 through 1844, it was estimated that at least 223 km^2 (86 mi^2) of coastal wetlands were present along the west shore of Green Bay (Bosley, 1976). In the mid-1970s, Bosley (1978) estimated that the west shore wetland areas had decreased to approximately 63 km^2 (24.3 mi^2) at low water levels and about 45.3 km^2 (17.5 mi^2) at high water levels. This represents a loss of 72 percent to 80 percent of the west shore wetlands. In 1981, the USFWS estimated that there were approximately 63.5 km^2 (25.5 mi^2) between the mouths of the Fox and Menominee Rivers, similar to Bosley's (1978) estimate.

Schideler (1994a) documented the loss of wetland areas between 1951 and 1986 resulting from natural processes, specifically water level fluctuations and storm effects. Schideler (1994a) analyzed the size and extent of Long and Little Tail Points and their associated wetlands. The Long Tail Point area included the point and all wetlands from just east of the Fox River mouth to the location where Long Tail Point joins the shore. This area included the Duck Creek delta, Peats Lake, Atkinson Marsh, Peters Marsh, Dead Horse Bay, and the other bayhead islands between Long Tail Point and the mouth of the river, including the Cat Island Chain and Grassy Island. Much of this area is shown on Figure 4-7. The Little Tail Point area included the point and all wetlands from just south of the Suamico River to just north of the Little Suamico River.

Estimated net wetland losses in the Long and Little Tail Point areas between 1951 and 1986 were approximately 420 hectares (1,040 acres) and 200 hectares (500 acres), respectively (Schideler, 1994a). The net loss (or gain) of wetland is the total difference between total wetland losses and total wetland gains. Typically, there is some amount of loss in one area with wetland gains occurring in other areas. The most significant periods of high water levels found during this time frame were in 1952-53, 1973-74, and 1985-86. As mentioned above, although the wetlands of Green Bay are pulse-stable systems, extended periods of high water reduce overall wetland areas. Additionally, if significant wind action, wave action or storms occur during these periods of high water, significant sediment volumes may be displaced, thereby disturbing, reducing, or destroying the wetland. Schideler (1994a) observed such results in the Long Tail Point area and the specific areas of wetland losses are listed below and shown as blackened areas on Figure 4-7.

Wetland Losses in Select Areas of Lower Green Bay, 1951-1986.

Location	1951-1982 Hectares (Acres)	1982-1986 Hectares (Acres)	Total losses Hectares (Acres)
Long Tail Point	57.6 (142.3)	50 (123.6)	107.6 (265.9)
Duck Creek Delta	136 (336.2)	82.8 (204.5)	218.8 (540.7)
Duck Creek (Upstream)	12.2 (30.1)	18.9 (46.6)	31.1 (76.7)
Peters Marsh/Peats Lake	40.9 (101.1)	11.1 (27.4)	52 (128.5)
Dead Horse Bay	2.4 (6)	10.5 (26)	12.9 (32)
Cat Island Chain	16.7 (41.3)	2.1 (5.3)	18.8 (46.6)
Other Bayhead Islands	5.0 (12.3)	0 (0)	5.0 (12.3)
Bay Port	12.4 (30.7)	13.1 (32.3)	25.5 (63.0)
TOTALS	**283.3 (700)**	**188.5 (465.7)**	**471.8 (1,165.7)**

Most of the wetlands within this area are exposed to bay waters; therefore, the day-to-day wind/wave actions, storms, and water level fluctuations all impact these wetlands. The greatest wetland losses were associated with Long Tail Point and the Duck Creek delta, where over 324 hectares (800 acres) of wetlands were lost (Figure 4-7). Conversely, the wetland losses for Dead Horse Bay, which is largely protected from bay wave/wind action and storms by Long Tail Point, were only about 2.4 hectares (6 acres) during this time period. The most significant event affecting wetland losses between 1951 and 1982 was the April 1973 storm described in Section 3.5.2.1.

Water levels were high during 1973-74 and in April 1973 a strong storm blowing out of the northeast struck Green Bay. Significant wetland losses resulted from this storm. It is estimated that most of the wetland loss listed for the Duck Creek delta occurred during this storm, as flood waters washed into Duck Creek and destroyed wetlands upstream of the mouth (Erdman, 1999a). Long Tail Point was also severely eroded during this storm; so much so, that a large lighthouse that had been located just off the tip of the point since the 1800s was completely destroyed (Erdman, 1999a).

The Cat Island Chain was also virtually destroyed following the April 1973 storm, as all portions of the chain that had previously been above water were eroded below the water surface. The Cat Island Chain was a group of three large islands and approximately eight to ten smaller islands (Schideler, 1994a) (Figure 4-7) that had been a stable and constant feature in Green Bay since the first navigational charts were drawn in 1845 (Neville Public Museum). This chain acted as barrier islands, protecting the other shoreline wetlands in this area (Smith, 1999a). Review of the 1905 Green Bay Lake Survey Chart 725 (USACE, 1905) indicates that emergent vegetation was present over much of the area south and west of the Cat Island Chain, except in the immediate area of Peats (Peaks) Lake. It is speculated that loss of the Cat Island Chain resulted from the armoring of the shoreline in the vicinity of the Bay Port CDF (Smith, 1999a). Wetlands located on the bay side of the reinforced shoreline were completely eroded during the storm (Schideler, 1994a). The armored shore provided no dampening effect to absorb wave energy in the south end of the bay; therefore, the wave energy was simply reflected back into the bay (Smith, 1999a). Consequently, the bayhead islands, including those of the Cat Island Chain, were affected by severe wave action from both the bay and shore side, thereby facilitating erosion. Based on the high water level, the sediments composing these islands were removed and dispersed throughout the lower bay. Due to the recent low water level conditions, only about 37.2 m^2 (400 ft^2) remains of the chain today (USACE, 1998c).

Although there was an overall net loss of wetlands in the Long Tail Point area during this time frame, there were some wetland gains (Schideler, 1994a). The most important of these gains, in Schideler's opinion, was the construction of the Kidney (Renard) Island CDF. This facility and its construction are discussed in more detail in Section 4.2.3.3. Other small increases in wetland areas were noted in Dead Horse Bay, Peats Lake, Peters Marsh, and along the shoreline of the Bay Port facility.

Wetland losses were also documented for the Little Tail Point area (Schideler, 1994a). Between 1951 and 1974, this area experienced a net loss of just 2 hectares (5 acres). However, between 1974 and 1986, the net wetland loss was approximately 200 hectares (495 acres) (Schideler, 1994a). The majority of these losses were associated with Little Tail Point and the nearby mainland (85 hectares or 210 acres), the Sensiba SWA (44 hectares or 109 acres), and the mouths of the Suamico and Little Suamico Rivers (29.5 hectares or 73 acres and 43 hectares or 106 acres, respectively).

Schideler (1994b) completed a similar review of the Oconto, Pensaukee, and Peshtigo wetland areas over the same period of time. Between the early 1950s and 1974, the Oconto and Peshtigo areas actually had a net gain of about 15.8 hectares (39 acres) and 1.8 hectares (4.5 acres), respectively, while the Pensaukee area had a net loss of about 3.4 hectares (8.4 acres) (Schideler, 1994b). However, from 1974 through about 1987, all these wetlands decreased in size. The Pensaukee wetlands lost approximately 74 hectares (183.1 acres) while the Oconto and Peshtigo wetlands decreased by about 170 hectares (419 acres) and 145 hectares (358 acres), respectively. The wetland losses observed for all of the west shore wetlands likely resulted from increased water levels. The west shore wetland areas are likely re-establishing themselves based on the low water levels Green Bay is currently experiencing (USACE, 2000b).

4.2.3.3 Proposed Wetland Restoration Projects

Wetland redevelopment has been identified as a priority for restoration of the Green Bay area and ecosystem (RAP Biota & Habitat Work Group, 1994 & 1996). Three of the top four priorities identified by the Green Bay RAP Committee in 1994 included the following: 1) restoration of the Cat Island Chain; 2) protection, enhancement, and restoration of the river and bay wetlands; and 3) enhancement or creation of near-shore and in-lake habitat. In addition, establishment of the Kidney (Renard) Island CDF has facilitated wetland restoration east of the Fox River mouth. However, because sediments placed within this CDF are contaminated with PCBs, the overall impacts, both positive and negative, are still debated.

The USACE, along with the USFWS and other governmental and private agencies, are currently reviewing plans to re-establish the Cat Island Chain. The Cat Island Chain restoration proposal plans to use sediments from the northern most end of the navigation channel or further north in the bay, which are less likely to contain significant concentrations of PCBs or other chemical compounds (Smith, 1999b). The restored Cat Island Chain would provide additional bird and fish habitat in this area. The islands would also protect and facilitate recovery of the other west shore wetlands in lower Green Bay (Smith, 1999b). These wetland areas include Peats Lake, Peters Marsh, the Duck Creek delta, and the remaining portions of Atkinsons Marsh. The current plans include constructing three man-made islands of dredged material along the previous landforms. The USACE believes the work could commence in 2002 and would begin with the western most island, located closest to the western shore of Green Bay (Campbell, 1999). The three islands would be approximately 62.7 hectares (155 acres), 21.5 hectares (53 acres), and 15.6 hectares (38.6 acres), respectively (USACE, 1998c). Based on the fact that Kidney Island, which is about 21 hectares (52 acres), has already received more than 2.1 million m^3 (2.7 million yd^3) of sediment, it is possible that these three islands could receive well over 9.2 million m^3 (12 million yd^3) of sediment. Revegetation activities must also be undertaken in conjunction with island restoration to prevent exotic species from overtaking these areas (Nikolai, 2000a).

In addition to the Cat Island Chain restoration project, other activities would be undertaken to facilitate wetland and habitat recovery. Reintroduction of SAV in the area of the Duck Creek delta and Peats Lake would provide habitat for fish fry, as well as facilitate wetland recovery. Additionally, the riprapped areas of shoreline in the southern bay would be softened by promoting the growth of emergent vegetation and through creation of nearby sandbars. Softening this shoreline would reduce wave energy in the south end of the bay, thereby allowing further establishment of more SAV and emergent vegetation along the shore.

Kidney Island CDF has received over 2.1 million m^3 (2.7 million yd^3) of sediment since 1979 and has been a controversial project in the Green Bay area. Some consider the CDF an unsuitable habitat restoration alternative, due to the fact that PCBs and other chemical compounds contaminate the sediments contained therein. Also, the location of the CDF immediately offshore of Green Bay's historic Bay Beach has been a concern to some local residents. Concerns for the Kidney Island CDF were included in the Final Environmental Impact Statement (EIS), completed when expansion of the CDF was proposed (USACE, 1985). However, the presence of the CDF has fostered re-establishment of emergent vegetation around the perimeter of the island, especially in the quiet water between the CDF and the shoreline to the south. Some colonial nesting birds (e.g., terns) use the island as nesting grounds (Erdman, 1999b).

Neither the Bay Port nor Kidney Island CDFs have achieved their original project objectives. The Bay Port Industrial Park has not yet become the port facility originally intended and Kidney Island has not evolved into the wetland habitat and possible marina that was envisioned. Consequently, future island restoration projects like that proposed for the Cat Island Chain, and further use of CDF sediments contaminated by significant levels of PCBs or other chemical compounds may be of concern to some Green Bay area stakeholders (Erdman, 1999b).

The MDNR (1998) released a restoration and management plan for Portage Marsh. This marsh is located along the west shore of Green Bay south of the city of Escanaba (Figure 4-6). A dike system was established to facilitate access to the marsh in 1984; however, the dikes have impeded water exchange between the bay and marsh and limited water level fluctuations. Therefore, areas that were once wetlands are becoming uplands. Also, continued use of the area by off-road vehicles has contributed to further degradation. Therefore, the restoration and management plan called for prohibition of off-road vehicle use within the marsh and removal or opening of some dikes in order to allow water exchange between the bay and marsh as well as facilitate water level fluctuations (MDNR, 1998). Also, because wet meadow areas of the marsh were beginning to see the establishment of various trees (marking transition to a shrub swamp or swamp forest type wetland), the MDNR proposed controlled burning of select areas. This burning would facilitate growth of wet meadow plant species and, in select areas, provide more open water spaces for increased use by wildlife (especially migratory waterfowl).

4.2.4 Riverine Habitat of the Lower Fox River

Riverine aquatic systems refer to the rivers and tributaries of the Great Lakes whose water quality, flow rate, and sediment loads are controlled in large part by their drainage basins. Tributary rivers typically have a low flow volume, although the flow volume may vary significantly due to seasonal influences. Tributaries such as the Fox River are also influenced by the amount of the development immediately adjacent to the riverbanks or within the drainage basin.

The *Habitat Characterization Assessment* (Exponent, 1998) divided the Lower Fox River into two parts, upstream and downstream of the De Pere dam. The upstream portion is comprised of the LLBdM, Appleton to Kaukauna, and Kaukauna to De Pere reaches, while the downstream portion is comprised of the De Pere to Green Bay Reach. Eight different aquatic habitats were identified within the Lower Fox River (Exponent, 1998). These habitat types and the percentage of each type within the river are listed on Table 4-2 and shown for each reach on Figures 4-1 through 4-4.

The largest category described by Exponent (1998) was the Island/Peninsula habitat (Table 4-2). Most areas where island/peninsula habitat was observed are small, unnamed outcroppings and areas within the Lower Fox River which were formed during lock and dam construction and channelization of the river in the 1800s. A few notable areas for this habitat type are Stroebe and James Islands in LLBdM (Figure 4-1), the Thousand Islands Nature Conservancy near Kaukauna (Figure 4-2), and the unnamed islands associated with the Cedar, Combined, Rapide Croche, and Little Rapids Locks (Exponent, 1998).

Backwater, cuts, and coves are the second largest habitat category observed within the river (Table 4-2) (Exponent, 1998). These areas are relatively undisturbed by human activities and, thus, they are very desirable for wildlife and fish (Exponent, 1998). These habitat areas are also generally small and scattered throughout the river, making them an important habitat for maintenance of current fish and wildlife populations that use them. These areas are shown on Figures 4-1 through 4-4.

Two other important habitat types are the dam riffles and submerged rock, piling, or ruin environments. Although these two habitats constitute just over 12 percent of the Lower Fox River, game fish are often associated with these areas. Fish such as walleye prefer rocky substrates with fast running water for spawning purposes. Walleye are an important game fish of the Lower Fox River. Although, sandbars and silt deposits are rare along the Lower Fox River, they are important for turtle nesting and shorebird feeding activities (Nikolai, 2000b).

In addition to reviewing the aquatic habitat, Exponent (1998) evaluated the riverbanks and substrate characteristics. The shoreline classifications are shown on Figures 4-1 through 4-4 (Exponent, 1998). The river shoreline was divided into both developed and natural riverbank, with subcategories of each (Table 4-3). About 44.6 percent of the river shoreline is developed and protected with either riprap or bulkheads while the remaining 55.4 percent is natural bank (Table 4-3).

Slightly more than 22.4 km (13.9 mi) of the 28 km (17.4 mi) of developed shoreline is protected with riprap (Table 4-3) and, according to Exponent (1998), riprap is preferable to bulkheads. Riprap tends to offer some habitat possibilities as some fish will find protection and feeding opportunities and some birds will nest in the crevices and gaps of the riprap. Bulkheads offer little in the way of habitat due to the smooth surfaces and vertical walls.

The Lower Fox River has about 34.8 km (21.6 mi) of natural shoreline (Table 4-3). Almost 44 percent of the entire river shoreline is classified as riparian canopy, which includes tree-lined and forested banks of the river (Exponent, 1998). About 15.9 km (9.9 mi) of riparian canopy shoreline is situated between the Cedars and Little Rapids locks (Figure 4-2). This is one of the least developed portions of the Lower Fox River, with steep banks that inhibit significant agricultural or urban development. Shorelines with either groundcover or wetland comprise almost 6.8 km (4.2 mi) while sand and gravel beaches comprise less than 1 percent of the shore (Table 4-3).

The river substrate summary is included on Table 4-3 (Exponent, 1998). The areal extent of the river is about 21.8 km^2 (8.4 mi^2). Soft silty sediment (Type 1) comprises about 11.7 km^2 (4.5 mi^2) or about 53 percent of the river bottom. Compact sand and gravel (Type 3) accounts for about 6.3 km^2 (2.4 mi^2), or about 29 percent of the river bottom (Table 4-3). The river bottom downstream of LLBdM is essentially made up of either Type 1 or Type 3 sediments. Half of the bottom material in LLBdM is Type 2, semi-compact sand/clay, sediments. The most prevalent areas of Type 3 sediment (compact sand/gravel) are located between the Appleton and Little Rapids dams (Table 4-3), suggesting the increased current velocities associated with the generally narrow river width, transport silt and other fine-grained sediments further downstream of these areas. Between Appleton and Little Rapids, the only significant accumulation of soft silty Type 1 sediment is in the part of the river where the Thousand Island Nature Conservancy and wetlands are located.

Downstream of the Little Rapids dam, the majority of the river bottom is Type 1 soft, silty sediments. The areal extent of the river from Little Rapids to the mouth of the Lower Fox River is almost 9.1 km^2 (3.5 mi^2), but only 0.3 km^2 (0.12 mi^2) of Type 3 river bottoms were noted in this stretch (Table 4-3). These results confirm the sediment sampling results of previous investigations, which found long, continuous deposits of soft sediment between Little Rapids and the river mouth (WDNR, 1995 and 1998; GAS/SAIC, 1996; Exponent, 1998).

4.2.5 Lacustrine Habitat of Green Bay

4.2.5.1 Overview

The lacustrine habitat of Green Bay is very different than the riverine habitats of the Lower Fox River. Lacustrine systems have deeper water, allowing a temperature stratification (thermocline) to develop. A thermocline is a thin layer of water that has a significant temperature gradient, separating warmer water above from colder water below. The presence of a thermocline provides large water bodies the ability to host many different species of fish and other aquatic organisms that may have a particular temperature preference. Numerous fish species can be found within different areas and at various depths of lacustrine habitat based on the water depth, temperature, and currents. Additionally, water temperature is a significant biological factor and indicator for many aquatic organisms.

Other unique aspects of lacustrine environments are related to water currents, sediment deposition and erosion, and the wetland complexes that develop therein. Unlike rivers, which normally have a unidirectional current (gravitational), lacustrine currents are more complex, variable, and weaker (Maitland and Morgan, 1997). Sediments transported from the Lower Fox River and other tributaries into Green Bay are deposited down current from the mouth as the river and bay waters mix and the water velocities decrease. Together with littoral transport, which moves sediments along a lake shore, these factors result in sediment accumulations (like the Duck Creek delta) and the spits, shoals, and shallows located near the tributary mouths on the west side of the bay (refer to Figures 3-4 through 3-6). Because wind, wave action, and currents are the primary causes for erosion and redeposition within the Great Lakes (USACE, 1998d), sediment erosion within Green Bay is largely confined to shore and near-shore areas where water depths are shallower. These actions may resuspend deposited sediment and move it through the bay. Lacustrine environments typically develop larger wetlands than riverine systems, especially in areas of extensive shallow water and low current velocities.

Lacustrine environments are generally categorized based on the biological conditions of the system and the three classifications are eutrophic, oligotrophic, and dystrophic. Lower Green Bay is eutrophic and hypereutrophic (extreme eutrophic conditions) while the northern portion of the bay is generally oligotrophic. The general characteristics of eutrophic and oligotrophic conditions are listed below (Maitland and Morgan, 1997). In addition, Green Bay is also mesotrophic in areas; the mesotrophic condition is an intermediate classification between the eutrophic and oligotrophic conditions.

General Trophic Classifications Which Apply to Green Bay

Character	Eutrophic	Oligotrophic
Basin shape	Broad and shallow	Narrow and deep
Substrate	Organic silt	Stones or inorganic silt
Shoreline	Weedy	Stony
Water transparency	Low	High
Water color	Green or Yellow	Blue or Green
Dissolved solids	High (much N/Ca)	Low (poor in N)
Suspended solids	High	Low
Oxygen	Low (especially under ice or thermocline)	High
Phytoplankton	Few species/high numbers	Many species/low numbers
Zooplankton	Few species/high numbers	Many species/low numbers
Macrophytes	Many species/some abundant	Few species/rarely abundant
Zoobenthos	Many species/high numbers	Many species/low numbers
Fish	Many species	Few species

Eutrophic lakes are nutrient rich, usually shallow, turbid waters that may experience oxygen deficiencies under the ice or in deeper areas at certain times of the year (Maitland and Morgan, 1997). Oligotrophic lakes are typically deep, clear waters that are nutrient poor and rarely, if ever, have oxygen deficiencies (Maitland and Morgan, 1997).

4.2.5.2 Inner Bay Water Quality

The southern end of Green Bay is a lacustrine estuary, which is a zone of transition from a riverine to lacustrine environment. An estuary is typically defined as a submerged river mouth, which may extend for some distance into a large body of water. Water depths in the AOC are generally less than 1.8 m (6 feet). This area ranges from eutrophic to hypereutrophic (Sager and Richman, 1991) and it has a long history of being a eutrophic water body.

The silty substrates, shallow water depths, extensive wetlands, and green color were all observed by the earliest explorers of the region. The process of eutrophication is natural and generally occurs over an extended period of time, as fresh waters tend to become silty. Potential nutrients within bottom sediments are typically only released when the water becomes shallow enough that macrophytes utilize them (Maitland and Morgan, 1997). This was the general state of the inner bay (particularly the southern end) when European settlers arrived in the region.

The hypereutrophic conditions of the lower bay were likely brought on by development, which greatly accelerated eutrophication. The Lower Fox River served as the primary disposal system for domestic and industrial wastes, which contributed significant quantities of nutrients (particularly phosphorous and nitrogen), to the bay through much of 20th century. Intense farming with heavy application of fertilizers, especially in the lowland areas of the rivers and lakes leads to enrichment of runoff waters with nutrients (Maitland and Morgan, 1997), and this has occurred in the Lower Fox River and Green Bay area (Harris, 1994).

Fish dies-offs on the east side of the bay in 1938-39 (Wisconsin State Board of Health, 1939) indicated the impacts of poor water quality and the lack of DO within the inner bay. Water quality and benthic community studies throughout the mid-1900s showed low DO. and degraded water quality. Recent waste treatment practices have greatly reduced the loads of organic material in the river and bay since the 1960s and 1970s and resulting in DO concentrations generally remaining above the standard of 5 mg/L (Harris, 1994). Since at least 1975 there have not been any large fish die-offs related to low DO levels (Lychwick, 2000c). However, DO concentrations have dropped below 5 mg/L during summer months when algal blooms occur (Harris, 1994). Recurring algal blooms are one sign that the eutrophic conditions of the southern bay continue today.

The shoal extending from Point Au Sable to Long Tail Point reduces the mixing ability within this part of the bay; water south of the shoal is hypereutrophic while water north of this area is classified as eutrophic (McAllister, 1991). There is also a trophic gradient within the inner bay that results from the currents described previously (Section 3.4). Satellite images from 1984 indicated that eutrophic water conditions extended along the east shore of the bay from the mouth of the Lower Fox River to Sturgeon Bay (Sager, 1986). Water along the east shore of the bay was more eutrophic than was the water flowing along the west side of the bay (McAllister, 1991). However, following the reduction of phosphorous and other chemical loadings during the 1980s, the water clarity north of the Long Tail Point improved, allowing re-establishment of wild celery in some west shore wetland areas (Harris, 1991; McAllister, 1991).

4.2.5.3 Outer Bay Water Quality

Sager and Richman (1991) documented that the northern half of Green Bay (the outer bay) is generally oligotrophic to mesotrophic. Much of the outer bay, especially in the deep-water areas of the eastern half, is oligotrophic, while conditions become mesotrophic moving south towards and past Chambers Island. Eutrophic conditions may be present in the shallow areas of Big Bay de Noc during the summer, as waters within both Big Bay de Noc and Little Bay de Noc are well mixed (Schneeberger, 2000). Conditions along the northwest shore of Green Bay, from Menominee, Michigan, to the north end of Little Bay de Noc, are suitable areas for mesotrophic conditions. The wetland areas, shallow waters, and bay tributaries located on the western shore likely foster eutrophic conditions, while the cold, oligotrophic waters of Lake Michigan flow through the central portion of the bay and along the western shore. Therefore, depending on the time of year and the local weather conditions, the north and northwest sides of the bay may experience all three water quality conditions.

4.3 Benthic Communities

The benthic macroinvertebrates of the Lower Fox River and Green Bay environment include adult and larval insects, mollusks, crustaceans, and worms that predominantly burrow directly into the fine-grained substrate for most of their life cycle. The benthic macroinvertebrate community plays a vital role in ecosystem functions such as nutrient cycling and organic matter processing. These creatures are also an important food resource for the benthic and pelagic fish communities, and semi-aquatic organisms such as birds and mammals feed on them occasionally as well.

Many of the benthic community surveys have focused on oligochaetes, chironomids, and the burrowing mayfly (*Hexagenia*). The oligochaetes and chironomids are thought to be tolerant of organic enrichment and/or degraded habitats, like that of the Lower Fox River and lower Green Bay, whereas other species are less tolerant of enriched/degraded habitats. *Hexagenia* are considered to be pollution sensitive or intolerant taxa.

Historical macroinvertebrates surveys completed between 1938 and 1978 examined populations and taxa richness near the mouth of the Lower Fox River and in lower Green Bay (Markert, 1978). The 1938-39 pollution survey found that oligochaetes and chironomids dominated the benthic communities. *Hexagenia* were also detected at 16 of 51 stations sampled in 1938-39 (Markert, 1978), suggesting that water quality conditions had not reached their worst in the bay. In addition, very low numbers of leeches, sowbugs, scuds, clams, and snails were all observed at various locations in 1938-39 (Markert, 1978).

Water quality deteriorated significantly between 1938-39 and 1952 as measured by the benthic community populations. Comparison of the 1938-39 and 1952 sampling data indicated that both the oligochaete and chironomid populations had increased. During 1938-39 oligochaetes and chironomids were completely absent in a few locations in the southern bay (Surber and Cooley, 1952). However, in 1952 established populations of both groups were observed at locations as far north as Oconto and Little Surgeon Bay, indicating that the water quality in the southern bay was progressively worsening (Surber and Cooley, 1952).

Similar deteriorating water quality results were noted in 1978 (Markert, 1978). In 1978, the density of oligochaetes and midges was greater than in 1938-39, while *Hexagenia* were not observed at all in 1978, indicating further degradation of water quality was continuing. However, comparison of the 1952 and 1978 sample results indicated that there was some improvement in water quality since the 1950s (Markert, 1978).

A number of studies completed in the late 1980s and 1990s evaluated the macroinvertebrate taxa richness and diversity in the Lower Fox River and Green Bay (Integrated Paper Services [IPS], 1993a, 1993b, 1994, and 1995; and WDNR, 1996). Similar to the historic surveys, these studies generally found that the benthic infauna of the Lower Fox River and Green Bay were dominated principally by oligochaetes and chironomids with round worms, flat worms, scuds, caddisflies, leeches, and sow bugs completing the inventory (IPS, 1993a and 1993b). Benthic macroinvertebrate communities from upstream reference sites and locations in Green Bay far from the mouth of the river were higher in taxa richness than the Lower Fox River sites. Similar to the historical results, mayflies were not found in the Lower Fox River or lower Green Bay, but were found in both the reference sites (WDNR, 1996 [*Caenis* sp.], Call, *et al.,* 1991 [*Hexagenia*]). However, it remains inconclusive if these lower infaunal and species counts were a result of organic enrichment, chemical contamination, poor physical conditions, or other factors.

The 1992-93 results reflect recovery from the severely impaired conditions found in the 1960s and 1970s (IPS, 1994). These results were bolstered in 1994 by the presence of snails, clams, and mussels at the LLBdM sites in deposits D and POG (IPS, 1995). The results of these early 1990s studies indicated that the density of the benthic community populations had increased significantly compared with studies completed during the 1980s in LLBdM (IPS, 1995). Downstream of LLBdM, in deposits N and EE/FF, the 1992-1994 benthic community results indicated that benthic community populations increased; however, oligochaetes and chironomids were still dominant and there was no corresponding increase in community diversity to accompany the population increase. Similarly, conditions in the middle and outer portions of Green Bay seemingly reflected an improvement in general water quality due to an increase in scuds and sow bugs, which were typically observed in more northern reaches of the bay (IPS, 1995). However, the presence of zebra mussels probably signals future difficulty for the benthic communities of Green Bay due to the ability of this exotic species to out-compete the local benthic species for food and habitat (IPS, 1995).

4.4 Fish

The WDNR has completed a number of fish surveys in the Lower Fox River and inner Green Bay. However, due to the numerous factors that may effect fish populations, simple review and comparison of the survey results from various years is not valid. Year to year fish populations do not necessarily indicate whether conditions within the river and bay are degraded or improving because other environmental, physical, or biological factors may be impacting select species at any given time. Surveys reviewed for the Lower Fox River and Green Bay zones 1 and 2 provide data on the fish present within the system. In addition, the personal observations from WDNR and MDNR personnel familiar with both the commercial and sport fisheries of Green Bay are included. The RA addresses the possible population impacts that result from anthropogenic and natural stresses.

Fish samples collected for PCB analysis are included in the FRDB and the fish surveys summarized herein are population counts only and include those species evaluated in the RA or RA food web model. Therefore, this discussion is not intended to be a comprehensive evaluation of all species in the system. Rather, this summary provides insight into the role that fish have in PCB uptake into the food chain. Further analysis of PCB uptake are included in the RA.

Environmental degradation of the Lower Fox River and Green Bay either directly or indirectly impacts the resources of the Oneida and Menominee Nation Trust Lands. Issues of concern to both tribes are addressed herein. The fisheries of the Lower Fox River and Green Bay are important to the Oneida and Menominee Indian Nations for cultural reasons. Fish have historically been a staple part of the diet of the Oneida and Menominee people as a major source of protein because fish can be dried, canned, salted, or smoked for use throughout the year (Stratus, 1999b).

4.4.1 LLBdM to De Pere Dam Fish Surveys

The WDNR has conducted a number of fish population surveys of the Lower Fox River in association with water quality studies. The surveys listed below consist of tabulated data only and are unpublished. They were completed during several time periods with a variety of survey equipment and for different purposes. Therefore, is not appropriate to analyze whether particular data indicates an increasing or decreasing population because the factors affecting fish populations are much more complex than the survey numbers may suggest.

WDNR Lower Fox River Fish Surveys

Survey Area	Year(s)	WDNR Investigators	Purpose
LLBdM to De Pere	1976	Marinac & Coble	Determine species present and relative abundance
Rapide Croche to Wrightstown	1976	Langhurst	Evaluate stocks as water quality improves in the future
LLBdM to Wrightstown	1977	Meyers	Community and populations
LLBdM	1983	Meyers	Evaluate northern pike populations and spawning areas
LLBdM to Wrightstown	1993/1994	Bruch & Lychwick	Fisheries and habitat status
Little Rapids to De Pere	1994/1995	Lychwick	Population surveys

The fish population results from these studies are summarized on Table 4-4. At least 43 different fish species were identified in the river upstream of the De Pere dam (Table 4-4). Twenty-four species were game fish and nineteen species were non-game fish (as defined by state statute). The 1983 LLBdM fish survey indicates that approximately 60 percent of the species captured were game fish, and that black bullhead and black crappie were the predominant type (Table 4-4).

Population results for the LLBdM to the De Pere dam indicate that game fish typically comprise about 30 percent to 40 percent of the fish captured (Table 4-4). Yellow perch, walleye, white bass, and bullheads have all been the dominant game fish species at one point or another. The 1994-95 walleye results for the Little Rapids to De Pere Reach suggests that improved water quality due to decreases in the suspended solid load have facilitated an increase in the walleye populations. (Lychwick, 2000b). Carp was the most prevalent fish observed upstream of the De Pere dam. Carp typically accounted for 50 percent to 90 percent of non-game fish and approximately 50 percent to 60 percent of the all fish captured in the surveys.

4.4.2De Pere to Green Bay/Duck Creek Fish Surveys

WDNR has conducted surveys in Green Bay zones 1 (the De Pere to Green Bay Reach) and 2 and in Duck Creek. These surveys are discussed together because these areas are interconnected and fish found within any of these waters may also inhabit other areas.

The Oneida Indians came to Wisconsin from New York in the 1800s. Duck Creek lies within the Oneida Reservation and became an important resource for the tribe because of the abundant waterfowl and fish associated with it. Because PCBs have been found within fish caught in Duck Creek, the results of the 1998 Duck Creek fish assessment are summarized here. The assessment was completed cooperatively by the USFWS, WDNR, and Oneida Nation. Although the Duck Creek assessment is published (Cogswell and Bougie, 1998), the 1987 through 1998 survey data for the De Pere to Green Bay Reach are only tabulated and unpublished. The two surveys summarized in this section are listed below.

WDNR Green Bay Zones 1 and 2 Fish Surveys

Survey Area	Year(s)	WDNR Investigators	Purpose
De Pere to Green Bay	1987/1998	Lychwick	Evaluate early spring spawning populations
Duck Creek Assessment	1995/1996	Cogswell/Bougie	Populations survey spring through fall

The fish population results from these studies are summarized on Table 4-5. Annual fyke net surveys were completed by WDNR for the De Pere to Green Bay Reach between 1987 and 1998 (Table 4-5). Only the data from April of each year is listed on Table 4-5 due to the different length of time each survey was conducted.

Game fish account for 70 percent to 90 percent of the total captured fish population. The dominant game fish typically include yellow perch, which is also one of the primary commercial species in the bay, as well as walleye, white bass, and white perch. Furthermore, walleye is the only other game fish that generally comprises more than 10 percent of the total fish population (Table 4-5). This may reflect the success of the historic WDNR walleye stocking programs, as there is now a sustainable natural reproducing population (Lychwick, 2000b). Non-game fish below the De Pere dam are predominantly carp, white sucker, drum, and quillback.

In Duck Creek, 21 species (7 non-game and 14 game fish) were observed that were also present in the De Pere to Green Bay Reach (Cogswell and Bougie, 1998). In addition to the species listed on Table 4-5, 34 other fish species were also observed in Duck Creek. However, many of these were small non-game fish like shiners, chubs, and darters. Cogswell and Bougie (1998) found that the fish-supporting capacity of Duck Creek is limited by several factors, including low water flow, low DO, high water temperatures, and degraded water quality. Duck Creek is an intermittent stream and has been significantly impacted by the agricultural activities of the watershed. Sediment erosion from tilled fields has been found to account for over 75 percent of the total phosphorous load in the creek (WDNR, 1997).

Walleye and northern pike of Green Bay frequented several tributaries during their life. Walleye and northern pike originally tagged within the Lower Fox River were found in Duck Creek, and 46 percent of the northern tagged in Duck Creek were recaptured at several locations in Green Bay (Cogswell and Bougie, 1998). Also, the age and size range of the walleye captured in Duck Creek was similar to those in the Lower Fox River during spring (Cogswell and Bougie, 1998), indicating fish migration between Green Bay and its tributaries. Similarly, Lychwick (2000a) indicated that tagging studies in the De Pere to Green Bay Reach (Green Bay Zone 1) and Green Bay Zone 2 revealed that fish migrate between the bay and river. These results suggest that the fish move to locations where food and habitat characteristics are favorable.

4.4.3 Green Bay Fishery Observations and Habitat

To facilitate analysis of PCB uptake in the RA, the Project Team has categorized fish of Green Bay into four groups (Table 4-6). These groups include salmon/trout, benthic, pelagic, and game fish. Many of the salmon and trout of the region are found in cold-water fisheries of the northern part of Green Bay. The benthic fish are those that generally feed or live near the bottom of the bay while the pelagic fish are those which typically feed or live near the water surface. The game fish listed on Table 4-6 are those typically sought by sport or commercial fisherman.

The general spawning areas in Green Bay for each of these fish groups is shown on Figures 4-8 and 4-9 (NOAA, 1997c). The NOAA (1997c) spawning data only extended to a line just north of Door County, Wisconsin. Therefore, additional spawning observation data for the remaining portion of Zone 4 were obtained from the Great Lakes Commission (GLC) (2000). Whereas the NOAA (1997c) data identified the spawning locations by select fish group and species, the GLC (2000) data did not include such distinctions. Rather, GLC (2000) data is simply shown as points on Figures 4-8 through 4-12 indicating locations where fish spawn.

Spawning areas for the salmon/trout are in the vicinity of the tributaries and the central portion of the bay, where water temperatures are generally colder (Figure 4-8). The spawning areas for the pelagic and benthic fish are similar (Figures 4-8 and 4-9) and concentrated mainly in the areas of significant wetlands (Figures 4-5 and 4-6). Game fish spawning areas are also similar but include additional areas on the east side of the bay, likely due to the fact that some species, like walleye, prefer gravel beds to the SAV associated with the wetlands.

Most of the species discussed herein are pelagic fish (shiners, gizzard shad, smelt, and alewife) as indicated on Table 4-6. Yellow perch and walleye are game fish, carp and sturgeon are benthic species, and brown trout represent the salmon/trout group. Identified spawning areas for most of these fish in the southern half of Green Bay are shown on Figures 4-10 through 4-12. In the northern portion of the bay, walleye spawn in the river tributaries, and along the reefs, shorelines, and islands of both Big Bay de Noc and Little Bay de Noc while yellow perch spawn in the shallow waters of these bays (Schneeberger, 1999). Alewife, gizzard shad and shiners all spawn in the nearshore waters of both bays while carp are concentrated in the northern end of Little Bay de Noc and along the shoreline of Big Bay de Noc (Schneeberger, 1999). Smelt historically ran in most of the rivers and streams in the area but have recently been spawning in more offshore waters as well (Schneeberger, 1999).

The Green Bay fishery habitat varies based on the water characteristics and bay bathymetry. Green Bay zones 2 and 4 are quite different in terms of their physical characteristics and this affects species distribution and trophic complexity. Green Bay Zone 2 is hypereutrophic (warm and highly productive), while Zone 4 is meso-oligotrophic (cooler and less productive). Related distinguishing characteristics of Zone 4 are lower population densities of fish, less trophic complexity, clearer water, and less human development compared to Zone 2 (Brazner and Beals, 1997; Sager and Richman, 1991).

The following summary is based on the observations and personal communications of Mike Toneys and Brian Belonger (WDNR) and Phil Schneeberger (MDNR).

Green Bay south of the Peshtigo Reef (west side) and Sturgeon Bay (east side) is generally a warm water fishery, with eutrophic water conditions, significant plankton populations, and numerous fish species (Toneys, 1999; Belonger, 2000). This fishery is separated from the cold-water fishery to the north by localized currents between the Peshtigo Reef and Sturgeon Bay (Figures 3-2 and 3-3) and differing trophic conditions in this area (Lychwick, 2000b). North of Peshtigo Reef and Sturgeon Bay the fishery is a cold water, meso-oligotrophic system with reduced plankton populations and fewer fish species (Schneeberger, 2000).

Heavily pursued sport fish south of the Sturgeon Bay-Peshtigo line include walleye, yellow perch, northern pike, and spotted muskellunge (muskie). Small mouth bass, brown trout and salmonids are also pursued north of Sturgeon

Bay-Peshtigo (Toneys, 1999; Belonger, 2000). The yellow perch and alewife are the predominant commercial species in the southern area, especially during the summer. During the winter, the lake whitefish become an important commercial species. The whitefish prefer cold waters and are fished in the northern bay year-round. However, whitefish migrate south in pursuit of food when water temperatures decrease in the southern end of the bay (Toneys, 1999; Belonger, 2000). Tagging studies of yellow perch and small mouth bass indicate that these fish tend to stay within the area where they were caught. For example, yellow perch caught in the warm waters of the southern bay do not typically migrate to the cold water fishery in the northern bay (Toneys, 1999). Similarly, the Sturgeon Bay Canal is prone to seiche effects and water temperature changes of 5.5°C to 11°C (10°F to 20°F) in a single day, which tend to limit the movement of fish through this channel (Toneys, 1999). Therefore, fish within Green Bay may move into Lake Michigan and vice-versa, but this canal is not a significant migration route (Toneys, 1999).

A thermocline has been observed in the Sturgeon Bay-Peshtigo area, and this also influences fish movement in the bay. The thermocline tends to form and stay near a depth of 3 to 12 m (10 to 40 feet), based on weather conditions. If a consistent northeast wind is experienced, this may push the thermocline down to depths of approximately 18 m (60 feet) (Belonger, 2000).

In northern Green Bay, walleye, yellow perch, northern pike, splake, chinook salmon, small mouth bass, white bass, and carp are all sought by sport fishermen. In Michigan, the annual sport catch of walleye may range between 30,000 and 90,000 kg (66,100 and 198,400 pounds) while the yellow perch catch is on the order of 10,000 to 80,000 kg (22,050 to 176,400 pounds) (Schneeberger, 2000). Lake whitefish and rainbow smelt are the main commercial species. The annual whitefish catch ranges from 1 million to 1.5 million kg (2.2 million to 3.3 million pounds) while the smelt catch is on the order of 50,000 to 200,000 kg (110,230 to 440,900 pounds) (Schneeberger, 2000).

The commercial fishery for lake whitefish has increased significantly over the last 20 years and the catches are near an all-time high (Belonger, 2000; Schneeberger, 2000). In the northern half of Green Bay, the walleye fishery ha; also increased in the number of fish caught for each hour of fishing and the total numbers of walleye taken (Schneeberger, 2000).

The overall patterns of fish abundance, species distribution, and habitat use in Green Bay have been recently well characterized by Brazner and colleagues at the University of Wisconsin (Brazner, 1997; Brazner and Beals, 1997, Brazner and Magnuson, 1994). Each of these papers summarized data collected from 24 stations extending the whole length of Green Bay (eight stations in each zone). All of these stations were along the western side of Green Bay except for one station near Point Au Sable on the eastern side of Zone 2. The two habitats targeted for sampling were wetlands (12 stations) and sandy beaches (12 stations). Half of the stations for both of these habitats were located in developed areas while the other half were located in undeveloped areas.

The stations were sampled in the summer and fall of 1990 and 1991, and in the spring of 1991. Almost 42,000 fish were caught and analyzed over these sampling periods and these fish represented 54 species and 20 families. Most of these fish (86 percent) were immature (younger than 2 years old), likely because of the small mesh sampling gear used which favored selection of younger age classes of fish.

These data collected by Brazner and colleagues were analyzed to determine to what degree fish preferentially used different regions of the bay, the habitats within those regions, and to what degree human development impacted habitat use. Statistical analyses including cluster analysis, ordination, and discriminant analysis, indicated that regional differences most strongly influenced fish assemblages, followed by habitat differences, and the least determining factor was development status.

Brazner and Magnuson (1994) found that more fish preferred the near shore wetland habitats to beaches, which have fewer plants and stronger wave action. Brazner (1997) indicated that fish populations in the vicinity of undisturbed wetlands were greater than those in disturbed wetlands or beach areas. More forage species and the majority of the game fish captured, including yellow perch and bluegills, were taken in the vicinity of undisturbed wetlands. The highly productive (eutrophic) southern bay provided a better forage base for fish than did the meso-oligotrophic northern end (Brazner, 1997). This is very important for young fish, which almost all forage on zooplankton at some point during maturation (Brazner, 1997).

Approximately half (49 percent) of all the fish collected came from Zone 2, most of them captured in undeveloped wetlands, and only 16 percent came from Zone 4. Not only was abundance greater in Zone 2, but also species richness. Of the regional characteristics measured, turbidity was determined to be the best predictor of fish abundance. Other important regional characteristics included water temperature, conductivity, and pH (Brazner and Beals, 1997).

Habitat differences adequately defined fish assemblages for Green Bay zones 3 and 4, but they were not a good predictor for Zone 2 (Brazner and Beals, 1997).

Macrophyte level was the habitat characteristic that best predicted fish assemblages. When macrophyte cover and richness is high, the same is generally true of fish richness and abundance (Brazner and Beals, 1997). An exception to this is where macrophyte cover is so dense that it has limited utility for fish.

Turbidity, in addition to being a primary regional characteristic, is a key limiting factor to macrophyte growth and, therefore, habitat differences (Brazner and Beals, 1997). Areas that are highly turbid, such as Green Bay Zone 2, have less developed macrophytes, whereas Zone 4, which has clear waters, has well developed macrophytes. Overall, these differences have resulted in lower biomass, and vegetation-dependent fish in Zone 4 (centrarchids, northern pike, golden shiners) and higher biomass, more turbidity-tolerant fish communities in Zone 2 (gizzard shad, white bass, common carp) (Brazner and Magnuson, 1994). Turbidity in Zone 2 is assumed to be equally influenced by biotic (phytoplankton production) and abiotic (erosion, runoff, and resuspension) factors (Brazner and Beals, 1997). Brazner and Beals (1997) estimated that 70 percent of the water contained within Zone 2 (Long Tail Point to Point Sable) originates from the Lower Fox River.

In terms of individual species, spottail shiners were the most abundant fish, with over 122,000 individuals caught in the spring of 1991 (Brazner, 1997). Catch of this species was not dependent on habitat type, but was dependent on region; 93 percent of the catch was obtained from Zone 2. Excluding the Zone 2 catch data, spottail shiners were still one of the top five most abundant species caught. The remaining top five species caught were yellow perch, alewife, spotfin shiner, and bluntnose minnow. Yellow perch represented about 25 percent of the approximately 42,000 fish caught, and spottail shiner represented approximately 22 percent.

For 21 of the 54 fish species caught, either more than 80 percent of the individuals or at least a significant number of them were caught in one zone. These results demonstrate that regional differences were stronger determining factors of fish assemblage than habitat or development. Of these 21 zone-biased fish species, freshwater drum, white bass, and gizzard shad were caught almost exclusively in Zone 2, and golden shiners, pumpkinseeds and logperch were most often caught in Zone 4 (Brazner, 1997). Although rainbow smelt, trout, perch, and banded killfish were predominantly caught only in Zone 3, none of these were the most abundant fish taken in this zone.

The bay zone and habitat of the specific fish species that have been selected for risk evaluation of the Lower Fox River and Green Bay are summarized below (Brazner, 1997).

Fish Species	Dominant Zone Occurrence	Dominant Habitat
Yellow Perch	Green Bay Zone 2 (74 percent)	wetland habitat (74 percent)
Spottail Shiner	Green Bay Zone 2	beach habitat
Alewife	Throughout bay	beach habitat
Gizzard Shad	Green Bay Zone 2	various habitat
Emerald Shiner	Green Bay Zone 2	various habitat
Common Shiner	Throughout bay	wetland habitat
Golden Shiner	Green Bay Zone 4	undeveloped wetland habitat
Common Carp	Green Bay Zone 2	undeveloped wetland habitat
Rainbow Smelt	Green Bay Zone 3	beach habitat
Trends for brown trout and walleye were not evaluated because an insufficient number of individuals were collected. Only two brown trout and nine walleye were caught as part of these efforts		

4.4.4 Life Histories of Fish Species in the Lower Fox River and Green Bay

The section describes the important receptor species identified in the RA. The discussion also illustrates the interactions of fish within the Lower Fox River and Green Bay system and the uptake of PCB into the food chain. The fish discussed herein represent only a small segment of the fish community in the system.

4.4.4.1 Shiners (Minnows)

Shiner species found in the Lower Fox River and Green Bay include golden shiner (*Notemigonus crysoleucas*), emerald shiner (*Notropis atherinoides*), and common shiner (*Notropis cornutus*). The shiners, as well as carp, are in the family Cyprinidae.

All shiner species are relatively small forage fish that average 5 to 10 cm (2 to 4 in) in length. Golden shiners are silver with a dusky stripe along their side and a small, almost vertical mouth. Common shiners are olive on top with a dark stripe running down the middle of their back, and one or two stripes along their upper sides. Emerald shiners are light olive on top, with a dusky stripe along their back, a silver stripe with emerald reflections along their side, and a large mouth.

Shiners generally inhabit shallow areas with limited current and are rarely found in riffles, but common shiners can tolerate some turbidity (Becker, 1983). Frequently these fish are found over similar substrates (sand, mud, gravel), but common and golden shiners are more dependent on vegetation than emerald shiners (Becker, 1983). Water temperatures can strongly influence the distribution of these fish; preferred temperature is 25˚C (77˚F), but common and golden shiners have been shown to tolerate temperatures up to 34˚C (93˚F) (Becker, 1983). These open water fish rarely go below the thermocline (11 to 15 meters). Interestingly, golden shiners have a remarkable ability to survive under low dissolved oxygen conditions. In Michigan lakes when oxygen levels were between 0 and 0.2 mg/kg, golden shiners have survived where other fish have not (Becker, 1983).

Due to the number of species present in Wisconsin, spawning occurs between May and August (Becker, 1983). Shiners are typically stream spawning fish (USFWS, 1983b), and typically prefer to spawn over gravel shoals and bottoms or other silt-free, firm substrates where water currents are prevalent and sufficient to supply much-needed dissolved oxygen to the eggs. However, the golden shiner is an exception to this rule, since this species spawns over beds of submerged vegetation and have even been noted to fail to spawn within pools in which aquatic vegetation was absent (Becker, 1983). Most species of shiners will spawn in the nests of other fish. The most important factor affecting spawning is water temperature, with different species spawning instinct reacting to different water temperature regimes (Becker, 1983). The number of eggs that develop within the female is largely related to age and body weight and dependent upon the species of concern.

Most species of shiners are omnivorous, feeding equally on plant and animal matter (USFWS, 1983b). They are known to feed at the bottom of streams or lakes, in the wet column and near the surface. Males typically grow faster and larger than females, and they range in lengths from about 9 to 20 cm (3.5 to 8 inches), depending on the age, sex, and species of shiner observed (USFWS, 1983b; Becker, 1983).

Due to their relatively small size, shiners are preyed upon by many game fish, including bass, crappies, walleye, northern pike, and muskellunge. Birds such as pied-billed grebes, mergansers, bitterns, green herons, night herons, kingfishers, and bald eagles also prey on shiners (Becker, 1983).

4.4.4.2 Gizzard Shad

Gizzard shad (*Dorosoma cepedianum*) is an abundant omnivore in many central and southern United States lakes (Shepherd and Mills, 1996), and are found throughout the Lower Fox River and the southern half of Green Bay. Gizzard shad, along with alewife, are members of the herring family Clupeidae. Adults are generally 28 cm (11 in) in length. Gizzard shad have a distinctive whip-like dorsal ray. They are silver-blue colored above, silver-white on the sides, and they have six to eight dark stripes on their top and upper sides.

Gizzard shad thrive in warm, fertile, shallow water bodies with soft, muddy bottoms and high turbidity (USFWS, 1985), which essentially describes lower Green Bay. If few predators abound, gizzard shad populations can quickly explode and become a nuisance. Additionally, gizzard shad are often abundant in large sluggish rivers, lakes, swamps, and bayous (USFWS, 1985), and they typically travel in schools close to the surface. Spawning typically occurs between late April/early May through August (Becker, 1983), and may extend over a period of 2 weeks for any given female. Gizzard shad typically spawn in shallow rivers and streams. Females may produce upwards of 380,000 eggs (Becker, 1983), although some researchers have found mean egg production to be about 13,000 eggs per individual (USFWS, 1985). However, after age two, the gizzard shad's egg production generally declines, sometimes rapidly.

Gizzard shad typically live less than 6 years, reaching lengths of 28 to 41 cm (11 to 16 in) and weighing around 0.91 kg (2 pounds). However, specimens ranging up to 52.1 cm (20.5 in) and weighing 1.6 kg (3.5 pounds) (Becker, 1983) and other specimens age 10 or 11 have been recorded (USFWS, 1985).

Gizzard shad feed in both the limnetic zone and along bottom sediment, with their diet being controlled largely by the local environment. Shad captured in open water have been observed to feed on free-floating plankton whereas shad captured in streams were found to feed on littoral vegetation and small aquatic insect larvae (USFWS, 1985). In lakes, young fish feed almost exclusively on zooplankton while larger fish feed on zooplankton, phytoplankton, insect larvae, and detritus (USFWS, 1985).

Being an essentially an open water species, living at or near the water surface (Becker, 1983, USFWS, 1985), they are preyed on by numerous species. Young-of-year (YOY) shad are important to sport fish and water fowl because of their rapid growth rates, making them a "short and efficient link in the food chain that directly connects basic plant life with sport fish" (Becker, 1983). They are also an important food source for numerous waterfowl and wading birds (Becker, 1983).

4.4.4.3 Rainbow Smelt

Rainbow smelt (*Osmerus mordax*) are widespread and abundant non-indigenous pelagic planktivores in the Great Lakes (Jones, *et al.,* 1995). Smelt are common and are an important prey in Green Bay but are not found above the De Pere dam in the upper Fox River. These fish average 15 to 20 cm (6 to 8 in) in length, but despite their small size, they have comparatively large mouths. Rainbow smelt are olive colored on top, and sliver with blue or pink iridescence on their sides. They also have a silver stripe on their sides.

Spawning occurs on sandy beaches near river mouths in the Great Lakes between late March and early May when the water temperatures reach 4˚C (39°F), and lasts approximately 2 weeks. Spawning in Green Bay may be a week or two behind spawning in northern Lake Michigan because Green Bay remains covered with ice longer (Becker, 1983). Female smelt typically release no more than 50 eggs during each spawning session and, once released, the eggs sink immediately to the bottom of the stream, where they become attached to the substrate (Becker, 1983). Development of the eggs takes about 20 to 30 days, and once hatched, smelt fry are transparent and about 5.5 to 6 mm (0.22 to 0.24 in) long (Becker, 1983).

While YOY fish are pelagic, they move towards a bottom existence as they age. The fish often school offshore, prefer cool clear water, and are most abundant in water depths of 18 to 26 m (59 to 85 ft), although they can be found in water depths of 14 to 64 m (46 to 210 ft) (Becker, 1983). Optimum temperatures range from 6.1˚C to 13.3˚C (43˚F to 56˚F), and feeding temperatures peak at 10˚C (50˚F). Rainbow smelt reach sexual maturity in approximately 2 years (at that time they are about 170 mm [6.7 in] in length) and can live up to 8 years (Becker, 1983). Males live approximately 5 years, reaching a length of about 21.8 cm (8.6 in), while females typically live about 7 years and reach a length around 31 cm (12.2 in) (Becker, 1983).

Full-grown smelt subsist principally on larger crustaceans (like opossum shrimp). However, in the inshore waters they may consume a large number of fishes, including YOY alewife, YOY smelt, and sticklebacks, while other researchers have found them to feed on smelt, shiners, yellow perch, burbot, and rock bass, as well as mayfly larvae and chironomid (Becker, 1983). Smelt have supplanted chubs as the principal food of Lake Superior's trout population and their importance on the food chain in Lake Michigan may be similar. Brook trout, brown trout, lake trout, whitefish, herring, walleye, yellow perch, northern pike, and burbot all prey on smelt.

Rainbow smelt are an exotic species in the Great Lakes, belonging to the family Osmeridae, which is essentially a marine family (Becker, 1983). Smelt were likely introduced into the Great Lakes as forage fish for salmon. The first recorded smelt catch was off the coast of Michigan in 1923 (Becker, 1983). Originally, these fish were regarded as a nuisance species, with hordes of them invading and becoming entangled in nets (UWSGI, 2000a). However, in the 1930s, smelt runs up the small streams and tributaries of Lake Michigan developed into an avid sport using dip-nets or seining and the cities of Oconto and Marinette, Wisconsin attracted 20,000 to 30,000 people to festivities scheduled to coincide with these runs (UWSGI, 2000a; Becker, 1983). Smelt are only found within the Lake Michigan and Lake Superior basins.

Smelt have suffered occasional die-offs that have significantly reduced the populations. According to local Green Bay fisherman, smelt runs typically last only one night, when previously, these runs might have lasted anywhere from seven to ten days (Stiller, 1998).

The decline in the commercial smelt catch and the shorter smelt runs in the Green Bay tributaries may be due to a number of factors, including the following:

- Increased predation of smelt by burbot, trout, and salmon (Belonger, 2000), or
- Spawning occurring within the shallow waters and nearshore habitat of Green Bay rather than in the tributaries (Belonger, 2000).

4.4.4.4 Alewife

Alewife (*Alosa pseudoharengus*) are non-indigenous small anadromous pelagic planktivores that prefer open water and sandy habitats. Alewife, along with shad sardines, and menhaden, are members of the herring family Clupeidae, which are predominantly marine species. Individuals of these landlocked populations are generally half the size (averaging approximately 16 cm [6.3 in] in length) of the marine alewife (approximately 36 cm [14.2 in] in length) (Scott and Crossman, 1973). Alewife are blue-green colored on top and sliver on the sides, with thin dark stripes on their top and upper sides.

The alewife is abundant in Lake Michigan and Green Bay, and Becker (1983) indicated that alewives constituted 70 to 90 percent of the fish biomass in Lake Michigan. Alewives inhabit all levels of the lake and bay over all bottom types. However, they avoid cold water when possible, and during winter they migrate to the deepest and warmest water of the lake/bay (Becker, 1983). Alewives swim in dense schools and are the major prey of the trout, salmon, and other fish in the lake (UWSGI, 2000b). In 1974, it was estimated that coho salmon consumed approximately 36 to 45 million kg (80 to 100 million pounds) of alewife, which was about 5 percent of the total alewife biomass (Becker, 1983). Also, more than

8.16 million kg (18 million pounds) have been caught and processed primarily as poultry feed since 1966 (Becker, 1983).

Alewife populations in Lake Michigan have varied widely. In the 1920s in Lake Michigan, sea lampreys were introduced and greatly reduced the number of large predatory fish. Therefore, when the alewife were introduced in the 1940s, they had few predators and populations had an opportunity to increase. In the 1960s and early 1970s, alewife were the dominant forage fish accounting for 70 to 90 percent of fish by weight in Lake Michigan. Lamprey populations peaked in the 1950s, but in the late 1950s lamprey populations control methods were found. Since then, lamprey populations have been markedly reduced. In the early 1980s, alewife populations in Lake Michigan began to decline dramatically (Mason and Brandt, 1996). This decline, and the continued lower levels of alewife, are believed to be related to predation by trout and salmon which are its primary predators (Flath and Diana, 1985); walleye and perch also prey on alewife. Additionally, alewife die-offs are believed to occur because of rapid temperature changes and wide fluctuations in temperature (Hewett and Stewart, 1989). Severely cold winters, and the spring and summer return of alewife to shallow warmer waters, can initiate die-offs (Scott and Crossman, 1973). This species is likely more temperature sensitive than other species because it is naturally adapted to marine conditions where temperature variations are not as dramatic.

Alewife travel in dense schools, move towards nearshore waters in the spring (mid-March and April), and spawn during the early summer. Spawning occurs from June to August and in Lake Michigan; peak spawning occurs in the first 2 weeks of July (Becker, 1983). Preferred temperatures for spawning have been estimated at 13˚C to 16˚C (55˚F to 61˚F) in Lake Ontario, although temperatures can also vary widely from 5˚C to 22˚C (41˚F to 72˚F).

Spawning typically occurs from June through August, in water less than 3.05 meters (10 feet) deep with no preference concerning bottom type (Becker, 1983). Females produce from 11,000 to 22,000 eggs. In Lake Michigan, schools of 5,000 to 6,000 spawning fish have been observed densely packed in areas of 4.5 to 6 meters (15 to 20 feet) in diameter (Becker, 1983). Alewife typically live less than 8 years, generally reaching lengths of 15.2 to 20.3 cm (6 to 8 inches) and weighing 113 to 227 grams (g) (4 to 8 ounces [oz]) (UWSGI, 2000b; Becker, 1983). Alewife fry are both phototropic and pelagic, feeding on zooplankton. However, as they grow, the water depth in which the fish feed largely controls the diet. Zooplankton predominate for fish which feed nearshore, while amphipods are consumed in water depths over 9 meters (29.5 feet) deep (Becker, 1983). Additionally, gastropods have been found in alewives captured in the littoral zone, indicating the alewives feed on the bottom to some extent. Researchers have found that alewife consume *Daphnia* preferentially in the southern portion of Green Bay (Becker, 1983). Brandt, *et al.,* (1980) found that the distribution of juvenile and adult alewives differs with temperature. YOY alewives reach maximum abundance when daytime water temperatures exceed 17˚C (62.5˚F) while adult alewives prefer water temperatures of 11˚C to 14˚C (52˚F to 57˚F).

The alewife is an exotic species, first noted in Lake Erie in 1931; by 1953 these fish had made their way throughout the Great Lake system and were observed in Lake Superior. Although the presence of the alewife has had some positive aspects, there are significant negative consequences associated with this exotic species. Alewives have reduced the number of perch, herring, chubs, and minnows through direct competition with the young of those species for plankton and other small aquatic organisms which compose the diet of these fish (UWSGI, 2000b). Alewife also prey on the young of the species (Becker, 1983). Additionally, annual die-offs litter the beaches, resulting in aesthetically displeasing odors. Alewife have also been known to clog the intake pipes of power plants and municipal water filtration plants (Becker, 1983).

4.4.4.5 Yellow Perch

Yellow perch (*Perca flavescens*) are native to the Lower Fox River and Green Bay, and are one of the most important fish of Wisconsin and Michigan in terms of both the commercial and sports fishing industries. The yellow perch, along with the walleye, is a member of the perch family Percidae. Yellow perch average 15 to 25 cm (6 to 10 in) in length. They are green colored on top, whitish on the underside, and they have distinct green-brown vertical bands extending down yellow sides.

Preferred habitat for yellow perch is shoreline areas with sand, gravel or muddy sediments, modest to moderate amount of aquatic vegetation, and water depths of less than 10 m (30 ft) in clear lakes with temperatures of 18˚C to 21˚C (64˚F to 70˚F) (Becker, 1983; Scott and Crossman, 1973; USFWS 1983a). A study examining the frequency of littoral fishes in a Wisconsin lake determined that yellow perch (YOY and adults) were highly associated with complex macrophyte beds (Weaver, *et al.,* 1997). Of the sites examined, the only locations where yellow perch were not caught were two sites having the lowest abundance of vegetation. Turbidity adversely affects growth of juveniles and temperatures of 32˚C (90˚F) can be lethal, but yellow perch are tolerant of low oxygen levels. In Lake Michigan, oxygen levels of 0.1 to 0.3 parts ppm killed numerous yellow perch, but many also survived (Becker, 1983). Bluegill, largemouth bass, and walleye are fish species that cannot survive low oxygen concentrations.

Perch are a schooling species that feed during the day and rest on the bottom at night. Schools of yellow perch may range from 50 to 200 fish and usually are associated with feeding activities conducted during daylight hours.

Yellow perch normally spawn shortly after ice-out in April or early May, when water temperatures range between 7.2˚C and 11.1˚C (45˚F and 52˚F), and may continue for 8 to 19 days (Becker, 1983). During spawning, the eggs are usually deposited in sheltered areas and they are frequently draped over emergent and submergent vegetation or submerged brush in water depths of 0.6 to 3 m (2 to 10 ft). Rocks, sand or gravel may be used when submergent vegetation is not available (USFWS, 1983a). The fish may travel long distances during the migration. Lake Winnebago perch may swim from 48 to 81 km (30 to 50 mi) up the Fox River before they reach suitable spawning habitat (Becker, 1983). Egg production in the female yellow perch is extremely variable and depends on the size of the fish; researchers have observed anywhere from less than 1,000 to 210,000 eggs in select fish in Minnesota and Wisconsin (Becker, 1983), with greater fecundity in larger individuals. Eggs are released in strands up to 2.15 m (7 ft) in length and up to 10 cm (4 in) in width (Becker, 1983).

Similar to walleye, yellow perch provide no protection for the eggs or fry (Becker, 1983), which hatch anywhere from 8 to 27 days following spawning. The speed with which hatching occurs depends on water temperature (Becker, 1983). Shorter hatching periods are typically associated with warm water while 27-day hatching periods have been observed in 8.5˚C to 12˚C (47˚F to 53˚F) water (Becker, 1983). Larvae are approximately 0.5 cm (0.2 in) upon hatching and they swim to the surface, where they remain in the upper 0.9 to 1.2 m (3 to 4 ft) of water for the first 3 to 4 weeks. Microscopic zooplankton are important to the survival of perch fry. If the zooplankton are too large, the young fry perish (Becker, 1983). YOY perch continue to consume zooplankton and other aquatic insects until they are quite large. Perch do not typically begin to feed on other fish until they have reached a length of about 18 cm (7 in) or more, sometime between the age of 3 and 4 years (Becker, 1983).

Mature yellow perch generally range in length from 15 to 25 cm (6 to 10 in) and from 170 to 454 g (6 to 16 oz) (UWSGI, 2000c). Males reach maturity in about 1 year while females mature in 2 years in Green Bay (Belonger, 2000). In Wisconsin waters, yellow perch generally live about 7 to 10 years (USFWS, 1983a). Brandt, *et al.,* (1980) found that the distribution of juvenile and adult perch differs with temperature. Juvenile perch catches are highest in waters 15˚C to 20˚C (59˚F to 68˚F) while catches of adult perch are greatest in waters that are 7˚C to 8˚C (44.5˚F to 46.5˚F).

Young yellow perch are preyed upon by all fish-eating species, including muskie, northern pike, burbot, smallmouth and largemouth bass, bowfins, bullheads, and lampreys (Becker, 1983). However, walleye and yellow perch have a special relationship. Each species preys on the other at different times in the life cycle: large walleye feed on yellow perch, while yellow perch feed on walleye fry. Additionally, perch eggs are eaten by aquatic birds and other animals, and the fish are eaten by gulls, terns, mergansers, herons, grebes, ospreys, and kingfishers (Becker, 1983).

Populations of yellow perch in Lake Michigan have widely fluctuated. As previously discussed, yellow perch year-class strength has been inversely related to abundance of alewife (Brandt *et al.,* 1987; Mason and Brandt, 1996). Between 1889 and 1970, average catch rates were 2.4 million pounds per year from Green Bay. However, because of the dramatic decline in perch since 1990 (a loss of 80 percent of the population), Wisconsin banned commercial fishing and reduced daily recreational limits to five individuals per day. These restriction became effective in January 1997. Additional factors that possibly adversely affect the yellow perch populations include the following:

- Increase in white perch populations, which feed on the YOY perch and also compete with adult perch for food.

- Introduction of zebra mussels into the benthic community, which aggressively compete for the zooplankton species which yellow perch fry and YOY also consume (Belonger, 2000).

4.4.4.6 Carp

Carp (*Cyprinus carpio*) is an abundant bottom-dwelling species found in southern Green Bay. Along with shiners, the carp are within the minnow and carp family Cyprinidae. Adult carp have been found to range in length from 41 to 58 cm (16 to 23 in) and weigh from 1 to 10 kg (2.2 to 22 pounds) (Weber and Otis, 1984). Carp have two distinct barbles on each side of the upper jaw. These fish are grey/grey-green colored on top, have a dark edge on the upper side, white to yellow on the underside.

Carp tolerate of turbidity, low dissolved oxygen, pollution, and rapid temperature changes better than most any other fish in North America (Becker, 1983). Although they are tolerant to a wide range of conditions, they prefer shallow lakes and streams that have abundant aquatic vegetation and are warm (Becker, 1983). Part of its ability to tolerate low oxygen is because it can use atmospheric oxygen. The preferred temperature for this fish in Wisconsin is 32˚C (90˚F), but this is within the range of temperatures that have been found to be lethal (31˚C and 34˚C), and above a temperature at which spawning could occur (Becker, 1983).

Carp have the ability to range widely; some tagged fish have traveled 1,090 km (680 mi), and a carp tagged in Lake Winnebago was recaptured 148 km (92 mi) away (Becker, 1983). Most tagging studies of carp have found that they are generally recaptured within a few kilometers (Becker, 1983). Generally carp are wary and bolt for vegetation and cover or deeper water with little provocation. The exception to this behavior is during spring when spawning occurs (Becker, 1983).

Spawning occurs from April to August in Wisconsin and peaks in late May to early June when temperatures range from 18˚C to 28˚C (64˚F to 82˚F) (Becker, 1983; Scott and Crossman, 1973). An investigation of spawning carp in Lake Winnebago and nearby lakes, determined that carp preferred to spawn in areas of shallow vegetated waters (0.15 to 1.2 m [.49 to 3.9 ft] deep) (Weber and Otis, 1984). These preferences have also been supported by other authors (Becker, 1983; Scott and Crossman, 1973). A single female carp may release 50,000 to 620,000 eggs during the primary spawning period (Becker, 1983). Carp eggs float through the water and, due to an adhesive coating surrounding the egg, attach themselves to underwater vegetation, debris, or any other object to which the egg will adhere (USFWS, 1982). Spawning over areas with dense vegetation will increase the success of reproduction, but some studies have indicated that carp will not spawn in water cooler than 16˚C (60˚F).

Incubation lasts for 3 to 16 days depending on the temperature (Becker, 1983). Young move off vegetation 4 to 5 days after hatching, and go to the bottom (Becker, 1983). Through their first summer, carp fry are strongly associated with vegetation as protective cover in 15 to 30 cm (6 to 12 in) of water (Weber and Otis, 1984). Young carp leave this shallow weedy habitat when they are 76 to 102 mm (3 to 4 in) and generally too large for predators to consume (Becker, 1983). After the first season of growth, carp are generally 13 to 19 cm (5 to 8 in) long (Scott and Crossman, 1973). Although young carp are food for both birds and other fish, when they reach 1.4 to 1.8 kg (3 to 4 pounds), they are too large to be a prey item. Carp are generally mature at age 2 (males) or 3 (females) and usually live for 9 to 15 years (Becker, 1983).

Carp are omnivorous, feeding equally on plant and animal matter (USFWS, 1982). The fry initially feed on zooplankton, but will also feed on phytoplankton if necessary. As young fish grow, they feed on littoral and later bottom fauna, taking in worms and the larvae of insects as well as vegetation, such as seeds, algae, and detritus (USFWS, 1982). Adult carp are opportunistic feeders, and are able to utilize any available food source (USFWS, 1982; Becker, 1983). Male carp generally mature between 2 and 4 years while female carp take about 3 to 5 years to mature. Typically, carp grow to be about 38 to 56 cm (15 to 22 in) in length and weigh up to 3.2 kg (7 pounds) (UWSGI, 2000d). However, the maximum weight reported for carp in north America is 42.1 kg (93 pounds) (USFWS, 1982).

Carp have been harvested commercially from the Great Lakes since the first recorded catch in 1893 until contaminants closed the fisheries in the early 1980s in Green Bay. Carp, especially young carp, are preyed upon by many game fish, including bass, crappies, northern pike, bowfin, turtles, snakes, loons, grebes, and mergansers, and carp eggs are preyed upon by minnows, catfish, and sunfish (Becker, 1983).

4.4.4.7 Walleye

Walleye (*Stizostedion vitreum*) is a popular, year-round game and commercial fish found in Lake Michigan, generally in areas less than 7 m (23 ft) deep (Magnuson and Smith, 1987). The walleye is the largest member of the perch family (Percidae - a group that includes sauger, darters, and yellow perch) in North America. It is not a member of the pike family as commonly believed. Walleye have strong canine teeth and very large mouths that extend past the eye (Becker, 1983). Walleye are yellow-olive/brown colored on top and brassy yellow-blue along sides. They have five to twelve dusky saddles that become less visible as they age (Becker, 1983).

Walleye are found throughout the Fox and Wolf River basins and their connecting lakes, as well as Green Bay (Becker, 1983). Walleye are tolerant of a range of environmental conditions, particularly turbidity and low light, but they are not tolerant of low oxygen levels. Winter kills due to low DO conditions have occurred in Wisconsin (Becker, 1983). Walleye prefer quiet waters over sand, gravel, and mud substrates (Becker, 1983). They generally rest in deep dark waters during the day and migrate to rocky shoals and weed beds to feed at night, but they may be active during the day if it is cloudy or the waters are turbid (Becker, 1983). YOY fish can be found near the sediments in 6 to 10 m (19.7 to 32.8 ft) of water (Scott and Crossman, 1973), but can be caught in surface waters up to lengths of approximately 35 mm (1.5 in) (WDNR, 1970). Larger fish are generally in depths of 14 m (45.9 ft) or less and form loose schools (Scott and Crossman, 1973). Schooling is common during feeding and spawning.

Walleye generally spawn between mid-April and early May, and they have specific spawning habitat requirements (Becker, 1983; USFWS, 1984). Preferred spawning habitat are shallow shoreline areas, shoals, riffles, and dam faces with rocky substrate and good water circulation from wave action and currents (USFWS, 1984). The fish may travel long distances to spawn. Lake Winnebago walleye, for instance, may swim 100 miles up the Wolf River before they reach suitable spawning habitat (Becker, 1983). The female walleye will lay an average of 50,000 eggs and generally spawns out completely in one night. Summer territories and spawning grounds are distinct areas. The range of summer area is generally limited to 3 to 8 km (1.9 to 5 mi), but the recorded range has varied from 0.8 to 110 km (0.5 to 68.4 mi). A study of walleye in Lake Poygan found that walleye traveled an average distance 47 km (29.2 mi) (Becker, 1983).

Walleye spawn soon after the ice melts and temperatures reach 3˚C to 7˚C (37˚F to 45˚F), and spawning peaks when temperatures are 6˚C to 10˚C (43˚F to 50˚F) (Becker, 1983). In Lake Winnebago, the timing of spawning has been recorded as a 2- to 3-week period between the first week in April and the first week in May (WDNR, 1970). Walleye from Green Bay move upstream into the Fox River to spawn; however, their movement is restricted by the De Pere dam (Magnuson and Smith, 1987). Walleye do not build nests and spawning occurs at night generally on gravel bottoms, but they can spawn on vegetation. In Lake Winnebago, flooded marsh areas are preferred spawning grounds (Becker, 1983). Continuous flowing water over the eggs is important for hatching success.

Fry move off wetlands a day or two after hatching and obtain an open water existence. They stay in open water until they are about 30 mm (1.25 in) and then return to shore around June (Becker, 1983). By the end of July, walleye in Lake Winnebago are about 75 mm (3 in) or larger. At this size, walleye shift from a zooplankton-only diet to also include fish and invertebrates. By fall they are generally 130 mm (5 in) (Becker, 1983).

Female walleye grow faster and become larger than males; however, growth of the walleye is dependent upon the food supply, temperature, and population density (USFWS, 1984). Female walleye reach maturity in 3 to 6 years and males reach maturity in 2 to 4 years (Scott and Crossman, 1973). In Wisconsin waters walleye generally live about 7 to 10 years (UWSGI, 2000e), but walleye can live more than 20 years (Lychwick, 2000a) in Green Bay.

4.4.4.8 Brown Trout

Brown trout (*Salmo trutta*) is a popular, seasonally caught game fish in Green Bay. These fish range in length from 41 to 61 cm (16 to 24 in) and weigh from 0.9 to 3.6 kg (2 to 8 pounds). These fish are light brown to brown-black in color with red and black spots, but on the lower sides and stomach, they are generally silver in color. Brown trout have large jaws.

As compared to other species of trout, brown trout grow faster, live longer, and better tolerate degraded habitats, warm temperatures (up to 29˚C [84°F]), and turbidity (Becker, 1983). They are fairly common in cold waters of Wisconsin, and self-sustaining populations in Lake Michigan are enhanced with stocking. In Green Bay, this species is generally limited to the northern two-thirds of the Bay, which contain deeper and colder waters. Preferred temperatures are 10˚C to 18˚C (50˚F to 64˚F) (Becker, 1983). In addition, brown trout tagging studies indicate that these fish move between the waters of northern Green Bay and Lake Michigan (Toneys, 1999).

Brown trout are most often found along the shore in waters no deeper than 15 m (50 ft) (Becker, 1983) and they have been known to inhabit waters along the west shore of Green Bay from the towns of Oconto and Marinette (Magnuson and Smith, 1987). Wild brown trout fingerlings that were tagged have been found to travel an average of 16 km (10 mi) in 1 year. Hatchery-reared trout released in Wisconsin waters generally remained within 24 km (15 mi) of the release point, but some tagged fish after 1 year were found to range up to 323 km (200 mi) (Becker, 1983).

Spawning occurs when waters are close to 8˚C (46˚F), in autumn and early winter (October to December). Spawning areas are shallow waters with gravel bottom substrate, generally stream headwaters rather than rocky shores, but spawning does occur in lakes along rocky reefs. Females build nests and males defend them. Unlike salmon, these fish do not die after they spawn and most individuals spawn more than once. During spawning these fish may school; crowding and schooling are not tolerated when these fish are not spawning (Becker, 1983). Generally, brown trout are sexually mature at 2 years old and live for approximately 7 years.

Brown trout tend to be nocturnal feeders, and food items can include aquatic and terrestrial insects, crustaceans, mollusks, frogs, shrimp, salamanders, and other fish. Zooplankton are an important food source for small brown trout (Becker, 1983). Up to about 229 mm (9 in) they are insect feeders and past this length they dominantly (70 percent of the diet) consume fish such as young trout, sculpins, minnows, darters, and lampreys (Becker, 1983). Magnuson and Smith (1987) found that brown trout collected in the spring from Green Bay Zone 3 dominantly consumed alewife (73 percent of the diet); rainbow smelt were the other 27 percent of the identified forage fish consumed. Half of the brown trout collected in the fall in this region of the bay had empty stomachs and, therefore, prey consumption was not evaluated (Magnuson and Smith, 1987). Presumably, this was about the same time as their spawning. It is suspected that over the summer, brown trout, like walleye, increase their consumption of rainbow smelt (Magnuson and Smith, 1987).

4.4.4.9 Sturgeon

The Menominee Indians have lived in Wisconsin longer than any other tribe. The lake sturgeon is included in this section because it was the most important fish to the Menominee Indians for both cultural and religious reasons. The Menominee Nation historically celebrated the return of the lake sturgeon (*Namä'o* in Menominee) at Keshena Falls on the Wolf River, a tributary of the Lower Fox River (Beck, 1995). Return of the sturgeon in spring was a cause for religious celebration because of its importance as a food source after the winter, when the supply was typically lowest (Beck, 1995).

Prior to the 1800s, lake sturgeon (*Acipenser fulvescens*) were common and abundant in the Lake Michigan, Lake Superior, and Mississippi River drainage basins (Becker, 1983). Lake sturgeon were also abundant in Green Bay and the larger tributaries, including the Fox-Wolf, Menominee, Peshtigo, and Oconto rivers (USFWS, 1998). Native American populations, especially the Menominee Nation, utilized the sturgeon for various cultural and spiritual purposes and annually celebrated the return of the sturgeon to its ancestral spawning grounds within the Lake Winnebago-Wolf-Upper Fox River system (USFWS, 1995). Areas where sturgeon either spawn or have been observed within the Lower Fox River or Green Bay are shown on Figures 4-1 through 4-4 and 4-10. Because the sturgeon are a threatened species, spawning locations are approximate and are shown as a block representing the nearest township, range and section (Natural Heritage Inventory, 2000).

Following the establishment of the commercial fishing industry, sturgeon were viewed as a nuisance fish because they became entangled in and ripped fishing nets. During this period, they were simply thrown onto the shore and left to rot (Becker, 1983; Beck, 1985). After 1870, a large commercial fishing industry subsequently evolved for sturgeon. The roe was prized for caviar, the flesh was delicious either smoked or fresh, and the high-quality gelatin material isinglass was obtained from the swim bladder.

Due to the aggressive fishing and length of time required for sturgeon to mature and reproduce, the abundance of lake sturgeon had declined so much that by the 1880s and 1890s it was no longer worth pursuing (USFWS, 1998). Along with the loss of suitable spawning habitat and the construction of dams along many of the significant tributaries, especially on the Lower Fox River, sturgeon populations declined to levels from which they have never fully recovered. Becker (1983) recounts that the Lake Michigan sturgeon catch in 1880 was 1,741,600 kg (38,839,600 pounds); in 1966 only 907 kg (2,000 pounds) of sturgeon were taken from the lake. The state of Michigan has listed the lake sturgeon as a threatened species (Table 4-6).

Sturgeon were also valued by Native American populations due to its large size and longevity. Lake sturgeon typically live 50 and 80 years, growing to lengths up to 2.4 meters (8 feet) long and maturing slowly (Becker, 1983; USFWS, 1998). Historical records from the 1800s indicate that lake sturgeon weighing over 45.4 kg (100 pounds) and measuring over 2 meters (6.5 feet) were captured near Milwaukee (USFWS, 1998). Previous researchers found that over 97 percent of sturgeon captured which were more than 30 years old were female (Becker, 1983).

The slow growth and maturity rate of sturgeon may be one reason that significant decreases in sturgeon populations over a very short period have had such a crucial impact on the current and future populations. Males typically mature in about 15 years and are usually about 114 cm (45 inches) at this age. Additionally, most males spawn every 1 to 2 years. However, female sturgeons mature more slowly and spawn less frequently. Females typically mature when they are about 24 to 26 years old and about 140 cm (55 inches) long. Unlike the males, female sturgeon only spawn once every 4 to 6 years and typically produce and release anywhere between 50,000 and 700,000 eggs (Becker, 1983).

Without teeth, sturgeons rely on suction to feed, much like suckers and other bottom-feeding fish. Sturgeon feed on small organisms including insect larvae, snail, leeches, small clams, and other invertebrates. Although not typically preyed upon by other fish, Becker (1983) notes that otter have been noted to drag sturgeon from the water onto the ice of Lake Winnebago in the winter and that suckers, carp, crayfish, and other sturgeon may prey upon the sturgeon eggs.

4.5 Birds

The terrestrial and aquatic habitats of the Lower Fox River and Green Bay provide food, protective cover, nesting areas, and resting locations for both regional and migratory birds and waterfowl. Birds associated with the river and bay are divided into seven groups, and include the following:

- Passerines
- Gulls and Terns
- Diving Birds

- Shorebirds
- Wading birds
- Waterfowl
- Raptors

Some of the most common birds in the region are shown on Table 4-7. The species list (Table 4-7) was developed by the Project Team for use in the RA, based on the species' importance with respect to uptake of PCBs into the food chain within each group and its status as a threatened or endangered species. A brief description of each bird group is presented below.

Information about the probability of sighting a specific bird was taken from Temple, *et al.* (1997), which is a summary of data collected by WDNR, the University of Wisconsin, and the Wisconsin Society for Ornithology. Sightings have been collected by professional and amateur bird watchers using a standardized format since 1982. Figure 4-13 shows the general distribution of the birds within these groups throughout Green Bay (NOAA, 1997c). As with the fish data in Zone 4, bird data obtained from the GLC (2000) did not differentiate specific species. Therefore, locations where birds of concern either nest or have been observed in Green Bay Zone 4 are simply shown as points on Figures 4-13.

4.5.1 Passerine Birds

A large number of passerine birds exist within the Lower Fox River and shorelines of Green Bay. Common passerine species include blackbirds, wrens, sparrows, and swallows (Table 4-7). These birds typically feed on insects, seeds, and small invertebrates found through foraging along the ground. The passerines listed on Table 4-7 for the Green Bay area include six species of blackbirds, wrens, and sparrows. A large number of blackbirds, wrens, sparrows, and swallows feed on the insects or insect larvae which are found in and above the surface water of the Lower Fox River and Green Bay. Additionally, typical habitats for these birds are wetlands, open meadows, and grasslands (Exponent, 1998; Harrison and Greensmith, 1993). The blackbirds tend to nest in loose colonies while sparrows and wrens typically nest individually (Harrison and Greensmith, 1993). These birds are migrant to partially migrant, and dependent on local winter weather conditions and food supply (Harrison and Greensmith, 1993). None of the passerines are listed on state or federal endangered/threatened species list (Table 4-7).

The red-winged blackbird (*Agelaius phoeniceus*) is the most common bird within this group found in Wisconsin. The annual probability of sighting this bird is well over 95 percent and they are typically found in Wisconsin from late February through late November (Temple, *et al.,* 1997). The likelihood of sighting the other birds in this group (Table 4-7) ranges from approximately 35 to 55 percent, and these species are usually sighted between April and October (Temple, *et al.,* 1997).

Tree swallows (*Tachycineta bicolor*) are also common migratory songbirds that breed in and migrate through the Lower Fox River and Green Bay. Tree swallows nest in semi-colonial groups in natural cavities (trees, posts, streambanks) near water. Tree swallows feed exclusively on insects, predominately aquatic insects. Tree swallow population data is not available from the Lower Fox River and Green Bay because studies of these birds in this region have used artificial nest boxes rather than relying on naturally nesting populations (Ankley, *et al.,* 1993; Custer, *et al.,* 1998). The annual probability of sighting this bird is about 80 percent and they are typically found in Wisconsin from April through September (Temple, *et al.,* 1997).

Both the red-winged blackbird and the tree swallow are protected under the Migratory Bird Treaty Act.

4.5.2Gulls/Terns

The gulls/terns group for the Green Bay area includes two species of gulls and four species of terns (Table 4-7). All six of these species feed on fish, insects, and eggs, as well as scavenging for other food over open water or in wetland areas (Exponent, 1998; Harrison and Greensmith, 1993). These birds tend to nest in large colonies (Harrison and Greensmith, 1993). The black (*Chilidonias niger*) and Forster's (*Sterna forsteri*) terns prefer to nest in marsh areas while the other four species prefer to nest on the ground, often on remote islands or in areas protected from predators (Exponent, 1998). The annual probability of sighting the tern species in Wisconsin ranges from approximately 25 percent to 45 percent, while the likelihood of sighting the two gulls is about 65 percent (Temple, *et al.,* 1997). The two gulls remain in the area throughout the year, while the terns migrate to other areas. The terns are typically present in Green Bay from April through October (Temple, *et al.,* 1997).

The Forster's, Common (*Sterna hirundo*), and Caspian (*Sterna caspia*) terns are migratory species of colonial waterbirds that breed in the Great Lakes and generally winter in more southern coastal areas. In Wisconsin, the Caspian, Common, and Forster's terns are endangered species while Caspian and Common terns as threatened species in Michigan (Table 4-7). All three of these terns are protected under the Migratory Bird Treaty Act (Exponent, 1998). Due to the tern's endangered status within Wisconsin, the locations of tern nests in the

Lower Fox River and Green Bay area are presented as blocks on Figures 4-1 through 4-4 and 4-13.

Based on the protected status of these three terns, a number of studies have been conducted to evaluate the remaining Green Bay populations, as well as the effects of PCB uptake through the consumption of bay fish. These birds typically nest on islands where they are generally safe from predators. The primary nesting locations for Forster's terns are the Bay Port and Kidney Island CDFs, Long Tail Point, and the Oconto Marsh. Common terns primarily nest on Kidney Island and the Pensaukee Dredge Spoil Island while the Caspian tern nesting colonies are on Gravelly and Gull Islands, located just south of Summer Island between Green Bay and Lake Michigan (Stratus, 1999c).

Tern populations have generally been increasing over the past 20 years. From 1978 and 1987 the nesting pairs of Forster's terns observed in the state of Wisconsin increased from 136 pairs to 435 pairs, while the population of Common terns increased from 60 pairs to 600 pairs between 1979 and 1986. Similarly, the number of Caspian tern nests located on Gravelly and Gull Islands increased from about 600 to over 1,000 between 1977-78 and 1991. This increase is reflective of the overall Great Lakes Caspian tern population, which has grown by at least 90 percent since the 1970s (Stratus, 1999c). Although the tern populations continue to increase, the impacts of PCB uptake are evident and well documented (Stratus, 1999c).

Both common and Forster's tern were listed in 1979 as endangered in the state of Wisconsin. To enhance population success, Forster's tern platforms were placed at several locations in the state, including Green Bay. The six monitored island platforms in Green Bay indicated feeding, but not nesting activity. For the common tern, fencing and ring-billed gull control have been used to enhance breeding success. However, due to the difficulty in maintaining them, these platforms are no longer placed in these areas (Nikolai, 2000b).

Around the Green Bay area, nesting Forster's terns have been reported since the late 1930s, although they were likely nesting without record prior to this period. The Forster's tern preferred habitat is around wetlands, and terns feed mainly on small fish (alewife, emerald shiner, and rainbow smelt) and on some aquatic invertebrates. Forster's tern population levels are generally believed to have declined over the past 100 years in Wisconsin due in part to marsh draining and other habitat disturbance, plume hunting, and potential chemical contamination (Mossman, 1988). For example, nesting at the Duck Creek delta was abandoned in 1973, likely because of high water and loss of emergent vegetation; nesting pairs moved to the Bay Port CDF (Mossman, 1988). In 1987, Kidney Island was the only known nesting location in Green Bay.

Population data reported in June 1997 for the previous year indicates that for both species, population status is uncertain and requires additional study (Matteson, 1998). Six common tern colony sites are present in Wisconsin and two are in Green Bay: Kidney Island CDF and the Pensaukee Dredge Spoil Island, with an estimated number of breeding pairs of 16 and 75, respectively. Similarly, nine Forster's tern colony sites are located in Wisconsin, and Long Tail Point and the South Oconto Marsh have about 70 and 45 breeding pairs, respectively.

As with the Forster's tern, both inland and coastal populations of Common terns have faced recent historical population declines during the 1950s to the 1980s. It is believed that these declines were due to nesting site competition with ring-billed gulls, decreased adequate habitat, high water levels, human disturbance, predation, and organochlorine contamination (Matteson, 1988). For the Great Lakes region, some of the highest population levels were measured in the 1980s. In Southern Green Bay, there were 135 recorded nesting pairs in 1976, 427 in 1985, 577 in 1986, and 280 in 1987. In 1997, one Common tern nesting pair was recorded at Kidney Island and 74 nesting pairs were recorded at Pensaukee (Cuthbert, 1998).

4.5.3 Diving Birds

Diving birds include the horned and pied-billed grebes, double-crested cormorants, common loon, and belted kingfisher. All of these birds feed on fish, diving beneath the water to capture their prey; the two grebes also feed on aquatic insects (Exponent, 1998; Harrison and Greensmith, 1993). All of the birds tend to nest along the shore or in wetlands, with the two grebes preferring shallow water nests, while the cormorant may also nest slightly off the ground (Exponent, 1998; Harrison and Greensmith, 1993). Both the loon and kingfisher are listed as migrant birds, while the other three species are listed as partial migrants (Harrison and Greensmith, 1993).

The annual probability of sighting most of the birds ranges from 50 percent to over 80 percent in Wisconsin, and the best times are between March and November (Temple, *et al.,* 1997). The exception is the horned grebe, which only migrates through the area to locations further north; therefore, the likelihood of sighting this bird is less than 30 percent and chances are best between March and May and again between September and December (Temple, *et al.,* 1997). None of the diving birds are listed on state or federal endangered/threatened species list.

Double-crested Cormorants. Double-crested cormorants (*Phalacrocorax auritus*) are a migratory species of colonial waterbird that breed in the Great Lakes and generally winter in coastal areas, including Alaska. These birds nest in large communities in a variety of habitats including cliffs, grassy slopes, low bushes, or dead trees. Cormorants consume approximately 25 percent of their body weight each day and on average weigh 1.9 kg (4.2 pounds). Their primary food is small fish, such as rainbow smelt, alewife and even perch, when available.

Similar to the terns described above, numerous studies have been conducted to evaluate double-crested cormorant populations and the effects of PCBs. Prior to the 1960s, it is estimated that at least several hundred nesting pairs of cormorants were located throughout the state. Beginning in the 1950s and continuing through the 1970s, the double-crested cormorant population in the Great Lakes region experienced large population declines, largely from the presence of contaminants. More recently, populations of double-crested cormorants in the Great Lakes region have greatly increased (Weseloh, *et al.,* 1994).

In 1972, the double-crested cormorant was listed as a Wisconsin state endangered species due to the lack of nesting pairs of birds in the state. Beginning in 1973, state, academic and federal agencies (WDNR, USFWS, National Parks Service, University of Wisconsin, Wisconsin Society of Ornithology) combined efforts to catalog the colony location, size, and reproductive success of the double-crested cormorant throughout Wisconsin. By 1986, populations in the state increased such that the double-crested cormorant was removed from the Wisconsin state endangered species list.

Prior to 1979, inland breeding populations exceeded the number of nesting birds on the Great Lakes. Since 1990, however, the Great Lakes population of double-crested cormorants has exceeded the inland population levels by approximately five times (Matteson, 1998). The nesting population in the Green Bay and Lake Michigan region, as of 1997, accounted for 81 percent of the total breeding population (Matteson, *et al.,* 1998). The largest colonies for double-crested cormorants in Green Bay are Cat, Jack, Hat, and Snake islands (Stratus, 1999c). Of these islands, Cat Island is located closest to the mouth of the Fox River and contains the second highest density of double-crested cormorants. Cormorant nesting locations along the Lower Fox River and Green Bay are shown on Figures 4-1 through 4-4 and Figure 4-13.

4.5.4 Shorebirds

The shorebirds group for the Green Bay area includes eight species of plovers, sandpipers, and snipe (Table 4-7). As indicated by the name, birds within this group feed and nest along the shore, typically foraging for small crustaceans, insects, worms, and other invertebrates (Harrison and Greensmith, 1993). These birds nest along the ground, sometimes on rocky or sandy shores and others within marsh or wetland areas.

The common snipe and spotted sandpiper are the most sighted birds within this group in Wisconsin. These birds are generally present from April/May through September/October and have an annual sighting probability of about 50 percent (Temple, *et al.,* 1997). The likelihood of sighting the other birds within this group ranges from approximately 15 percent to 25 percent as these species generally migrate further north. Therefore, these birds are generally present around May, and then may be sighted between late June and October (Temple, *et al.,* 1997). The piping plover is very uncommon in the region and it is listed on Michigan, Wisconsin, and federal endangered species lists (Table 4-7).

4.5.5Wading Birds

The wading birds group for the Green Bay area includes 13 species of heron, woodcock, rail, egret, bittern, and crane (Table 4-7). As indicated by the name, birds within this group typically feed in shallow, near-shore waters and emergent wetland areas. They typically forage for small fish and crustaceans, amphibians, insects, worms, and other invertebrates (Harrison and Greensmith, 1993).

Within this group, the bitterns, rails, and woodcock are generally small birds, ranging in height from 18 to 51 cm (7 to 20 inches). These birds, along with the sandhill crane, generally nest on the ground. The herons, egrets and cranes are much larger birds, ranging from 61 to 122 cm (24 to 48 inches). The herons and egrets generally prefer to nest in trees but, if necessary, will nest in marshes and lowlands if suitable habitat is not available (Harrison and Greensmith, 1993). Rookeries for both the great blue and black-crowned night herons are located in the Thousand Islands Nature Conservancy as well as in Green Bay (Nikolai, 1998). The herons, woodcock, and crane, are common in Wisconsin and the UP from mid-spring through mid-fall (Temple, *et al.,* 1997), as these are all migratory birds. However, the likelihood of sighting a bittern is less than 30 percent, and both egrets and rails are very uncommon in the area (Temple, *et al.,* 1997). The king rail, least bittern, snowy egret, and yellow rail are each included on one of the state or federal threatened or endangered species lists (Table 4-7). However, yellow rail habitat is maintained in the Seney National Wildlife Refuge, located north of Lake Michigan in the central portion of the UP where these birds have been consistent summer residents since the 1800s (De Vore, 1999).

4.5.6Waterfowl

The waterfowl of the Green Bay area includes 21 different species (Table 4-7). These birds typically feed in the water on plants, insects, aquatic organisms, shellfish, crustaceans, and occasionally on small fish (Exponent, 1998; Harrison and Greensmith, 1993). Waterfowl tend to nest in or very near water, generally preferring swamps and marshes to open water habitat (Exponent, 1998; Harrison and Greensmith, 1993). Some of these birds may nest in loose colonies while others nest individually.

Waterfowl are typically migratory birds; however, the location of their summer and winter destinations plays a significant role of when particular species are present in the Green Bay area. Mallard and Black ducks as well as Canada geese are present in the area throughout the year and the annual probability of sighting for these species ranges from 50 percent up to about 95 percent (Temple, *et al.,* 1997). Coot, teal, ruddy, and wood ducks are all present in the bay from early spring through late fall and are somewhat common, with sighting probabilities ranging from 50 percent to 75 percent (Temple, *et al.,* 1997). A number of species migrate further north into Canada during the summer; some winter in the Green Bay region, while others migrate further south, spending only a short time in the area. The species which winter in the area include mergansers, goldeneye, the greater scaup, and bufflehead. These species are fairly common in the area, with sighting probabilities of 30 percent to 60 percent (Temple, *et al.,* 1997). Species which pass through the region, typically found anywhere between March and May and again in October and November, include the canvasback, redhead, and ring-necked ducks, as well as the lesser scaup, northern shoveler, and whistling swan. These species are also fairly common, with sighting probabilities ranging from 35 percent to 55 percent (Temple, et *al.,* 1997). Being migratory in nature, waterfowl are generally protected under the Migratory Bird Treaty Act (Exponent, 1998). However, many of the ducks and geese included in this group are game species, with an established hunting period that occurs during October in Wisconsin and Michigan.

Since at least 1975, WDNR has completed a mid-winter waterfowl survey to evaluate the numbers of migratory waterfowl wintering along the Lower Fox River. The results from these surveys indicate that, overall, the number of migratory water fowl in the region have increased from between 1,000 to 2,000 individuals in the 1970s to well over 4,000 individuals recently. These populations are controlled by many factors, including the severity of the winter weather and access to an adequate supply of food. However, increases in bird populations, especially among the primarily piscivorous birds, like the goldeneye and the mergansers, suggests that the populations are increasing from survey lows observed in the 1960s and 1970s (Nikolai, 1998).

4.5.7 Raptors

The raptors included in this group are the bald eagle, osprey, peregrine falcon, and merlin. The bald eagle and the osprey tend to be piscivorous, feeding on suckers, northern pike, muskellunge, bullheads, as well as small mammals, waterfowl, other birds, and carrion (Exponent, 1998; Harrison and Greensmith, 1993). Eagles and ospreys prefer open water areas, but, when necessary, eagles will hunt in open meadow and light woodlands (Harrison and Greensmith, 1993). Bald eagle and osprey nesting locations (both active and inactive nests) in the Lower Fox River are shown on Figure 4-1 through 4-4 while nesting locations within Green Bay are shown on Figure 4-13. The two falcon species typically hunt other birds or small mammals. Preferring open land, they are not generally found in heavily forested areas (MDNR, 2000).

Typically, these birds nest in high places, such as the tops of trees or rock ledges (Exponent, 1998; Harrison and Greensmith, 1993). Of the four species listed on Table 4-7, the eagle and osprey are more common in Wisconsin than the peregrine falcon or merlin. The annual probability of sighting the eagle and osprey is around 55 percent and 45 percent, respectively (Temple, *et al.,* 1997). The likelihood of sighting the two falcons is less than 25 percent, as both are less common in the area. The eagle winters within the Green Bay/Lake Michigan area, simply moving as necessary in order to find open water for hunting (MDNR, 2000). However, the osprey and the falcons are migratory birds and generally return to the region from March through October (Temple, *et al.,* 1997). The peregrine falcon is listed as an endangered species in both states and federally (Table 4-7). The bald eagle, osprey, and merlin are listed threatened species in Michigan and federally, while in Wisconsin only the osprey is listed as a threatened species (Table 4-7). These birds are also protected under the Migratory Bird Treaty Act (Exponent, 1998).

Bald Eagles. Of the raptors within the Lower Fox River and Green Bay, bald eagles are of special concern because of their federally protected status, and their known sensitivity to chlorinated hydrocarbons. Eagle populations around the Great Lakes were virtually eliminated in the 1960s - an occurrence believed to be mostly the result of chlorinated hydrocarbon toxicity (Bowerman, 1993). This correlation is supported by the fact that as DDE and PCBs were banned from use in the United States in the mid-1970s, evidence of bald eagle nesting success increased. However, there was a lag time of approximately 10 years before bald eagle nesting success noticeably increased.

Bald eagles (*Haliaeetus leucocephalus*) are one of the largest raptors in North America. Their preferred habitat is one in which there is a large water-to-land edge area and where there are large areas of unimpeded view (Palmer, 1988). Eagles are not generally found in areas of high human use (EPA, 1993a). Within the Great Lakes area, some eagles are present throughout the year, while others are transient and winter in more southern locations (Palmer, 1988). The Green Bay region contains one of the largest number of nesting eagles in the United States, excluding Alaska (Palmer, 1988).

The return and recovery of bald eagles has been well documented in both Wisconsin and Michigan (Bowerman, 1993; Dykstra and Meyer, 1996; Meyer, *et al.,* 1997), and includes surveys along the Lower Fox River and Green Bay. These studies have been summarized by the USFWS (Stratus, 1999c). The following section summarizes the Stratus (1999c) analysis of the information taken principally from those reports.

Bald eagle populations have generally been increasing throughout the Great Lakes (Stratus, 1999c). However, despite population increases, the eagles nesting on the shores of Lake Michigan still exhibit reproductive rates lower than those of neighboring birds in inland Wisconsin and Michigan (Dykstra and Meyer, 1996 citing Colborn, 1991; Bowerman, 1993). The overall productivity of Green Bay/Lake Michigan eagles was reported at more than 60 percent below the normal rate of inland Wisconsin eagles (Dykstra and Meyer, 1996).

The return of the bald eagle to Green Bay began in 1974, when a single pair of nesting eagles were observed. Both the WDNR and the MDNR initiated annual surveys, and between 1974 and 1986 only one to two pairs of nesting eagles were observed in Green Bay and the eastern side of the Door Peninsula. Beginning in 1987, nesting pairs increased and by 1997 there were 14 nesting pairs (Stratus, 1999c). Bald eagles returned much later to the Lower Fox River. The number of breeding pairs of eagles nesting along the Lower Fox River went from one in 1986 to three in 1994 to two since 1995 (Stratus, 1999c).

Bald eagles arrive back at their nesting territories in the assessment area in February, and the young fledge between early June and July. Depending upon ice conditions, bald eagles may remain in the assessment area during the winter; up to 12 have been recorded in December on the Lower Fox River (Howe, *et al.,* 1993). Thus, breeding bald eagles spend a substantial part of the year in the assessment area.

Eagle nesting locations within the Lower Fox River and Green Bay are shown on Figure 4-1 through 4-4 and 4-13, respectively. There are two active nests within the Lower Fox River; one within the Little Lake Butte des Morts Reach (Figure 4-1), and one at Kaukauna in the Appleton to Little Rapids Reach (Figure 4-2).

Within the bay (Figure 4-13), there is one nest active in Green Bay Zone 2, two nests in Zone 3A, and nine nests were active in Green Bay Zone 4. There are no reported nests in Zone 3B along the Green Bay side of the Door Peninsula, but there is a single active nest at the northernmost tip on the Lake Michigan side.

Overall, nesting success for Wisconsin bald eagles remains high. The most recent census for Wisconsin was conducted by WDNR in 1997, and showed that of the 632 active nests throughout Wisconsin a total of 739 young were produced. However, productivity within Green Bay bald eagle nests remained significantly reduced, relative to nests in inland Wisconsin and Michigan (Dykstra and Meyer, 1996). Mean annual production rates for the inland nests has been at, or exceeded one young per nest annually; this rate is necessary to maintain a healthy, self-reproducing population (Kubiak and Best, 1991). In contrast, Green Bay nests have oscillated considerably between no to few young in the late 1970s to 1994, to only recently achieving at, or above one per nest (Stratus, 1999c). By contrast, the nests within the Lower Fox River produced greater than one young per active nest, with the nest at Kaukauna producing two to three per nest since 1988, and the Mud Creek nest (near Little Lake Butte des Morts) between one and three per nest since 1994. These eagle data are analyzed further in the RA.

4.6 Mammals

Important small mammals that utilize the aquatic resources of the Lower Fox River/Green Bay basin include beaver, mink, muskrat, raccoon, and river otter. Beaver is found in several of the feeder streams to the River and Bay, and may be an incidental user, but is not considered to be a resident. Both muskrat and otter are found in Green Bay. Muskrat are principally habitat-limited to backwater sloughs or marshes. Raccoons are ubiquitous throughout the basin. Otter returned to the Lower Fox River area sometime in the mid-1980s and mink slides and scat are observed during mid-winter surveys; however, populations of both animals are low (Nikolai, 1998).

There is only anecdotal information concerning mink populations along the Lower Fox River (Patnode, 1998). WDNR trapping records show mink upstream of LLBdM but there are no records downstream of the lake (WDNR, unpublished data). This information may indicate that the mink population is restricted by lack of appropriate habitat or due to high contaminant levels in this part of the river. A review of studies in which PCB uptake in mink was analyzed is included in the RA.

A study to evaluate possible impacts to bat populations may also be undertaken by WDNR (Rezabeck, 1998). Like tree swallows and other birds mentioned in the previous section, bats also feed on insects found in and above the waters of the Lower Fox River and Lake Winnebago. A bat colony located in the bluffs of the Niagara escarpment east of the Lower Fox River may be studied as part of such an effort. In addition, there is a likely bat colony in the Red Bank Glades Scientific Area just north of the mouth of the Fox River (Nikolai, 2000a).

4.6.1 Mink

A summary of suitable and preferred mink habitat is presented below. In addition, information regarding the domestic production of mink in Wisconsin is also presented because it was mink ranchers and associated research which first found that PCBs had a detrimental influence on mink reproduction and mortality. Therefore, a brief summary of the mink farming operations in Wisconsin is included.

4.6.1.1 Mink Habitat

Mink are semi-aquatic, predatory mammals associated with lakes, streams, rivers, and marshes. Mink are generally nocturnal creatures that feed on fish crayfish, waterfowl, muskrat, rabbits, and rodents. The availability of prey greatly influences the density and distribution of mink populations in a given area. Mink are active throughout the year, feeding on whatever prey is available (USFWS, 1986). Their dens are generally located near the water's edge and studies suggest mink typically remain within 200 m (660 ft) of open water. In Michigan, studies indicated that mink are most commonly associated with brushy or wooded areas adjacent to aquatic habitats. Preferable foraging and den areas in wetland environments include dense vegetation and irregular shorelines while the preferred lacustrine habitat include small oligotrophic lakes with stony shores. Streams or rivers surrounded by either marsh vegetation or abundant downfall/debris provides cover and pools for foraging. Studies in Quebec, Canada show that mink activity decreases as stream flow increases. Additionally, the channelization of rivers in Mississippi and Alabama caused a decline in mink populations as it was accompanied by a decrease in shoreline configuration diversity, loss of aquatic vegetation, and reductions in prey availability and habitat quality (USFWS, 1986).

Channelization of the Lower Fox River has contributed to a general decline of mink habitat in the region. The habitat suitability, as determined by Exponent (1998), was based on shoreline characteristics included in WDNR wetland maps and WISCNLAND GIS maps of the project area and are shown for the Lower Fox River on Figures 4-14 through 4-17. The suitability definitions are as follows:

- **Good**: forest shrub/scrub, forest wetland, broadleaf deciduous or lowland wetland areas

- **Moderate**: emergent wetland, meadow, or wetland less than 0.8 hectares (2 acres)

- **Marginal**: grassland or agricultural areas

- **Poor**: golf course, low intensity urban

- **Unsuitable**: aquatic beds/flats, open water, barren, high intensity urban

As previously discussed, much of the shoreline has been developed between Neenah and Kaukauna and between De Pere and Green Bay. Most of the shoreline in the LLBdM Reach and between Appleton and Kaukauna is characterized by Exponent as either "poor" or "unsuitable" on Figures 4-14 and 4-15, respectively. This reflects the development of these areas. However, in the less developed areas of the Appleton to Little Rapids and Little Rapids to De Pere reaches, large tracts of the shoreline are characterized as "marginal" to "good" habitat (Figures 4-15 and 4-16, respectively). Mink habitat suitability in the De Pere to Green Bay Reach is largely characterized as "unsuitable" (Figure 4-17), which is similar to the LLBdM Reach.

In Zone 3, mink habitat suitability characterization efforts in Green Bay extended only just beyond Marinette, on the west side, and Sturgeon Bay, on the east side, (Figures 4-18 and 4-19). The shoreline in Green Bay zones 2A and 3A, on the west side, are generally characterized as "marginal to good" (Figures 4-18 and 4-19, respectively). The habitat in Zone 2B is generally characterized as "poor to "unsuitable," although "moderate" to "good" habitat is present with increasing distance from the mouth of the Lower Fox River (Figure 4-18). The habitat suitability in Zone 3B is generally characterized as "moderate" to "good" except in areas where development has occurred, such as the cities of Dyckesville and Sturgeon Bay (Figure 4-19).

4.6.1.2 Domestic Mink Production in Wisconsin

Due to demand, mink have been raised domestically to provide a reliable source of pelts. Wisconsin has long been a leader in the production of domesticated mink. According to NASS (2000) data, the 82 mink farms in Wisconsin produced the most mink pelts (almost 732,000) in the United States during 1999. Additionally, the NASS (2000) data for Michigan indicate that 13 farms produced 51,000 pelts in 1999.

In the late 1950s and early 1960s, mink ranchers in Wisconsin and other areas bordering the Great Lakes faced a crisis as production rapidly decreased due to the mortality of mink kits and infertility of female mink (Gilbertson, 1988). In the 1960s and 1970s, researchers concluded that PCBs in Great Lakes fish (specifically coho salmon from Lakes Michigan and Erie) adversely affected domestic mink production, causing reproductive failure in the females and mortality in both kits and adults. Female mink that were fed fish containing PCBs often failed to mate, and when they did, the mortality rate of the kits often approached 100 percent (Gilbertson, 1988). PCBs accumulate in the brain, liver, and kidneys of the mink and concentrations of about 5 to 11 ppm were present in these organs following death. Further, a wild mink found in a marsh located along Green Bay had a similar kidney PCB concentration as those observed during laboratory studies (Gilbertson, 1988). These results suggest that PCBs effect both wild and domesticated mink populations.

4.6.1.3 Wild Mink in the Study Area

Wild mink population estimates for Wisconsin and Michigan are not available. Approximately 22,600 mink were trapped in the state of Wisconsin in 1998-99 (WDNR, 1999b). However, these records do not indicate how many were collected in the counties along the Lower Fox River or Green Bay.

WDNR has approximately 40 laboratory reports (unpublished data) from analysis of mink tissue and organ samples from specimens trapped in 1992 and 1994. The results indicate that PCBs, as well as mercury and other metals, are present in these wild mink tissues/organs. The majority of the mink were trapped within Marinette County but others were taken in Brown, Oconto, and Winnebago counties as well. Typically, these reports include only general trapping location information. Because these mink were collected more than 6 years ago, assessing the current health and stability of wild mink populations in the area is not practical from these analytical results.

4.6.2Otter

WDNR harvest records for 1998-99 suggest that otter are present in the counties along the Lower Fox River and west side of Green Bay but not in counties along the east side of the bay. This may either be due to habitat requirements or it may reflect the influence of chemical contamination. Because the WDNR records do not indicate where selected fur-bearing species are trapped (other than a specific county) it is difficult to assess which factor (habitat or chemical contamination) is more restrictive. WDNR (1999b) records show that a combined 26 otters were collected in Outagamie and Winnebago counties while 56 otters were collected in Marinette and Oconto counties separately in 1998-99. However, only one otter was taken in Brown County (WDNR, 1999b). According to Gilbertson (1988), no otters were trapped in Door and Kewaunee Counties in 1984 and the 1998-99 harvest records suggest that this trend continues (WDNR, 1999b).

4.7 Endangered and Threatened Species

A number of different animals have been or are currently on the Wisconsin, Michigan, or Federal Endangered and Threatened Species List. According to the 1973 Endangered Species Act, the term endangered species means "any species which is in danger of extinction throughout all or a significant portion of its range" while a threatened species is "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."

Listed endangered or threatened animals which have historically been found in the vicinity of the Lower Fox River or Green Bay include: ospreys, Common terns, Forster's terns, Caspian terns, and great egret (Matteson, *et al.,* 1998). The ospreys, Common terns, and Forster's terns have nested along the Lower Fox River as well as at upstream locations in Lake Winnebago, Lake Butte des Morts, and Lake Poygan. The osprey have been sighted near Kaukauna and have attempted to nest in the vicinity of Combined Locks, while the terns have been observed farther upstream. Additionally, Common, Caspian, and Forster's terns as well as great egrets have nested on some of the islands located in Green Bay. Very few nesting pairs have been observed over the past few years and recovery of these populations is slow (Matteson, *et al.,* 1998).

As mentioned above, populations of both eagles and the double-crested cormorants have recovered to the point where both birds have been removed from the Wisconsin endangered species list. Other populations, specifically wild mink and otter, have been found to be declining around the Lower Fox River and Green Bay, but are not currently listed by state or federal agencies. WDNR also reported a bed of clams or mussels which may be threatened. The sediment bed which these clams/mussels inhabit is approximately 20 feet wide and 100 feet long and it is located near the mouth of Mud Creek in the Lower Fox River (Szymanski, 1998).

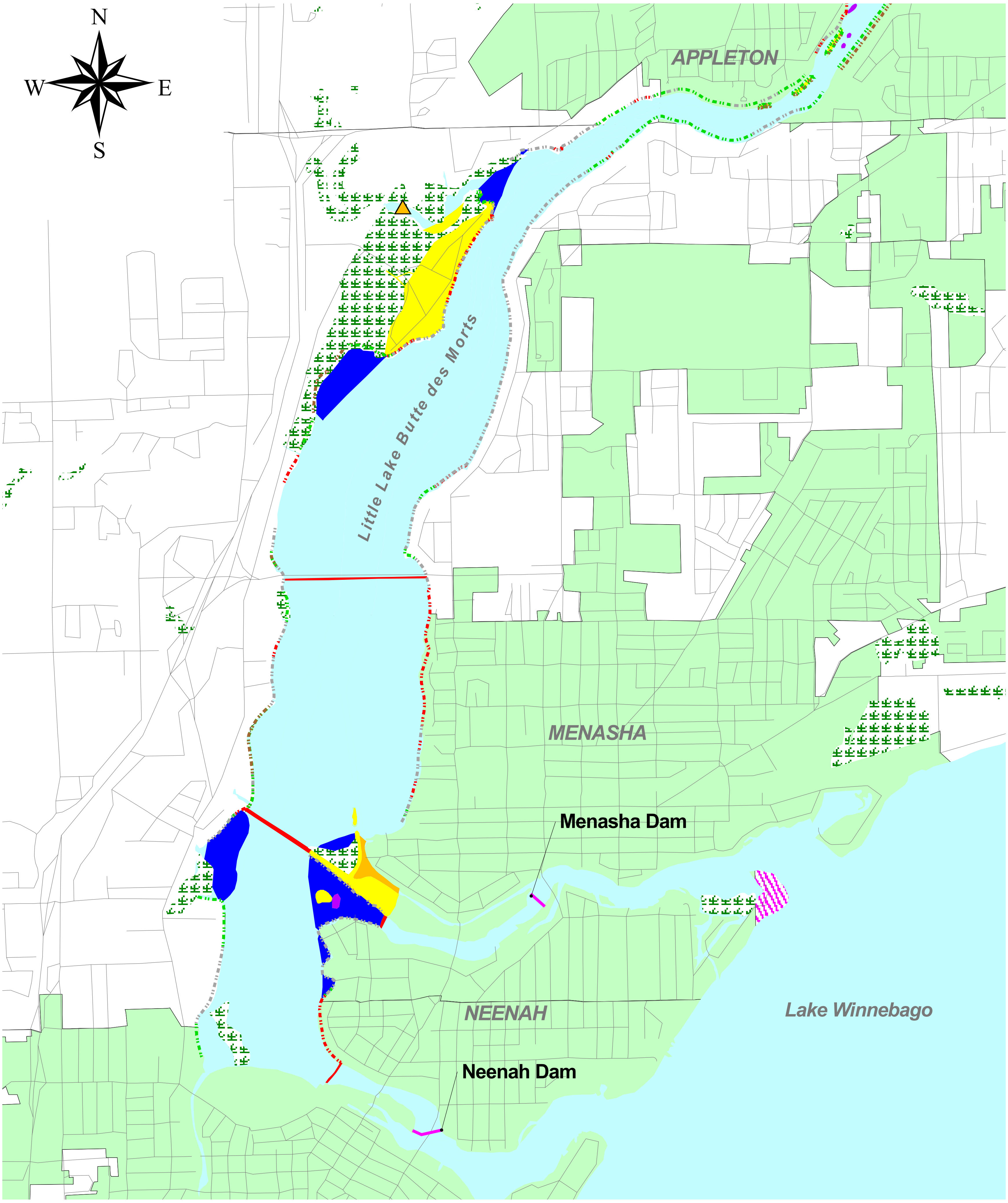
The endangered and threatened mammals, fish, and birds of the region are listed below.

Endangered/Threatened Species in Wisconsin & Michigan

List	Endangered	Threatened
Mammals		
Wisconsin	Timber wolf and pine marten	None
Michigan	Timber wolf, cougar, lynx, prairie vole, and Indiana bat	Least shrew
Federal	Timber wolf, Gray bat, Indiana Bat, and Ozark Big-eared bat	Lynx
Fish		
Wisconsin	None	None
Michigan	None	Lake Sturgeon, Sauger
Federal	None	None
Birds		
Wisconsin	Peregrine Falcon, Caspian Tern, Common Tern, Foster' Tern, Piping Plover, and Snowy Egret	Osprey and Yellow Rail
Michigan	Peregrine Falcon, Piping Plover, and King Rail	Bald Eagle, Merlin, Osprey, Caspian Tern, Common Tern, Least Brittern, and Yellow Rail
Federal	Peregrine Falcon, Piping Plover, and King Rail	Bald Eagle and Piping Plover

4.8 Section 4 Figures and Tables

Figures and tables for Section 4 follow this page, and include:



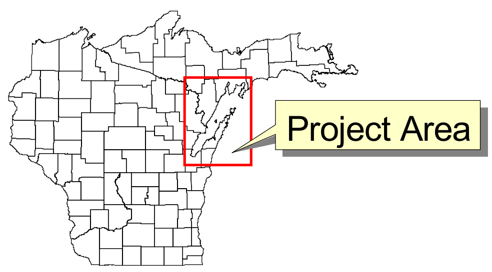
Physical Habitat Features
- Bridge
- Cuts, Coves, Backwaters
- Dam Riffles
- Island
- Lock Channel
- Submerged piling, ruin, rock
- Tributary

Shoreline Features
- Bulkhead
- Grass
- Gravel Cobbles
- Riprap
- Sand
- Sandy beach
- Soft Sediments
- Trees

- Wetlands
- Bald Eagle Nesting Sites

Threatened or Endangered Resources
- Lake Sturgeon
- Dam Locations
- Roads
- Water

Civil Divisions
- City
- Township
- Village

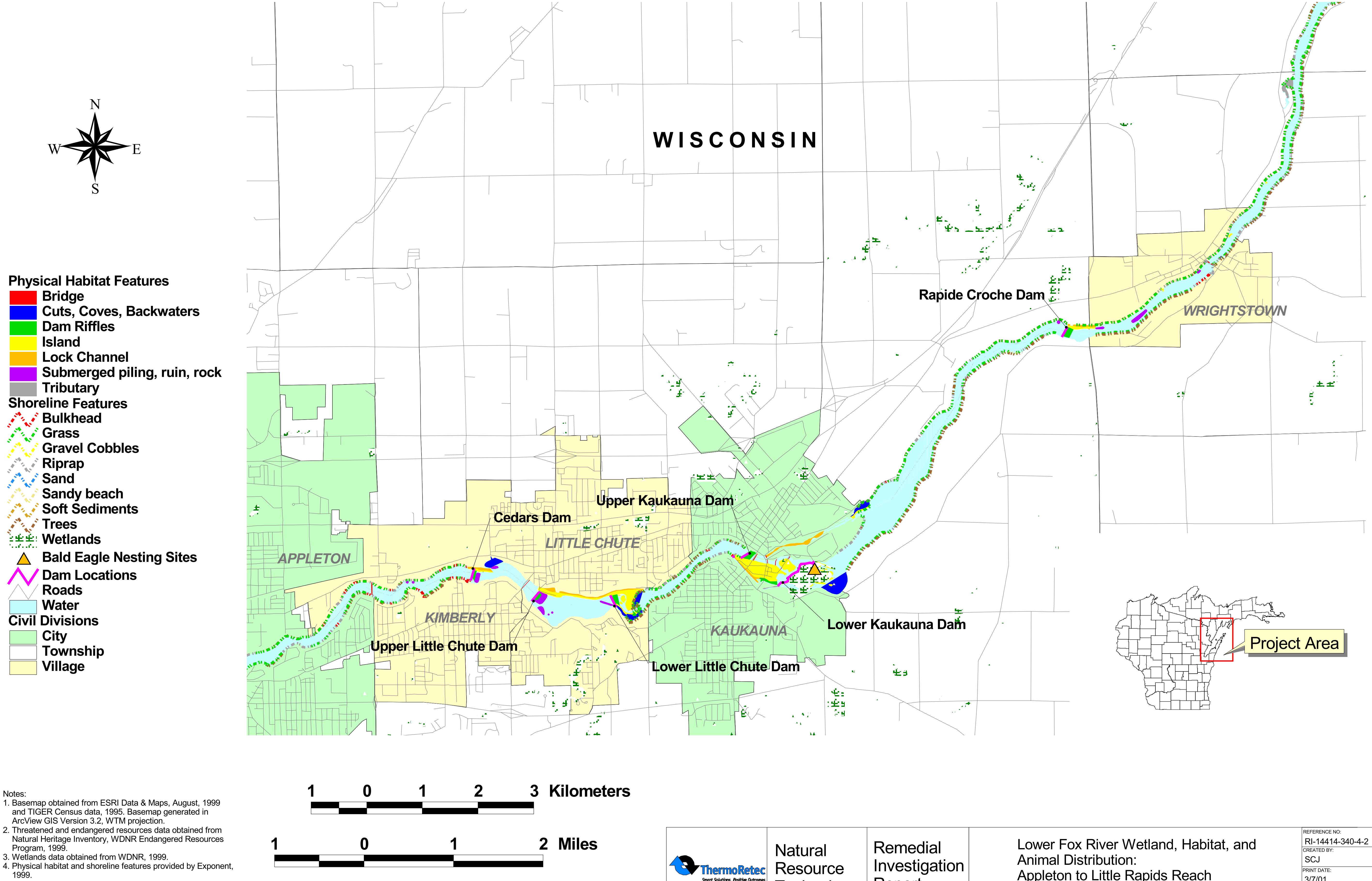


0.5 0 0.5 1 Kilometers

0.5 0 0.5 1 Miles

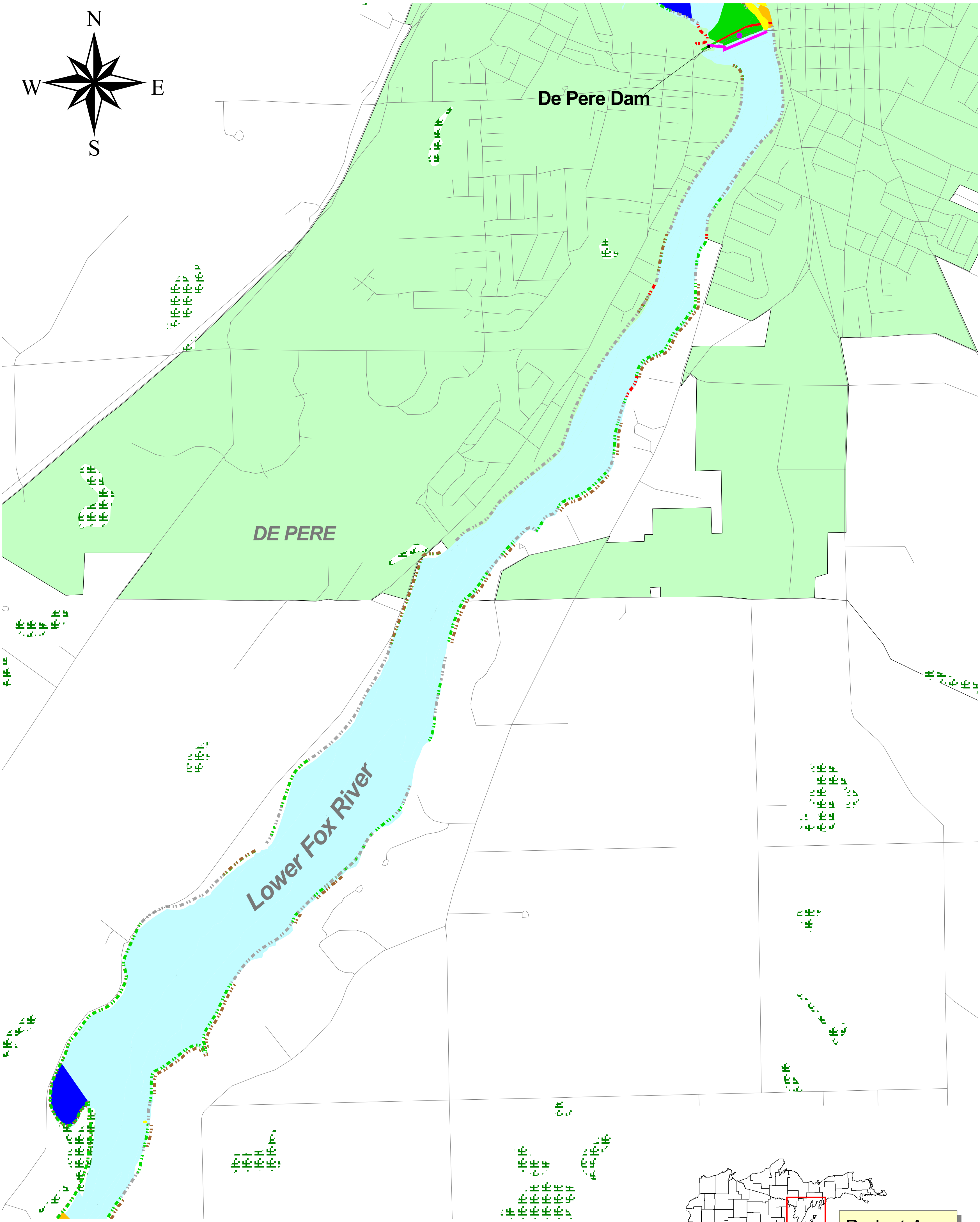
Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Threatened and endangered resources data obtained from Natural Heritage Inventory, WDNR Endangered Resources Program, 1999.
3. Wetlands data obtained from WDNR, 1999.
4. Physical habitat and shoreline features provided by Exponent, 1999.

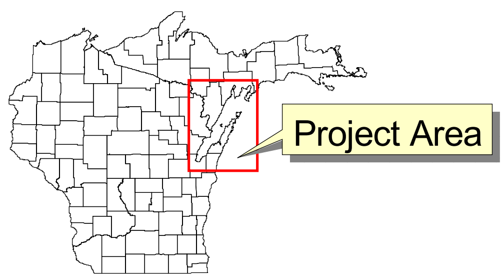
ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Lower Fox River Wetland, Habitat, and Animal Distribution: Little Lake Butte des Morts Reach	REFERENCE NO: RI-14414-340-4-1
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE 4-1	APPROVED: AGF



Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Threatened and endangered resources data obtained from Natural Heritage Inventory, WDNR Endangered Resources Program, 1999.
3. Wetlands data obtained from WDNR, 1999.
4. Physical habitat and shoreline features provided by Exponent, 1999.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Lower Fox River Wetland, Habitat, and Animal Distribution: Appleton to Little Rapids Reach	REFERENCE NO: RI-14414-340-4-2
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE 4-2	APPROVED: AGF





Physical Habitat Features
- Bridge
- Cuts, Coves, Backwaters
- Dam Riffles
- Island
- Lock Channel
- Submerged piling, ruin, rock
- Tributary

Shoreline Features
- Bulkhead
- Grass
- Gravel Cobbles
- Riprap
- Sand
- Sandy beach
- Soft Sediments
- Trees

- Wetlands
- Dam Locations
- Roads
- Water

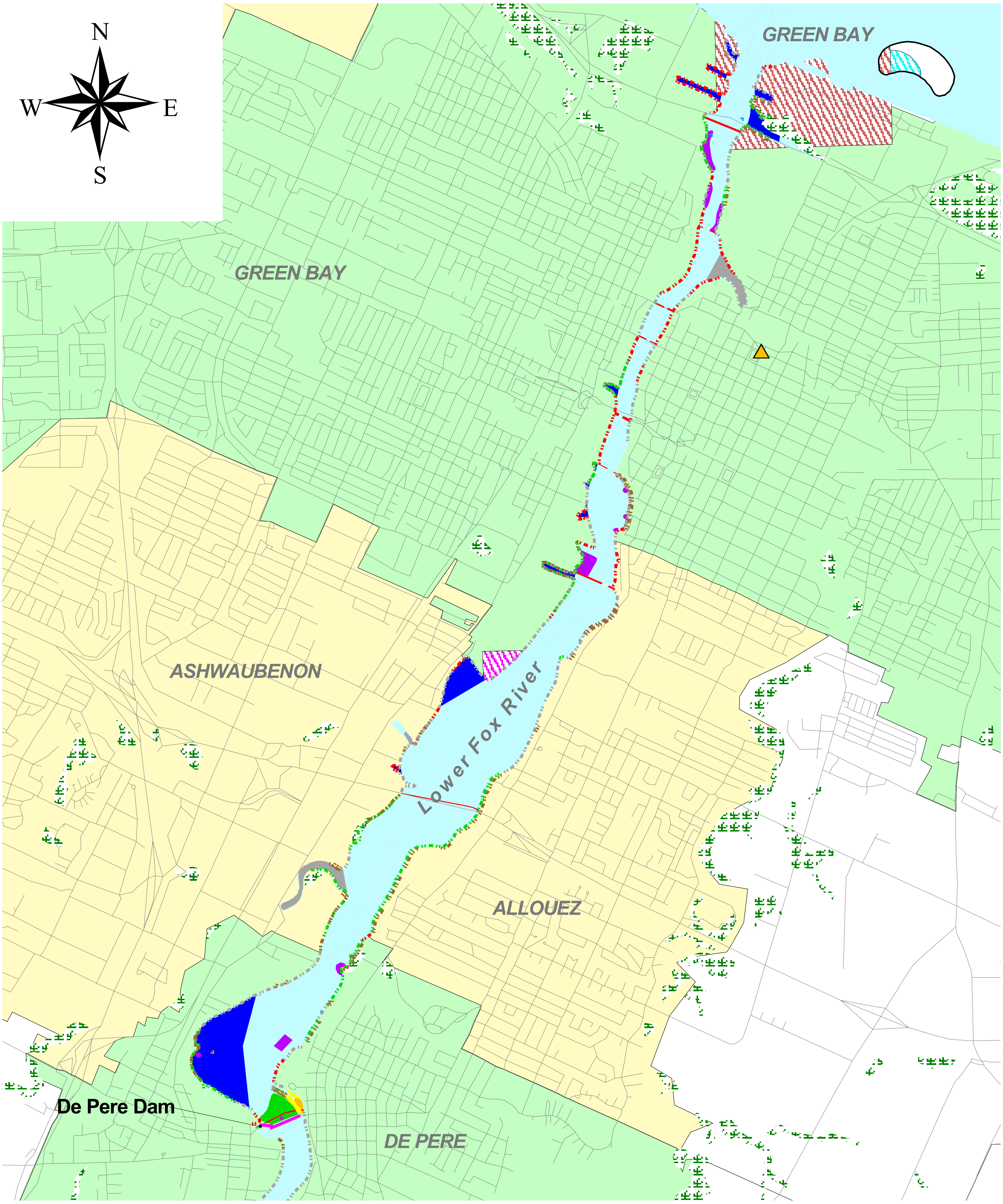
Civil Divisions
- City
- Township
- Village

0.5 0 0.5 1 Kilometers

0.5 0 0.5 Miles

Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Threatened and endangered resources data obtained from Natural Heritage Inventory, WDNR Endangered Resources Program, 1999.
3. Wetlands data obtained from WDNR, 1999.
4. Physical habitat and shoreline features provided by Exponent, 1999.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Lower Fox River Wetland, Habitat, and Animal Distribution: Little Rapids to De Pere Reach FIGURE 4-3	REFERENCE NO: RI-14414-340-4-3 CREATED BY: SCJ PRINT DATE: 3/7/01 APPROVED: AGF



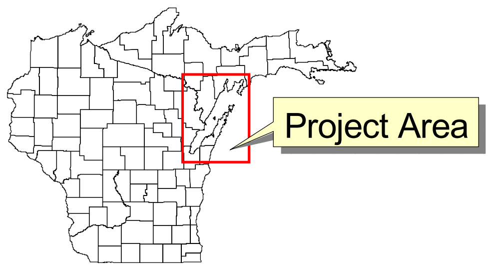
Physical Habitat Features
- Bridge
- Cuts, Coves, Backwaters
- Dam Riffles
- Island
- Lock Channel
- Submerged piling, ruin, rock
- Tributary

Shoreline Features
- Bulkhead
- Grass
- Gravel Cobbles
- Riprap
- Sand
- Sandy beach
- Soft Sediments
- Trees

- Wetlands
- Bald Eagle Nesting Sites

Threatened or Endangered Resources
- Caspian Tern
- Forster's Tern
- Lake Sturgeon
- Dam Locations
- Roads
- Water

Civil Divisions
- City
- Township
- Village

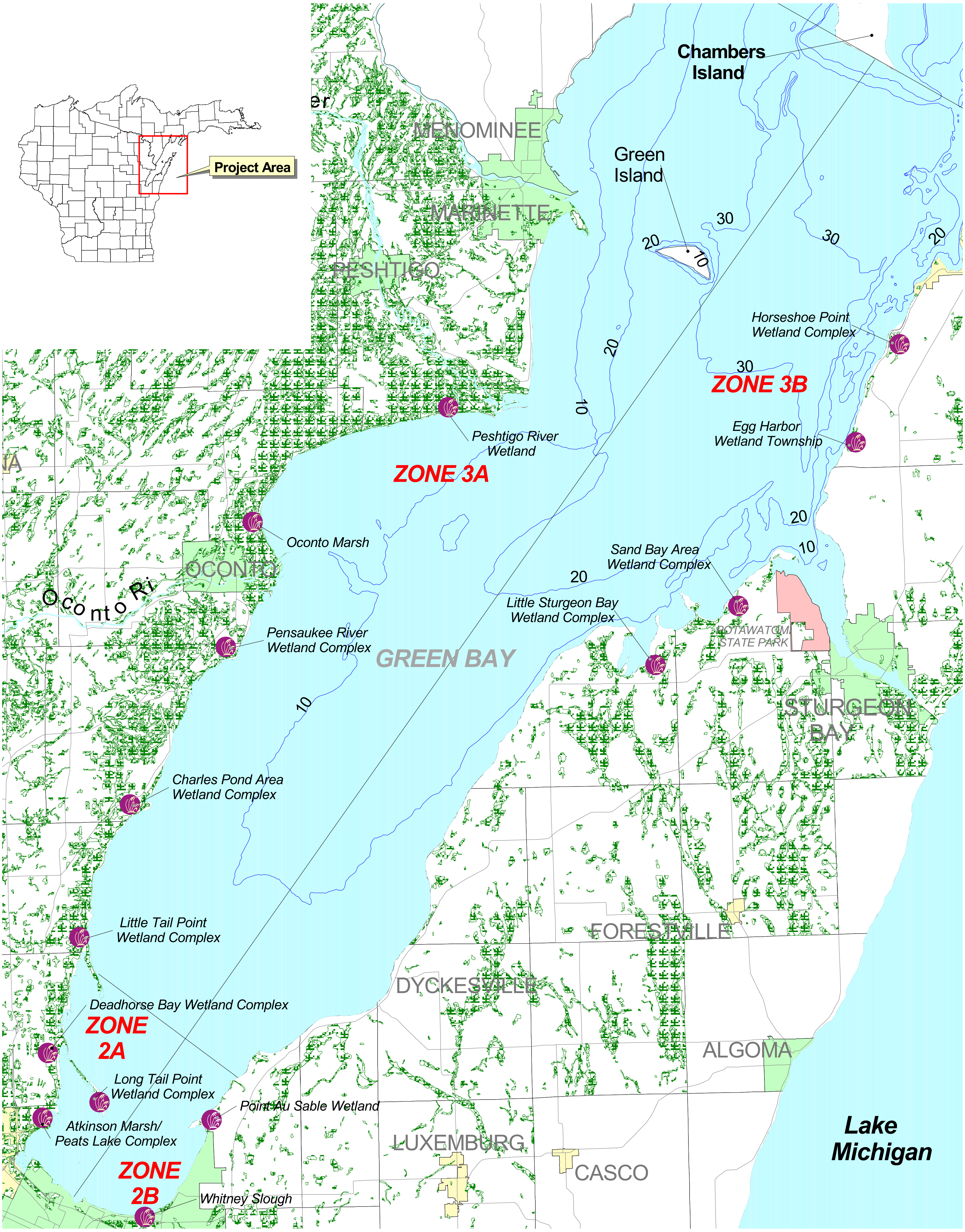


Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Threatened and endangered resources data obtained from Natural Heritage Inventory, WDNR Endangered Resources Program, 1999.
3. Wetlands data obtained from WDNR, 1999.
4. Physical habitat and shoreline features provided by Exponent, 1999.

1 0 1 Kilometers

0.5 0 0.5 1 Miles

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Lower Fox River Wetland, Habitat, and Animal Distribution: De Pere to Green Bay Reach FIGURE 4-4	REFERENCE NO: RI-14414-340-4-4 CREATED BY: SCJ PRINT DATE: 3/7/01 APPROVED: AGF



Wetland Areas > 40 Hectares (100 acres)
Bathymetry Contours (10 m)
Roads
Wetlands
Wisconsin State Parks
Water

Civil Divisions
City
Township
Village

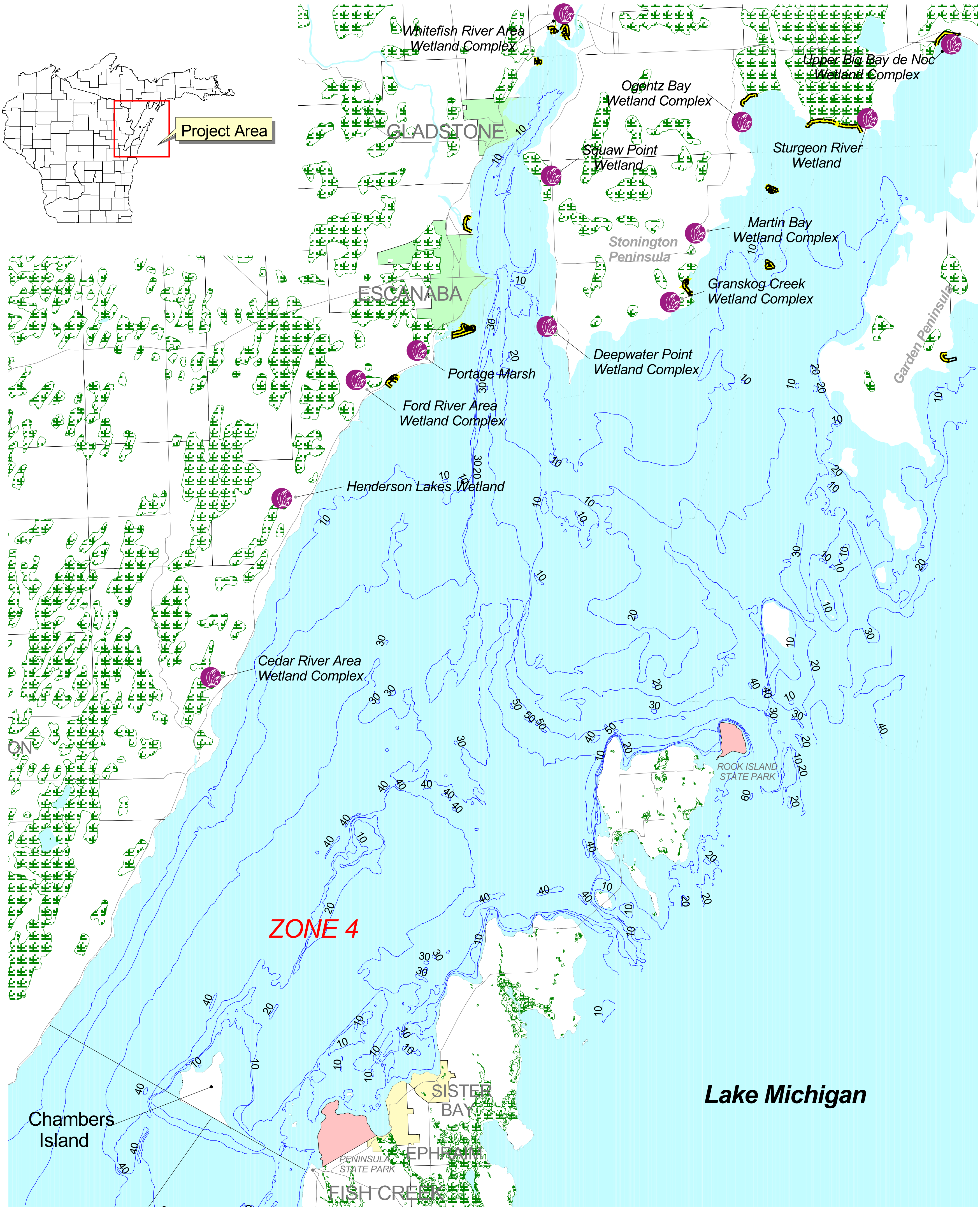
5 0 5 10 Kilometers

5 0 5 Miles

N W E S

NOTES:
1. Basemap generated in ArcView GIS, Version 3.2, from ESRI data and maps on CD-ROM and TIGER census data.
2. Aerial ground surveys and survey resource data collected in 1991 and 1992. Data compiled from USFWS, WDNR, Michigan DNR, Bureau of Endangered Resources, Bay-Lake Regional Planning Commission, USACE, and several historical societies.
3. Bathymetry contours in meters, obtained from NOAA, 1999.

ThermoRetec	Natural Resource Technology	Remedial Investigation Report	Wetland Distribution: Green Bay Zones 2 & 3	DRAWING NO: RI-14414-340-4-5
			FIGURE 4-5	PRINT DATE: 1/23/01
				CREATED BY: SCJ
				APPROVED: AGF



Wetland Areas > 40 Hectares (100 acres)
Bathymetry Contours (10 m)
Roads
Delta County Environmental Areas
Water
Wetlands
Area Parks
Civil Divisions
City
Township
Village

5 0 5 10 15 Kilometers

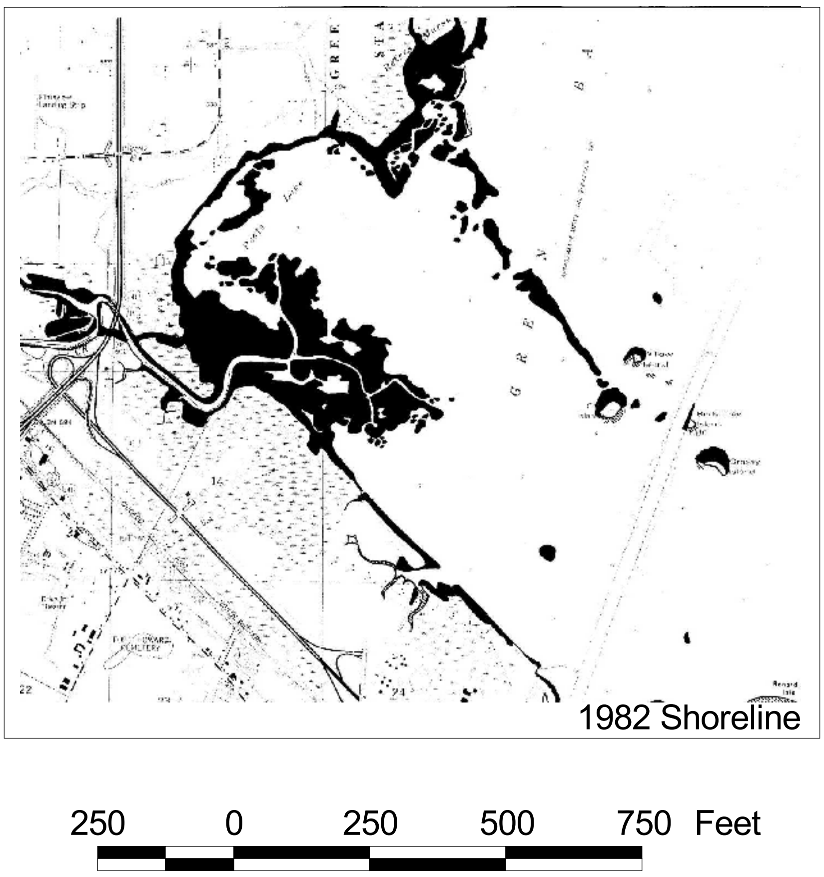
5 0 5 10 Miles

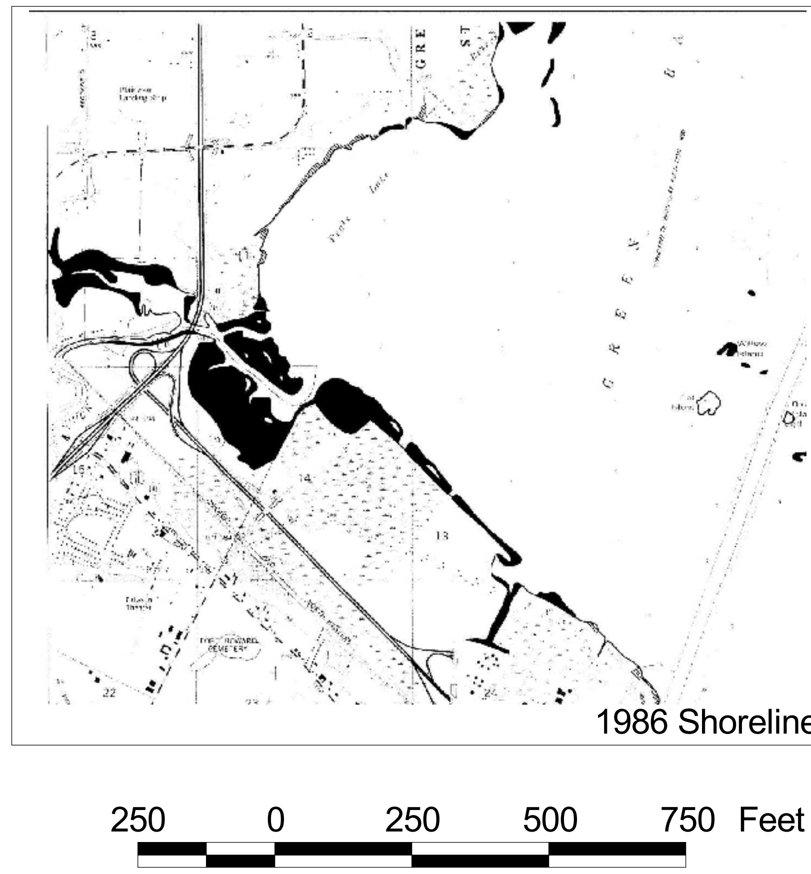
N
W E
S

NOTES:
1. Basemap generated in ArcView GIS, version 3.2, from ESRI Data & Maps on CD-ROM and TIGER census data.
2. Aerial ground surveys and survey resource data collected in 1991 and 1992. Data compiled from USFWS, WDNR, Michigan DNR, Bureau of Endangered Resources, USACE, Bay-Lake Regional Planning Commission, and several historical societies.
3. Bathymetry contours in meters, obtained from NOAA, 1999.
4. Delta County Environmental Area Boundaries provided by Michigan Dept. of Environmental Quality.
These are sensitive areas established by MDEQ.

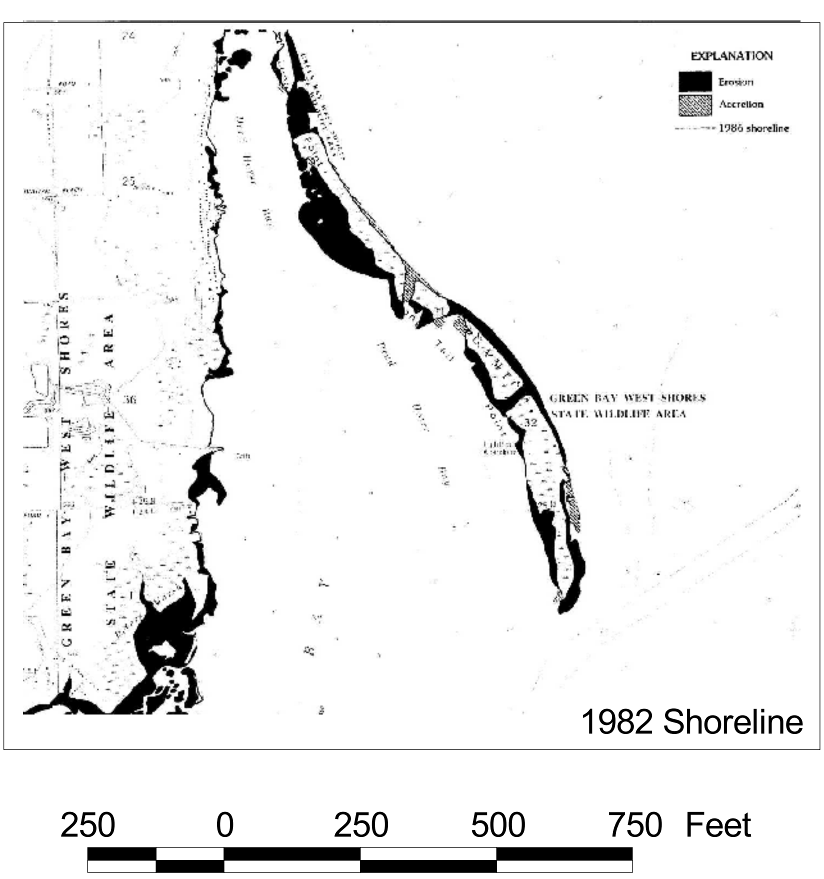
ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Wetland Distribution: Green Bay Zone 4	DRAWING NO: RI-14414-340-4-6
				PRINT DATE: 1/23/01
				CREATED BY: SCJ
			FIGURE 4-6	APPROVED: AGF

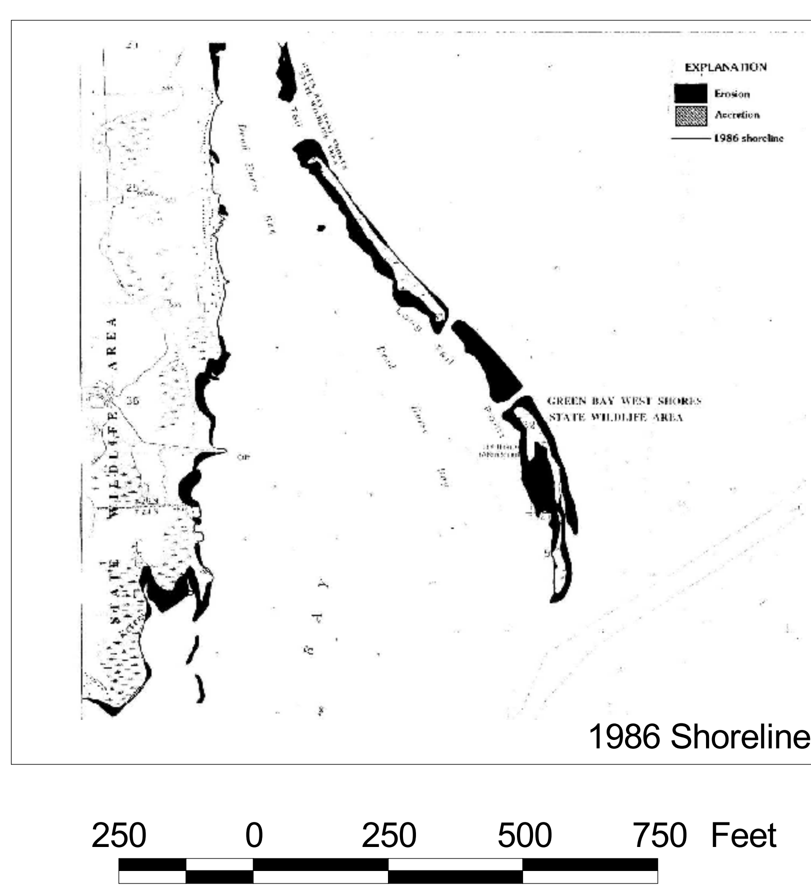
Duck Creek and Cat Island Chain Area





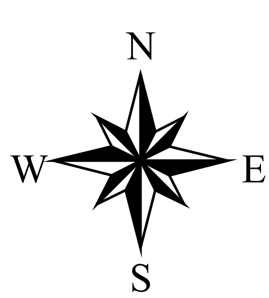
Long Tail Point Area

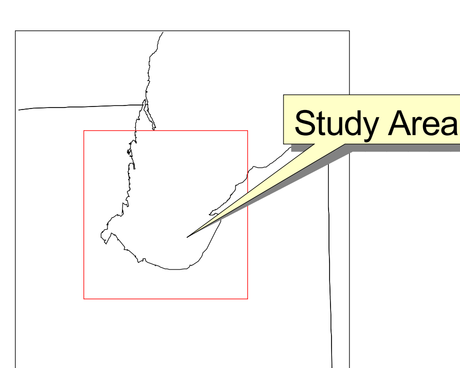




Wetland Losses

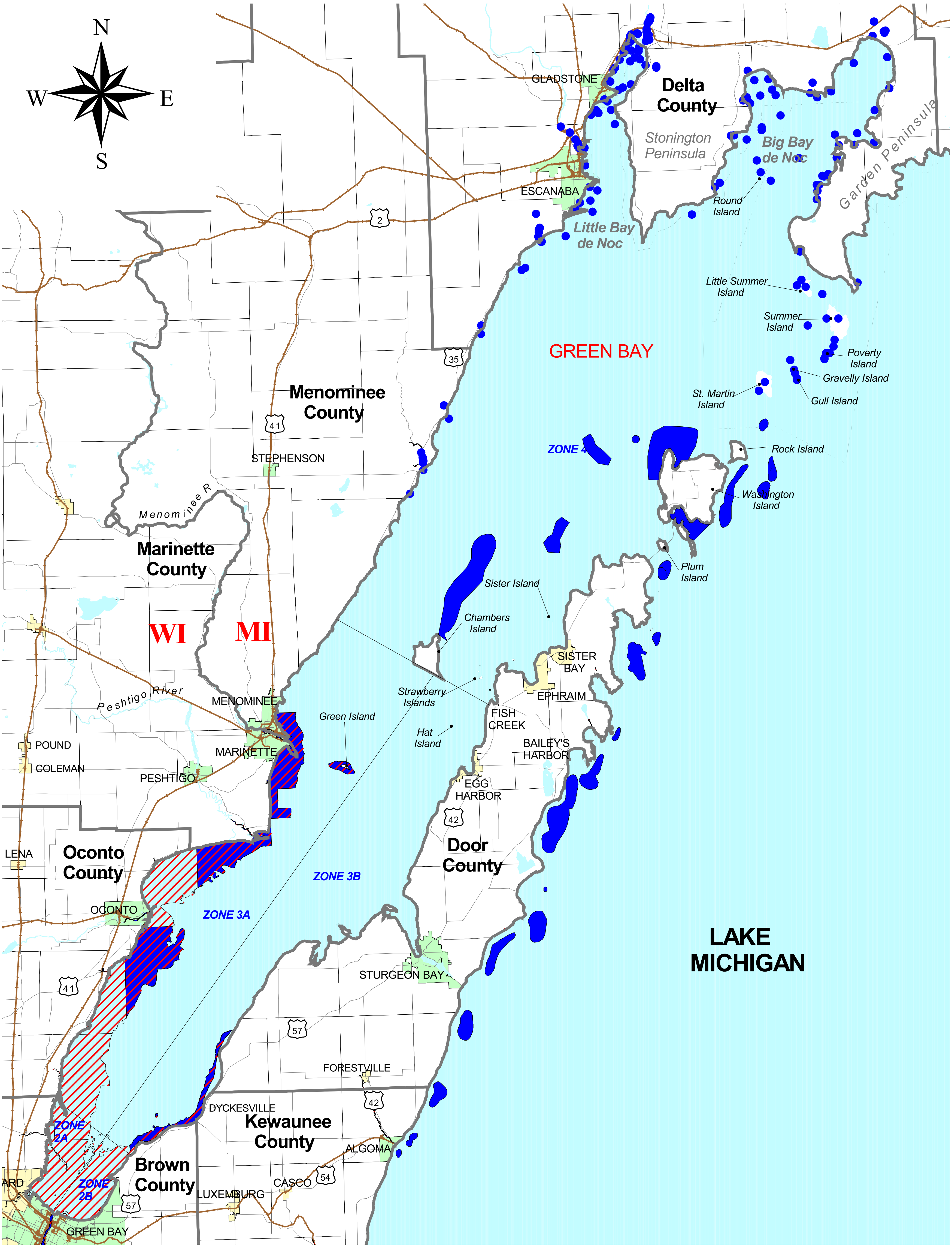
Wetland Gains





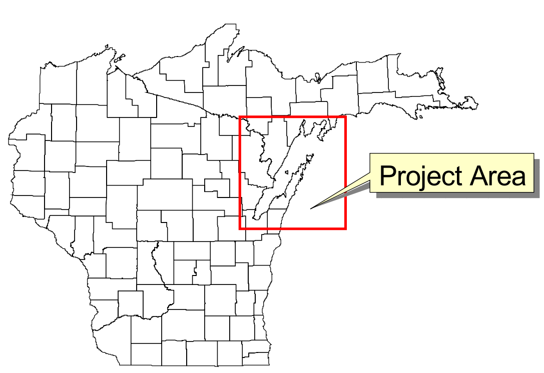
Reference: G.L. Schideler, USGS 1994
Map MF - 2254

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Wetland Losses in Green Bay: Duck Creek, Cat Island Chain, & Long Tail Point FIGURE 4-7	DRAWING NO: RI-4414-340-4-7 PRINT DATE: 3/7/01 CREATED BY: SCJ APPROVED: AGF



County Boundaries
Benthic Fish
Salmon/Trout
Michigan Fish Locations (Species Not Identified)
Major Roads
Railroads
Water

Civil Divisions
City
Township
Village

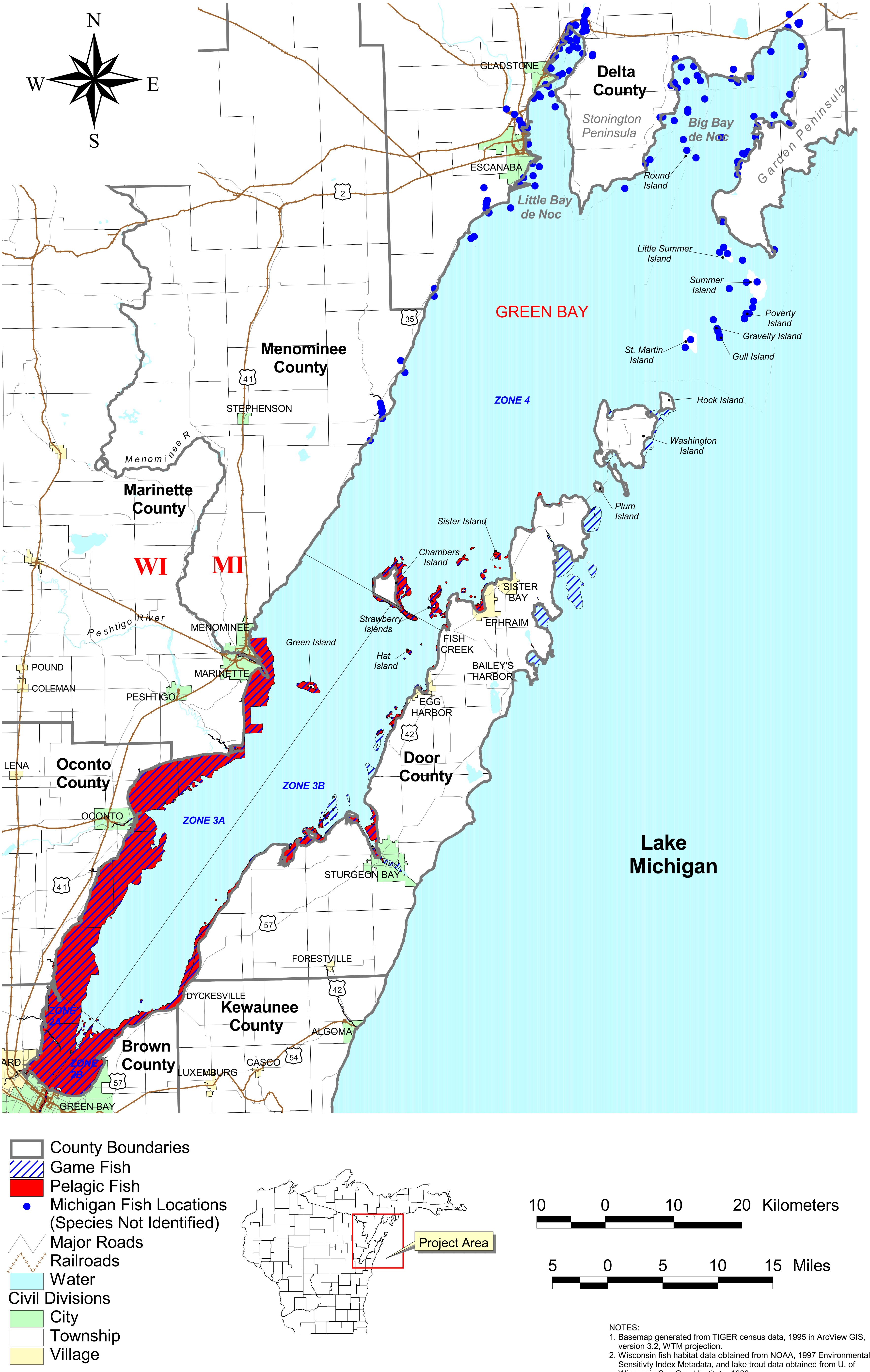


10 0 10 20 Kilometers

5 0 5 10 15 Miles

NOTES:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, version 3.2, WTM projection.
2. Wisconsin fish habitat data obtained from NOAA, 1997 Environmental Sensitivty Index Metadata, and lake trout data obtained from U. of Wisconsin Sea Grant Institute, 1980.
3. Michigan fish locations provided by Great Lakes Commission, 1980.

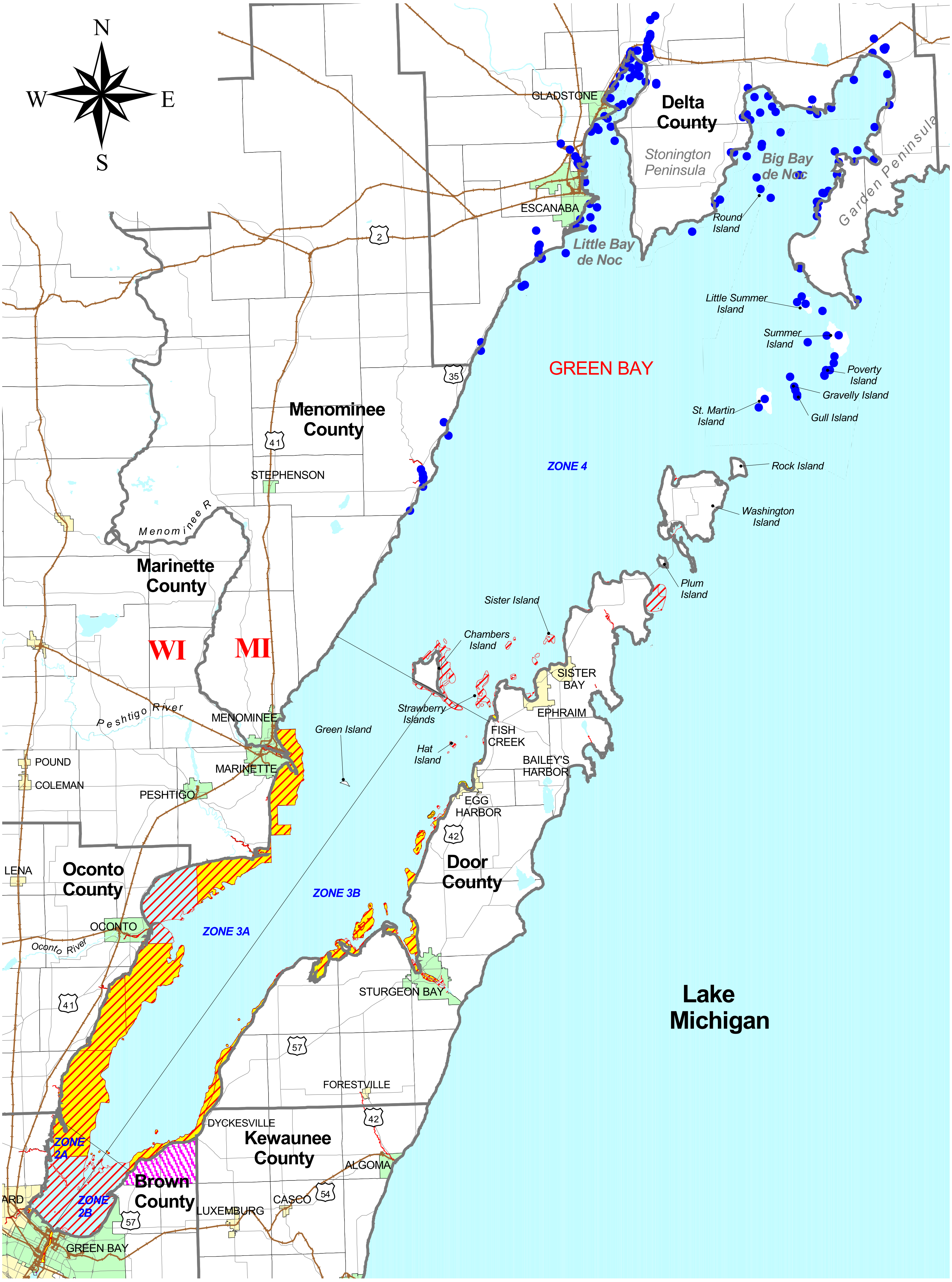
ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Green Bay Spawning Areas by Fish Types: Salmon/Trout and Benthic Fish	DRAWING NO: RI-4414-340-4-8
			FIGURE 4-8	PRINT DATE: 3/7/01
				CREATED BY: SCJ
				APPROVED: AGF



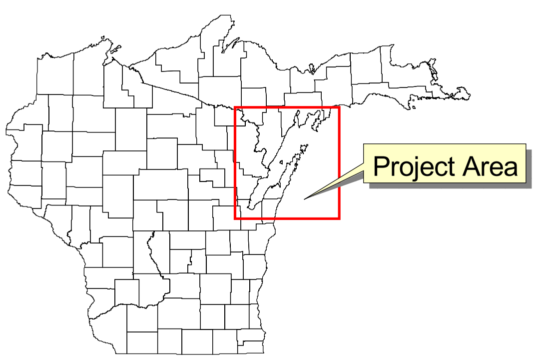
NOTES:

1. Basemap generated from TIGER census data, 1995 in ArcView GIS, version 3.2, WTM projection.
2. Wisconsin fish habitat data obtained from NOAA, 1997 Environmental Sensitivty Index Metadata, and lake trout data obtained from U. of Wisconsin Sea Grant Institute, 1980.
3. Michigan fish locations provided by Great Lakes Commission, 2000.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Green Bay Spawning Areas by Fish Types: Pelagic and Game Fish	DRAWING NO: RI-4414-340-4-9
				PRINT DATE: 1/23/01
				CREATED BY: SCJ
			FIGURE 4-9	APPROVED: AGF



County Boundaries
Lake Sturgeon
Yellow Perch
Walleye
Michigan Fish Locations (Species Not Identified)
Major Roads
Railroads
Water
Civil Divisions
City
Township
Village



10 0 10 20 Kilometers

5 0 5 10 15 Miles

NOTES:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, version 3.2, WTM projection.
2. Wisconsin fish habitat data obtained from NOAA, 1997 Environmental Sensitivty Index Metadata, and lake trout data obtained from U. of Wisconsin Sea Grant Institute, 1980.
3. Michigan fish locations provided by Great Lakes Commission, 2000.
4. Door Peninsula fish habitat data obtained from U. of Wisconsin Sea Grant Institute, 1980.
5. According to Phillip Schneeberger of MDNR (telecon 1999), Walleye commonly spawn in the Whitefish, Escanaba, Ford, Cedar, and Menominee tributary rivers. Yellow Perch commonly use the shallow waters of both bays De Noc.

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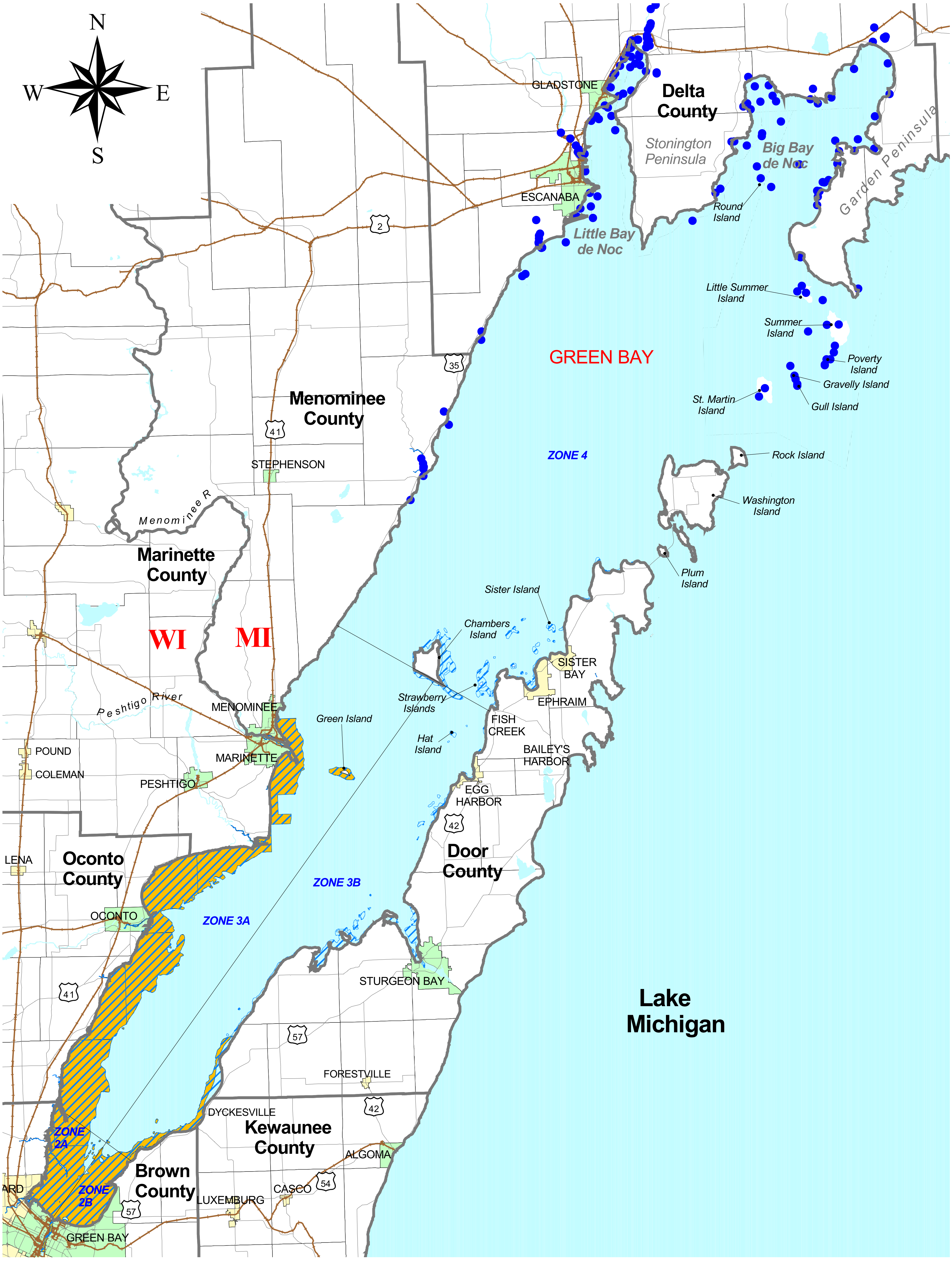
Natural Resource Technology

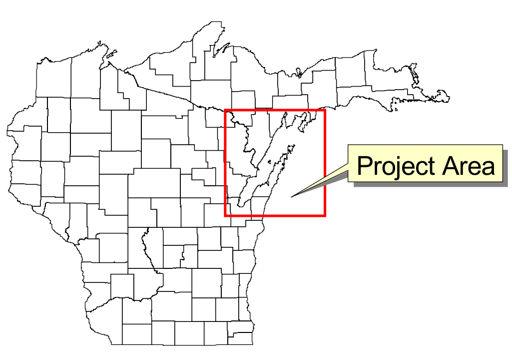
Remedial Investigation Report

Green Bay Spawning Areas by Fish Species: Walleye, Yellow Perch, and Sturgeon

FIGURE 4-10

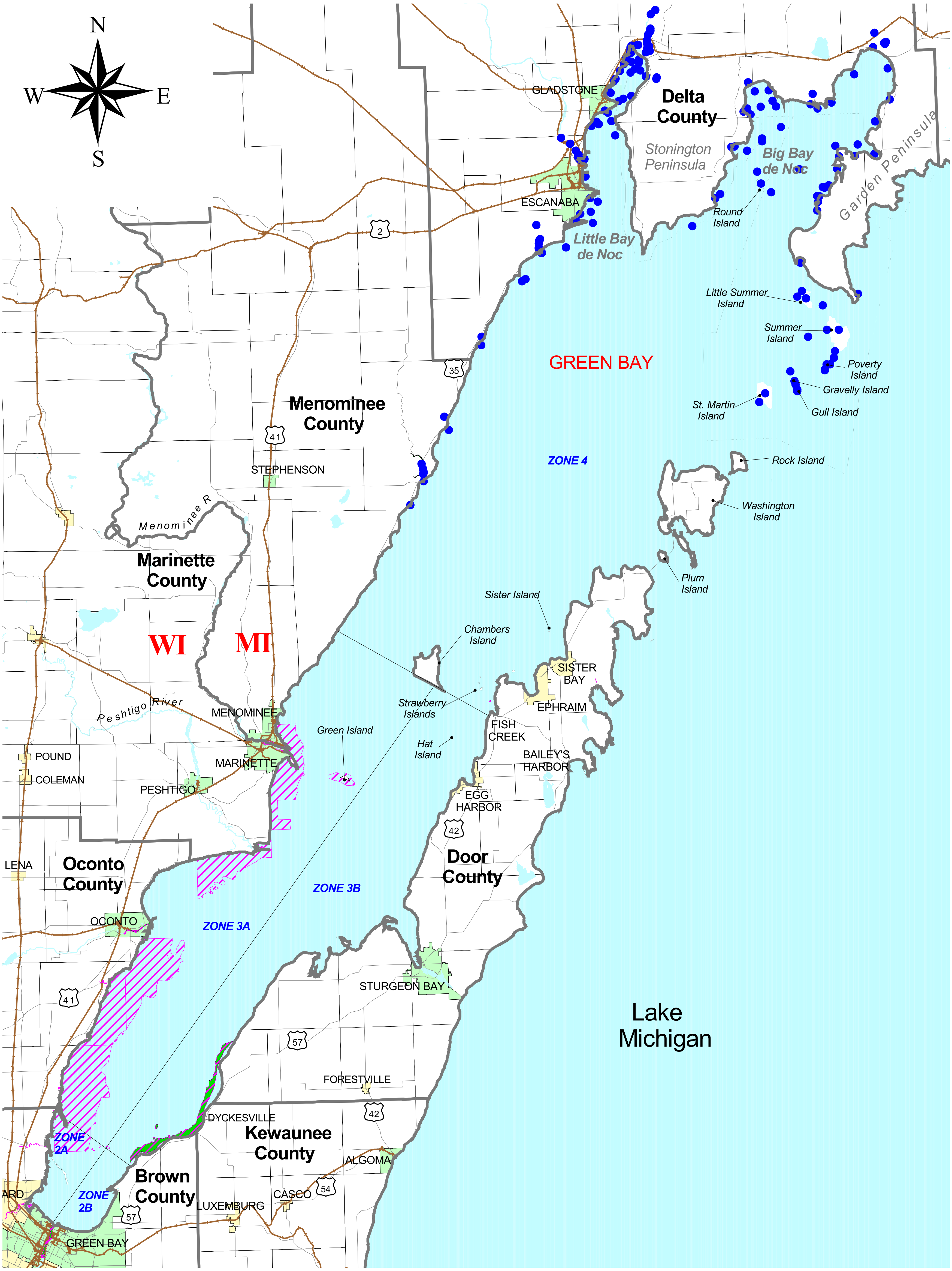
DRAWING NO: RI-4414-340-4-10
PRINT DATE: 3/7/01
CREATED BY: SCJ
APPROVED: AGF

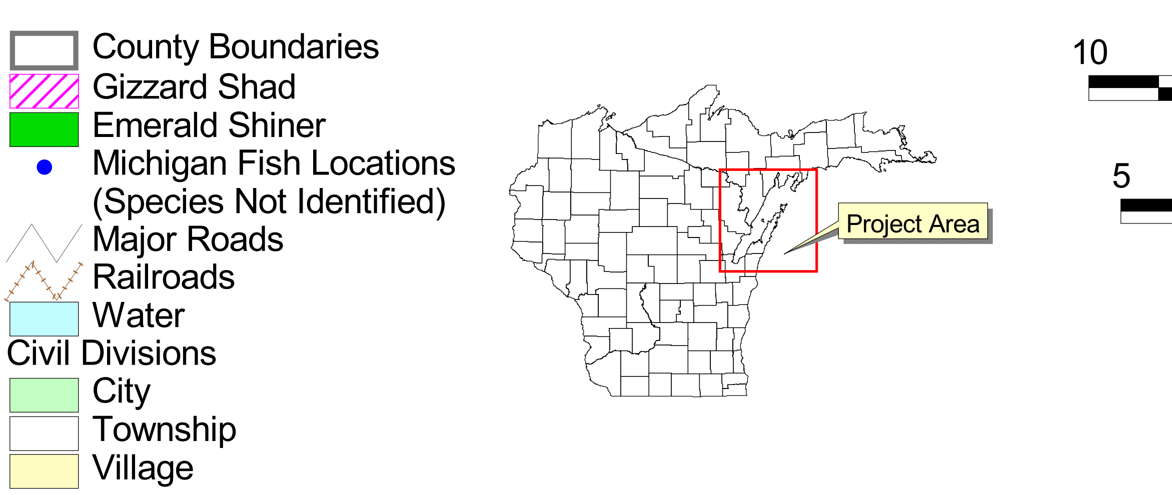


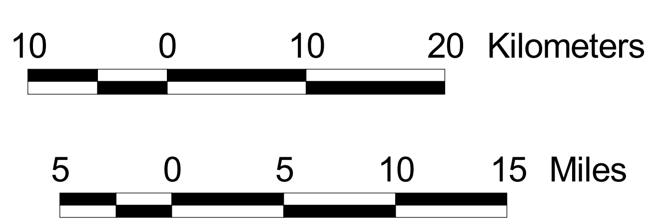


NOTES:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, version 3.2, WTM projection.
2. Wisconsin fish habitat data obtained from NOAA, 1997 Environmental Sensitivty Index Metadata, and from U. of Wisconsin Sea Grant Institute, 1980.
3. Michigan fish locations obtained from Great Lakes Commission, 2000.
4. According to Phillip Schneeberger of MDNR (telecon 1999), carp spawning is concentrated in the northern end of Little Bay de Noc, and along the shorelines of Big Bay de Noc.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Green Bay Spawning Areas by Fish Species: Carp and Alewife	DRAWING NO: RI-4414-340-4-11
				PRINT DATE: 3/7/01
				CREATED BY: SCJ
			FIGURE 4-11	APPROVED: AGF

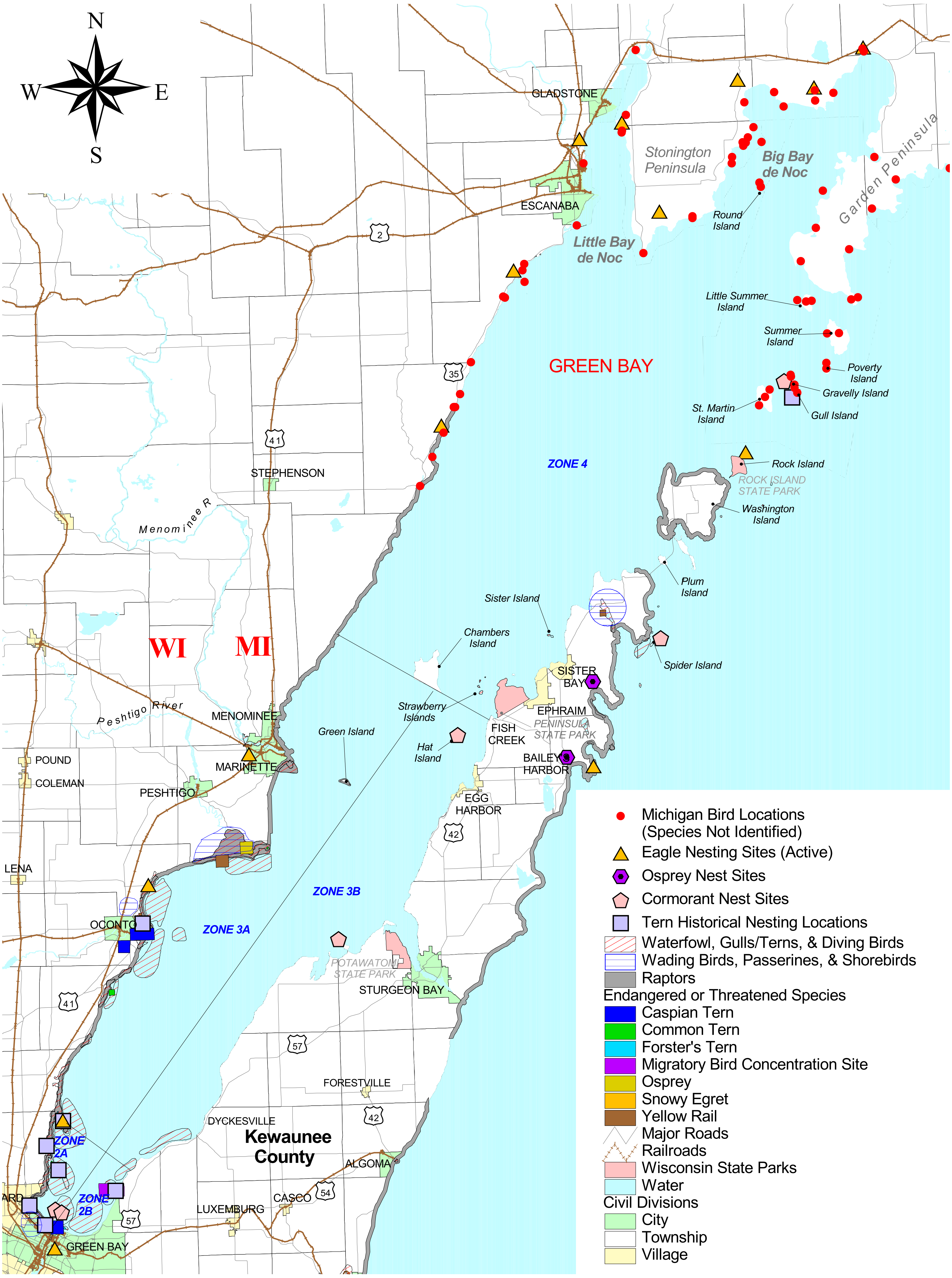


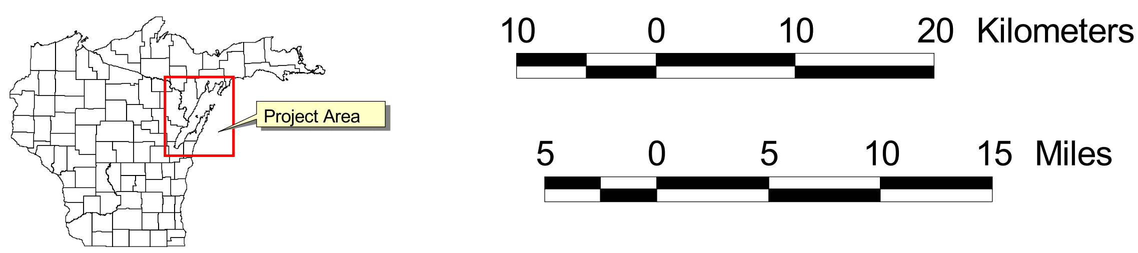




NOTES:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, version 3.2, WTM projection.
2. Wisconsin fish habitat data obtained from NOAA, 1997 Environmental Sensitivty Index Metadata, and lake trout data obtained from U. of Wisconsin Sea Grant Institute, 1980.
3. Michigan fish locations obtained from Great Lakes Commission, 2000.
4. According to Phillip Schneeberger of MDNR (telecon 1999), these fish spawn in the shallow waters of both bays of De Noc, but gizzard shad are rare.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Green Bay Spawning Areas by Fish Species: Emerald Shiners and Gizzard Shad	DRAWING NO: RI-4414-340-4-12
				PRINT DATE: 3/7/01
				CREATED BY: SCJ
			FIGURE 4-12	APPROVED: AGF



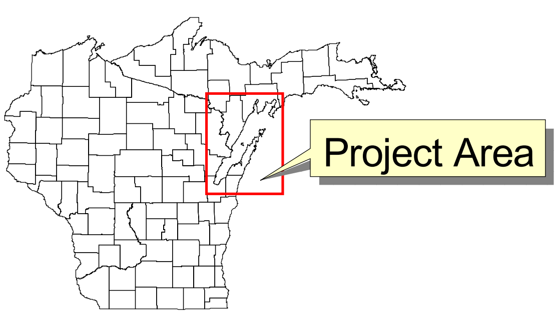


NOTES:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, version 3.2, WTM projection.
2. Wisconsin bird habitat data obtained from NOAA, 1997 Environmental Sensitivty Index Metadata, and from U. of Wisconsin Sea Grant Institute, 1980.
3. Michigan bird locations obtained from Great Lakes Commission, 2000.
4. Bird nesting sites obtained from USFWS/Stratus, 1999 Bird Injury Report and S. Stubevoll of WDNR, 1998.
5. Threatened and endangered resources provided by Natural Heritage Inventory, WDNR Endangered Resources Program, 1999.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Distribution of Birds in Green Bay: Select Species and Groups	DRAWING NO: RI-4414-340-4-13
				PRINT DATE: 3/7/01
				CREATED BY: SCJ
			FIGURE 4-13	APPROVED: AGF

Mink Habitat (100m Buffer)
- Good
- Moderate
- Marginal
- Poor
- Unsuitable
- Dam Locations
- Roads
- Water

Civil Divisions
- City
- Township
- Village

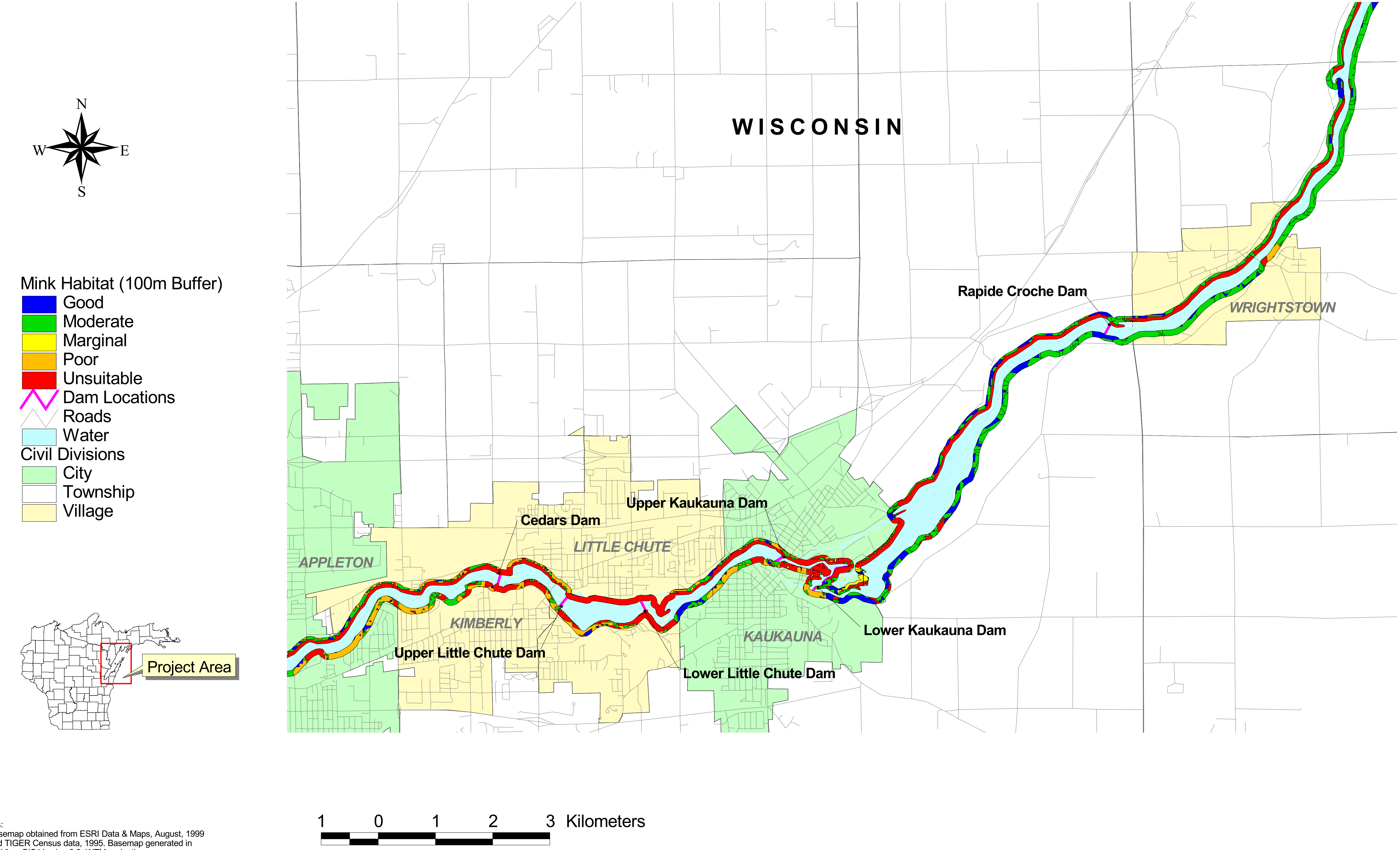


0.5 0 0.5 1 Kilometers

0.5 0 0.5 Miles

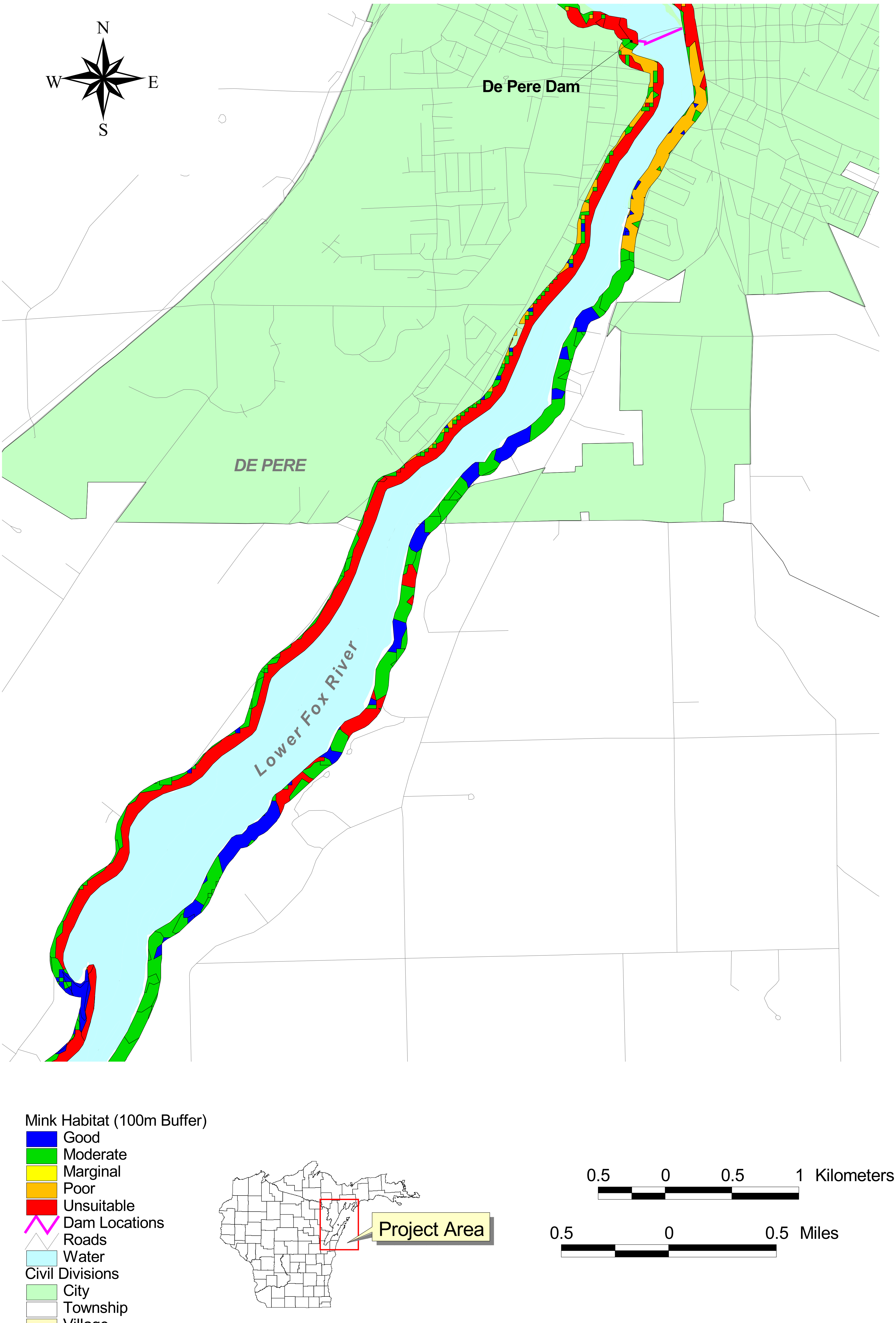
Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Mink data obtained from Exponent, 2000.
3. Suitability Index based on WISCLAND land use maps and WDNR wetland maps. Good = forest shrub/scrub or lowland wetland. Moderate = emergent wetland, meadow. Marginal = grassland, agricultural acres. Poor = low intensity, urban, or golf course. Unsuitable = mud plats, open water, high intensity urban.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Lower Fox River Mink Habitat Suitability: Little Lake Butte des Morts Reach	REFERENCE NO: RI-14414-340-4-14
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE 4-14	APPROVED: AGF



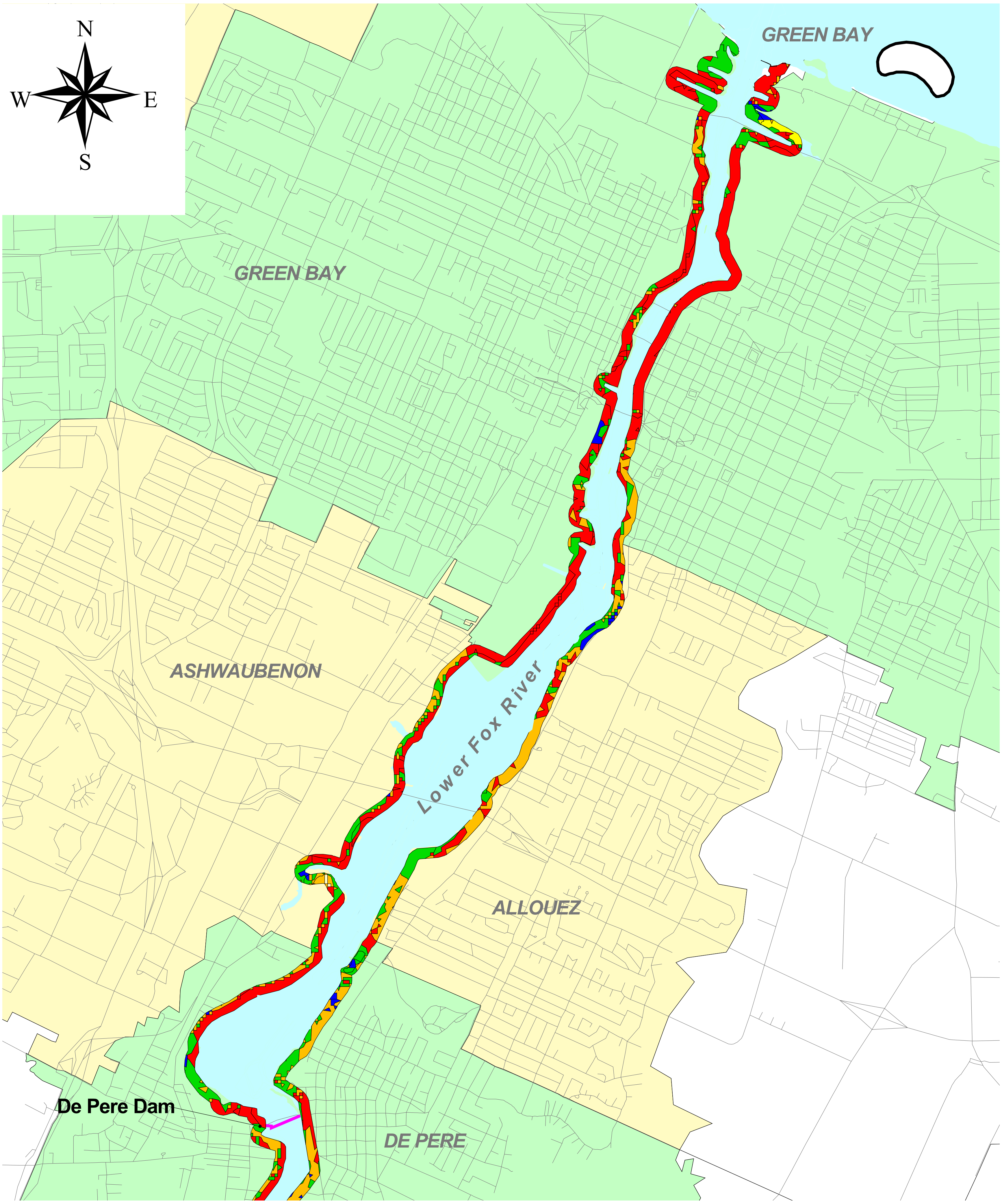
Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Mink data obtained from Exponent, 2000.
3. Suitability Index based on WISCLAND land use maps and WDNR wetland maps. Good = forest shrub/scrub or lowland wetland. Moderate = emergent wetland, meadow. Marginal = grassland, agricultural acres. Poor = low intensity, urban, or golf course. Unsuitable = mud plats, open water, high intensity urban.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Lower Fox River Mink Habitat Suitability: Appleton to Little Rapids Reach	REFERENCE NO: RI-14414-340-4-15
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE 4-15	APPROVED: AGF



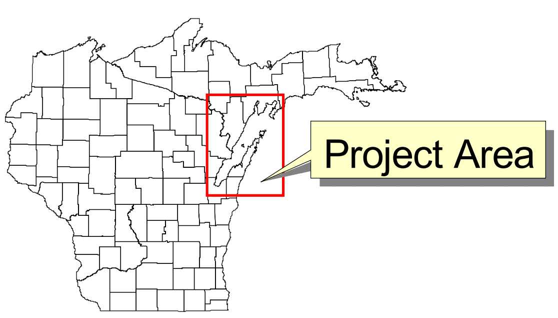
Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Mink data obtained from Exponent, 2000.
3. Suitability Index based on WISCLAND land use maps and WDNR wetland maps. Good = forest shrub/scrub or lowland wetland. Moderate = emergent wetland, meadow. Marginal = grassland, agricultural acres. Poor = low intensity, urban, or golf course. Unsuitable = mud plats, open water, high intensity urban.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Lower Fox River Mink Habitat Suitability: Little Rapids to De Pere Reach	REFERENCE NO: RI-14414-340-4-16
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE 4-16	APPROVED: AGF



Mink Habitat (100m Buffer)
- Good
- Moderate
- Marginal
- Poor
- Unsuitable
- Dam Locations
- Roads
- Water

Civil Divisions
- City
- Township
- Village

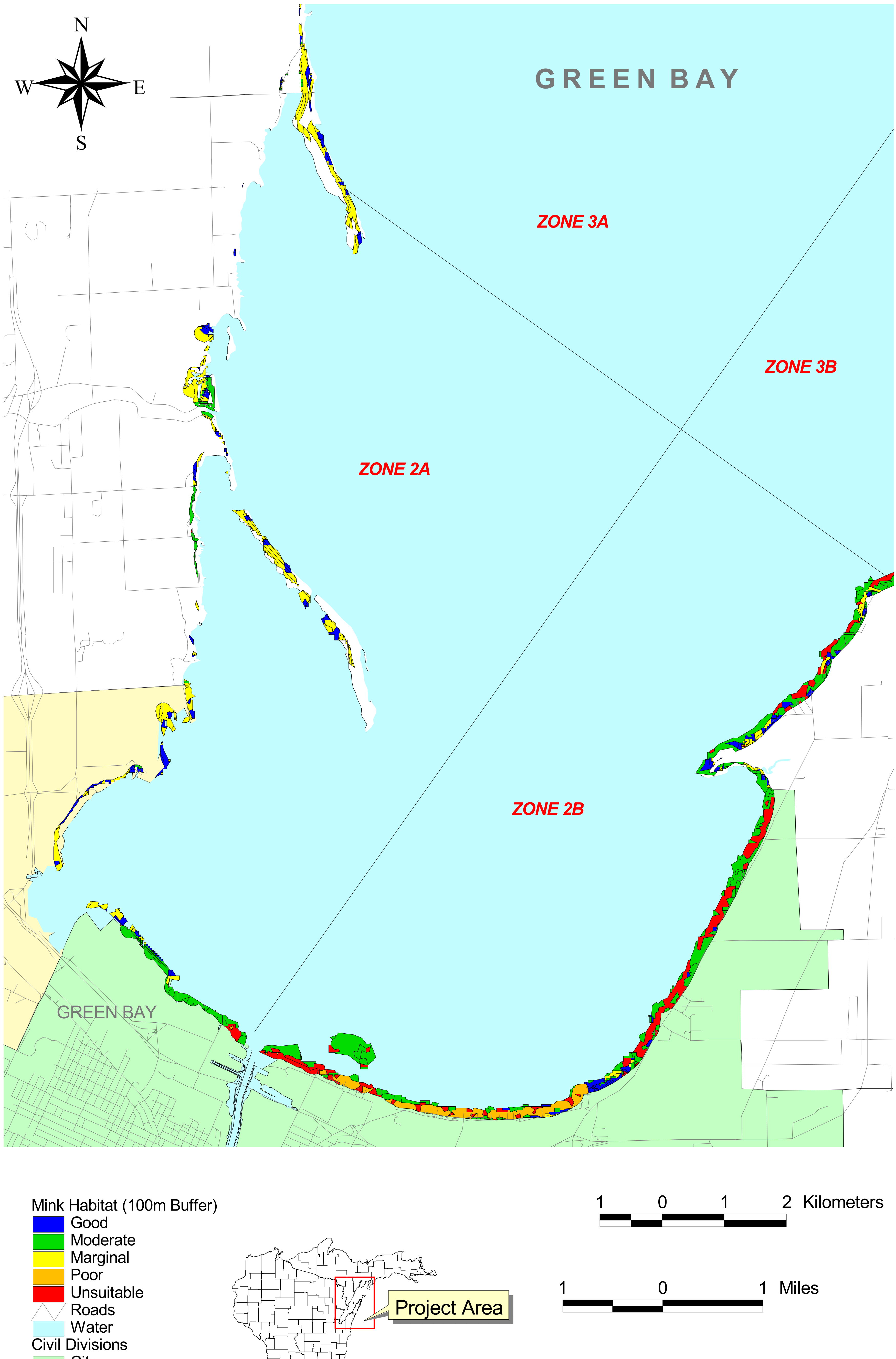


0.5 0 0.5 1 1.5 Kilometers

0.5 0 0.5 1 Miles

Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Mink data obtained from Exponent, 2000.
3. Suitability Index based on WISCLAND land use maps and WDNR wetland maps. Good = forest shrub/scrub or lowland wetland. Moderate = emergent wetland, meadow. Marginal = grassland, agricultural acres. Poor = low intensity, urban, or golf course. Unsuitable = mud plats, open water, high intensity urban.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Lower Fox River Mink Habitat Suitability: De Pere to Green Bay Reach	REFERENCE NO: RI-14414-340-4-17
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE 4-17	APPROVED: AGF



Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Mink data obtained from Exponent, 2000.
3. Suitability Index based on WISCLAND land use maps and WDNR wetland maps. Good = forest shrub/scrub or lowland wetland. Moderate = emergent wetland, meadow. Marginal = grassland, agricultural acres. Poor = low intensity, urban, or golf course. Unsuitable = mud plats, open water, high intensity urban.

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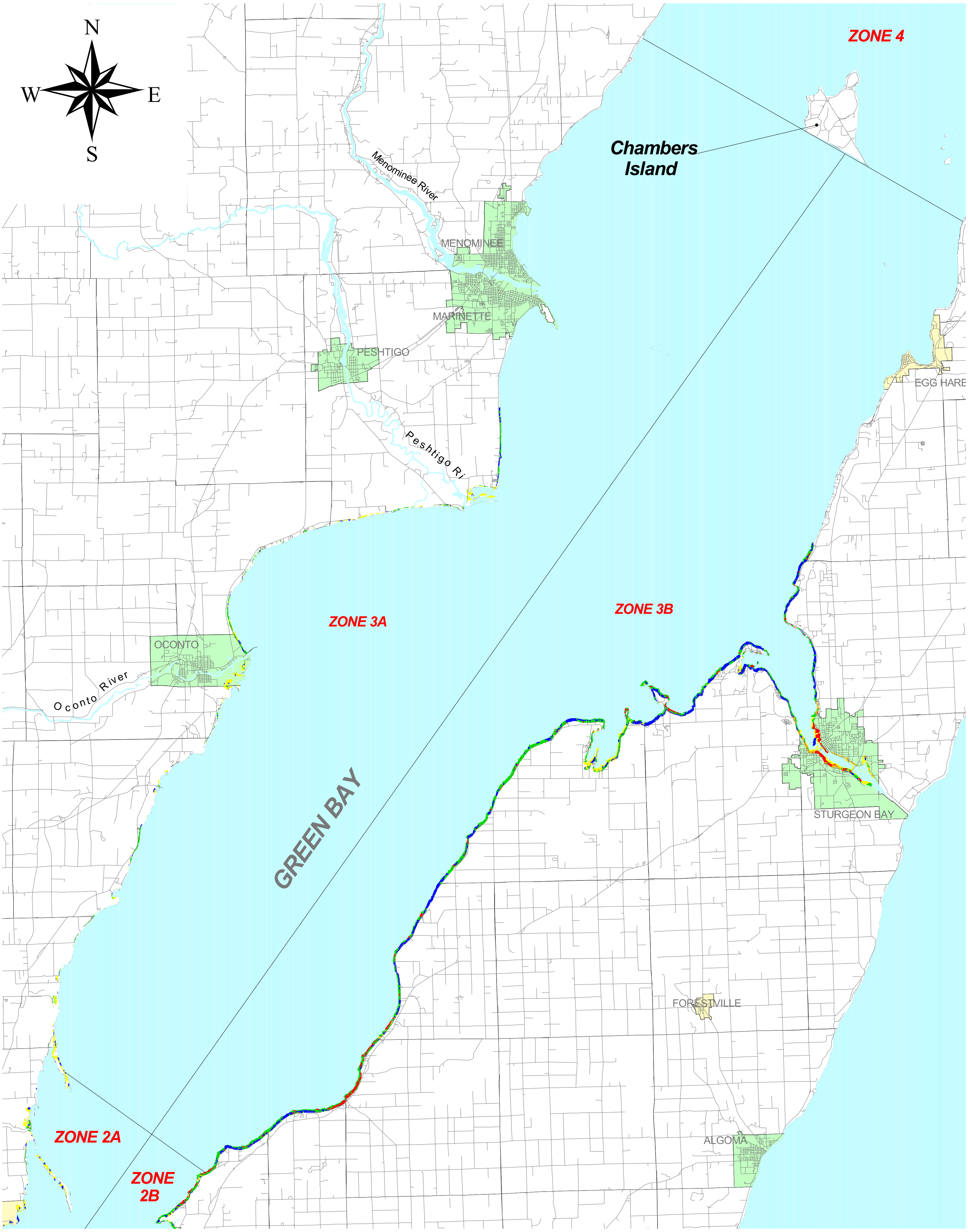
Natural Resource Technology

Remedial Investigation Report

Green Bay Mink Habitat Suitability: Zone 2

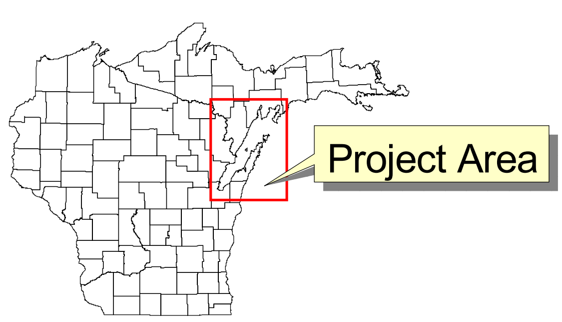
FIGURE 4-18

REFERENCE NO: RI-14414-340-4-18
CREATED BY: SCJ
PRINT DATE: 3/7/01
APPROVED: AGF



Mink Habitat (100m Buffer)
- Good
- Moderate
- Marginal
- Poor
- Unsuitable
- Roads
- Water

Civil Divisions
- City
- Township
- Village



3 0 3 6 9 Kilometers

3 0 3 6 Miles

Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Mink data obtained from Exponent, 2000.
3. Suitability Index based on WISCLAND land use maps and WDNR wetland maps. Good = forest shrub/scrub or lowland wetland. Moderate = emergent wetland, meadow. Marginal = grassland, agricultural acres. Poor = low intensity, urban, or golf course. Unsuitable = mud plats, open water, high intensity urban.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Green Bay Mink Habitat Suitability: Zone 3	REFERENCE NO: RI-14414-340-4-19
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE 4-19	APPROVED: AGF

Table 4-1. Major Green Bay Wetland Areas/Complexes[1]

Wetland Area or Complex	State	Areal Extent		Wetland Type
		Acres	Hectares	
East Shore of Green Bay				
Horseshoe Point Wetland Complex	WI	272	110.1	P
Egg Harbor Township Wetland	WI	130	52.6	P
Sand Bay Area Wetland/Complex	WI	120	48.6	L
Little Sturgeon Bay Wetland Complex	WI	315	127.5	P
Point Au Sable Wetland	WI	112	45.3	L/P
Whitney Slough	WI	457	184.9	P
West Shore of Green Bay				
Atkinson Marsh/Peats Lake Complex	WI	509	206.0	L/P/R
Deadhorse Bay Wetland Complex	WI	322	130.3	L/P
Long Tail Point Wetland Complex	WI	163	66.0	L/P
Little Tail Point Wetland Complex	WI	210	85.0	P/L
Charles Pond Area Wetland Complex	WI	170	68.8	L/P
Pensaukee River Wetland Complex	WI	490	198.3	L
Oconto Marsh	WI	9,370	3,791.9	L/P/R
Peshtigo River Wetland	WI	5,040	2,039.6	L/P/R
Cedar River Area Wetland Complex	MI	1,556	629.7	L/P/R
Henderson Lakes Wetland	MI	253	102.4	P
Ford River Area Wetland Complex	MI	389	157.4	L/R
Portage Marsh	MI	1,302	526.9	L
North Shore of Green Bay				
Whitefish River Area Wetland Complex	MI	641	259.4	L
Squaw Point Wetland	MI	729	295.0	L/P
Deepwater Point Wetland Complex	MI	265	107.2	L
Granskog Creek Wetland Complex	MI	729	295.0	L
Sand Bay Wetland Complex	MI	181	73.2	P
Martin Bay Wetland Complex	MI	514	208.0	L
Ogontz Bay Wetland Complex	MI	1,759	711.8	L
Sturgeon River Wetland	MI	6,697	2,710.2	L
Upper Big Bay de Noc Wetland Complex	MI	9,555	3,866.8	L
Wetland Areal Total		**Acres**	**Hectares**	**Miles^2**
East Shore Wetland Totals		1,406	569	2.2
West Shore Wetland Totals		19,774	8,002	30.9
North Shore Wetland Totals		21,070	8,527	32.9
Wisconsin Wetland Total		17,680	7,155	27.6
Michigan Wetland Total		24,570	9,943	38.4
Total Wetlands Area		**42,250**	**17,098**	**66**

Notes: 1) This table only includes wetlands and complexes larger than 100 acres in 1981 (USFWS, 1981).
L = Lacustrine wetland
P = Palustrine wetland
R = Riverine wetland

Table 4-2. Lower Fox River Habitats

Habitat Type	Description	Upstream of De Pere Dam	Downstream of De Pere Dam	River Totals
Lock Channels	These border the dams and provide habitat for fish, birds, and wildlife.	9.74%	0.38%	10.12%
Bridge Abutments	These create eddies which attract forage fish feeding on plankton. Swallows also nest beneath bridges.	0.01%	< 0.01%	0.01%
Backwaters, cuts, & coves	These serve as refuge and foraging sites for fish and wildlife. Piscivorous birds feed in these areas.	20.93%	6.91%	27.84%
Islands & Peninsulas	These provide habitat for birds and wildlife. The shores and shallows provide spawning grounds.	43.16%	0.48%	43.64%
Tributaries	Wetlands often develop at the mouths and provide habitat for fish, birds, and wildlife.	2.10%	4.09%	6.19%
Dam Riffles	Turbulent water is preferred spawning habitat of walleye and other fish. These areas attract many fish to feed, which attracts piscivorous birds.	4.22%	1.56%	5.78%
Submerged rock, piling, or ruins	Outcroppings, rocky shallows, and abandoned former piers and pilings provide excellent habitat for aquatic organisms and nesting or roosting sites for birds.	3.49%	2.93%	6.42%
Deadfall and overhang	Features vegetated shoreline, offering favorable habitat for fish, wildlife, and piscivorous birds and nesting sites for passerines. Habitat density upstream of De Pere dam was generally moderate to high while downstream it was generally low.			

Prepared from information compiled by Exponent (1998).

Table 4-3. Lower Fox River Shoreline and Substrate Types

Shoreline Type & Distance (km)	Upstream of De Pere Dam						Downstream of De Pere Dam					LFR Shoreline Totals	
	Area 1	Area 2	Area 3	Area 4	Area 5	Totals	Area 1	Area 2	Area 3	Area 4	Totals	Distance	Percent
Developed Shoreline													
Riprap	5.99	1.85	3.12	1.73	4.46	**17.15**	1.44	1.46	0.66	1.67	**5.24**	**22.39**	**35.7%**
Bulkhead	1.88	1.18	0.00	0.20	0.19	**3.46**	0.08	0.17	0.61	1.33	**2.18**	**5.64**	**9.0%**
Total	7.87	3.03	3.12	1.94	4.65	**20.61**	1.52	1.63	1.28	2.99	**7.42**	**28.03**	**44.6%**
Natural Shoreline													
Riparian Canopy	1.48	2.89	7.93	7.96	3.91	**24.16**	1.79	0.72	0.43	0.41	**3.35**	**27.51**	**43.8%**
Groundcover/wetland	2.17	1.48	1.95	0.20	0.47	**6.27**	0.55	0.02	0.00	0.00	**0.57**	**6.84**	**10.9%**
Sand/gravel	0.00	0.00	0.00	0.10	0.28	**0.38**	0.00	0.02	0.00	0.00	**0.02**	**0.41**	**0.6%**
Total	3.65	4.37	9.88	8.26	4.65	**30.81**	2.34	0.77	0.43	0.41	**3.94**	**34.75**	**55.4%**
Total Shoreline (km)	**11.51**	**7.40**	**13.00**	**10.20**	**9.30**	**51.41**	**3.86**	**2.40**	**1.70**	**3.40**	**11.36**	**62.78**	**100.0%**
River Substrate Types and Area (km^2)													
Type 1	1.62	0.00	1.85	0.01	3.23	**6.70**	1.89	1.62	0.49	0.95	**4.95**	**11.65**	**53.3%**
Type 2	2.70	0.15	0.37	0.05	0.15	**3.43**	0.11	0.09	0.00	0.00	**0.19**	**3.62**	**16.6%**
Type 3	1.08	1.35	1.85	1.71	0.23	**6.21**	0.06	0.00	0.00	0.01	**0.07**	**6.28**	**28.8%**
Type 4	0.00	0.00	0.00	0.00	0.15	**0.15**	0.04	0.00	0.01	0.04	**0.09**	**0.24**	**1.1%**
Type 5	0.00	0.00	0.02	0.01	0.02	**0.05**	0.00	0.00	0.00	0.00	**0.00**	**0.05**	**0.2%**
Total Coverage (km^2)	**5.40**	**1.50**	**4.08**	**1.78**	**3.78**	**16.54**	**2.10**	**1.70**	**0.50**	**1.00**	**5.30**	**21.84**	**100.0%**

Prepared from information compiled by Exponent (1998).

Descriptions of the Areas (Exponent, 1998).

Area 1: LLBdM to Appleton Lock 1
Area 2: Appleton Lock 1 to Cedars Lock
Area 3: Cedars Lock to Rapide Croche Lock
Area 4: Rapide Croche Lock to Little Kaukauna Lock
Area 5: Little Kaukauna Lock to De Pere Dam

Area 1: De Pere Dam to Highway 172 Bridge
Area 2: Highway 172 Bridge to Ft. Howards (Ft. James) RR trestle
Area 3: Fort Howard RR trestle to E. Mason Street Bridge
Area 4: E. Mason Street Bridge to mouth of the Fox River

Descriptions of Substrate Types (Exponent, 1998).

Type 1 = Soft, aqueous, silty sediments
Type 2 = Semi-compact to compact sands and/or clay
Type 3 = Compact sand, gravel, or cobble deposits
Type 4 = Combination of Types 1 and 2
Type 5 = Cobble/boulder size rocks

Table 4-4. Lower Fox River Fish Species Composition

SPECIES	LLBdM 1983		LLBdM to Little Rapids 1976 - 1977		LLBdM to Little Rapids 1993 - 1994	
	Total Catch	Percent of Catch	Total Catch	Percent of Catch	Total Catch	Percent of Catch
Non-Game Fish [A]						
Alewife	0	0.0%	0	0.0%	0	0.0%
Bowfin	0	0.0%	0	0.0%	0	0.0%
Burbot	77	1.4%	2	0.0%	0	0.0%
Carp	1,995	36.1%	2,997	52.9%	533	54.1%
Creek Chub	0	0.0%	1	0.0%	0	0.0%
Drum (freshwater)	0	0.0%	137	2.4%	73	7.4%
Gizzard Shad	0	0.0%	11	0.2%	4	0.4%
Shortnose Gar	0	0.0%	5	0.1%	2	0.2%
Longnose Gar	0	0.0%	1	0.0%	0	0.0%
Redhorse	0	0.0%	0	0.0%	0	0.0%
Silver Lamprey	0	0.0%	0	0.0%	0	0.0%
Emerald Shiner	0	0.0%	82	1.4%	7	0.7%
Golden Shiner	0	0.0%	6	0.1%	1	0.1%
Spotfin Shiner	0	0.0%	4	0.1%	0	0.0%
Spottail Shiner	0	0.0%	1	0.0%	0	0.0%
White Sucker	180	3.3%	527	9.3%	3	0.3%
Quillback Carpsucker	1	0.0%	157	2.8%	15	1.5%
Log Perch	0	0.0%	42	0.7%	0	0.0%
Trout Perch	0	0.0%	43	0.8%	38	3.9%
Total: Non-game fish	2,253	40.8%	4,016	70.9%	676	68.6%
Game Fish						
Bluegill	2	0.0%	1	0.0%	0	0.0%
Rock Bass	0	0.0%	27	0.5%	3	0.3%
Largemouth Bass	0	0.0%	0	0.0%	0	0.0%
Smallmouth Bass	0	0.0%	6	0.1%	1	0.1%
White Bass	8	0.1%	46	0.8%	189	19.2%
Yellow Bass	1	0.0%	0	0.0%	0	0.0%
Black Bullhead	1,407	25.5%	933	16.5%	0	0.0%
Brown Bullhead	83	1.5%	0	0.0%	0	0.0%
Yellow Bullhead	0	0.0%	11	0.2%	0	0.0%
Channel Catfish	0	0.0%	1	0.0%	0	0.0%
Flathead Catfish	0	0.0%	0	0.0%	1	0.1%
Black Crappie	1,540	27.9%	96	1.7%	7	0.7%
White Crappie	0	0.0%	0	0.0%	0	0.0%
Spotted Muskie	0	0.0%	0	0.0%	0	0.0%
Northern Pike	171	3.1%	59	1.0%	12	1.2%
White Perch	0	0.0%	0	0.0%	0	0.0%
Yellow Perch	22	0.4%	360	6.4%	18	1.8%
Pumpkinseed	0	0.0%	15	0.3%	0	0.0%
Sauger	0	0.0%	0	0.0%	7	0.7%
Green Sunfish	2	0.0%	0	0.0%	0	0.0%
Brook Trout	0	0.0%	0	0.0%	0	0.0%
Lake Trout	0	0.0%	0	0.0%	0	0.0%
Rainbow Trout	0	0.0%	0	0.0%	0	0.0%
Walleye	34	0.6%	94	1.7%	72	7.3%
Total: Game Fish	3270	59.2%	1649	29.1%	310	31.4%
Totals	5,523	100%	5,665	100%	986	100%

Notes:

A) As Listed in Wisconsin State Statute Chapter 29.01.

B) No differentiation made between Shortnose/Longnose Gar - value listed for Shortnose Gar represents both species.

C) No differentiation made between Bullheads (black, brown, yellow) - value listed for black bullhead represents all three species.

Table 4-4. Lower Fox River Fish Species Composition (Continued)

	Little Rapids to De Pere					
SPECIES	1975 - 1976		1983 - 1985		1994 - 1995	
	Total Catch	Percent of Catch	Total Catch	Percent of Catch	Total Catch	Percent of Catch
Non-Game Fish [A]						
Alewife	221	3.4%	0	0.0%	46	0.5%
Bowfin	1	0.0%	0	0.0%	1	0.0%
Burbot	0	0.0%	156	0.8%	4	0.0%
Carp	3,425	53.1%	12,570	65.1%	2,611	28.2%
Creek Chub	1	0.0%	0	0.0%	0	0.0%
Drum (freshwater)	156	2.4%	1,661	8.6%	928	10.0%
Gizzard Shad	3	0.0%	2,903	15.0%	1,081	11.7%
Shortnose Gar	5	0.1%	0	0.0%	6	0.1%
Longnose Gar	1	0.0%	2	0.0%	0	0.0%
Redhorse	0	0.0%	36	0.2%	76	0.8%
Silver Lamprey	0	0.0%	0	0.0%	0	0.0%
Emerald Shiner	1	0.0%	1	0.0%	71	0.8%
Golden Shiner	1	0.0%	0	0.0%	0	0.0%
Spotfin Shiner	0	0.0%	0	0.0%	55	0.6%
Spottail Shiner	0	0.0%	0	0.0%	77	0.8%
White Sucker	648	10.0%	545	2.8%	24	0.3%
Quillback Carpsucker	15	0.2%	92	0.5%	208	2.2%
Log Perch	0	0.0%	0	0.0%	37	0.4%
Trout Perch	1	0.0%	4	0.0%	315	3.4%
Total: Non-game fish	4,479	69.4%	17,970	93.0%	5,540	59.8%
Game Fish						
Bluegill	2	0.0%	5	0.0%	38	0.4%
Rock Bass	7	0.1%	69	0.4%	110	1.2%
Largemouth Bass	0	0.0%	1	0.0%	1	0.0%
Smallmouth Bass	0	0.0%	10	0.1%	493	5.3%
White Bass	174	2.7%	85	0.4%	293	3.2%
Yellow Bass	0	0.0%	0	0.0%	1	0.0%
Black Bullhead	1,024	15.9%	61	0.3%	0	0.0%
Brown Bullhead	0	0.0%	9	0.0%	0	0.0%
Yellow Bullhead	0	0.0%	11	0.1%	1	0.0%
Channel Catfish	2	0.0%	34	0.2%	411	4.4%
Flathead Catfish	0	0.0%	8	0.0%	11	0.1%
Black Crappie	188	2.9%	290	1.5%	269	2.9%
White Crappie	0	0.0%	0	0.0%	2	0.0%
Spotted Muskie	0	0.0%	0	0.0%	1	0.0%
Northern Pike	46	0.7%	228	1.2%	57	0.6%
White Perch	0	0.0%	0	0.0%	327	3.5%
Yellow Perch	396	6.1%	112	0.6%	535	5.8%
Pumpkinseed	59	0.9%	2	0.0%	1	0.0%
Sauger	1	0.0%	19	0.1%	9	0.1%
Green Sunfish	2	0.0%	0	0.0%	10	0.1%
Brook Trout	0	0.0%	0	0.0%	0	0.0%
Lake Trout	0	0.0%	0	0.0%	0	0.0%
Rainbow Trout	0	0.0%	0	0.0%	0	0.0%
Walleye	74	1.1%	404	2.1%	1,153	12.4%
Total: Game Fish	1975	30.6%	1348	7.0%	3723	40.2%
Totals	6,454	100%	19,318	100%	9,263	100%

Notes:

A) As Listed in Wisconsin State Statute Chapter 29.01.

B) No differentiation made between Shortnose/Longnose Gar - value listed for Shortnose Gar represents both species.

C) No differentiation made between Bullheads (black, brown, yellow) - value listed for black bullhead represents all three species.

Table 4-5. Lower Fox River Fish Populations in the De Pere to Green Bay Reach

SPECIES	1987 Catch	1987 % Catch	1988 Catch	1988 % Catch	1989 Catch	1989 % Catch	1990 Catch	1990 % Catch	1991 Catch	1991 % Catch	1992 Catch	1992 % Catch
Non-Game Fish												
Alewife*	3	0.0%	-	0.0%	-	0.0%	-	0.0%	1	0.0%	-	0.0%
Burbot	19	0.1%	25	0.1%	12	0.1%	12	0.1%	12	0.1%	12	0.1%
Carp*	1,220	5.4%	659	3.7%	1,322	6.6%	886	9.6%	863	4.6%	1,382	8.7%
Drum (freshwater)*	259	1.1%	210	1.2%	998	5.0%	652	7.1%	391	2.1%	1,242	7.8%
Gar	28	0.1%	20	0.1%	35	0.2%	17	0.2%	9	0.0%	58	0.4%
Gizzard Shad*	2	0.0%	8	0.0%	4	0.0%	104	1.1%	13	0.1%	34	0.2%
Longnose Sucker	4	0.0%	2	0.0%	6	0.0%	-	0.0%	3	0.0%	12	0.1%
Mooneye	-	0.0%	-	0.0%	1	0.0%	-	0.0%	-	0.0%	8	0.1%
Quillback	30	0.1%	7	0.0%	72	0.4%	176	1.9%	280	1.5%	866	5.4%
Redhorse*	16	0.1%	12	0.1%	17	0.1%	11	0.1%	22	0.1%	17	0.1%
Trout-perch*	2	0.0%	5	0.0%	10	0.1%	7	0.1%	-	0.0%	32	0.2%
White Sucker*	1,554	6.9%	1,002	5.6%	2,071	10.4%	724	7.9%	852	4.5%	817	5.1%
Total Non-Game Fish	**3,137**	**13.9%**	**1,950**	**10.9%**	**4,548**	**22.8%**	**2,589**	**28.2%**	**2,446**	**13.0%**	**4,480**	**28.1%**
Game Fish												
Black Bullhead*	274	1.2%	608	3.4%	960	4.8%	599	6.5%	64	0.3%	18	0.1%
Black Crappie*	413	1.8%	181	1.0%	602	3.0%	427	4.6%	730	3.9%	255	1.6%
Bluegill*	4	0.0%	2	0.0%	29	0.1%	53	0.6%	10	0.1%	17	0.1%
Brook Trout	1	0.0%	-	0.0%	1	0.0%	-	0.0%	-	0.0%	1	0.0%
Brown Bullhead	5	0.0%	10	0.1%	13	0.1%	1	0.0%	-	0.0%	1	0.0%
Channel Catfish	52	0.2%	55	0.3%	125	0.6%	315	3.4%	74	0.4%	238	1.5%
Flathead Catfish	-	0.0%	2	0.0%	10	0.1%	22	0.2%	8	0.0%	35	0.2%
Hydrid Muskie	-	0.0%	39	0.2%	4	0.0%	4	0.0%	2	0.0%	12	0.1%
Largemouth Bass*	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%
Muskie*	1	0.0%	-	0.0%	-	0.0%	2	0.0%	1	0.0%	1	0.0%
Northern Pike*	94	0.4%	116	0.6%	222	1.1%	79	0.9%	127	0.7%	192	1.2%
Pumpkinseed*	2	0.0%	3	0.0%	3	0.0%	4	0.0%	-	0.0%	1	0.0%
Rainbow Trout*	-	0.0%	-	0.0%	-	0.0%	13	0.1%	9	0.0%	1	0.0%
Rock Bass*	26	0.1%	13	0.1%	49	0.2%	46	0.5%	13	0.1%	23	0.1%
Sauger	1	0.0%	-	0.0%	-	0.0%	1	0.0%	5	0.0%	12	0.1%
Smallmouth Bass*	6	0.0%	3	0.0%	4	0.0%	14	0.2%	19	0.1%	13	0.1%
Walleye	3,017	13.4%	1,531	8.6%	1,781	8.9%	635	6.9%	1,392	7.4%	1,957	12.3%
White Bass*	723	3.2%	534	3.0%	357	1.8%	419	4.6%	962	5.1%	766	4.8%
White Perch*	-	0.0%	-	0.0%	3	0.0%	137	1.5%	5	0.0%	212	1.3%
Yellow Bullhead*	6	0.0%	7	0.0%	20	0.1%	7	0.1%	2	0.0%	-	0.0%
Yellow Perch*	14,763	65.5%	12,797	71.7%	11,220	56.2%	3,817	41.6%	12,889	68.7%	7,718	48.4%
Total Game Fish	**19,388**	**86.1%**	**15,901**	**89.1%**	**15,403**	**77.2%**	**6,595**	**71.8%**	**16,312**	**87.0%**	**11,473**	**71.9%**
Total Fish	**22,525**	**100.0%**	**17,851**	**100.0%**	**19,951**	**100.0%**	**9,184**	**100.0%**	**18,758**	**100.0%**	**15,953**	**100.0%**

* Indicates that this fish species was observed in Duck Creek during the 1995/1996 survey assessment (Cogsewll and Bougie, 1998).

Table 4-5. Lower Fox River Fish Populations in the De Pere to Green Bay Reach (Continued)

	1993		1994		1995		1996		1997		1998	
SPECIES	Catch	% Catch	Catch	% Catch	Catch	% Catch	Catch	% Catch	Catch	% Catch	Catch	% Catch
Non-Game Fish												
Alewife*	2	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%
Burbot	38	0.2%	35	0.3%	38	0.8%	16	0.4%	23	1.0%	34	0.4%
Carp*	216	0.9%	866	6.7%	102	2.2%	161	3.6%	129	5.6%	218	2.8%
Drum (freshwater)*	156	0.7%	533	4.1%	86	1.9%	63	1.4%	55	2.4%	420	5.3%
Gar	7	0.0%	25	0.2%	5	0.1%	-	0.0%	-	0.0%	8	0.1%
Gizzard Shad*	1	0.0%	84	0.6%	5	0.1%	1	0.0%	-	0.0%	-	0.0%
Longnose Sucker	3	0.0%	3	0.0%	1	0.0%	-	0.0%	2	0.1%	1	0.0%
Mooneye	1	0.0%	3	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%
Quillback	554	2.4%	239	1.8%	54	1.2%	72	1.6%	8	0.3%	72	0.9%
Redhorse*	55	0.2%	73	0.6%	10	0.2%	41	0.9%	17	0.7%	107	1.4%
Trout-perch*	7	0.0%	1	0.0%	27	0.6%	-	0.0%	1	0.0%	-	0.0%
White Sucker*	824	3.6%	1,807	13.9%	204	4.4%	256	5.7%	121	5.3%	848	10.8%
Total Non-Game Fish	**1,864**	**8.2%**	**3,669**	**28.2%**	**532**	**11.5%**	**610**	**13.6%**	**356**	**15.5%**	**1,708**	**21.7%**
Game Fish												
Black Bullhead*	21	0.1%	51	0.4%	2	0.0%	12	0.3%	8	0.3%	8	0.1%
Black Crappie*	33	0.1%	281	2.2%	35	0.8%	20	0.4%	2	0.1%	22	0.3%
Bluegill*	1	0.0%	1	0.0%	2	0.0%	2	0.0%	-	0.0%	1	0.0%
Brook Trout	1	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%
Brown Bullhead	-	0.0%	2	0.0%	2	0.0%	-	0.0%	-	0.0%	-	0.0%
Channel Catfish	44	0.2%	369	2.8%	46	1.0%	27	0.6%	10	0.4%	227	2.9%
Flathead Catfish	3	0.0%	23	0.2%	1	0.0%	4	0.1%	3	0.1%	21	0.3%
Hydrid Muskie	1	0.0%	9	0.1%	-	0.0%	-	0.0%	-	0.0%	1	0.0%
Largemouth Bass*	-	0.0%	-	0.0%	1	0.0%	-	0.0%	-	0.0%	-	0.0%
Muskie*	1	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	8	0.1%
Northern Pike*	19	0.1%	135	1.0%	24	0.5%	17	0.4%	37	1.6%	120	1.5%
Pumpkinseed*	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%
Rainbow Trout*	-	0.0%	6	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%
Rock Bass*	16	0.1%	4	0.0%	8	0.2%	17	0.4%	4	0.2%	18	0.2%
Sauger	16	0.1%	25	0.2%	2	0.0%	8	0.2%	2	0.1%	25	0.3%
Smallmouth Bass*	6	0.0%	20	0.2%	22	0.5%	27	0.6%	21	0.9%	40	0.5%
Walleye	3,442	15.1%	3,952	30.4%	1,024	22.1%	1,539	34.4%	1,509	65.9%	3,821	48.6%
White Bass*	333	1.5%	267	2.1%	60	1.3%	219	4.9%	11	0.5%	140	1.8%
White Perch*	159	0.7%	1,450	11.2%	327	7.1%	325	7.3%	55	2.4%	866	11.0%
Yellow Bullhead*	1	0.0%	-	0.0%	2	0.0%	1	0.0%	-	0.0%	-	0.0%
Yellow Perch*	16,843	73.9%	2,729	21.0%	2,546	54.9%	1,647	36.8%	272	11.9%	829	10.6%
Total Game Fish	**20,940**	**91.8%**	**9,324**	**71.8%**	**4,104**	**88.5%**	**3,865**	**86.4%**	**1,934**	**84.5%**	**6,147**	**78.3%**
Total	**22,804**	**100.0%**	**12,993**	**100.0%**	**4,636**	**100.0%**	**4,475**	**100.0%**	**2,290**	**100.0%**	**7,855**	**100.0%**

* Indicates that this fish species was observed in Duck Creek during the 1995/1996 survey assessment (Cogsewll and Bougie, 1998).

Table 4-6. Green Bay Fish Species

Common Name	Species Name	Food Web	Wisconsin Listing	Michigan Listing	Federal Listing
Salmon and Trout					
Atlantic salmon	Salmo salar				
Brown trout	Salmo trutta				
Chinook salmon (king)	Oncorhynchus tshawytscha				
Coho salmon (silver)	Oncorhynchus kisutch				
Pink salmon (humpy)	Oncorhynchus gorbuscha				
Rainbow trout (steelhead)	Salmo gairdneri				
Brook trout	Slavelinus fontinalis				
Lake trout	Slavelinus namaycush				
Benthic Fish					
Black bullhead	Ictaluras melas				
Brown bullhead	Ictalurus nebulosus				
Carp	Cyprinus carpio	X			
Channel catfish	Ictalurus punctatus				
Yellow bullhead	Ictalurus natalis				
Shorthead redhorse	Moxostoma macrolepidotum				
Silver redhorse	Moxostoma anisurum				
White sucker	Catostomus commersoni				
Pelagic Fish					
Common shiner	Notropis cornutus	X			
Emerald shiner	Notropis atherinoides	X			
Gizzard shad	Dorosoma cepedianum	X			
Lake sturgeon	Acipenser fulvescens			T	
Rainbow smelt	Osmerus mordax	X			
Redfin shiner	Notropis umbratilis	X			
Spottail shiner	Notropis hudsonius	X			
Alewife	Alosa pseudoharengus	X			
Game Fish					
Lake whitefish	Coregonus clupeaformis				
Muskellunge	Esox masquinongy				
Northern pike	Esox lucius				
Sauger	Stizostedion canadense			T	
Walleye	Stizostedion vitreum	X			
Yellow perch	Perca flavescens	X			
Black crappie	Pomoxis nigromaculatus				
Bluegill	Lepomis macrochirus				
Largemouth bass	Micropterus salmoides				
Pumpkinseed	Lepomis gibbosus				
Rock bass	Ambloplites rupestris				
Smallmouth bass	Micropterus dolomieui				
White bass	Morone chrysops				

E = ENDANGERED D = DELISTED
T = THREATENED X = Included in Risk Assessment Food Web Models.

Table 4-7. Lower Fox River and Green Bay Bird Species

Common Name	Species Name	Food Web	Wisconsin Listing	Michigan Listing	Federal Listing
Raptors					
Bald eagle	Haliaeetus leucocephalus	X	D	T	T
Merlin	Falco Columbarius			T	
Osprey	Pandion haliaetus		T	T	
Peregrine falcon	Falco peregrinus		E	E	E
Gulls and Terns					
Black tern	Chilidonias niger				
Caspian tern	Sterna caspia		E	T	
Common tern	Sterna hirundo	X	E	T	
Forster's tern	Sterna fosteri	X	E		
Herring gull	Larus argentatus				
Ring-billed gull	Larus delawarensis				
Diving Birds					
Belted kingfisher	Megaceryle alcyon				
Common loon	Gavia immer				
Double-crested cormorant	Phalacrocorax auritus	X			
Horned grebe	Podiceps auritus				
Pied-billed grebe	Podilymbus podiceps				
Passerine Bird					
Brewer's blackbird	Euphagus cyanocephalus				
Red-winged blackbird	Agelaius phoeniceus				
Yellow-headed blackbird	Xanthocephalus xanthocephalus				
Marsh wren	Cistothorus palustris				
Sedge wren	Cistothorus platensis				
Tree swallows	Tachycineta bicolor				
Swamp sparrow	Melospiza georgiana				
Shorebird					
Common snipe	Capella gallinago				
Dunlin	Calidris alpina				
Least sandpiper	Calidris minutilla				
Pectoral sandpiper	Calidris melanotos				
Piping plover	Charadrius melodus		E	E	E/T
Sanderling	Calidris alba				
Semipalmated sandpiper	Calidris pusilla				
Spotted sandpiper	Actitis macularia				

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Table 4-7. Lower Fox River and Green Bay Bird Species (continued)

Common Name	Species Name	Food Web	Wisconsin Listing	Michigan Listing	Federal Listing
Wading Birds					
American bittern	Botaurus lentiginosus				
American woodcock	Philohela minor				
Black-crowned night heron	Nycticorax nycticorax				
Cattle egret	Bubulcus ibis				
Great blue heron	Ardea herodias				
Green-backed heron	Butorides striatus				
King rail	Rallus elegans			**E**	
Least bittern	Ixobrychus exilis			**T**	
Sandhill crane	Grus canadensis				
Snowy egret	Egretta thula		**E**		**E**
Sora rail	Porzana carolina				
Virginia rail	Rallus limicola				
Yellow rail	Coturnicops noveboracensis		**T**	**T**	
Waterfowl					
American coot	Fulica americana				
Black duck	Anas rubripes				
Blue-winged teal	Anas discors				
Bufflehead	Bucephala albeola				
Canada goose	Branta canadensis				
Canvasback	Aythya valisineria				
Common goldeneye	Bucephala clangula				
Common merganser	Mergus merganser				
Common moorhen	Gallinula chloropus				
Greater scaup	Aythya marila				
Green-winged teal	Anas crecca				
Lesser scaup	Aythya affinis				
Mallard	Anas platyrhynchos				
Northern shoveler	Anas clypeata				
Oldsquaw	Clangula hyemalis				
Red-breasted merganser	Mergus serrator				
Redhead	Aythya americana				
Ring-necked duck	Aythya collaris				
Ruddy duck	Oxyura jamaicensis				
Whistling swan (tundra swan)	Olor columbianus				
Wood duck	Aix sponsa				

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